Proposed Project for Ground-Water Investigations in Support of the OMVS Water Data Collection and Analysis Program

Senegal River Basin

Mali, Mauritania, and Senegal
West Africa

Prepared by
CH2M HILL, International

On behalf of
The U. S. Agency for International Development

October 1979

Contents

Illustrations

1.0 Summary

1.1 This report presents a proposal for ground-water monitoring, data collection, and analysis in accordance with OMVS water management objectives for the Senegal River basin. The duration of the project would be 5 years. The work would be concentrated in the Senegal valley between Kayes and St. Louis and would include a strip 20 to 25 km wide on either side of the valley. The project would be staffed, managed, and operated by the OMVS. However, technical assistance would be provided in the second and subsequent years of the project for data interpretation and analysis in such fields as water quality, ground-water hydraulics, water budget and salt balance analysis, and mathematical modeling.

1.2 Problems of water-logging and/or salination occur in diked irrigated perimeters, and similar problems may develop as irrigation is intensified. Therefore, ground-water monitoring and water-quality observation are particularly important in and near these perimeters. There is a need for better understanding of (1) the recharge-discharge relations between the Senegal River and its valley aquifer and contiguous regional aquifers; (2) the changes in the ground-water regime caused by the construction of the Diama and Manantali Dams and the alterations of the flow regime of the river; and (3) development potential of ground water for either supplemental irrigation or with surface water in the Matam-Boghé sector.

2.0 Introduction

This report was prepared by George C. Taylor, Jr., of CH2M HILL, International, as contractor, in response to a request from USAID/OMVS, Dakar, for an assessment of the need, if any, of a ground-water investigation project in support of the OMVS water data collection and analysis program in the Senegal River basin. To carry out this assessment, the writer spent 6 weeks in the basin in consultations with national and international agencies concerned with ground-water resources and irrigation development; in review of prior studies and proposals available at OMVS and USAID/OMVS headquarters in Dakar and at the OMVS Documentation Center in St. Louis; in field inspections of representative irrigation perimeters, village and livestock wells (puits), and piezometers and tubewells (forages) installed during earlier ground-water studies; and in preparation of this report.

2.1 Antecedent studies and proposals:

2.1.1 The number of studies that have been made of the ground-water resources of various parts of the Senegal River basin is impressive. More than 100 reports are reported to exist (Greenman 1977). As pointed out by Greenman, and with few exceptions, virtually all of these studies have been directed to short-term objectives of describing the occurrence of ground water and its availability for village, livestock, and public water supply. Most of these studies have been made by foreigners, with limited attention given to the training of local ground-water specialists and technicians. National teams are now needed for long-term OMVS ground-water monitoring and water management in the Senegal River basin.

2.1.2 Of the studies reviewed, that of Illy (1973), sponsored by OMVS/FAO, perhaps most pertinently describes and defines the hydrodynamic relationships between the regime of the river and those of its contiguous alluvial aquifer and underlying regional aquifers. The principal conclusions of the Illy study were that (1) the river and its contiguous alluvial aquifer form a line source of recharge for deeper regional aquifers in the Continental Terminal, Eocene, and Maestrichtian formations underlying the Senegal River basin; (2) the alluvial aquifer is alternately recharged by the river during floods and depleted by drainage to the river during dry seasons, thereby sustaining most of the base flows of the river below Bakel; and (3) hydrogeologic conditions are favorable for development of ground water for irrigation in the Matam-Boghé sector of the valley, but additional observations, exploratory drilling, and aquifer testing are needed to determine the limits of such development. Illy recommended continued monitoring of water levels and water quality in piezometers constructed during his investigation (1971-72). Water-level and water-quality observations in Illy's piezometers were continued by Hamdinou of the OMVS during 1973-74. Observations were subsequently discontinued, however, for lack of operating funds, personnel, and vehicles. Illy also recommended a small pilot project for development of ground-water irrigation in the Matam-Boghé sector. This recommendation was not accepted, possibly because it was considered premature in view of the emphasis being given by OMVS to surface-water development at that time.

2.1.3 Another important study sponsored by OMVS/FAO was that of Audibert (1970). Audibert concentrated his work on the Senegal River delta. He concluded that (1) virtually all the important aquifers beneath the delta and in the lower reach of the valley as far upstream as Podor contain brackish or saline ground water; (2) highly saline ground water is generally present beneath most of the delta at a depth of less than 3 m; and (3) systems of deep drains would be essential components of irrigated perimeters to control water-logging and soil salination. Audibert also pointed out the need for monitoring ground-water levels and water quality as part of water management in irrigated perimeters. In the absence of careful management, large investments could, in the long term, be partly or completely lost.

2.1.4 In April 1976, a study program prepared for USAID by the U.S. Bureau of Reclamation included recommendations for the installation of an observation well network in the Senegal River valley downstream of Bakel. The suggested objectives of the proposed network were to monitor the response of the water table to changes in the river regime and irrigation activities and to obtain data on ground-water recharge and discharge. No details were given in the report as to the number, location, and specifications of the observation wells. Nor did the report state which aquifers would be monitored, or the estimated costs of the project.

2.1.5 In 1975-76, USAID financed a feasibility study by Bechtel (1976) entitled, "Development of Irrigated Agriculture at Matam." Based on this study, Bechtel proposed the development of ground water to irrigate 2,800 hectares of sandy "dieri" lands for the production of vegetables. The OMVS states did not accept this proposal because the relationships of the river, its alluvial aquifer, and the underlying regional aquifers were not yet sufficiently understood. The member states believed embarking on large-scale ground-water development for irrigation might adversely affect wells used for village and livestock water supply.

2.1.6 In July 1977, D. W. Greenman of the U.S. Geological Survey undertook an evaluation of previous ground-water reports and proposals, including the responses of the OMVS member states to the Bechtel (1976) Matam study. In his report, "Proposal to Assemble Ground-water Data in the Senegal River Basin," Greenman set forth a basin-wide program of ground-water data collection and analysis. His program included training and institutional development to meet long-term OMVS requirements for water management. The Greenman report proposed a 1-year first phase, in which requirements for data collection, program formulation, and institutional development would be identified with the assistance of an expatriate advisor. The second phase of a long-term project would be designed by technical experts.

2.1.7 During 1977-78, USAID financed a series of studies by Gannett, Fleming, Corddry, and Carpenter, entitled "Assessment of Environmental Effects of Proposed Developments in the Senegal River Basin" (GFCC 1979). The ground-water report, which contains a comprehensive review of earlier studies, concludes that (1) ground-water levels and saline water from the shallow aquifer will tend to rise in the periphery of the impoundment created by the Diama dam in the Senegal delta; (2) water-logging and salinity problems are likely to develop in diked irrigated perimeters with inadequate water management; (3) increasing use of fertilizers and pesticides in irrigated perimeters could affect adversely the potability of the shallow ground water tapped by domestic and livestock wells (puits); and (4) the regulation of river flows by construction of the Manantali dam would somewhat reduce recharge to ground water in the alluvial and underlying regional aquifers. The report concludes with a strong recommendation for a monitoring program of ground-water levels and water quality to achieve OMVS water management objectives in the Senegal River basin.

2.1.8 The writer has also reviewed ground-water project proposals received from concerned technical agencies in Mali, Mauritania, and Senegal to proposals contained in the Greenman report. Most recently, the writer has reviewed the OMVS terms of reference for a hydrogeologic study of the Senegal River basin dated February 1979.

2.2 Justification for proposed project

2.2.1 At present, several diked irrigated perimeters are under construction or have recently been completed with the financial aid of various donors, including the IBRD, FED, and USAID. Multimillion dollar investments have already been made in these perimeters. Perimeters under construction and those planned for construction in the next decade will cost more than $100 million. Yet despite these investments, there is little attention given to <u>water management</u>

in any of the irrigated perimeters of the Senegal valley, with the possible exception of the sugar plantations of the Compagnie Sucrière Sénégalaise at Richard Toll. As a consequence, water-logging and salination problems are already observable in the M'Pourié rice perimeter near Rosso, in the newly completed Dagana perimeter, and in the Nianga perimeter, which has been operational for only a few years. Problems may be impending elsewhere in the valley. Good water management of irrigated perimeters includes accurate measurement of gross pumpage, water use by crops, evapotranspiration, losses by leakage from canals and by deep percolation from irrigated fields, and monitoring of any build-up in ground-water levels and salinity that may result from such losses. In the absence of good management, large investments in irrigated perimeters can be wasted in a few years by water-logging and/or salination. Such problems are likely to be most critical in the immediate future in the irrigated perimeters of the Senegal delta and in the valley downstream of Podor, but the same problems could develop eventually in the middle and upper valley.

2.2.2 Earlier ground-water studies have also shown that the Senegal River and its alluvial aquifer provide an important source of recharge to regional aquifers, which sustain the water supplies of hundreds of domestic and livestock wells. The alluvial aquifer is alternately replenished by floods from the river during high water and then depleted by ground-water flow to the river during dry seasons. Such drainage from the alluvial aquifer is the principal source of the base flows (dry season discharge) of the river downstream of Bakel. As all these relationships are as yet imperfectly understood, one of the objectives of the project would be quantification through ground-water monitoring and analysis of related aquifer data.

2.2.3 The Diama and Manantali dams will change the regime of the river and the regime of ground water in contiguous aquifers. The Diama dam, located near the mouth of the river, will prevent upstream incursion of salt water from the sea, thereby creating a fresh-water impoundment. However, the loading effects of the reservoir could cause shallow saline ground water to migrate laterally toward areas proposed for irrigated perimeters, which could aggravate those problems that might be caused by irrigation itself. Thus, ground-water monitoring takes on added importance in the delta, particularly in the vicinity of the reservoir.

2.2.4 The Manantali dam will regulate and alter the flow regime of the Senegal River. These alterations could result in a net loss of recharge to the alluvial aquifer and, indirectly, to contiguous regional aquifers. Ground-water monitoring established prior to the initiation of regulation will provide important base-line information for quantifying the magnitude of the changes.

2.2.5 Another potential problem is possible contamination of the shallow ground water by fertilizers and pesticides, which are increasingly used in the irrigated perimeters. This same ground water sustains domestic and livestock wells located in and near irrigated perimeters. One of the objectives of the project would be to monitor ground-water quality.

2.2.6 Finally, the Illy (1973) and Bechtel (1976) studies have shown that important potential exists in the Matam-Boghé sector of the valley for development of ground water for irrigation. Further quantification of the limits of such development will be provided by ground-water monitoring and analysis of aquifer data.

2.3 Scope of proposed project:

2.3.1 A review of available and pertinent earlier reports and proposals and visits to many irrigated perimeters and water points show a need for a project of ground-water monitoring, data collection, and analysis oriented toward OMVS water-management objectives in the Senegal River valley. The project here proposed would be basic and more modest in its objectives than the Greenman report. The project life would be 5 years, in order to provide the time necessary to accumulate significant observational data. A 5-year project also takes into account personnel and funding constraints of the technical agencies of the member states and of OMVS itself. The project provides for a strong component of training, especially of subprofessional technicians needed for ground-water monitoring. The OMVS desires to manage the project and field operations with its own staff. Thus, the technical assistance component would be delayed until the second and subsequent years of the project. During the last 4 years, expert advisors could help analyze and interpret data collected during the earlier stages.

2.3.2 In the project here proposed, the OMVS directorate would assume responsibility for staffing all the professional, technician, and support positions called for in the project. Adequate skills are available in the technical agencies of the three member states and in the permanent staff of OMVS. The OMVS would be expected to provide office space for personnel at St. Louis and warehouses for equipment, vehicles, and materials to be procured under the project. USAID/OMVS, Dakar, would provide assistance in procurement of offshore commodities. The OMVS, however, would assume responsibility for tubewell (forage) and deep piezometer construction contracts with drilling companies based in Dakar.

2.3.3 Although arrangements for funding the proposed project cannot be specifically identified at this time, it seems likely that USAID, as the donor agency, would consider funding equipment, vehicle, materials, technical assistance, and contract construction. Support of costs for OMVS personnel assigned to the project as well as for office space and warehousing for equipment, vehicles, and materials would be subject to negotiation.

2.3.4 The following sections outline the project objectives; work components; institutional and personnel requirements; technical assistance required; and equipment, materials, contract construction, and vehicle requirements. Estimated costs and time schedules for personnel, work components, and contract construction are also presented.

2.3.5 By the end of the 5-year project, the OMVS staff would have gained the experience and skills necessary for routine ongoing data collection and analysis. They would also be prepared to undertake more complex ground-water analyses necessary for the development and management of ground water for irrigation in the Senegal River valley and adjacent areas.

3.0 Objectives:

Monitor and investigate existing and potential problems of ground-water development and management related to:

3.1 Water-logging and salination in existing and proposed irrigated perimeters.

3.2 Deterioration of water quality in domestic and livestock wells.

3.3 Recharge-discharge relationships of the Senegal River, its valley aquifer, and contiguous regional aquifers.

3.4 Changes in the ground-water regime caused by the construction of the Diama and Manantali Dams and the resulting alterations of the flow regime of the river.

3.5 Irrigation development potential of ground water for either supplemental irrigation or with surface water, in the Matam-Boghé sector.

4.0 Work components:

The area to be covered is the Senegal River valley from Kayes downstream to St. Louis, including a strip 20 to 25 km wide on either side of the valley.

The work components of the project can be divided into planning, data compilation and analysis, training, field operations, and construction.

4.1 Among planning activities that would be initiated early in the project:

4.1.1 Devise an appropriate system for filing hydrogeologic data, construction details, location, and equipment inventories for each existing open well (puits), tubewell (forage), piezometer, and observation well in the project area.

4.1.2 Design an appropriate schedule (fiche) for recording the hydrogeologic data, construction details, location, and equipment for each existing open well (puits), tubewell (forage), piezometer, and observation well in the project area as well as for proposed piezometers and observation tubewells.

4.1.3 Devise an appropriate system for filing periodic water-level and specific conductivity measurement data at project headquarters in St. Louis.

4.1.4 Design an appropriate schedule (fiche) for recording water-level and specific conductivity measurements for each observation well and piezometer.

4.1.5 Plan a network of observation wells with an average density of about one for each 100 km2 throughout the valley downstream of Kayes and the strip about 20 to 25 km wide on either side of the valley. Carefully selected open wells (puits) now existing can be used for observation with proposed piezometers.

4.1.6 Plan a network of shallow piezometers for each existing diked irrigation perimeter in the valley with an area exceeding 100 hectares. At least one piezometer should be installed in each 100-hectare block. Piezometers should also be installed immediately outside perimeters for purposes of comparison.

4.1.7 Plan a network of shallow piezometers adjacent to the proposed Diama reservoir to monitor the effects of impoundment on ground-water levels and water quality in the delta.

4.1.8 Plan a network of shallow and deep piezometers in the Matam-Boghé sector to study in greater detail the observations of Illy (1973) on the recharge-discharge relationships of the Senegal River, its valley aquifer, and contiguous regional aquifers. This sector holds the greatest promise for ground-water development for irrigation, both in the valley as well as in the adjacent "dieri."

4.2 Data compilation activities would be initiated early in the project and would continue throughout the project life. Data analysis would not begin until the middle and later stages of the project, after a fund of information has been collected.

4.2.1 The first data compilation task would be updating the well inventories and related ground-water data initiated during the OMVS/FAO Hydroagricultural Study. The OMVS/FAO study included work by Audibert (1970) in the delta and by Illy (1973) and Hamdinou (1974) in the valley.

4.2.2 The second task would be the search and identification of all published reports and data pertaining to identified objectives (3.0) in the defined area of the project (4.0). This work would be done at the OMVS Documentation Center in St. Louis.

4.2.3 The third task would be a search and identification of unpublished data in the files of the Malian Direction de l'Hydraulique and the OVSTM, at Bamako; the Mauritanian Direction de l'Hydraulique and the SONADER, at Nouakchott; the Senegalese Direction Général d'Hydraulique et Equipment Rurale (DGHER), at Dakar; and the SAED at St. Louis.

4.2.4 When sufficient water-level and water-quality data have been accumulated, data analysis and interpretation activities could begin. These activities would include:

4.2.4.1 Construct maps for ground-water salinity, depth-to-water (below land-surface datum), and the water-table contour (with respect to sea-level datum) of the larger diked irrigation perimeters.

4.2.4.2 Construct and analyze hydraulic profiles along lines of piezometers showing the pressure head and water-quality relationships of the river, the valley fill aquifer, and deeper regional aquifers, particularly in the Matam-Boghe sector.

4.2.4.3 Study water-quality fluctuations in domestic and livestock wells and seasonal and/or long-term trends in ground-water levels.

4.2.4.4 Study water budget and salt balance of selected irrigation perimeters. These studies would be based on water-table and water-quality fluctuations compared with irrigation applications, infiltrations, and evapotranspiration estimates.

4.3 Training activities would begin early in the project and continue intermittently throughout. Training elements would include:

4.3.1 Instruction in the use and maintenance of electric tapes, water sampling equipment, specific conductivity meters, leveling instruments, water-level recorders, and other field equipment.

4.3.2 Instruction in the systematic recording of field measurements on standard schedules (fiches). Fiches would include the dates and times of measurements and any local observations of conditions that might affect measurements.

4.3.3 Training surveyors (géomètres) to operate in teams of three.

4.3.4 Training well observers to operate alone or in pairs.

4.3.5 Training would be achieved in intensive workshops coupled with on-site instruction in the use of field instruments.

4.3.6 Periodic inspections of the activities of well observers and surveyors would be required of the supervisory staff at St. Louis to ensure quality control of data collection activities.

4.4 Operational activities at the field level, which would be carried out with close supervision by the St. Louis professional staff, would include:

4.4.1 Identify and select observation wells from among existing village and livestock wells. It is estimated that some 450 observation wells would be required in the network.

4.4.2 Establish measuring points at observation wells. Identify by painting appropriate, easily read markings on well curbings (margelles).

4.4.3 Refer measuring points to land-surface datum and to sea-level datum by instrumental levels.

4.4.4 Make a field check of lines of piezometers constructed for the Illy study at Kanel (left bank); Matam (right and left banks); Guedé (left bank); Nianga (left bank); Boghé (right bank); and Podor (left bank). Do the same for the Audibert (1970) study in the delta and the Bechtel (1976) study at Matam.

4.4.5 Rehabilitate or replace these piezometers as needed and desirable.

4.4.6 Select sites for in-house construction of new shallow piezometers with hand augers or power auger drilling equipment. Approximately 10 to 15 shallow piezometers would be installed in or near each major diked irrigation perimeter and about 25 to 30 in the vicinity of Diama reservoir. An overall total of about 450 shallow piezometers 3 m to 15 m deep would be required in and near the larger irrigated perimeters of the project area. About half of these could be installed by hand auger and the remainder by power auger.

4.4.7 Select sites for lines of combined shallow (less than 5 m), intermediate (5 to 30 m), and deep (30 to 60 m) piezometers along the lines of the Illy and Bechtel studies (4.4.4) and also at appropriate locations between Kanel and Kayes and near Dagana and at Rosso. Some piezometers will be set up as "three-hole batteries" with shallow, intermediate, and deep piezometers to measure pressure heads and water quality at different depths in aquifers at the same site. It is estimated that an average of about 25 piezometers would be required on each of 10 piezometer lines for a total of about 250. Of these, about 80 could be constructed with hand-powered equipment; another 80 by power auger; and 90 would be installed with percussion drilling equipment capable of reaching depths of 60 m.

4.4.8 Once observation wells are selected and identified in the field, periodic measurements can begin. An average frequency of about once a month is suggested in the beginning for all observation wells (puits), piezometers, and observation tubewells (forages). Both water levels and specific conductivity should be measured monthly wherever feasible.

4.4.9 Measurements by well observers should be mailed to OMVS St. Louis headquarters for compilation and analysis as soon as they are made. Check measurements should be made from time to time during field inspections by the OMVS technical staff to ensure that well observers are fulfilling their responsibilities.

4.5 Construction activities could begin at any time after the selection of sites for piezometers. With few exceptions all the piezometers would be 7.5 cm (3 inches) in diameter or less. Such a piezometer can readily accommodate an electric tape or other water-level measuring device and also a 2.5-cm tubular "bucket" for water sampling. The piezometer would generally be set in cement or grout to prevent removal of the pipe. They would be fitted with a threaded cap that could be removed only with a pipe wrench. Vandalism or willful destruction of piezometers by local inhabitants has been a chronic problem in past ground-water studies. Some means must be found to protect new installations against vandals, perhaps a counselling program undertaken with assistance from village chiefs or local police.

4.5.1 Piezometers less than 5 m deep (Fig. 1) would be constructed by in-house crews trained and directly supervised by the OMVS technical staff. About four crews of three to four men each could be kept continuously occupied during the life of the project installing shallow piezometers and replacing damaged ones. Shallow piezometers need be no more than a simple pipe with the lower 50 cm or so slotted and wrapped with a nylon mesh bag to serve as a filter; they would be installed about 2 m below the water table in a permeable, saturated sand.

4.5.2 Piezometers ranging from 5 to 30 m deep would be installed by a truck-mounted power auger under the control of an OMVS operator and crew. OMVS headquarters in St. Louis would supply technical supervision.

4.5.3 Piezometers greater than 30 m deep (Fig. 2) would be constructed under contract by a percussion drilling rig. (There are three experienced drilling companies, SONAFOR, INTRAFOR, and SASIF, based at Dakar.) Approximately one observation tubewell (forage) 8 inches (204 mm) in diameter and 30 to 60 m deep (Fig. 3) would be put down on each piezometer line for a total of 10 tubewells. Each of these would be equipped with a continuous water-level recorder housed in a locked concrete shelter. One well observer would be assigned to guard and maintain each recorder against vandalism. If such measures are not taken, the installations are likely to be short-lived.

Proposed Project for
Ground-Water Investigations in Support of the
OMVS Water Data Collection
and Analysis Program

Senegal River Basin

Mali, Mauritania, and Senegal
West Africa

Errata Sheet

Figure 1 - Change Descriptive References from "Sand" to "Sand or Gravel."

Page 29 - Change Columnar Total of Costs in U.S. Dollars from $1,156,277 to $1,218,896.

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On behalf of
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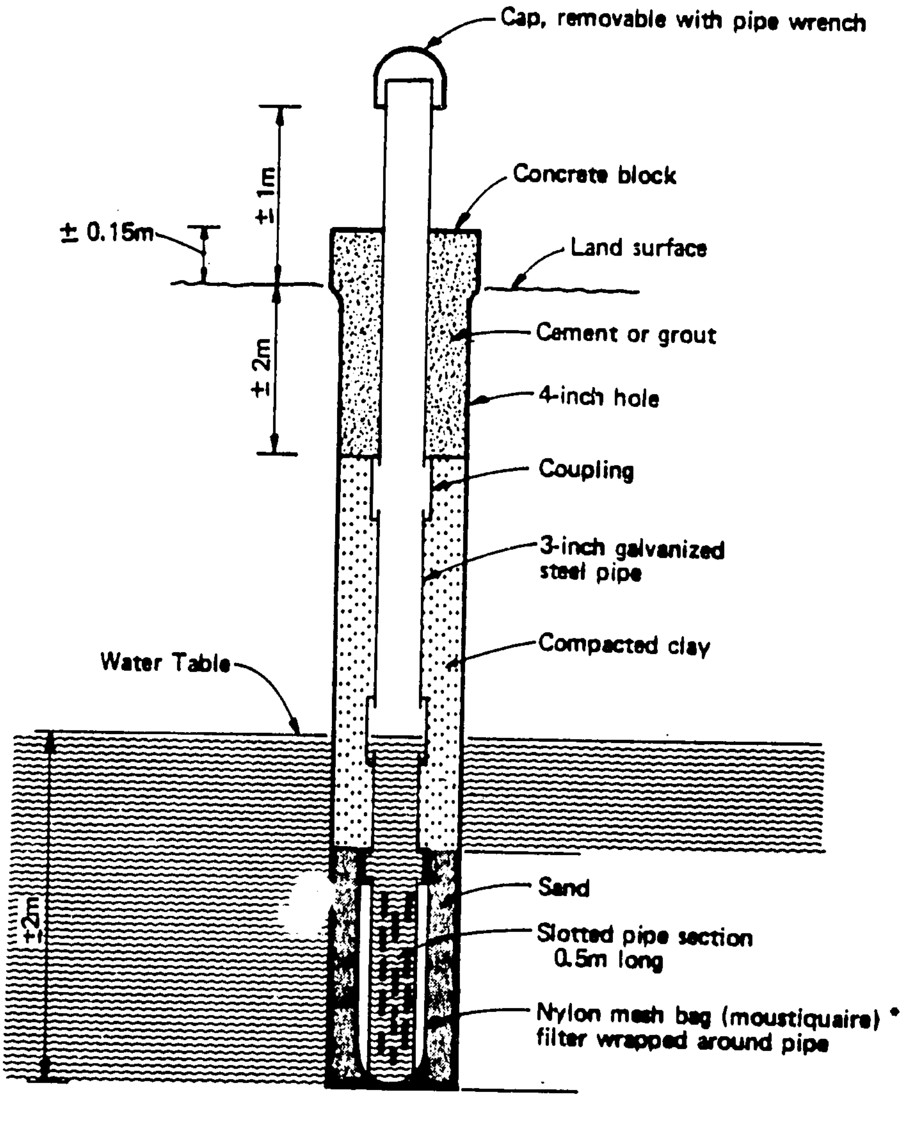
SKETCH SHOWING SUGGESTED DESIGN FOR SHALLOW AND INTERMEDIATE DEPTH PIEZOMETERS



Piezometers less than .5m deep would be installed with hand augers or hand drilling tools.

Piezometers greater than 5m but less than 30m deep would be installed by power aüger.

* This is material commonly used for mosquito nets

FIGURE 1

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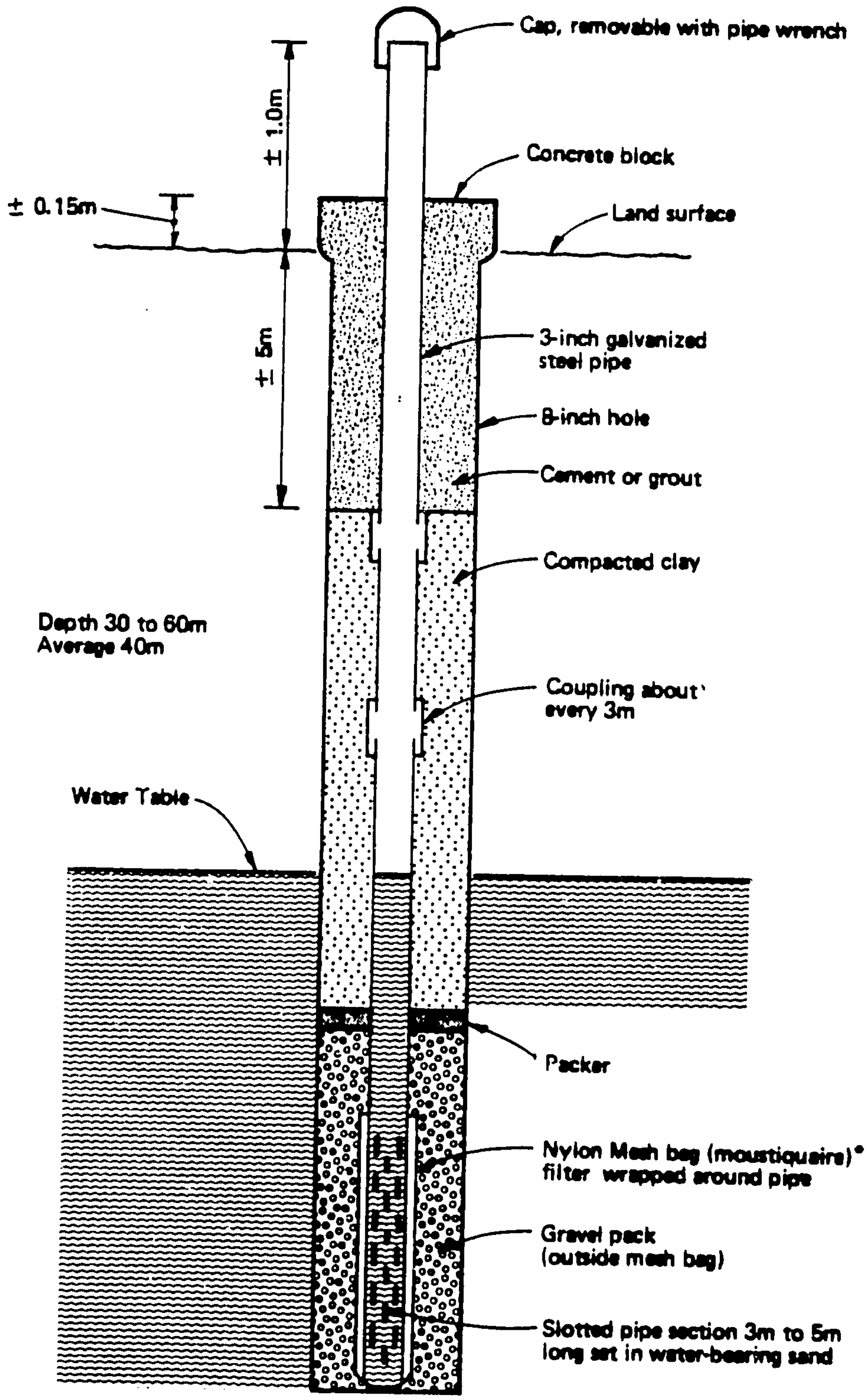
SKETCH SHOWING SUGGESTED DESIGN FOR DEEP PIEZOMETERS
(to be constructed under contract)



*This is material commonly used for mosquito nets

FIGURE 2

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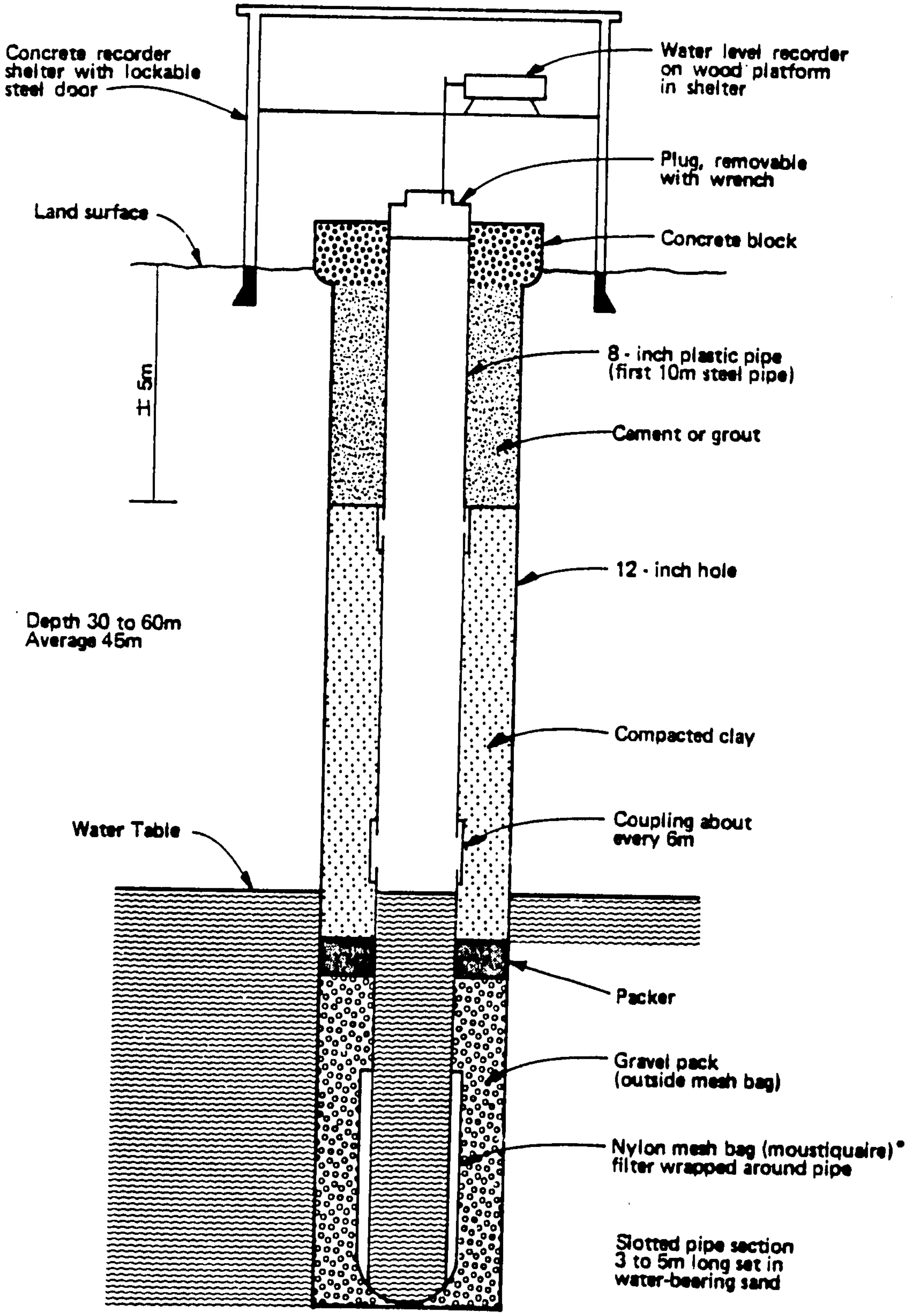
SKETCH SHOWING SUGGESTED DESIGN FOR OBSERVATION TUBEWELLS

(to be constructed under contract)



* This is material commonly used for mosquito nets

FIGURE 3

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5.0 Institutional and personnel requirements:

5.1 Overall policy guidance for the project would be provided by the OMVS High Commission in Dakar (Fig. 4).

5.2 Direction of field planning, training, operations, and construction for the project would be centered at the OMVS St. Louis headquarters in the hydrological branch, which already has a working nucleus.

5.3 The project chief would have a professional background in either hydrology or hydrogeology and would be a regular OMVS staff member.

5.4 Four technical assistant chiefs would be assigned on detached service to OMVS from appropriate technical agencies of member states. All these individuals should have technical background in either hydrology or hydrogeology.

5.5 The assistant chiefs would be in charge of (1) planning, and data compilation and analysis; (2) training of well observers and surveyors; (3) field supervision of well observers and surveyors and supervision in the field of data collection; (4) control and management of field equipment, vehicle maintenance, and in-house and contract construction activities.

5.6 Brief, short-term workshops and on-the-job training would be required intensively during the early stages of the project and intermittently thereafter.

5.7 Well observers and/or surveyors trained at and supervised from St. Louis could be stationed at St. Louis, Ross Bethio, Richard Toll, Guedé or Nianga, Aere Lao, Saldé, Matam, Semme, and Bakel; Rosso, Legcuiba, Bogué, Bababé, Kaédi, and Sivé; and Ambidedi and Kayes. It is now estimated that about 20 trained well observers and six surveyors would be needed for field data collection activities. The quality control of these activities would require frequent field inspections from St. Louis headquarters.

5.8 In-house construction crews of three to four men would be organized and trained at the local level to install shallow piezometers (less than 5 m deep) using soil augers or other hand-powered drilling equipment. Most shallow piezometers would be located in or near diked irrigation perimeters in the valley and in the delta. Approximately four crews would be required on a continuing basis for installation of new piezometers and replacement of damaged ones.

SUGGESTED ORGANIZATION OF THE GROUND-WATER INVESTIGATIONS PROJECT

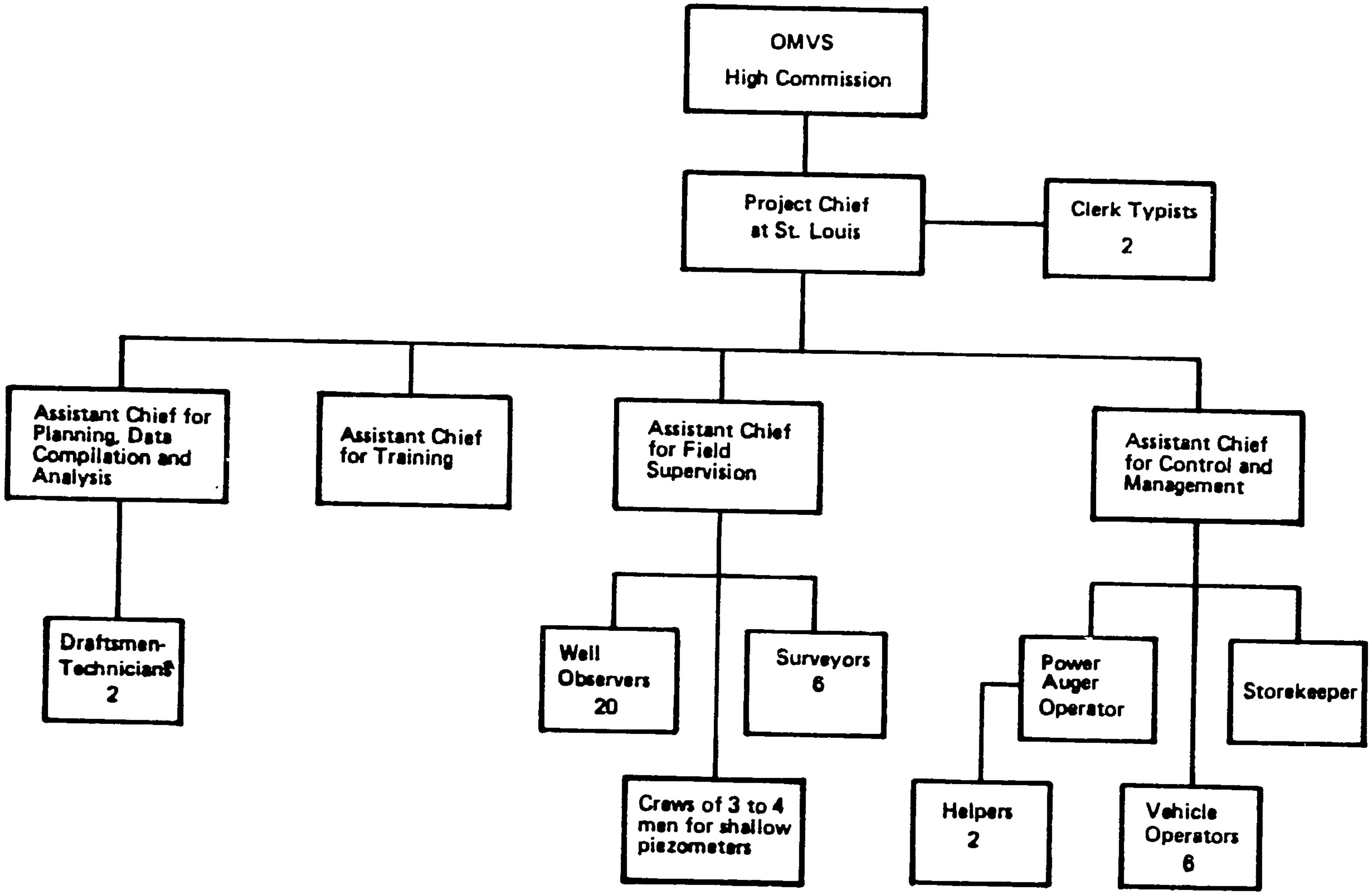

FIGURE 4

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5.9 For construction of piezometers of intermediate depth (5 to 30 m) an OMVS-controlled, truck-mounted power auger would be used. The crew would consist of a trained operator assisted by two helpers, all supervised by the assistant chief for control, management, and construction.

5.10 A contracted well-drilling company would be employed for construction of deeper piezometers (greater than 30 m) and for observation tubewells (forages).

5.11 The storekeeper, under supervision by the assistant chief for control, management, and construction, would be in charge of field equipment, hand drilling equipment, the stock of piezometer pipe, cutting and threading equipment, power auger, vehicles, etc., at St. Louis.

5.12 Two clerk-typists would work at OMVS staff headquarters in St. Louis and would report to the project chief.

5.13 Six vehicle operators and one power auger operator would be based at St. Louis under the assistant chief for control, management, and construction.

5.14 Two draftsmen-technicians would work at OMVS headquarters in St. Louis and report to the assistant chief for planning, and data compilation and analysis.

5.15 *Estimated personnel costs for individuals working under OMVS supervision on the project would be as follows:

No. of Positions	Type of Position	Yearly Cost (million FCFA)
1	Project chief	4.00
4	Asst. chief @ 3.0 million FCFA each	12.00
2	Clerk typist @ 1.04 million FCFA each	2.08
2	Draftsman-technician @ 1.04 million FCFA each	2.08
1	Storekeeper	1.40
1	Power auger operator	1.40
6	Instrument-level man @ 1.3 million FCFA each	7.80

No. of Positions	Type of Position	Yearly Cost (million FCFA)
6	Vehicle operator @ 0.78 million FCFA each	4.68
20	Well observer @ 0.65 million FCFA each	13.0
10	Unskilled workers for miscellaneous labor, including putting down piezometer holes @ 0.52 million FCFA each	5.2
	Personnel costs per year	53.64
5.16	*Costs for warehousing of equipment, vehicles, and supplies to be procured for OMVS is estimated @ 2.4 million FCFA per year	2.40
	Total costs per year	56.04

*Inflation factor not included in these estimates. Inflation currently is 20 to 25% per year.

5.17 Intermittent technical assistance to the project would be provided by short-term (TDY) specialists through international contracts with the donor agency. The types of services, the duration of such services, and the estimated costs, without consideration of the inflation factor, are given below.

No. of Man-Months	Type of Specialist	Estimated Cost ($US)
3	Water budget and salt balance analysis	$ 90,000
3	Water quality	$ 90,000
3	Ground-water hydraulics	$ 90,000
3	Mathematical modeling	$ 90,000
6	Miscellaneous	$180,000
		$540,000

The timing of these assignments would depend on the stage of development of the ground-water data compilation and collection activities., but probably no technical assistance would be needed until the middle or latter part of the project life.

6.0 Equipment, materials, contract construction, and vehicle requirements:

These can be broken down into four categories: technical equipment, materials, contract construction, and vehicles.

6.1 Items of technical equipment suggested for the project are as follows:

		Estimated Cost ($US)
10	Electric water-level tapes of M-scope or Soiltest types graduated in centimeters and meters with extra probes @ $152 per set	1,520
40	Cloth tapes graduated in centimeters with sampling bucket, combined with sounder for water-level measurement (local manufacture in Senegal) @ $50 each	2,000
10	Steel tapes, 30 m long, graduated in centimeters and meters, Lufkin black-face type w/reel @ $65 each	650
10	Steel tapes, 50 m long, graduated in centimeters and meters, Lufkin black-face type w/reel @ $110 each	1,100
10	Specific conductivity meters, portable, battery-operated for field water-quality measurements @ $400 each	4,000
10	Thermometers graduated in degrees Centigrade (°C) up to 100°C for water temperature measurements @ $15 each	150
5	Engineer's levels, dumpy-type with accessories, tripod and stadia rods for instrumental leveling @ $1,020 each	5,100
10	Compass, Brunton-type w/case @ $105 each .	1,050
10	Float-type water-level recorders with floats, pens, cable, gears, and counterweights. Leupold-Stevens type A-71 @ $1,500 per set	15,000
10	Hand earth post-hole augers, 4-inch-diameter with 10 1-meter extensions for each auger @ $1,400 per set	14,000

1	Power auger with helical, continuous spiral flights, in lengths of 1 meter, and good to depts of up to 30 m, truck-mounted on 1-ton pickup	30,000
2	Pipe cutting and threading sets for 3-inch pipe @ $500 per set.	1,000
	Miscellaneous hand tools, pipe wrenches, chain wrenches, etc.	1,500
2	Electric typewriters @ $500 each	1,000
2	Light tables for draftsmen @ $1,360 . . .	2,720
2	Sets of drafting equipment @ $300 each . .	600
	Technical equipment.	$81,390

6.2 Suggested materials required for the project are as follows:

Standard 3-inch (7.5-cm) galvanized pipe would be used for all piezometers. Assuming a cost of $1.44 per meter including requisite couplings and caps, the following would be required for the project.

No. of Installations	Average Depth (m)	Total (m)	Estimated Cost ($US)
Piezometer lines:			
80* (shallow)	6	480	692
80 (intermediate)	20	1,600	2,304
90** (deep)	40	3,600	5,184
Irrigated perimeters:			
225 (shallow)	6	1,350	1,944
225 (intermediate)	12	2,700	3,888
700		9,730	$14,012

* The piezometers would be slotted in the lower 3 to 5 m, encased in a nylon mesh bag tied around the slotted section, and gravel packed. (This type of construction has worked quite satisfactorily in past ground-water investigations.)

** To be constructed under contract; pipe provided to the drilling contractor.

Materials $14,012

6.3 Contract construction requirements suggested for the project are as follows:

10 Observation tubewells (forages): each 8 inches (20.4 cm) in diameter and 30 to 60 m deep and averaging 45 m deep for a total of 450 m of casing and hole. Each forage would be slotted in the lower 3 to 5 m; gravel packed; packers placed above the gravel; backfilled with clay in the annulus between the casing and the hole wall; cemented for 5 m below the land surface; and developed by compressed air.

Estimated cost per tubewell, including drilling, casing, and development by the contractor @ $10,000 each $100,000

90 Piezometers: each 3 inches (7.5 cm) in diameter and 30 to 60 m deep and averaging 40 m deep, drilled by contractor. Necessary 3-inch pipe, couplings, and caps would be provided from the project pipe stock. The contractor would drill the hole; install the pipe with the lower 3 to 5 m slotted; gravel pack; place packers above gravel; backfill with clay in the annulus between the casing and the hole wall; cement the first 5 m below land surface; and develop by compressed air.

Other than the piezometer pipe, the contractor would be expected to supply all materials and services.

Estimated cost per piezometer, without pipe, but including drilling and development by the contractor @ $2,500 each $225,000

Contractor services $325,000

6.4 Vehicle requirements for the project are suggested as follows:

6 Land-Rover type passenger vehicles for field transport of leveling crews, piezometer construction crews, and supervisory personnel @ $9,000 each. . . . . $ 54,000

1	Truck, 1 1/2 ton, for transport of pipe and supplies	$ 25,000
15	Motor bicycles (mobylettes) for transport of well observers @ $700 each	$ 10,500
	Spare parts @ 25% of the above costs . . .	$ 22,375
		$111,875

Fuel and maintenance of the Land Rovers and truck @ $200 per month per vehicle would be $1,400 per month, or $16,800 per year, or $84,000 during the 5-year project life, without an inflation factor.

6.5 Costs of shipping from Houston to Dakar and from Dakar to site are:

Ocean freight for pipe	$21,866
Ocean freight for vehicles	35,877
Miscellaneous	3,760
Shipping from Dakar to site	1,116
	$62,619

7.0 Time schedules for personnel, work components, and contract construction.

The suggested duration of the project would be 5 years. All required equipment, materials, and vehicles should be procured within the first 6 months of the project to permit work activities to proceed in an orderly manner. Suggested schedules for personnel (Fig. 5), work components, and contract contruction (Fig. 6) are shown in the following diagrams.

SUGGESTED TIME SCHEDULE FOR PERSONNEL

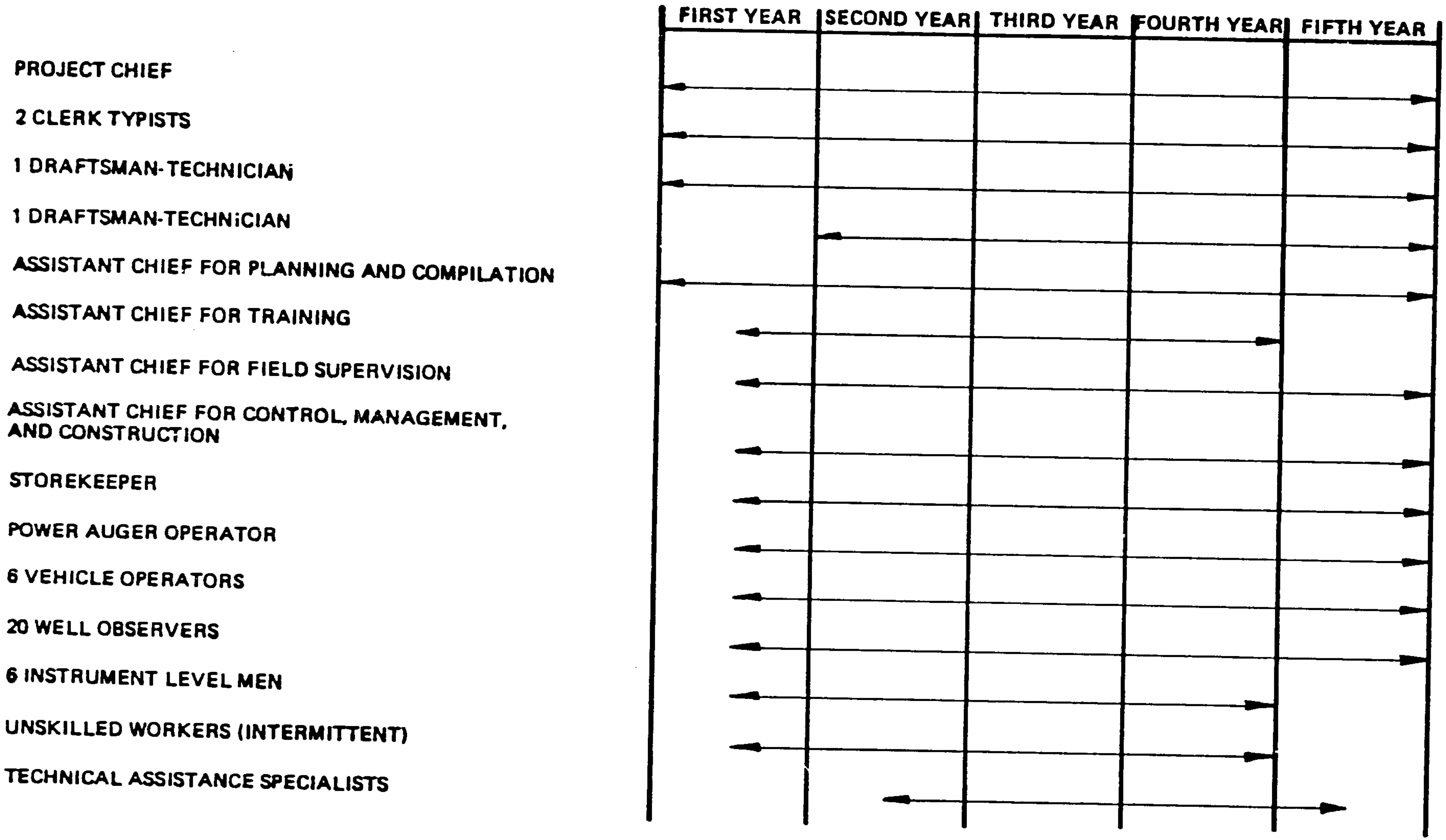

FIGURE 5

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SUGGESTED TIME SCHEDULE FOR WORK COMPONENTS AND CONTRACT CONSTRUCTION

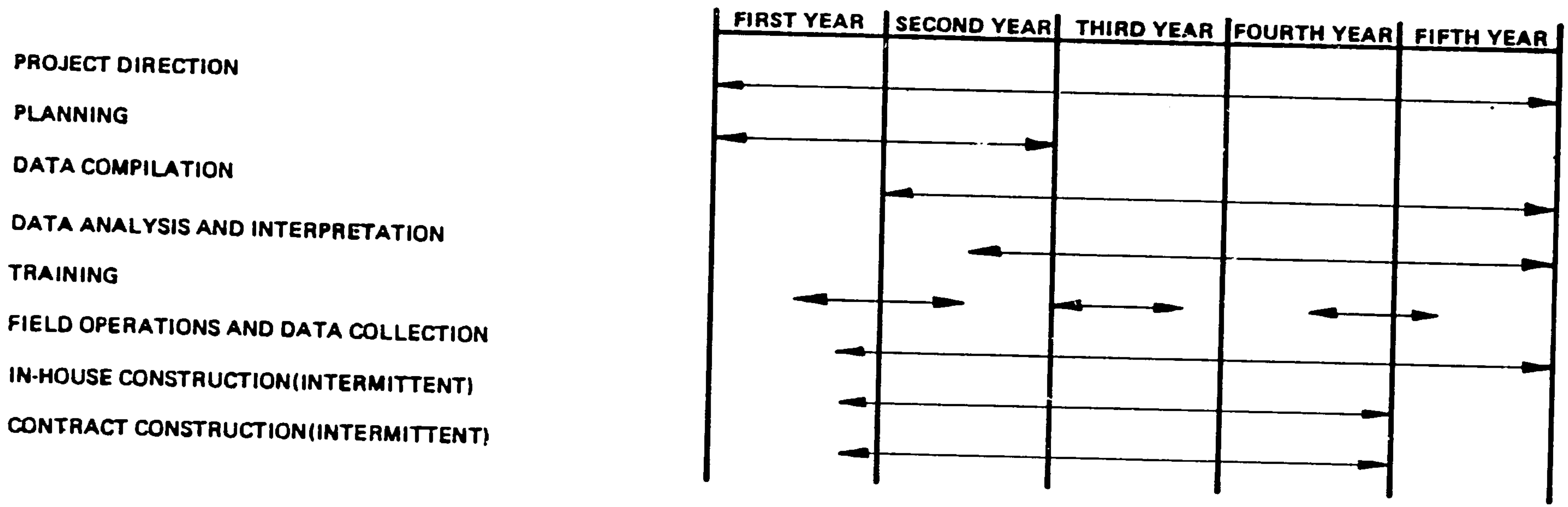

FIGURE 6

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Proposed Project for
Ground-Water Investigations in Support of the
OMVS Water Data Collection
and Analysis Program

Senegal River Basin

Mali, Mauritania, and Senegal
West Africa

Errata Sheet

Figure 1 - Change Descriptive References from "Sand" to "Sand or Gravel."

Page 29 - Change Columnar Total of Costs in U.S. Dollars from $1,156,277 to $1,218,896.

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On behalf of
The U.S. Agency for International Development

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8.0 Estimated overall costs for the 5-year project, without an inflation factor.*

Costs in U.S. Dollars:

International technical assistance personnel . .	$540,000
Equipment.	81,390
Materials.	14,012
Construction contracts	325,000
Vehicles	111,875
Fuel and maintenance of vehicles for 5 years . .	84,000
Shipping	62,619
	$1,156,277

FCFA Costs:

OMVS personnel @ 53.64 million FCFA per year for 5 years.	268.2 million FCFA
Warehousing for equipment, vehicles, and supplies @ 2.4 million FCFA per year for 5 years.	12.0 million FCFA
	280.2 million FCFA

* Inflation factor now estimated at 20 to 25%.

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