PN-ABD-634

GEDAREF WATER SUPPLY AND SOLID WASTE DISPOSAL FEASIBILITY STUDY - SUDAN

JANUARY 1983

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.
PASADENA, CALIFORNIA

COVER PHOTO: Digging a channel through rainy season siltation from the Showak water treatment plant intakes easterly to the shrunken flow of the Atbara River. Photo taken November 18, 1982 prior to the lowest river flow.

JAMES M. MONTGOMERY, CONSULTING ENGINEERS, INC.

250 North Madison Avenue, Pasadena, California 91101 / (213) 796-9141 or 681-4255

Cable Address: Montgomery Pasadena California Telex: 67-5420

LEE A. FRANCIS
Senior Vice President

January 27, 1983

Mr. Arthur Mudge
Mission Director
United States Agency for
International Development
49th Street, New Extension
Khartoum, Sudan

Subject: Feasibility Study Report
Gedaref Water Supply and
Solid Waste Improvement

Dear Mr. Mudge:

We are pleased to submit herewith ten (10) copies of our feasibility study. Two additional copies are being forwarded to AID, Washington, D.C. to the attention of Mr. Jack Snead.

This report contains our analysis of the technical, financial, economic, institutional and environmental aspects of providing improved water supply and solid waste disposal facilities to the general Gedaref-Showak service area and the refugee settlement of Tawawa.

The improvements recommended herein are essentially identical to those discussed with you and your staff on December 19, 1982, prior to our team's departure from Sudan. Some refinements in cost estimates have been made plus the escalation of U.S. and local currency component costs to conform with project implementation scheduling.

We really appreciated the assistance and cooperation offered by all members of the USAID Mission. We are looking forward to your comments on our report and the opportunity of providing further services in developing the Project Paper for this needed improvement program.

Very truly yours,

Lee A. Francis

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ABBREVIATIONS/ACRONYMS USED

A.I.D.	United States Agency of International Development, Washington, D.C.
CARE	Cooperative for American Relief Everywhere
C.R.S.	Commissioner for Refugees - Sudan
D.O.S.	Department of Statistics - Sudan
G.E.R.	Governorate for Eastern Region
G.O.S.	Government of Sudan
I.R.C.	International Rescue Committee
KPWC	Khartoum Province Water Corporation
M.E.M.	Ministry of Energy and Mining
M.O.I.	Ministry of Irrigation
N.A.W.	National Administration for Water
N.E.C.	National Electricity Corporation
P.E.W.C.	Public Electricity and Water Corporation
R.M.H.P.U.	Regional Minister for Housing and Public Utilities
R.W.A.	Rural Water Administration
S.S.U.	Sudan Socialist Union
UNHCR	United Nations High Commissioner for Refugees
U.S.A.I.D.	U.S. Agency for International Development - Dusan Mission

UNITS OF MEASURE

Abbreviations	Term Definition
BOD or BOD_5	biochemical oxygen demand, 5-Day, 20°C
°C	degrees celsius
cm	centimeters
cu.m.	cubic metres
dia.	diameter
g	gram
g/l	grams per litre
ha	hectares
HGL	hydraulic grade line
h	hours
HP	horesepower
kva	kilovolt amperes
kw	kilowatt
kwh	kilowatt-hours
km	kilometres
kv	kilovolt
lpcd	lires per capita per day
ls	litres per second
Ls.	Sudanese Pounds
m	metres
min	minute
MPN	most probably number (coliform organisms)
m^3/d	cubic metres per day
mg/l	milligrams per litre (equivalent to parts per million)
mm	millimetre
N.A.	not available
m/s	metres per second
mw	megawatt
No.	number
PPM	parts per million
PVC	polyvinyl chloride

Units of Measure
(Continued)

Abbreviations	Term Definition
Q	flow rate
SS	suspended solids
sec	seconds
TDH	total dynamic head
TDS	total dissolved solids
TP	treatment plant
v	velocity, of flow
o/o	parts per hundred (percent)

CHAPTER 1

INTRODUCTION

1.1 AUTHORIZATION

The study contained herein was contracted between the United States Agency for International Development (AID) and James M. Montgomery, Consulting Engineers, Inc. (JMM) by the execution of Work Order No. 1 on November 5, 1982. This was an instrument of the Indefinite Quantity Contract No. OTR-1406-I-00-1132-00 dated July 1, 1981 between AID and JMM.

Work Order No. 1 authorized the commencement of study activities on November 5, 1982 and established an estimated completion date of February 5, 1983 for submission of the draft final feasibility study report. This report constitutes this submittal requirement and is subject to review and comments by USAID, Sudan and AID, Washington, D.C.

1.2 SCOPE OF WORK

Appendix A presents the complete scope of work as contained in Work Order No. 1. The scope of the contractor's assignment was extensive in detail when compared with the completion timetable and manpower authorization.

Water supply problems in the Gedaref area of Sudan were found to be complex and serious due to the water source situation and the extensive nature of its service area. One high lift water pump transmitted treated river water to over 200,000 people through a single transmission line of 68.4 kilometres in length. Residents were receiving intermittant water supplies from this single system servicing a wide corridor in an area over 70 kilometres in length.

1.3 PURPOSE AND OBJECTIVES

The purpose of the study involved the following:

- Increase water production and improve existing water systems to satisfy water demands.
- Improve the adequacy and reliability of the solid waste disposal systems.

The objectives of the study included the following:

- Provide continuous potable water supplies to the service area population of the Gedaref-Showak system as forecasted at the end of calendar 1987.

- Provide water production to meet the projected demands at the end of 1987.
- Provide adequate potable water supplies to the refugee populations in the Tawawa settlement and those dispersed throughout the water service area.
- Develop institutional improvement recommendations required for efficient operation and maintenance of improved water systems.
- Develop financial programs to enable water supply operations to become a financially viable enterprise.
- Evaluate the economic and environmental impacts of investments in improved water supply.
- Develop recommended improvement alternatives that can be expeditiously implemented and that conform with presently available funding.
- Prepare improvement packages in sufficient detail to enable final design and tendering in an expeditious manner.
- Recommend programs to improve the collection and disposal of solid wastes within the water service area.

1.4 CONDUCT OF THE STUDY

The contractor fielded an initial study team of three specialists on November 9, 1982 for a six-week assignment in Sudan. The team consisted of a civil/sanitary engineer, a hydrogeologist and an institutional-financial analyst who served as team leader. Later, an environmental engineer joined the team for a 2-week assignment and an economist/demographer became involved for almost 4 weeks. Due to the short duration of the assignment in Sudan, the draft final feasibility report was completed at the contractor's home office in Pasadena. All team members visited the project area on several occasions and trips were made to New Halfa and the Eastern Regional Government headquarters at Kassala to discuss improvements and gather information.

Appendix C lists the various agencies and persons contacted during the team's assignment in Sudan. Basic data was often difficult to locate and occassionally required repeated trips between the province and capital city in order to finally locate certain essential information. All agencies and persons contacted were extremely helpful and cooperative in our attempts to acquire basic and important study information. The initial study team conducted exit briefings with USAID, Sudan personnel on December 19 and 20, 1982 and departed the country the following day.

CHAPTER 2

SUMMARY AND RECOMMENDATIONS

This is an abstract of the findings and recommendations contained in following chapters. Reference should be made to specific chapters for full background information and the rationale supporting our recommendations.

2.1 SUMMARY

The study team found that the water supply situation in the Gedaref-Showak service area was extremely serious and could lead to severe personal hardships and potentially dangerous reactions by the local population. Both the Sudanese people and the refugees from Ethiopia were affected by the water supply problems. The existing water system serves the villages of Showak, Er Rawashda, Umm Shegara, Al Abayo and Ghubeisha plus the Town of Gedaref. The refugee settlement at Tawawa indirectly receives its water supply from this system and from a highway construction well via water loads. The entire system is supplied by one pump and transmission line located at the water treatment plant on the Atbara River some 68.4 kilometres from the center of Gedaref.

Numerous problems plague the water supply facilities at the water treatment plant. The Atbara River recedes to the opposite bank and sometimes dries up completely. The rainy weather river flows are loaded with silt requiring cut-backs in treatment plant processing. The high lift supply pump is subject to frequent electric outages and has a history of frequent breakdowns. On October 25, 1982 the high lift pump motor broke down with a subsequent water outage lasting 3 days in a service area estimated to total 202,000 people. Just before the study team departed Sudan, the last operating electric motor driving the high lift pump failed again on December 17, 1982. The second pump motor was burned out and was stored in the pump house. The third motor was at the manufacturers in Vienna, Austria and was reportedly repaired and ready for shipment back to Sudan. These large electric motors weigh in the neighborhood of 4,000 kilograms each and are difficult to transport quickly. It is not known how long this latest water outage has lasted.

Emergency programs are currently under study to provide an immediate interim improvement to this water supply problem. The UNHCR has the availability of some emergency funding and the National Administration for Water (NAW) has submitted a corrective program estimated to cost U.S. $800,000 to UNHCR for consideration. Many recommendations in the NAW proposal have been reviewed in this study report and some of the improvements could negate certain recommended improvement costs set forth in Chapter 9 if they are properly engineered and installed. At the time this report was prepared, it was impossible to determine the status of actual approval and implementation of the emergency program or the beneficial impact it may have or ır proposed improvement program costs.

2.2 RECOMMENDATIONS

The following is a synopsis of our r ›mmendations contained in detail in following chapters.

2.2.1 Water System Improvement

To satisfy the projected w er demand at the end of 1987, the following improvements v ·e developed in accordance with planning criteria and fundir constraints:

	Late 1982 Prices
• Tawawa Supply and Othe mprovements	$ 359,700
• Abu Naga Well Field Imp ·ements	1,544,000
• Mixing and Chlorination ; Main Reservoir	13,000
• Atbara River Source Imp ·ements	905,000
• High Lift Transmission P ıping Improvements	350,000
• Showak Village Improven ıts	32,000
• Metering and Waste Cont l	432,000
• Other System Improveme s	50,000
• Operating Materials and uipment	90,000
• Training	15,000
Total	$ 3,790,700
Contingencies at 10%	379,100
Total - Late 1982 Cost	$ 4,169,800

These costs include the e ivalent local currency components. Costs are escalated to ti ; of construction and increased by other project implementat ı costs in Chapter 12. The total implementation costs are timated at U.S. $5,633,400. Local currency costs are also det ed in Chapter 12.

2.2.2 Solid Waste Disposal Impro ments

The investment in solid w :e disposal facilities was given low priority when compared wi the benefits and need of improving potable water supplies. A investment program costed at U.S. $118,800 was developed along with recommendations to strengthen and improve th organization and activities at the Gedaref Town Council le :l. Escalated and final costs of proposed solid waste hand ıg equipment are calculated to be $160,300.

2.2.3 Proposed Program Impleme ation

The recommended improve ents can start providing increased water supply by November, 1984 and should be fully operational by July or August 1985. Revenue programs are based upon this implementation scheduling. Figure 9-5 graphically depicts the project implementation plan.

The contractor has also provided recommendations for the methodology needed to satisfactorily complete full program implementation. This is contained in subsection 9.7.

2.2.4 Institutional Matters

Chapter 11 contains an evaluation of institutional capabilities and constraints and provides a number of recommendations for institutional improvement and strengthening. Of greatest impact is the need to clarify the present status of the urban water supply organizations and to provide technical support through some centralized agency or organization.

2.2.5 Financing and Economics

Chapter 12 sets forth a revenue plan to enable the water supply enterprise to become financially independent with water rate structures that are affordable to the people. Chapters 12 and 13 demonstrates the revenue requirement coverage that can be generated with the proposed revenue plan and its affect on the direct and indirect economic cost considerations.

2.2.6 Environmental Aspects

Chapter 14 contains an in depth evaluation of environmental aspects of the proposed water supply and solid waste disposal improvement program. Direct reference to this chapter should be made for the evaluation of, and conclusions about, the various environmental impacts.

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CHAPTER 3

DESCRIPTION OF THE PROJECT AREA

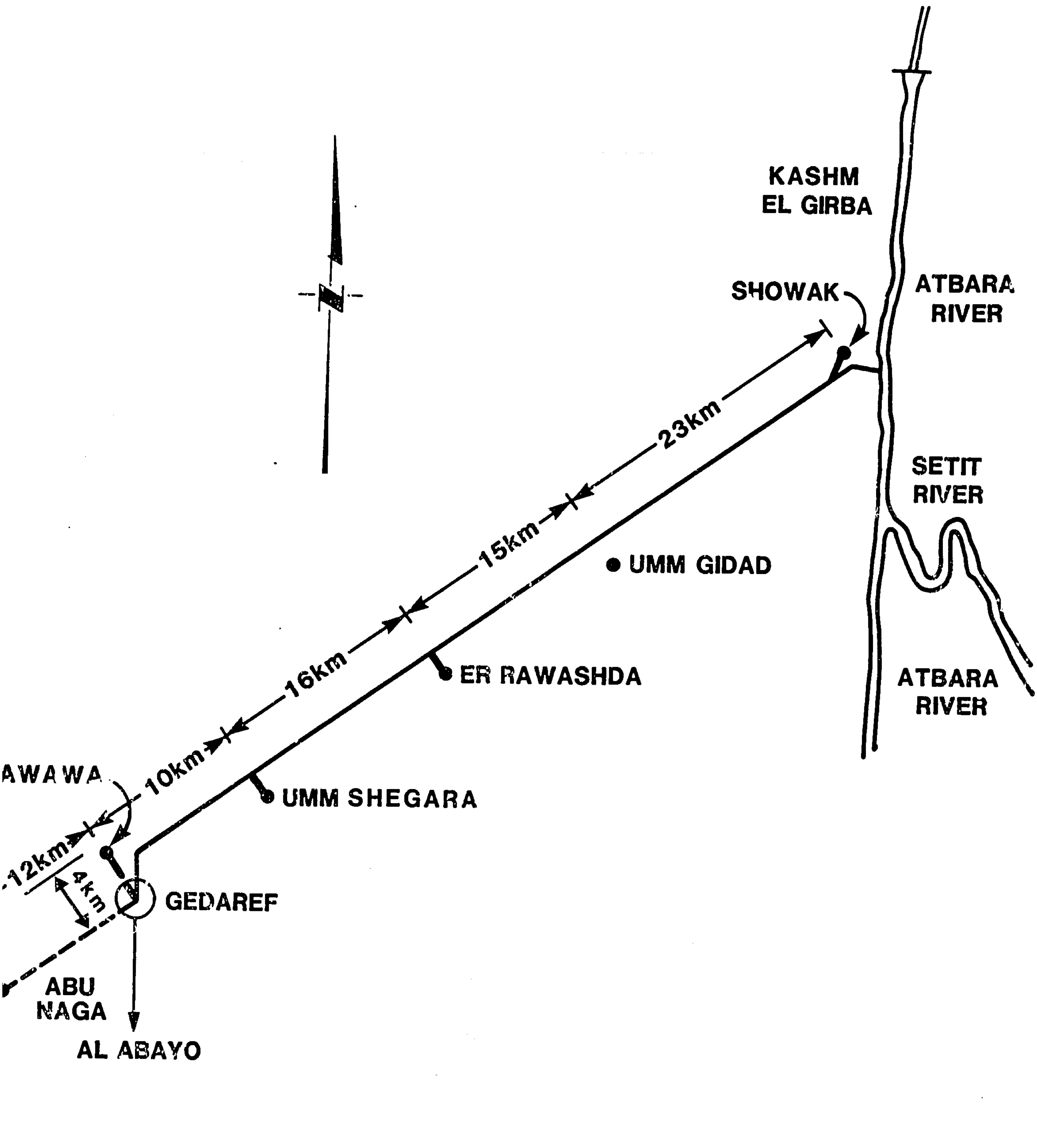
This Chapter presents a general overview of the project area as defined in the contractor's work order. Essentially, the project area is described as the existing urban areas within the Showak-Gedaref water distribution system that are presently receiving water supplies from this system and those areas included within the existing solid waste disposal service areas of the various town councils. The refugee settlement of Tawawa is included within the project area even though it presently does not receive water supplies directly from the Showak-Gedaref system. It is served through water loads hauled by water tank trucks, horse carts and donkey-transported water bags from Gedaref Town and Abu Naga. Areas outside the defined project area may be considered for locating water sources or disposal sites for solid wastes.

3.1 SERVICE AREA AND PHYSICAL SYSTEM

The project area centers around the town of Gedaref in the eastern Sudan providence of Kassala. Gedaref is located about 300 kilometres directly southeast of the Sudanese capital city of Khartoum. By road, the distance between the two cities is 421 kilometres.

The Gedaref water system serves an existing population of approximately 237,000 people, including an estimated 35,000 migrant workers whose residence is seasonal. These migrant workers are mostly located in the town of Gedaref, although a small percentage of them are scattered throughout the other towns and villages served by the system.

The present water supply source originates in the Atbara River near the town of Showak to the northeast of Gedaref. Near Showak, a water treatment plant was constructed in 1970 to utilize the surface waters of the Atbara River. The plant itself consists of intake facilities, a clarifier, three graded rapid sand filters, chlorination equipment and high lift transmission pumps. The high lift pumps convey the treated water through a 500 millimetre welded steel pipeline over a total distance of 68.4 kilometres terminating at a 9090 cubic metre reinforced concrete reservoir located on a small hill within the boundaries of the military compound at Gedaref. Along the transmission route, the town of Showak is served by a take-off point at kilometre 2.5, the village of Er Rawashda has a take-off point at kilometre 40.5 and the town of Umm Shegara is served at kilometre 56.5. Gedaref includes the villages of Al Abayo and Ghubeisha served by means of small booster pumps located within the distribution system. The refugee settlement of Tawawa receives hauled water from the Gedaref system. There is an elevational rise along the transmission line of 165 metres or 541 feet. Refer to Figure 3-1 for schematic details of existing service area.



GEDAREF WATER SUPPLY TRANSMISSION SYSTEM
SCHEMATIC OF EXISTING SYSTEMS
FIGURE 3-1

The towns of Gedaref and Showak have a rudimentary distribution system while the villages of Er Rawashda, Umm Shegara, Al Abayo and Ghubeisha have point source systems. The Al Abayo and Ghubeisha water supplies are further supplemented by shallow hand dug wells of questionable quality. The refugee settlement at Tawawa has a 25 cubic metre elevated steel tank, but the supply line from Gedaref to the tank has been disconnected.

Prior to the construction of the Showak water treatment plant, the town of Gedaref received all of its water supply from the Abu Naga well field located some 12 kilometres to the southwest of town. This well field consisted of 11 wells connected to the Gedaref distribution system by a 250 millimetre asbestos-cement main. After the Showak plant was commissioned, the Abu Naga wells were to be used as a stand-by, emergency source of supply. Through years of misuse and neglect, the overall system deteriorated and is not presently capable of supplying water directly to Gedaref. Two wells have been totally abandoned while several others have been filled in with rock and debris and are in need of rehabilitation. The lack of operation and maintenance has apparently caused the slotted casings in the few functional wells to become encrusted as evidenced by a very noticable drop in productivity between the original pump tests when the wells were first drilled and pump tests recently completed.

The upper layers of soil in the Gedaref area are locally referred to as "cotton soil." The top most 1.5 metres expand and contract greatly with the change in moisture content and this shifting of the soil has caused the 250 millimetre asbestos-cement main to rupture in several places, principally at the joints. At the time of our study, renovation of the Abu Naga supply system was ongoing but no water was reaching the Gedaref distribution system nor was the transmission main under repair.

3.2 POPULATION SERVED

The project service area currently contains an estimated 202,000 year-round population, 174,000 of which are located in the greater Gedaref area. The remaining 28,000 are located in Showak and the two villages of Er Rawashda and Umm Shegara north of Gedaref. The greater Gedaref area includes the villages of Ghubeisha and Al Abayo, the refugee camp at Tawawa and some scattered hut complexes near the town. At the present time, all of the service area inhabitants are assumed to be receiving water supplies either directly, or indirectly, from the existing Showak-Gedaref water supply system. No other significant water supply alternatives exist within the present service area. Approximately 28 open, shallow wells are scattered throughout the service area but most of these wells have been condemned by the local health officals.

Chapter 6 contains detailed calculations of the present populations within the service area.

3.3 ECONOMIC BASE

The major contributing factor in the Gedaref area economy is the agricultural production from farmland in the surrounding area. No other significant domestic or export industries exist there. Commercial activity is mainly oriented to service a population either linked primarily or secondarily to the local agricultural production. Production of processed foods, construction materials and warehousing of equipment is carried out only to satisfy local demand. Temporary fluctuations in population or permanent changes have been, in the recent past, related directly to the requirement for agricultural labor, or secondarily, to the service industry positions required to accommodate families whose incomes are derived from the agricultural activities. During the harvest season, which spans from November through April, large numbers of temporary laborers come to work in the Gedaref area. This influx increases requirements for support service activities within the local economy.

Much of the male population in the greater Gedaref area work in the fields surrounding the town, mainly devoted to the production and harvesting of dura (sorghum). Related activities in Gedaref include storage of dura in silos, and its processing to make bread for local consumption. The remainder of locally-based production industries include a salt packing facility, a candy processing facility, two soap manufacturing plants and a tile and brick plant. All of these industries manufacture products only for local consumption. Remaining activities in Gedaref include commerce, government employment and provision of services to the local population.

3.4 REFUGEE IMPACT

The greater Gedaref area and the Showak area contains significant numbers of refugees, either in designated settlements (as in Tawawa), or scattered among the local Sudanese population. The existance of these refugee settlements, and the recent growth of the refugee population through continued inmigration, has, along with growth from other sources, placed a strain on the provision of local goods and services. Among those services most affected by this increase in population are the provision of water supply, electricity, control of solid waste, schooling and medical facilities.

This situation has led to a potential for strained relations between the refugees and the local Sudanese population. Some local officials and many other local Sudanese residents believe the existence of large numbers of refugees in the Gedaref-Showak area (estimated to range from 20,000 to 40,000) causes shortages in water supplies, electricity and basic services which would otherwise not occur with only the indigenous population residing in the area. This problem has been exasperated by the "special aid programs" provided to the refugees in the Gedaref area.

The continued influx of refugees to the study area, with its current systems of finite supplies of water and electricity, could pose significant future problems. No accurate and confirmed figures are available for refugee inmigration to the study area. However, it is estimated that approximately 1,500 additional refugees have settled in Tawawa each year since 1979, and an additional undetermined, but significant, number has settled in the greater Gedaref area. Although future settlement in Tawawa is expected to diminish signficantly from its recent pace, continued inmigration in the remainder of the study area is a strong possibility. Although the extent and magnitude of such migration cannot be predicated, it is possible that it may be significant.

The political ramifications of the refugee situation described above have already been manifested in local government policy towards new projects affecting both groups of population. The amounts of water received by Tawawa from the Gedaref-Showak water system have been controlled. The pipeline which was built to connect Tawawa with the Gedaref-Showak system has been disconnected and remains out of use. In addition, government policy towards any new project designed to aid the refugees at Tawawa has been that it should also benefit the local non-refugee population. This political situation must be taken into consideration in the design of project alternatives, as it would impact the potential for administrative viability of the proposed improvement programs and the acceptance of the project by local officials and residents.

CHAPTER 4

EXISTING WATER SYSTEMS

The greater Gedaref water supply system serves the villages of Showak, Er Rawashda and Umm Shegara, plus the town of Gedaref, directly from the Showak-Gedaref river supply transmission system. The villages of Al Abayo and Ghubeisha receive water supply directly from the Gedaref Town distribution system. The Tawawa refugee settlement gets some water from the Gedaref area via water haulers. This service area contains an estimated 202,000 permanent residents (see Chapter 6).

This chapter sets forth our observations and evaluations of the existing operational water systems within the project study.

4.1 SOURCES OF SUPPLY

Water supply for the city of Gedaref is provided by two sources. These include treated surface water from the Atbara River and untreated ground water from the nubian sandstone. A brief description of the existing water supply intake facilities is provided in the following paragraphs. A more detailed discussion of the water resources is found in Chapter 7 and Appendix B.

4.1.1 Atbara River at Showak

The Gedaref water system intake facilities are located on the Atbara River at Showak some 64 kilometres (km) northeast of the city. The existing intake facilities were completed in 1971 and consist of a large concrete caisson constructed on the western bank of the river. The caisson is approximately 8 metres (m) in diameter by 20 m in depth and is designed with 3 sets of dual intake ports placed at different levels on the caisson wall to accommodate the wide range of river stage conditions. In the period between 1972 and 1982 over 7 m of silt has been deposited in the river adjacent to the intake facilities. This condition has resulted in the burial of the lower intake ports and the virtual abandonment of the original intake structure. The intake system in current use consists of centrifugal pumps placed near the bank of the river connected to two temporary intake pipes placed in the river channel. In order to maintain flow to the intake pipes during the dry winter months, a channel must be excavated across the mud flats to the eastern shore of the river channel. Water is then diverted to the intake pipes and pumped into the treatment plant facilities.

4.1.2 Abu Naga Well Field

Abu Naga well field was constructed in 1968 in an area approximately 13 km southwest of the city of Gedaref adjacent to the Sudan Railroad tracks. The well field consists of 11 boreholes constructed to depths ranging from 180 to 222 m below ground surface. The well field was operated from 1968 -1972, during which time it provided the principal source of water supply for the city of Gedaref. Although production records are not available, it is reported that the well field produced combined flows of up to 1,900 m^3 per day. When in operation, the wells pumped water to a storage tank and pump station located near the well field. From the storage tank, water was boosted through a 250 mm diameter pipeline some 12 km to the city. By 1972, when the Showak treatment plant and pumping station was completed, use of the Abu Naga well field was terminated. During the years that followed, well pumps and equipment from the generator and pumping station were removed. Following removal of the well pumps, vandalism occured and the wells were subsequently filled with stones and other miscellaneous debris.

In 1980, the UNHCR provided funds to the Rural Water Corporation (RWC) for a rehabilitation and redevelopment program of the Abu Naga well field. At the time of our field investigations, six wells had been redeveloped and tested for yield, drawdown and recovery. Three of the wells have been equipped with submersible pumps rated at about 22.7 m^3 per hour. Currently, the water from these wells is pumped to the Abu Naga storage tank where it is then distributed to local water vendors ("donkey boys"). No water can be pumped to the Gedaref distribution system. The actual volume of water being produced by these wells is currently unknown, however it is probably less than 100 cubic metres per day.

4.1.3 Tawawa Refugee Village

The refugee village at Tawawa is currently receiving water from two sources of supply. These sources include water from the Gedaref water system and ground water pumped from an isolated well located approximately 2 km southwest of the village. All water supply is hauled to Tawawa via mobile water containers. The well was originally drilled for use in construction of the Port Sudan Highway but has recently been redeveloped and equipped by the UNHCR for use at Tawawa. Actual ownership and rights to this well are under dispute. This well also taps ground water from the nubian sandstone.

4.2 TREATMENT FACILITIES

4.2.1 Showak Treatment Plant

The Showak water treatment plant is located on the west bank of the Atbara River, a distance of about 64 kilometres directly northeast of Gedaref. The initial stage of the plant was constructed in 1969-1970 with a planned capacity rated at 12,500 cubic metres per day. Treatment consists of an alum dosed sedimentation clarifier, graded rapid sand filtration and post chlorination.

The Showak treatment plant was originally designed as a four-stage project. The initial stage consisted of the intake structure, a clarifier, a three bank filter bed, a clearwell, chlorination facilities, automatic control systems, high lift supply pumps and a 500 mm transmission main to Gedaref. The second stage not yet constructed would double the clarifier and filtration capabilities. The third stage would parallel the existing transmission line and add another clarifier and three more filters and the forth stage would expand clairification and filtration capability. Each stage was purportedly designed to treat 12,500 cubic metres of raw river water per day. However, some questions remain as to whether the design considered an 18 hour or 24 hour operating day.

The design and feasibility study for the treatment plant was done internally by the Central Electricity and Water Corporation in Khartoum. The study team was unable to locate any of the design calculations or construction drawings generated for the project although the pressure profile for the 500 mm transmission line was located at the area Engineer's office in New Halfa.

The intake structure for the treatment plant is located on the west bank of the Atbara River. This structure is no longer in use due to the siltation of the river which has deposited over 7 metres of silt in front of the original intake ports over the past ten years. The present method of obtaining water from the river is by the use of two portable pumping units. One of the units is a Worthington Pump, having a rated capacity of 420 m^3/hr with a 27 metre total dynamic head. It is driven by a 415V, 3 phase Marelli motor having a 60 horsepower rating at 1450 rpm. The other pump is a Mather Platt type LONO 7/9 rated at 367 m^3/hr at 18 m TDH, driven by a 415V, 3 phase English Electric motor which is rated at 35 horsepower at 1450 rpm. These pumps are relatively small and are placed high on the river bank during flood stages. As the river recedes, the pumps are moved to the lower river bank levels. During the dry season, about 50 men are employed to manually dig channels through the silt in the river bed thus diverting what water remains in the river from its natural course on the east bank to the pumps on the west bank (see cover photo). These hand dug channels often reach a length of 150 metres, a width of 20 metres and a depth of up to five metres. In the past, when the river dried up completely, the pumps were moved to small ponds in the river bed in an attempt to obtain all the remaining surface water and maintain some water supply.

At the treatment plant, the raw water proceeds through a sedimentation clarifier where it is dosed with aluminum sulphate. The addition of lime was discontinued a year ago for lack of chemical supplies. The solutions of aluminum sulphate varies from 40 mg/l during the dry season to about 140 mg/l during the flood stages of the river when there is a very high silt content in the raw water. The six chemical feeders at the plant are broken and inoperative and all alum solutions are mixed by hand. The silt level has reached as high as 16 kilograms per cubic metre during the initial rushes of flood waters. The silt, which is clayey in nature, poses a problem during both the silt laden flood season and during the worst part of the dry season when the waters are agitated by workers digging the diversion channel.

The treatment plant sludge is continuously drawn off and returned to the Atbara River adjacent to the intake structure. The filters for the Showak treatment plant consist of three graded sand beds with approximate dimensions of 3 metres by 10 metres. No information was available as to the type of filter underdrains existing at these filters. Each filter was originally regulated by flow rate controllers. However, most of the plants pneumatic controls are non-functional and the filtration rates must be controlled manually. Like the clarification basin, the filters are freqently backwashed during the periods of heavy siltation.

After filtration, the water is disinfected by two Fisher-Porter, series 70-3400 solution feed gas chlorinators and is pumped from the clearwell to the transmission system. The two high lift service pumps are Worthingtons, type 6UZD1 rated at 420 m^3/hr with a 240 metre total dynamic head. These pumps are driven by Brown-Boveri type M SUK electric motors. The motors are 415 volt, 172 ampere, three phase, 50 hertz units rated for 460 kilowatts at 2950 rpm. Originally, there were two motors. A third was soon purchased as a standby unit. At the time of the contractor's visits, only one of the motors was in service. Of the other two, one was in Austria for rewinding and the other was at the pump house awaiting repairs. The high lift pumps are connected to the 500 mm Gedaref transmission main by 350 mm delivery pipes, each equipped with a gate valve and a check valve. One check valve is inoperative. There is a spring loaded check valve on the transmission main to protect against pressure surges.

The electric requirements for the treatment plant are supplied by the Kashm el Girba power generation station. The station itself had an original installed capacity of 15 MW provided by hydro power and supplemental diesel generation. The hydro generation varies with river flow and reservoir conditions and there is a constant shortage of spare parts for the diesel generators. Actual output from the station varies from 1 MW to 12 MW during the year. Records indicate that the Showak treatment plant receives between 0.5 MW (the minimum required) and 1.2 MW depending upon other electric demands.

Agriculture irrigation takes precedent over electrical power. Consequently, the hours of actual pumping from the treatment plant not only varies due to river silt load but also with the availability of electricity. Table 4.1 lists the hours of high lift pumping per month during 1980 and 1981. Although power is supposed to be available for 20 hours per day at the treatment plant, the average pump operation is a little over 16 hours per day on an annual basis. The worst months of power generation occur during the dry season when the impounding reservoir is at its lowest, indicating that the supplemental diesel generation capabilities of the power state are inadequate.

Table 4.2 shows the amount of water treated and pumped from the treatment plant. When constructed, the treatment plant was fully automated. The control room contains a large control panel which indicated plant conditions, recorded plant activity and had provision for remote control of valves and other plant equipment. Presently, all of the flow indicators and production recorders are inoperative and the only auxillary equipment functioning are the clarifier scrapers, the service pumps and one air compressor. The main reason for the general state of disrepair is the lack of spare parts and technical knowhow. The existing limited spare parts inventories consist of items originally supplied for the plant in 1970. Additional replacement parts have been requisitioned but never received. Purportedly, requests for parts were regularly sent to the head office in Khartoum. However, shortage of foreign currency has evidently blocked the ordering of needed spare parts.

4.2.2 Chlorination at the Main Reservoir

Chlorination at the 9,090 m^3 reservoir in Gedaref was accomplished by means of a Fisher-Porter gas chlorinator and two small booster pumps used to create sufficient back pressure for proper operation. The chlorination equipment was housed in a separate building approximately 50 metres from the main reservoir and the chlorine was introduced into the 500 mm transmission line just prior to the connection to the reservoir.

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TABLE 4.1

**SHOWAK TREATMENT PLANT
TRANSMISSION PUMPING HOURS**

Year	1980		1981	
	Monthly Operating Hours	Average Daily Hours	Monthly Operating Hours	Average Daily Hours
January	528	17.0	557	18.0
February	495	17.7	474	16.9
March	493	15.9	559	18.0
April	479	16.0	430	14.3
May	534	17.2	510	16.5
June	503	16.8	413	13.8
July	349	11.3	343	11.1
August	440	14.2	354	11.4
September	485	16.2	501	16.7
October	543	17.5	606	19.5
November	530	17.7	592	19.7
December	574	18.5	562	18.1
Total	5953	16.3[a]	5901	16.2[a]

a

Annual average pumping hours per day

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TABLE 4.2

SHOWAK TREATED WATER PRODUCTION

Month	Treated Water Pumped per month (in 1,000 m^3)	Daily Average (in m^3)
Aug 81	160.3	5,171
Sept	263.3	8,777
Oct	263.4	8,497
Nov	257.2	8,573
Dec	264.5	8,532
Jan 82	256.1	8,261
Feb	140.9	8,604
Mar	141.9	4,577
Apr	248.7	8,290
May	249.7	8,055
June	350.5	1,168
July	212.8	6,865
Aug	177.6	5,729
Average	229.8 Monthly	7,743 Daily

Note: Per PEWC reports - quantities are unmetered and estimated.

Unfortunately, an electrical fire developed in the control panel at the chlorine building in August, 1982 that partially destroyed the electrical connection, controls and chlorinator. The fire caused a chlorine gas leak that totally destroyed all equipment housed in the building and heavily corroded the 68 kilogram chlorine cylinders. As of the time of the contractor's field visits, the facilities had not been renovated or replaced. A cylinder mounted Capital Controls Advance chlorinator has been since ordered as a replacement. No additional chlorination of the treated water from Showak was being carried out. An analysis of the distribution system water revealed no free chlorine residual.

4.3 TRANSMISSION AND PUMPING

4.3.1 Showak Boosters

The Showak water treatment plant has two separate boosting systems. One system boosts the treated water from the clearwell to the village of Showak while the other directs the water through the 500 mm steel transmission line to Gedaref. The small booster pump for the village of Showak was a Harland IM4A, 16, powered by an English Electric type CMX motor capable of producing 40 Hp at 1485 rpm. This pumping unit is no longer in service and some question remains as to whether the motor burned out or the pump failed. The supply for the village of Showak is currently being drawn off the Gedaref transmission main through a blow off at a point some 2.5 kilometres distant from the plant. Although this practice provides the needed water, it is not energy efficient. The original pumping unit should be replaced.

The other booster pumps for the Gedaref line were mentioned in Section 4.2.1 as a major component of the treatment plant facilities. The motors for those pumps were supplied by Brown-Boveri of Milan, Italy and were commissioned on December 22, 1970. These motors frequently break down with one of the main problems being the brush lifting devices on the slip rings.

Due to the frequent breakdowns of the motors, technicians from Brown-Boveri visited the treatment plant and noted that the motors were overheating and operating near the heat limits of their insulating materials. They also pointed out excess vibration due to coupling and base mounting defects, faulty switchgear and damaged electric cables. On one occasion, when flooding of the station was imminent, the cables from the control system were simply cut so the motor could be removed. The control system was eventually spliced back together with electrician's tape but was never properly repaired.

Brown-Boveri listed the main problems at the plant as being 1) poor engineering design, 2) insufficient electric power and 3) inadequate maintenance. They recommended replacing the low voltage, high speed motors with high voltage (11 KVA), low speed (1,000 rpm), squirrel cage motors with a 1000:3200 gear box to bring them up to pump speed. These would require new controls.

4.3.2 Gedaref 500 mm Transmission Line

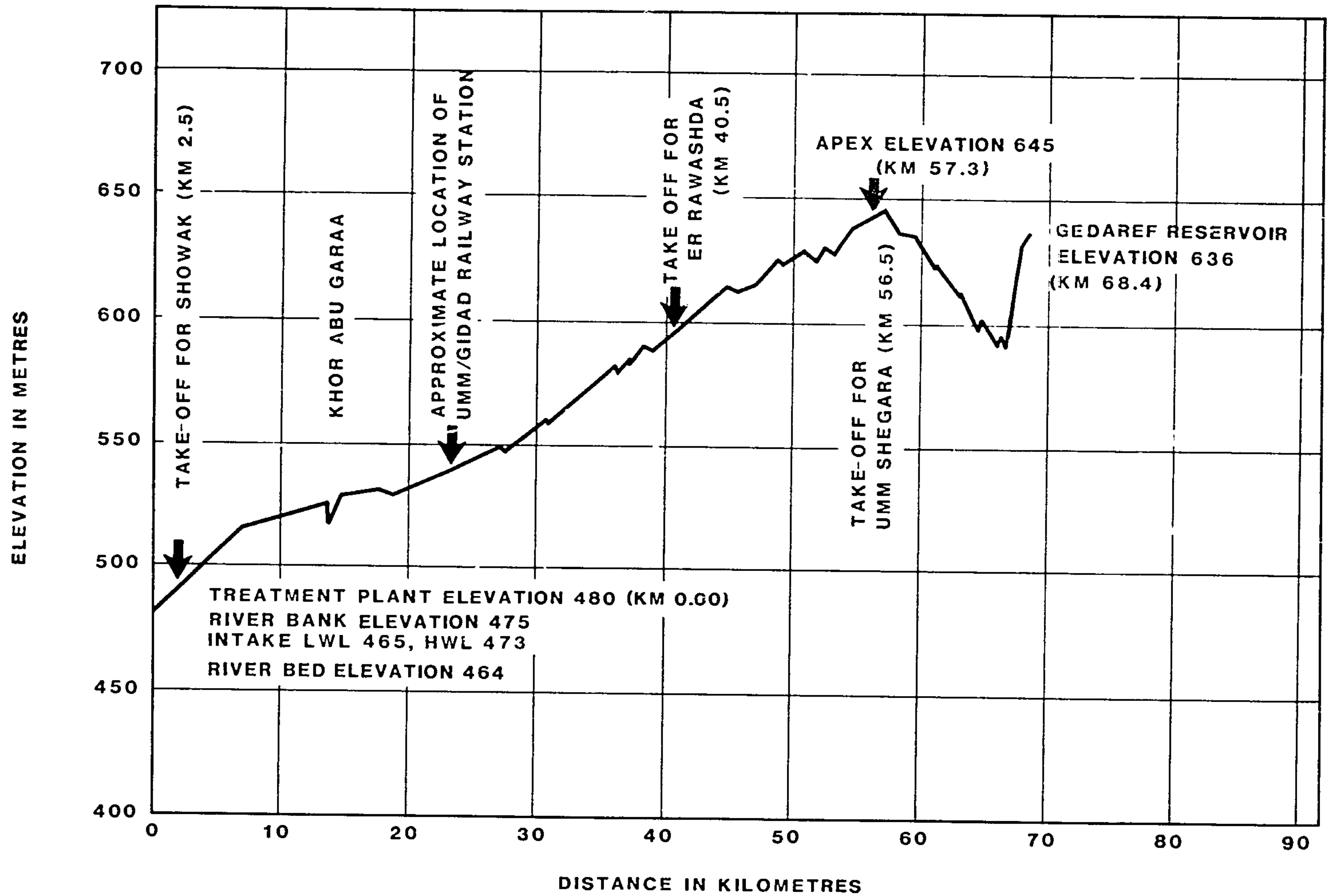
The treated water from Showak plant is conveyed to the main reservoir in Gedaref by means of a 500 mm bitumastic lined and coated steel transmission line. The line originates at the plant at an elevation of 480 metres and traverses a total distance of 68.4 kilometres to dischage in the reservoir at an elevation of 636 metres. The high point along the profile occurs at kilometre 57.3 where the apex reaches an elevation of 645 metres. Figure 4-1 is a profile of the transmission line.

Along the line, 20 air relief valves and 22 wash out valves are installed. It has been reported that the nomadic tribesmen occassionally destroy the air relief valves to provide water for their uses and the cattle and camel herds. The transmission main was constructed 60 metres to the south of the Sudan Railway line and the train crews are continually on the look-out for water losses on their Showak to Gedaref run. The PEWC maintains a repair crew whose only assignment is to monitor and maintain the transmission line.

At the main reservoir in Gedaref, there is evidence that some of the bitumastic lining of the pipe has sloughed off which will affect the pipe's carrying capacity. The extent of the deterioration is not known and a complete pressure profile of the line should be developed.

4.3.3 The Abu Naga Boosters

The Abu Naga well field supply was discontinued when the Showak system became operative. The well field has an 11 kva electric service with individual step down transformers at some well heads. The eleven wells previously pumped to the five 27 m^3 Braithwaite steel tanks near the pump house. The pump house itself is approximately 20 m by 12 m constructed with steel frames, brick walls and a corregated steel roof. The water was pumped into the Gedaref distribution system through a 250 mm asbestos cement pipe approximately 12 kilometres in length. No information is available about the original pumping equipment at this location. A second booster station along the 25 mm pipe had a 27 m^3 storage tank and a 100 mm Harland pump driven by a 40 Hp electric motor. This pumping equipment has since been removed.



500 MM SHOWAK-GEDAREF TRANSMISSION MAIN PROFILE

FIGURE 4-21

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There is some unused equipment still in the Abu Naga pump house but it's operational condition is unknown. Of the major equipment, there is one pump and two motors which might be functional. The pump is a Polish made WODZISLAVSKEZAMADY pump manufactured in 1964. It's identification plate states that it is capable of 200 m^3/hr at 112 m TDH when operating at 1450 rpm. Of the two motors, one is a SILNIK type SCUF, 240/415v, 184/106A, 3 phase 50 hertz, pulling 62 kw at 1455 rpm. It has a power factor of .89 and was manufactured in 1964. The other motor is an English Electric type C326. It is rated at 40 Hp, 1465 rpm, 3 phase, 50 hertz, 415 v and 55A. It is not known if either of these motors has been previously used or how effective they were.

4.3.4 Abu Naga 250 mm Transmission Main

The Abu Naga transmission line is asbestos cement pipe. Prior to the construction of the Showak water treatment plant, this line conveyed all of the Abu Naga water to Gedaref. Since Showak supply commenced, the line has not been maintained. There are several visible breaks in the line, particularly at the joints, and an indeterminate number of other cracks and ruptures which will not be located until the line is pressurized. The condition of the air relief valves and isolation valves has not been established. There is no information on the pipe's alignment or depth profile on record.

4.4 STORAGE FACILITIES

4.4.1 Main Reservoir

The foundations for the main 9090 m^3 reinforced concrete reservoir in Gedaref were laid in 1969. The tank is physically located in the Gedaref military reservation about 25 metres above the average town elevation. The reservoir was constructed as a two section storage unit so that either side may be independently dropped out of service for repairs or cleaning. Each side has approximate dimensions of 18 metres by 50 metres. Both halves of the reservoir are connected through gallery piping to equalize the water levels when maintenance is not required. The gallery piping also provides an off-take for the common water level indicator. There is a maximum side water level in the reservoir of 5 metres and an hourly log of reservoir levels is maintained by the operators.

Operation of the reservoir consists of opening or closing the valve to the distribution system. The distribution line is valved off when the water level in the reservoir drops to 1.5 metres of depth. This practice insures a certain amount of water for the following day in the event of a power outage, major line break or problems at the treatment plant. The actual length of

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time that water is delivered to the distribution system varies due to the demand and tank recovery. Figure 4-2 shows the recorded reservoir levels for the period of November 6, 1982 to November 17, 1982.

4.4.2 Abu Naga Tank

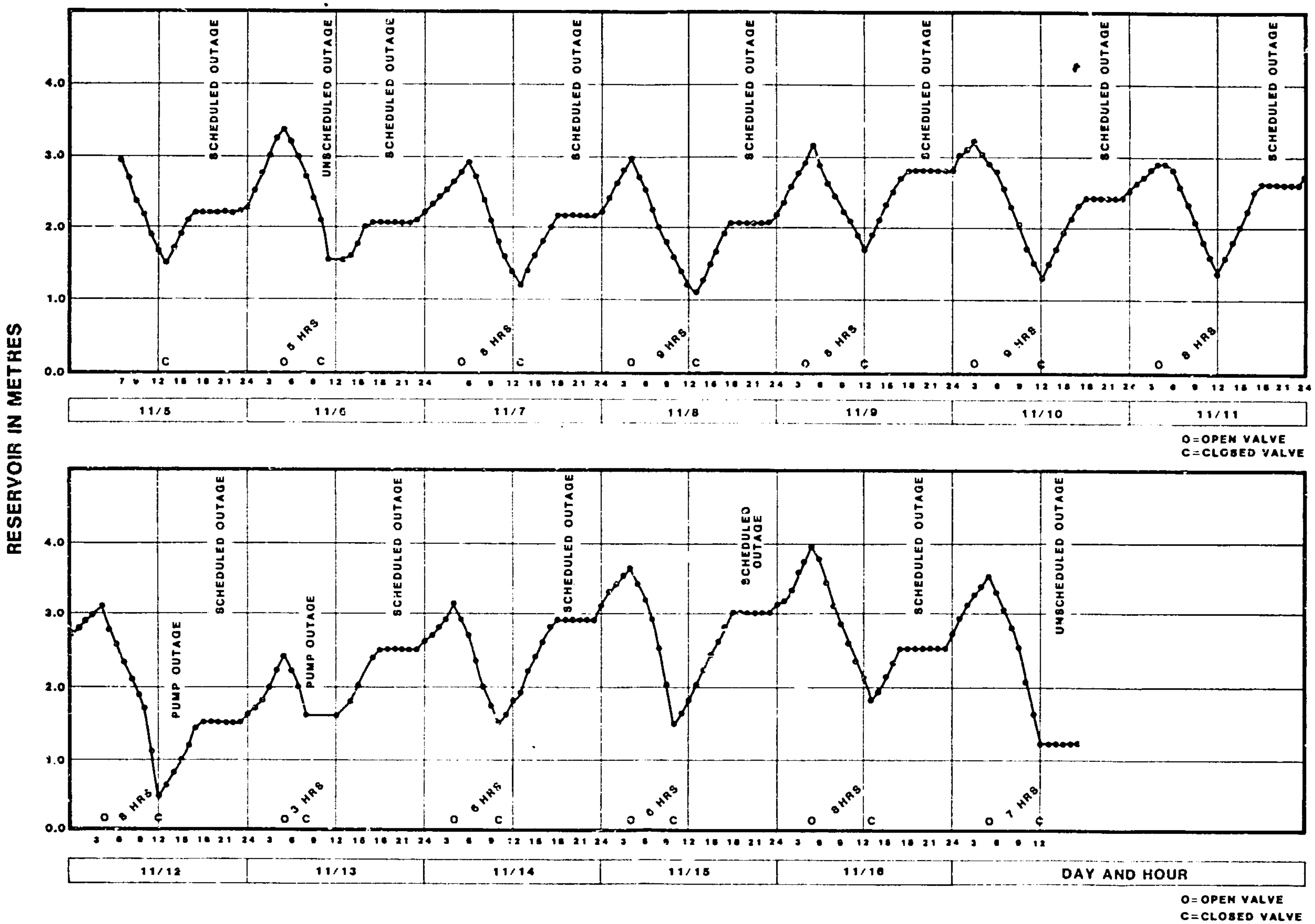
The five 27 m^3 Braithwaite steel tanks at the Abu Naga pump house have a bottom elevation of 4.5 metres above ground level. Due to the lack of water from the well field, it is not known if these tanks are still completely water-tight and serviceable. Some yard piping must be repaired if the tanks are to be used in the future.

4.4.3 Tawawa Tank

The elevated steel Braithwaite tank at the Tawawa refugee settlement has dimensions of 3 metres per side. This 27 m^3 tank is elevated 10 metres above ground level and is further elevated another 15 metres above the center of town by virtue of its location on the side of a large hill. The tank is not currently connected to any supply source although there is an 100 mm galvanized steel line connecting to the Gedaref distribution system. The line has been severed and plugged. If reconnected, however, the Tawawa tank can be filled by gravity from Gedaref when there is ample water supply. With the limited supply at Gedaref, the distribution lines are not pressurized long enough to serve Tawawa. The local water officials have recommended that the residents of Tawawa fund the construction of an intermediate storage reservoir and purchase a booster pump to obtain a predetermined amount of daily supply from Gedaref during water service hours.

4.4.4. Tanks at Showak, Er Rawashda and Umm Shegara

Elevated steel Braithwaite tanks have also been erected in the villages of Showak, Er Rawashda and Umm Shegara. The tanks vary slightly in elevation and each has a capacity of about 50 m^3. They are filled from the top and require operators to open and close the supply valves. The tank at Showak is the only one of the three that has deteriorated to the point where there is substantial leakage along its bottom edges. The tanks at Er Rawashda and Umm Shegara draw off the Showak-Gedaref transmission line through connections made at blow-off valves. The supply lines are metered to determine the useage for each village. The Showak tank would normally be filled from the treatment plant but is presently connected to the same transmission line because of pumping equipment failure at the plant.



RECORDED RESERVOIR LEVELS
IN 9090 m^3 GEDAREF TANK
NOV. 5 THRU NOV. 16, 1982
TANK OVERFLOW ELEVATION -5.0 METRES
FIGURE 4-2

4.4.5 Fire Protection Tanks

In the Town of Gedaref, there are additional elevated steel tanks which are used expressly for fire protection. These tanks are generally placed near the fire stations and in a few, select locations where fire hazards are the greatest (such as in neighborhoods comprised of the native grass huts). The tanks are filled from the distribution system without benefit of separate lines from the main storage reservoir.

4.5 DISTRIBUTION SYSTEM

4.5.1 Description

The distribution networks for the villages served by the Gedaref water supply system generally consist of small 50 and 100 mm lines extending from the individual storage tanks to the standpipes. There are very few individual connections in these villages with the exception of Showak. The Town of Gedaref has a fairly extensive, although incomplete, distribution network. Due to the lack of available information, the locations of the water lines and their sizes was reconstructed based on the memories of some PEWC maintenance and construction personnel. The resultant map of the system is shown on Figure 4-3.

4.5.2 Location and Size of Mains

The map in Figure 4-3 shows the location and sizes of the lines in the Gedaref distribution network. As far as could be determined, there is a total of 83,825 metres of various diameter pipe in the system which is composed mainly of asbestos cement and galvanized steel pipe. Polybutylene pipe has been used in the 50 mm sizes.

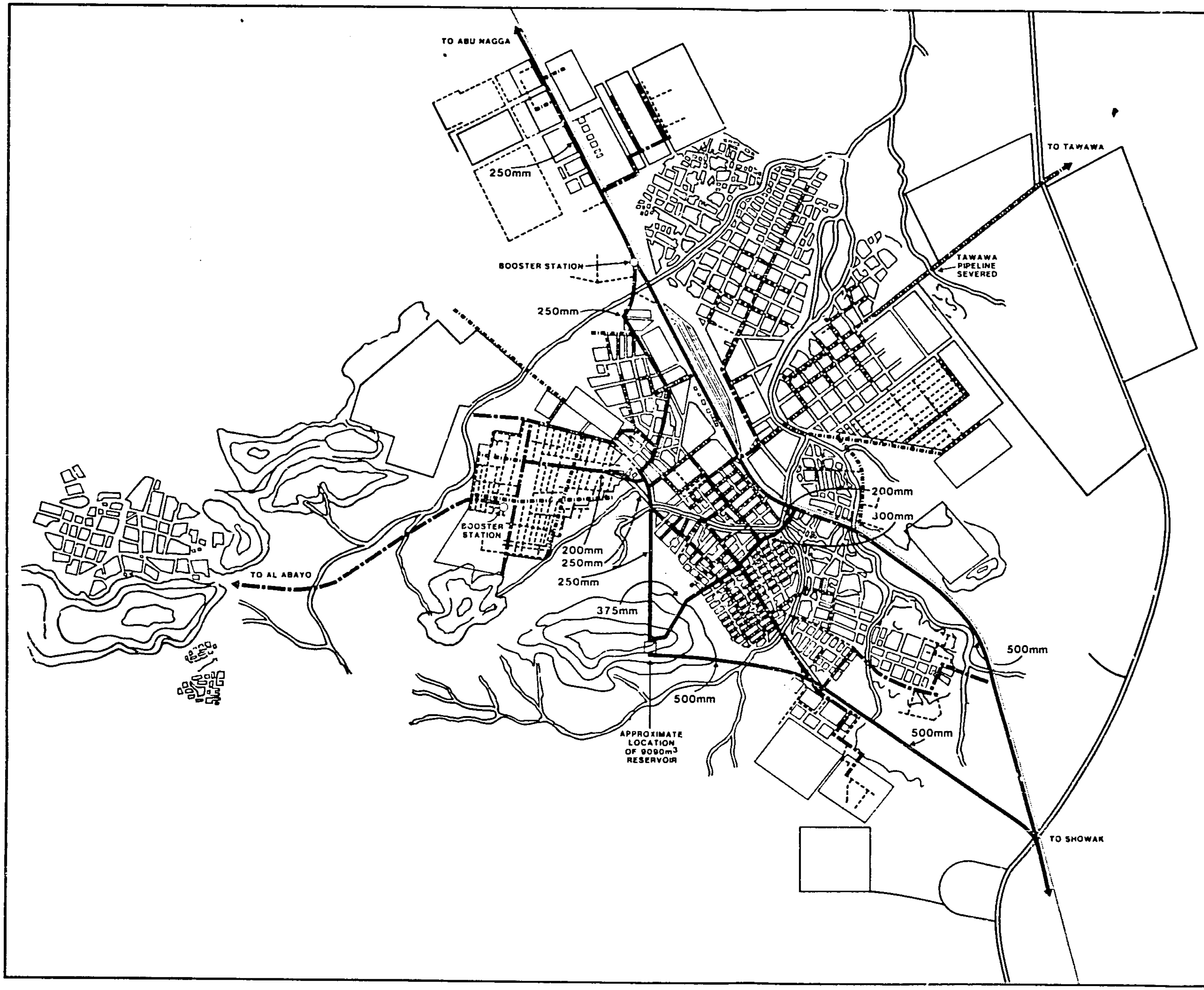
There are 44,745 metres of 50 mm pipe which represents over 53% of the total network. There are 18,410 metres of 100 mm pipe and 14,070 metres of 150 mm pipe. The 200 mm, 250 mm, 300 mm and 375 mm diameter pipe totals 6,600 metres in length.

The 250 mm pipe, which is 4,380 metres in length, is actually a portion of the transmission line from the Abu Naga well field. There are so many taps and connections to this main that it must be considered a distribution line as it approaches the outskirts of town.

4.5.3 Valves and Appurtenances

The valving scheme for the Gedaref distribution network is reported to be quite extensive. The location and condition of the valves, however, was not verified due to time constraints and the

2H



LEGEND

PIPE SIZES

- 50MM
- 75MM AND 100MM
- 150MM
- LARGER SIZES (AS NOTED)

DISTRIBUTION SYSTEM - GEDAREF AREA WATER SUPPLY

SCALE 1:10,000

FIGURE 4 - 3

lack of valve boxes and location maps. The valves at the main reservoir show evidence of leaking around the packing glands. No standing water was noted in the streets that could have been attributed to leaky valves or broken lines. The stock yard at the Public Electricity and Water Corporation contained a few 100 mm and 150 mm valves and a few repair parts such as valve bonnets, gates and stems. Other fitting in various sizes were also available. These items included companion flanges, couplings, bends, crosses, tees, service saddles and underground fire hydrants. The exact quantities of the various inventories was not determined. A moderate supply of asbestos cement pipe of smaller diameter was in storage but no galvanized steel pipe was available in stores.

4.5.4 Service Connections

There are approximately 6000 service connections in the Gedaref water system. From conversations with PEWC personnel, the number of public standpipes totals 39. The balance of the service connections are mostly multiple use services with some individual house connections. The majority of these connections are 25 mm galvanized steel pipe with spigots although some establishments have internal piping. There are also a few 50 mm and 100 mm connections to the system. Among these larger users are the Mechanized Farming Corporation and the grain storage elevator complex.

4.5.5 Physical Conditions of the System

In general, the Gedaref distribution system appears to be in good servicable condition. Samples of pipe material recovered by repair and maintenance crews showed little evidence of external corrosion or internal tuberculation. With the exeption of some badly leaking faucets, no breaks in the distribution network were noted. The reason that few breaks are evident could be attributed to the short duration of water supply to the town and the dryness of the soil.

4.6 METERING, RATES AND REVENUE

Information concerning meters, tariffs and water revenues was developed from available information at the PEWC Water Engineer's headquarters in Gedaref and the Chief Engineer's area office at New Halfa. A random selection of 10.6 percent of the active customer accounts was also analyzed to determine average consumption, large users, inoperative water meters and estimating techniques. Basic information regarding the number of services by customer class and an inventory of larger service meters was not available in sufficient accuracy to justify inclusion in this report. Sections in this report dealing with breakdowns of customer classes and details on larger service connections are estimated based upon past experience and information about similar urban water systems in developing countries.

4.6.1 Water Meters and Services

a) Active Services: The latest available information established the total installed water meters at 5,985 on September 1, 1982. It is estimated that 120 of these services were inactive, making the active metered connections equal to 5,865. During the 12-month period ended September 1, total service connections increased by 473 for an annual increase of 8.6%. In December, over 100 new service applications were pending and paid by applicants but were not yet installed.

A random analysis of 10.6% of the active service connections revealed that 50.4% of the installed meters were broken or inoperative during the previous 6 months, or longer. The sampling indicated that 49.6% of the meters were still registering consumption at the customer's service line.

b) Description of Water Meters: Over 93% of the installed water meters provide domestic, or residential, service. The inside diameters (meter inlet/outlet) range from 1/4-inch to 3/4-inch including 1/2-inch and 5/8 by 3/4 inch sizes.

Installed meters include mostly positive displacement types along with single-jet turbine meters. All meters observed in the water system were the gear-operated registration style requiring shop repairs and parts inventories. Predominate manufacturers are Kent and Leeds, both from the United Kingdom. No stocks of new water meters were on hand at the Gedaref headquarters. Applicants for new water service connections must purchase a satisfactory water meter from local plumbing supply merchants in Gedaref Town or elsewhere.

c) Meter Maintenance: The PEWC office compound in Gedaref contains a very small meter maintenance shop and a staff of six emloyees assigned meter repair duties. The workshop contains a few hand tools but no meter cleaning equipment or meter test benches. Several small reconditioned meters were observed in the meter shop along with a large box of used meter parts and partially disassembled meters. No inventory of new meter parts was available for repair purposes. The random sampling of active service connections revealed that additional customer meters were being reclassified from operative to inoperative status every month so that the 50.4% inoperative factor will continuously increase into the immediate and near future. It can be assumed that customers receiving estimated water bills due to inoperative meters will not be very careful in their use and wastage of available supplies.

4.6.2 Water Rates and Other Charges

The water rates applied in the Gedaref system are some of the highest in the urban centers of Sudan. Only Port Sudan is reported to have the same rates. The other 3 urban water systems in the Eastern Region, located at Kashm el Girba, New Halfa and Kassala, have rates 37% lower than Gedaref for a monthly usage of 20 m^3. Existing rates are as follows:

	Monthly Minimum Charge	Allowance Under Minimum	Unit Cost Over Minimum
Gedaref System	Ls. 2.00	10 m^3	Ls. 0.26 m^3
Kashm el Girba, New Halfa & Kassala	Ls. 2.00	15 m^3	Ls. 0.175 m^3

The project planning criteria of 50 lpcd for the average residential use would put many customers within the minimum allowances shown above and, therefore, they would receive identical bills of Ls. 2.00 in all four systems.

Other established charges in the Gedaref system include Ls. 60.00 for a new domestic service connection, Ls. 6.00 as a security deposit and Ls. 2.00 for reestablishing service after disconnection. The applicant for a new service connection must provide the meter, pipe and fittings and the Ls. 60.00 charge is levied to cover only the service line installation labor costs. The system currently realizes a profit from this fee arrangement since actual installation costs would average only about Ls. 25.00.

4.6.3 Water Revenues

a) Meter Reading and Billing: Meters are read, or estimated, each month and bills are prepared at the office for delivery by the meter reader on his reading route the following month. Cash flow suffers from this 30-day delay in presenting bills. Meter readers travel to their routes and read meters by foot or by bicycle. Meters readers travel to Showak village via the local bus service. Presently, there are 14 meter readers under the supervision of a Senior Meter Reader. Water meters are visited monthly although many meters are installed inside of property walls and fences and access to reading is often impossible because the reader cannot gain entry to the property. Assuming over

50% of the meters are inoperative, each meter reader has only 214 meters to read each month. This equates to about 9 per work day - a very small work load. Added to this work load, however, are an equivalent of about 9 additional readings of electric service meters, many of which are on the same premises as the water meters. The electricity services in the Gedaref area serve approximately 3,000 customers.

The water bill is prepared and posted in customer ledger books that contain unpaid balances and current receivable balances. Electric service bills and payments are also entered into these ledgers. Revenue is reported on the accrual basis, that is when billed and not when paid.

b) Analysis of Customer Accounts: The 10.6% random sampling indicated that many services are serving multiple families and that the average monthly consumption for functioning metered accounts is 23.7 m^3 and the average consumption on estimated accounts with inoperative meters is 17.6 m^3 monthly. Based on the operating meters and the planning criteria of 35-50 lpcd, each average service provides water to 3.4 families. This assumes an average of 5.2 people per family.

c) Estimated Revenue Losses: The results of the account sampling indicated consumption estimates averaging 17.6 m^3 per month for unmetered accounts. Assuming that customers with inoperative meters are using at least the same volume of water as those with working meters, an extrapolation of data results in the conclusion that at least 13% of the water revenues are lost due to inoperative meters. This would obviously be a larger loss because of the uncontrolled usage by the unmetered customers.

d) Collection Efficiency: It was not possible to acquire an accurate total of unpaid water bills (accounts receivable) or an ageing analysis of the oustanding receivables. However, an analysis was made of billings versus payments during the period of January 1, 1982 to May 1, 1982 and this indicated that 29.4% of the billing amounts were uncollected for a collection ratio of only 70.6%. Some of these accounts were governmental establishments who have a history of sporadic payment or of not paying at all. Services were being disconnected after arrears accumulated for more than three months but obvious exceptions were allowed to this collection enforcement program. If the 4-month analysis is representative of year-round conditions, a major income loss exists due to unpaid water accounts.

4.7 UNACCOUNTED FOR WATER

Based upon the monthly water production and consumption billing reports of PEWC in Gedaref, the loss between estimated water production and billings for metered or estimated consumption was 23.1% in fiscal year 1981-1982 and 40.1% in fiscal year 1980-1981. A variance of this magnitude is extremely unusual and could be caused by major system leakages over long periods of time in 1980-81 or by inaccurate production or consumption data. A water loss factor of 15% is usually considered acceptable in the water supply industry. The two-year average water loss of 31.6% is too high but may even be understated due to inaccurate water production estimates or inflated consumption data.

The major cause of high water loss should be attributed to the more than 50% of customers without operating water meters. Unmetered usage in developing countries often exceeds metered, or controlled, usage by 100% to 300%. Water system leakage does not appear to be significant as observation throughout the service area uncovered few apparent leak situations. However, many cases of water wastage were observed. These were ususally faucets running full open and unattended. Often, the open taps were being used to irrigate trees, shrubs and ornamental plants and excessive watering was evident. The practice of leaving faucets wide open is also caused by the intermittant nature of the water supply. Water starts flowing through distribution pipes around 5:45 in the morning until late morning hours when it is valved off at the main reservoir. Customers tend to leave faucets open all night so they can see or hear the renewed flows in early morning and also start to fill water containers left under the spigots. This situation is especially applicable to those customers with inoperative water meters. This outright wastage is estimated to consume at least 25% of the water produced at the Showak water treatment plant. The wastage also impacts the electric power cost of pumping water from Showak. This power cost represents 35% of the water system operating expense. A 25% reduction in wastage would provide an equal amount of water for additional residential uses or could reduce power costs by about Ls. 45,000 per year (the salaries of 20 higher paid PEWC employees). Universal metering or extemely constricted water service lines are the only practical solution to this water wastage problem.

4.8 QUALITY OF WATER SUPPLY SOURCES

4.8.1 Atbara River Source

Limited water quality data is available for the Atbara River, however, the water is generally considered suitable for domestic water supply purposes. The Atbara carries a very high silt load throughout much of the year. Suspended solids average approximately 6,000 milligrams per litre (mg/l) and may reach as much at 16,000 mg/l during high river flow conditions. Raw river water samples collected for analysis during the winter low

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flow conditions contained a total dissolved solids (TDS) content of 320 mg/l and a total hardness (as $CaCO_3$) of 155 mg/l. Although this water is slightly alkaline and hard, it meets the World Health Organization (WHO) Guidelines for Drinking Water Quality (Table B.3). The river water also contains a fluoride concentration of 0.5 mg/l which provides natural floridation to the inhabitants to Gedaref. The quality of water sampled from the treatment plant and Gedaref distribution system shows similar characteristics to that of the raw water. Through the addition of alum and rapid sand filtration much of the turbidity of the raw water is removed during the treatment process and small changes in pH, total dissolved solids, total hardness and alkalinity result.

4.8.2 Abu Naga Source

In general, ground water from the Abu Naga well field is considered to be good quality and suitable for domestic water supply purposes. Total dissolved solids of the Abu Naga ground water range from 440 to 540 mg/l and total hardness (as $CaCO_3$) ranges from 170 to 316 mg/l. Although samples are not available for each of the eleven wells located at the Abu Naga well field, analyses of wells 1 through 6 indicate that the water meets the WHO Drinking Water Quality Guidelines.

4.8.3 Tawawa Well Source

During February 1982, the UNHCR conducted a one week pump test of the Tawawa water supply well. Water samples were taken at the outset and completion of the pump test and submitted to the Ministry of Health in Khartoum for chemical analysis. The results indicate the quality of water is marginal and exceeds WHO Drinking Water Quality Guidelines in several constituents. The two samples showed that total mineral content increased with time of pumping. At the completion of the test, TDS reached 1,320 mg/l and total hardness (as $CaCO_3$) was 615 mg/l. In addition, fluoride concentration was 2.1 mg/l. The water produced from the well also has a distinct hydrogen sulfide (H_2S) or rotten egg odor. While the water from the Tawawa well exceeds WHO Drinking Water Quality Guidelines, it is currently the only dependable supply source available for the village and, therefore, is being used by local residents.

4.9 SYSTEM DEFICIENCIES

4.9.1 Source

As described in Section 4.1.1, the original intake structure at the Atbara River intake facilities has been abandoned due to heavy accumulations of silt and mud. Due to the high silt deposition, continual excavation is required during the low flow season to divert water from the eastern bank of the river to the intake

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pipes on the western shore. Additional deficiencies include the extremely low flows during the winter dry season and the high turbidity levels of the river water.

At the Abu Naga well field, the current source deficiencies are associated with the need to redevelop and rehabilitate the remaining wells to maximize yield and well efficiency. At the Tawawa water supply well, the principal deficiency results from the unsuitable ground water quality characteristics at that location, the lack of a source to distribution system connection and the dispute over water use at the existing well.

4.9.2 Treatment

The system deficiencies at the Showak treatment plant are numerous. The problem with the silt content of the Atbara River causes one of the major problems at the plant, overloading the clarifier and filtration facilities especially during the flood season. The filter beds should be cleaned out and the sand thoroughly washed, regraded and replaced. The underdrain system should also be completely inspected and repaired if necessary. The chemicals used, alumnimum sulphate and chlorine are sometimes in short supply and difficult to obtain, forcing the operators to cut back on the necessary dosages or eliminating them entirely until new supplies are obtained.

The dry dosing units are non-functional, requiring the chemical solutions to be mixed by hand. Only one air compressor at the plant is operational, decreasing the air scouring capabilities for the filter backwash operations.

Almost all of the plant's chart recorders, gauges and monitoring equipment is unuseable due to lack of ink, burned out drive units, lack of spare parts, etc. The main control panel needs repair and maintenance to function in an automatic mode, as designed. The plant's pneumatic system must also be repaired for the rate controllers on the filters to operate properly.

The main venturi meter on the Gedaref 500 mm transmission main needs to be replaced in order to acurately determine the quantity of water actually pumped toward Gedaref. Pressure gauges should be installed to check pumping heads and indicate problems along the transmission lines, including major breaks and accummulations of sediment. Currently, plant production and output is estimated from the rated capacities of the pump units without the benefits of pump curves and pressure heads. The entire electrical system for the plant must be completely revamped. The internal wiring was never properly repaired after being flood damaged and some of the control panels are not fully functional. Again, one of the biggest problems is to get spare parts, relays, microswitches and other electronic components.

Communication facilities between the production plant and the main reservoir in Gedaref need to be restablished. With only one high lift service pump operating, there isn't too much of a problem. However, if two pumps were running with uninterrupted power and there is sufficient raw water, there is a potential that the main reservoir could be overfilled. There is no way for the operator to signal the plant to cut back or shut off the pumps.

The lack of reliable power is another deficiency. Electric is not supplied to the plant on a 24 hour basis and there are problems with voltage and frequency fluctuations. Quite often, one phase of the three phase power is lost, causing extensive damage to the motors and plant equipment.

4.9.3 Transmission and Pumping

The transmission line from the Abu Naga well field is broken in several places. This asbestos cement line has to be repaired and pressure tested before it can be placed back in service.

The 500 mm transmission main from Showak to Gedaref cannot accommodate much more than the 12,500 m^3 per day that it is designed for. The wash out valves should be exercised to blow-off any accummulations of silt and debris in the line. All of the air relief valves must be checked to make sure they are in proper working order. Ideally, the transmission main should be relined if it could be taken out of service for a long enough period.

The pumping facilities utilize low voltage, high speed motors which are very tempermental. With the unreliable power supply plus sudden power cuts without warning, these motors frequently break down. Spare parts for the motors, such as brush lifting devices, are not readily available. The service pumps are operating at high heads, often as much as 244 metres (800 feet or 346 psi), which approaches the safe operating limits of the transmission line. Preferably, the whole pumping scheme should be changed to incorporate booster pumps in the transmission main which would lower the pressure heads on the main. Communications would also have to be established between any booster station, the treatment plant and the main reservoir in Gedaref. New control panels must be installed to protect the motors from the power fluctuations.

4.9.4. Storage

Storage of water is adequate at the main reservoir but storage capacities must be increased at Tawawa. The Showak storage tank is severely leaking and must be replaced. The storage tanks at Abu Naga must be filled, tested and repaired if necessary before they can be used.

4.9.5 Distribution

Compared to advanced water systems in developed countries, the Gedaref water distribtion system is inadequate with many dead ends, low pressure and undersized lines. Compared to most systems in developing countries, however, the Gedaref distribution network is fairly extensive. The deficiencies here are the inability, through the existing valving scheme, to isolate one section of the town or another. The relatively low pressure is the best that can be expected, given the physical layout of the system components. Increasing distribution pressure would require additional boosting facilities from the main reservoir which would be an unnecessary luxury at this point in time.

The distribution should be extended to serve those areas which do not presently have local standpipes, requiring the residents to fetch their water from several blocks away or to have the water brought to them by water vendors. The dead ends will eventually have to be looped to prevent stagnation. It is felt that these are problem areas which the water district personnel can rectify in due course of time.

The distribution networks of Showak, Er Rawashda and Umm Shegara are little more than point sources with water supplied to standpipes from an elevated storage tank. In these towns there is also a lack of pressure since the storage tanks are elevated approximately 10 metres above ground level.

In Tawawa, the existing distribution system appears to be one line from the storage tank to a point source consisting of five spigots on an exposed line. There was no water going into the system, preventing any further determination of the system conditions. Most of the water available is brought in by trucks and donkey carts and is therefore very expensive.

4.9.6 Metering and Waste Control

The condition of installed customer water meters is deteriorating each month. Presently, over one-half of the service connections are equipped with inoperative meters. This situation directly affects the level of operating revenues, control over excessive water use and wastage, and the quantity of water available to the service area population for essential sanitation and health purposes.

The PEWC has no stocks of new water meters nor does it have an inventory of new meter replacement parts. Meter maintenance equipment and workshop facilities are entirely unsatisfactory to maintain the existing installed meters.

The proposed improvement program will be capable of satisfying projected demands through the end of the year 1987 only if usage and wastage can be effectively controlled. Metering, coupled with realistic water tariffs, has a proven history of effective water waste abatement.

4.9.7 Operation and Maintenance

Water system O&M suffers similar shortcomings that deter proper water meter maintenance. Inventories of essential mechanical and electrical spare parts are almost nonexistant as are stocks of repair materials for service lines, distribution mains, valves and appurtenances. Parts, supplies and fittings are often improvised from available raw materials by inventive craftsman on the PEWC payroll. System operations are hampered by the lack of communication systems covering the 70 km long service area and between pumping plants and electric power sources at Kashm el Girba. Transportation facilities are also inadequate for providing timely response to emergency situations.

The present staffing level at PEWC appears to be adequate but several key, supervisory positions have remained vacant for many months even though budgetary approval has been granted. Lack of adequate supervisory organization and control causes an evident loss of productivity and direction for the large numbers of lower echelon workers. Present employees have not had benefit of any special training in the operation and maintenance of water supply systems.

Chapter 11 presents a more detailed analysis of O&M problems together with recommended institutional improvements.

CHAPTER 5

SOCIAL CONSIDERATIONS

The social aspects of the potential project-related improvements are considered in this analysis to provide input for the assessment of project benefits. The potential benefits connected with improvement of water quality, increase in quantity, provision of full-time water service and improvement of solid waste management are related to potential improvements in public health, personal hygiene and potential reduction in the cost of water to populations currently serviced through independent water purveyors. The extent and distribution of potential benefits to particular groups of beneficiaries can only be assessed if the following factors are considered:

- Social structure of different groups of beneficiary population;
- attitudes towards water use;
- access by different groups to potential benefits;
- political climate with regard to potential project acceptance and participation; and
- abilities of the existing systems and organizations to accommodate activities required by the project.

5.1 POTENTIAL BENEFICIARIES

The population of the study area includes several distinct groups of potential project beneficiaries. They include local Sudanese residents, resident refugees (mostly Ethiopian and some West African), landowners, renters, men, women, children, higher income groups, low income groups, and temporary residents. There is also at least one group of people who could potentially have their conditions worsened by the project. Those are the private water vendors.

According to Sudanese local government unofficial policy, the intended beneficiaries of the project would be all residents of the study area including both refugees and non-refugees. The improvement of water service to Tawawa would alleviate a burden on the entire system. In addition, changes to improve service in Tawawa could require improvements in the overall system. We have estimated that residents of Tawawa are currently receiving about 10 litres per capita day (lpcd) of water from the Gedaref-Showak system from private vendors and from four water tank trucks serving the village. Collection of rainwater during the rainy season is thought to be minimal. This level of water consumption is below the minimum standard for developing countries to provide minimal water for drinking, cooking, and personel hygiene. (Minimum of 20 to 25 lpcd established by A.I.D. Policy Paper entitled "Domestic Water and Sanitation" dated May, 1982).

It is estimated that water consumption in the town of Gedaref, served both by taps to individual homes and by point sources, averages approximately 25 lpcd over the year, ranging from an average of 17 lpcd during June to July to 32 lpcd during higher water production months. The difference between these figures and the planning criteria average of 44 lpcd consumption, which might otherwise be expected with continuous service, is due to the intermittent and restricted hours of water service availability. Improvements to the system resulting in improved water quality would benefit the populations of Gedaref, Tawawa, Al Abayo, Ghubeisha, Er Rawashda, Umm Shegara and Showak (e.g. the entire study area population). Improvements resulting in increased water quantity availability may not, however, benefit the populations of Er Rawashda, Umm Shegara and Showak, as those areas could presently have uninterrupted service directly off the Showak-Gedaref transmission line. Improvements in system reliability would reduce the frequency of prolonged shut-offs. During past shut-off periods, residents of the Gedaref area chose to drink from local shallow wells (containing water with a high salts and bacteria content), haffirs and other sources of poor quality drinking water to supplement their supplies of stored water. Connection to the water system would produce a benefit of less time spent on water transport and storage providing increased productive time to families.

5.2 BENEFIT PARTICIPATION BY VARIOUS GROUPS

Both men and women would benefit and participate in activities related to project implementation. The role of women in the participation of benefits would be significant due to their duties related to storage of water, cooking, washing of clothes, washing of children and general cleaning of the domicile area. Benefits related to an increase in water supply, quality and continuous delivery would mainly impact the areas of improved health for all users of the system water and increased convenience, especially for residents who currently receive water from vendors or public water faucets. Health improvement likely to result from improved water quality could include reduction in the incidence of some communicable waterborne diseases, as discussed in more detail in Chapter 14. To the extent that supplemental water carried to the domicile is carried mainly by women and children, these groups would thereby benefit. Children could possibly have less interference with school work. The proposed improvements should benefit all users of the system water with slightly more benefits for those currently receiving less water on an infrequent basis (e.g. residents of Tawawa and people who receive water at public water faucets and supplement their water supplies from local shallow wells and haffirs).

In terms of employment enhancement, implementation of this project would produce only temporary employment related to con .uction of project facilities in the Gedaref-Showak area. These positions would mostly be open to, or accepted by, men only. Possibly up to 100 temporary, non-skilled, positions could be available for up to 12 to 18 months. No significant manpower increase is projected for the operation and maintenance of the improved system except in the areas of meter reading, billing and collecting.

Other participation in project activities would be confined to the beneficiary population's roles as users of the system and beneficiaries of system improvements. The intended beneficiaries would likely provide extremely high rates of participation, if not complete participation, as populations receiving water from vendors are presently paying more per litre for water than they would be paying if connected to the system. Some residents at Tawawa are presently paying Ls. 2.00 for a gasoline drum full of water from water truck vendors which equates to Ls. 8.00 per cubic meter versus the water system rates of Ls. 0.26 per cubic meter. Their cost is 32 times greater than costs to customers of the water system.

5.3 SOCIO-CULTURAL CONTEXT

No current or recent data are available on family incomes of residents of the study area. A generalized discussion and analysis of ability to pay is provided in Chapters 12 and 13. It is possible, however, to form some conclusions with regard to relative income levels. The population of the refugee village of Tawawa, and scattered population of refugees living within Gedaref are likely to have lower incomes than the farmers, merchants and other permanent long-term residents of the Gedaref area. The villages of Umm Shegara and Er Rawashda are believed to have high concentrations of relatively high-income families and higher mean family incomes than Gedaref, Showak, and the other villages within the study area.

No political or organizational problems should impede the implementation of this project based on the projects' proposed benefits. However, the same organizational deficiencies which currently exist and act to impede efficiency of current operations and protection of water system investments would also apply to changes brought about through project implementation. This topic is discussed in detail in Chapter 11.

As previously mentioned, the role of women in storage and use of domestic water is highly significant. This is especially true in terms of public health and domestic hygiene related to the storage and handling of water. As implementation of this project would likely increase the amount of water available to a significant number of families within the study area, an education program for women regarding proper domestic water use and improved hygiene should be introduced in conjunction with the project implementation.

CHAPTER 6

POPULATION AND WATER DEMAND PROJECTIONS

The sizing of project facilities requires the projection of future system water demands which, in turn, requires the projection of future population totals that would be serviced by the Showak-Gedaref water system. This chapter develops those future projections. In addition, the locational distribution of planned project facilities is dependent upon future changes in land use within the project service area. Therefore, an examination of existing land uses and a projection of expected future changes in land use conditions is included in this analysis.

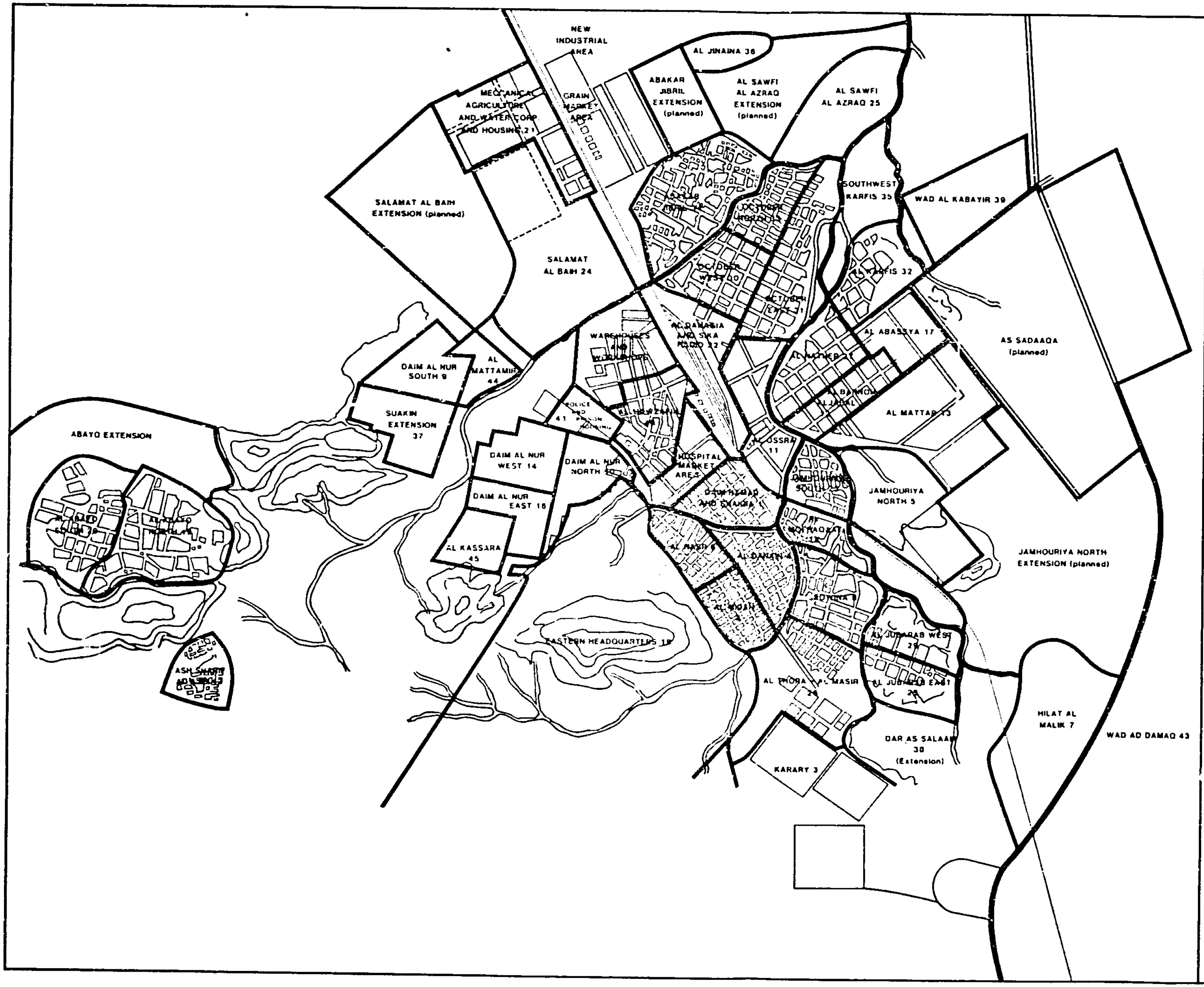
6.1 SERVICE AREA LAND USES

The project service area includes the urbanized areas of the towns of Gedaref and Showak, and the villages of Umm Shegara and Er Rawashda. The following discussion provides a detailed description of existing conditions in these areas, while expected future changes are discussed later in the discussion of future population conditions. Future industrial development is uncertain, and is not currently expected to impact future water demand to any significant degee.

6.1.1 Existing Area Land Uses

a) Gedaref: The town area includes large areas of high and medium density residential uses, scattered low density residential uses, a central market area, scattered public uses, and a few concentrations of small-scale industrial uses. It is surrounded by agricultural land use, and some areas of livestock grazing. The main market area occupies a portion of the town center adjacent to the hospital and the railroad yard. Another area of commercial use is located at the truck stop at the junction of the Wad Medani-Kassala and Tawawa roads.

The central portion of the eastern side of town is occupied by the Eastern Military Headquarters. There are two major industrial areas. The older, located near the central market and railyard, contains small workshops, small warehouses, a few food processing facilities, a salt packing facility, soap manufacturers and a tile and brick manufacturer. The new planned industrial area is located on the western boundary of the town, adjacent to the grain market and grain storage area. Currently, a grain silo and some warehouses exist in the area. Future development may include a mechanized farm equipment



GEDAREF AND VICINITY

PLANNING DISTRICTS/

FUTURE GROWTH AREAS

SCALE 1:10,000

FIGURE 6 - 1

storage facility, and a Pepsi-Cola bottling plant (both currently under consideration).[1,2,3]

Government offices are scattered throughout the town on major streets, as are schools and mosques.

Residential uses occupy the remaining land within the town. They are composed of two major types of one-story buildings; concrete, stone and/or brick, multi-room houses in planned areas, and unplanned villages of straw or mud reinforced straw huts (tuquls). Both types are scattered throughout the town divided into districts, as shown on Figure 6.1. Unplanned hut villages often include more than one hut per family used for various domestic purposes. Estimates of housing density were made by dividing 1982 census estimates for districts[4] by district area and then confirmed by counting permiter huts and houses. District areas were estimated from approximate boundaries as drawn on maps by Town of Gedaref planning personnel.[5] Estimated densities of unplanned hut villages ranged from 0.6 to 3.9 uni , per 1000 square metres. Densities in planned residential areas ranged from about 0.5 to 7.4 units per 1,000 square metres.

Table 6.1 presents total estimated existing housing units and housing density, 1982 census population estimates and estimated population density for each census district in Gedaref as well as estimates of capacities for additional population.

b) Showak: The major land uses in Showak include residential (generally of medium density), a market area and a public buildings complex. The village is stretched out along the west shore of the Atbara River east of the Gedaref-Kassala road. Agricultural and livestock grazing uses surround the village. No significant industrial uses exist there, but the market area contains a few garages or workshops. The market and government office complex are somewhat centrally located. A railroad station lies to the northwest of the village, while the water treatment plant and pumping station is on the river southeast of the village center.

Residences are of two types; concrete, mud and brick structures, and mud reinforced straw huts. They are mixed throughout the village. Assuming a 5.2 population per household ratio (confirmed in general by most offícals interviewed), approximately 2900 units would be located within Showak village.[1-3,6-8]

TABLE 6.1

ESTIMATED 1982 POPULATION AND HOUSING UNITS IN GEDAREF CENSUS DISTRICTS

	District/No.	Population[a]	Estimated Land Area (m^2)[b]	Housing Units[c]	Housing Density (Units/1,000 m^2)	Population Density (Persons/1,000 m^2)	Estimated Percent Developable	Estimated Additional Population[d]
1	Daim Hamad & Shaigia	2,600	280,000	500	1.8	9.3	0	0
2	Al Midan	3,600	250,000	692	2.8	14.4	0	0
3	Karary	6,400	780,000	1,231	1.6	8.2	50	6,400
4	Al Ganain	1,500	390,000	288	0.7	3.9	0	0
5	Al Jamhouriya North	5,000	660,000	962	1.5	7.6	20	1,250
6	Al Nasr	650	240,000	125	0.5	2.7	0	0
7	Hilat Al Malik	1,237	430,000	238	0.6	2.9	50	1,237
8	Rowina	4,300	370,000	827	2.2	11.6	0	0
9	Daim Al Nur South	4,500	340,000	865	2.6	13.2	10	500
10	Daim Al Nur North	6,000	260,000	1,154	4.4	23.1	10	667
11	Al Ossra	1,500	310,000	288	0.9	4.8	0	0
12	Al Barnoh Al Jabal	4,113	260,000	791	3.0	15.8	0	0
13	Al Mattar	10,000	820,000	1,923	2.4	12.2	10	1,111
14	Daim Al Nur West	5,000	330,000	962	2.9	15.2	10	556
15	Al Mofraqaat	2,500	210,000	481	2.3	11.9	10	278
16	Daim Al Nur East	10,000	260,000	1,923	7.4	38.5	0	0
17	Al Abassya	2,500	240,000	481	2.3	11.9	10	0
18	Eastern Headquarters	3,016	------[e]	580	---	----	0	0
19	Abayo North	4,700	700,000	904	1.3	6.7	0	0
20	Abayo South	4,300	660,000	827	1.3	6.5	10	478
21	Mechanical Agriculture & Water Corp.	3,000	640,000	577	0.9	4.7	0	0
22	Al Danagla & Sika Hadid	3,042	210,000[f]	585	2.8	14.5	0	0
23	Al Jamhouriya South	2,290	270,000	440	1.6	8.5	0	0
24	Salamat Al Baih	10,244	1,080,000	1,970	1.8	9.5	0	0
25	Al Sawfi Al Azraq	2,943	620,000	566	0.9	4.8	10	327
26	Ath Thora & Masir	3,522	400,000	677	1.7	8.8	20	881
27	Al Nather	4,416	340,000	849	2.5	13.0	0	0
28	Al Jubarab East	3,133	250,000	603	2.4	12.5	10	348
29	Al Jubarab West	2,297	290,000	442	1.5	7.9	10	255
30	October West	4,567	390,000	878	2.3	11.7	0	0

TABLE 6.1

(Continued)

	District/No.	Population[a]	Estimated Land Area (m^2)[b]	Housing Units[c]	Housing Density (Units/1,000 m^2)	Population Density (Persons/1,000 m^2)	Estimated Percent Developable	Estimated Additional Population[d]
31	October East	2,169	470,000[f]	417	0.9	4.6	20	542
32	Karfis	1,723	360,000	331	0.9	4.8	20	431
33	October North	6,280	310,000	1,208	3.9	20.3	0	0
34	Abakar Jibril	9,229	650,000	1,775	2.7	14.2	0	0
35	Karfis Southwest	358	370,000	69	0.2	1.0	90	3,222
36	Al Jinaina	1,068	140,000	205	1.5	7.6	10	119
37	Suakin Extension	689	350,000	133	0.4	2.0	80	2,756
38	Dar As Salaam	1,912	360,000[f]	368	1.0	5.3	60	2,868
39	Wad Al Kabayir	2,000	160,000[f]	385	2.4	12.5	60	3,000
40	Al Mawzafin	2,000	370,000	385	1.0	5.4	0	0
41	Police & Prison Housing	1,000	160,000	192	1.2	6.3	0	0
42	Ash Sharif Al Ajib	3,000	150,000	577	3.9	20.0	10	333
43	Wad Ad Damaq	500	160,000	96	0.6	3.1	60	750
44	Al Mattamir	1,000	190,000	192	1.0	5.3	10	111
45	Al Kassara	750	180,000	144	0.8	4.2	80	3,000
Total		156,548	16,660,000	30,106	1.8	9.4	--	31,420 (approx. 23,100 in outer areas)

a 1982 Census Preliminary Estimates, Gedaref Town Planning Department.

b Gedaref Town Planning Department, JMM estimate.

c Assuming 5.2 persons per unit (based on 1981 and 1982 surveys of Tawawa and Gedaref Town Council estimates).

d Based on estimates of percent of District developed and assuming similar densities in areas to be developed.

e Boundaries not applicable to population limitations.

f Developed area only (in Districts with a high percentage of undeveloped land).

Source: 1982 Census Preliminary Estimates, Gedaref Town Planning Department, Gedaref Town Council, JMM.

c) Er Rawashda, Umm Shegara and Ghubeisha: These villages (two to the north and one to the south of Gedaref) have similar characteristics. Their inhabitants are mainly farmers and/or livestock herders. Few non-residential uses exist, mainly limited to schools and mosques. Commercial activities of the inhabitants of these villages is generally conducted in Gedaref or its nearby truck stop. Most of the residences are mud-reinforced straw huts. Assuming family size averaging 5.2 persons, approximately 1,900 housing units exist in Umm Shegara and Ghubeisha, and 1500 in Er Rawashda.

d) Tawawa: Land uses at Tawawa are similar to those at the other villages near Gedaref, but more public buildings and workshops and handicraft shops are present. The October 1982 UNHCR survey of Tawawa found 1,762 residential units.

6.2 POPULATION

The projection of future service-area population was done by estimating current population totals, and then applying growth rates for the five-year project period based on recent growth trends.

6.2.1. Existing Conditions and Recent Trends

Current population totals for the town of Gedaref, its subdivisions and the villages of Showak, Er Rawashda, Umm Shegara, Tawawa and Ghubeisha were obtained or estimated from various sources. The most important of these sources were the 1982 Census preliminary estimates for Gedaref and all of the villages except Showak (whose estimate has not been completed as of December, 1982). The 1982 population total for Tawawa, was taken from a UNHCR survey cond cted in October 1982.[9] Other sources used to provide input to the consultant's estimates included Gifford and Partners, the Town Council of Gedaref and the Gedaref Northern Area Council. Although the latter estimates were not used directly, they provided additional input for the Showak and other village population estimates and corroboration of the census estimates. Visual inspection of the, villages and Gedaref provided additional input for the consultants estimates.

Recent trends in population growth are represented by a comparison of 1973 Census totals and related estimates with 1982 Census preliminary estimates. The following table provides 1973 and 1982 totals for project area villages and Gedaref Town:

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Table 6.2

Population per Census Data

Town/ Village	1973 Census	1982 Estimate Census	Annual Increase
Gedaref	66,465	157,000	9,000
Showak	4,824	10,000[a]	500
Er Rawashda	3,000[a]	8,000	500
Umm Shegara	3,000[a]	10,000	700
Tawawa	-	7,000	1,500 (since 1982)
Ghubeisha	3,000[a]	10,000	700
Total Project Area	80,289	202,000	

a JMM estimate

Source: 1982 Census Preliminary Estimates, Gedaref North Area Village Council, Gifford and Partners, 1982 UNHCR Survey, JMM estimates.

6.2.2 Peak Period Population

During the harvest season spanning November through March, migrant workers come to the Gedaref area, Tawawa, and, to a lesser extent, the Showak area. No appreciable numbers of migrant workers reside in the other villages during the harvest seasons. Reliable figures were not available for determining the number of temporary resident migrant workers in the region as a whole, or in the individual towns and villages. Estimates for Gedaref Town ranged from 10,000 to 100,000 but most opinions ranged from 20,000 to 40,000. They all agreed that the number varies with the size of the crop yield from year to year and that a large number of migrant laborers come each year with the excess leaving the Gedaref area once all available jobs are taken. Estimates for the Showak area ranged from 3,000 to 5,000 depending on the quality of the harvest, but it is clear that their impact on the village of Showak is likely to be less than the migrants' impact on Gedaref. The migrants in both areas spend most of their time in the field areas, with only sporadic visits to the towns. More impact is felt during the early portion of the harvest season and immediately following its end. Most estimates of migrant workers (mostly Ethiopians) residing in Tawawa during the harvest season totalled approximately 3,000.[1,2,6,7]

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6.2.3 Refugee Population

The study area contains refugees in three major areas; (1) The entire village of Tawawa, (2) interspersed throughout the Town of Gedaref, and (3) a smaller number residing in Showak. The population of Tawawa is approximately 7,100 according to the 1982 UNHCR survey, and this swells to about 10,000 during the latter stages or immediately following the harvest season. The additional 3,000 represent migrant workers, mainly Ethiopians, who are generally relatives or friends of permanent residents of Tawawa. The refugee population residing in Gedaref Town has been estimated to total from 10,000 to 40,000 depending on the source of the estimate. All sources admitted, however, that their figures were only guesses and the level of accuracy was uncertain. Based on the various estimates, this analysis assumes that a figure of 20,000 refugees scattered within Gedaref Town is more likely than the extremes of estimates given.[6,7]

6.2.4 Future Projections

Projections of total population in Gedaref and the project area villages during the project period 1983 to 1987 were made based on a straight-line projection using the growth rate from 1973 to January 1982 since no other reliable population data were available. The annual increase of the nine-year period 1973 to 1982 was applied to the six-year period of 1982 through 1987 since the 1982 Census Preliminary Estimates were taken in early 1982. Ths would reflect growth between early 1982 and 1983, the beginning of the project period. Special growth rates (differing from recent trends) were used for Tawawa and Showak due to the expected changes in conditions as explained on Table 6.3. Table 6.3 also forecasts 1987 populations for Gedaref and the project area villages. The total population of Gedaref is projected to total 211,000 by 1987, with the entire project area totalling 278,000. The peak period populations of the area would then range from approximately 231,000 to 251,000 for Gedaref, and approximately 304,000 to 326,000 for the entire project area.

These increases of population are expected to take place generally on the periphery of Er Rawashda, UMM Shegara, Ghubeisha and Tawawa; while growth in Showak is expected to take place generally in the north, south and to a lesser degree to the west along the Gedaref-Kassala road.[2] Growth in Gedaref would occur over the five-year project period in the form of in-fill development of the existing neighborhoods (districts) which are not completely developed, as well as in currently-planned extension areas as shown on Figure 6.1.[1,5] Capacities for additional population in the various census districts are shown on Table 6.1. Future development during

TABLE 6.3

1987 POPULATION PROJECTIONS FOR GEDAREF AND PROJECT AREA VILLAGES

Town/ Village	Annual Increase[a] 1973 to 1982	1987 Population	Peak Period Population 1987
Gedaref	9,000	211,000	231,000 - 251,000[b]
Showak	1,000[c]	16,000	19,000 - 21,000[d]
Umm Shegara	700	14,000	14,000
Er Rawashda	500	11,000	11,000
Tawawa	800[e]	12,000	12,000 - 15,000[f]
Ghubeisha	700	14,000	14,000
Total Project Area		278,000	301,000 - 326,000

a As derived on Table 6.2

b Migrant labor harvest season totals generally range between 20,000 and 40,000.

c Although the annual increase between 1973 and 1982 was slightly above 500, an increase of 1,000 per year was used in the projection as refugees are expected to continue to migrate to Showak, and the village has a larger economic infrastructure to draw migrants.

d Migrant labor harvest season totals generally range from 3,000 to 5,000.

e Although the population of Tawawa has increased by approximately 1500 per year since 1980, this rate is expected to decrease as new refugee villages are developed and planned. It was assumed that a rate of 800 per year would be more representative based on government policy and current plans.

f Migrant labor harvest season totals are estimated to range between 0 and 3,000.

Source: 1982 Census Preliminary Estimates, Sudan Department of Statistics; 1982 UNHCR Survey of Tawawa, JMM estimates, Gedaref North Area Village Council, Gedaref Town Council, Gedaref Town Engineering Department.

TABLE 6.4

PROJECTED MAJOR POPULATION GROWTH DISTRICTS OF GEDAREF 1982-1988

District/No.		Projected Increase
3	Karary	6,400
5	Jamhouriya Shimal	1,250
7	Hilat Al Malik	1,250
13	Al Mattar	1,100
35	Karfis Southwest	3,200
37	Suakin Extension	2,750
38	Dar As Salaam	2,850
39	Wad Al Kabayir	3,000
45	Al Kassara	3,000
	Planned Extensions[(a)]	
	As Sadaaqa	4,600
	Jamhouriya Al Shimal Ext.	4,600
	Salamet Al Baih Ext.	4,600
	As Sawfi Al Azraq Ext.	4,600
	Al Abayo Extension	4,600

(a) Based on estimated capacity for additional population in currently populated portions of Gedaref (See Table 6.1) as reduced from projected total 1988 population of Gedaref (211,000) leaving an increase of approximately 23,100; which was assigned in equal shares to each of the five planned extension areas not within census districts.

Source: 1982 Census Preliminary Estimates, Gedaref Town Planning Office, James M. Montgomery, Consulting Engineers, Inc.

the project period was projected by subtracting the total of population increase capacities of existing partially-developed Census districts from the total projected increase for Gedaref leaving the amount of projected increase which would occur in new neighborhoods or currently planned extensions. Table 6-4 shows these calculations as well as the distribution of the residual 18,600 population increase equally among the five currently-planned extension areas. In addition, the existing census districts which are projected to have the most significant increases are listed. Figure 6.1 also delineates the boundaries of the new extensions. It is assumed that the bulk of the population increase in the new extensions will occur in areas immediately adjacent to existing development as the development capacities of currently-planned extension areas would not be used up by the end of 1987.

6.3 WATER DEMAND CALCULATIONS

Water demand calculations were developed from water demand criteria established through a review of number of information sources. An analysis of the present per capita water supply indicated that the population served from the existing Gedaref-Showak system is averaging only 25 litres per person per day. This includes a significant wastage factor.

The residents of Tawawa refugee settlement are only receiving about 10 litres per person daily. The minimum requirements to meet drinking, cooking and personal hygiene standards was established at 20 to 25 lpcd by A.I.D. Policy Paper entitled "Domestic Water and Sanitation" dated May, 1982. Due to the nature of the urban area, its economics and the presence of a significant affluent element within the community, a high of 50 lpcd was selected for residential users with direct connections or close proximity to supplies. A lower demand factor of 35 lpcd was developed for approximately 40% of the service area population whose water supply sources would be more than 30 metres from the point of consumption or use. This planning criteria is based on the demand patterns that will be generated at the end of the project planning period, or at the end of December, 1987.

Accurate and detailed information on other customer class water demands was not available in the records of the Gedaref water agency. Therefore, certain assumptions were used to estimate demands for the commerical, institutional and industrial users. These customer classes are considered to be a small percent of total demand requirement since these customers only exist to service the local community and are not generating services or products for outside areas. The planning year water demand criteria are shown in Table 6.5.

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TABLE 6.5

.WATER DEMAND CRITERIA - PLANNING YEAR

Class	Customer Type	Litres per Capita Day
A	Residential users with direct connections or close proximity to supply sources	50
B	Residential users living beyond 30 metres of supply sources	35
C	Commerical, Institutional and Industrial	10% of Residential Demand
	Water Loss Factor (in 1987)	20%

Based on the above demand criteria and the projected population presented in this chapter, the following total water demand is calculated to meet the service area needs at the end of calendar 1987.

TABLE 6.6

TOTAL WATER DEMAND REQUIREMENTS - 1987

Demand Source	Projected Service Population	Cubic metres per day
Residential "A"	177,500	8,875
Residential "B"	118,300	4,140
Subtotal	295,800	13,015
Class "C" at 10%		1,302
Subtotal		14,317
Unaccounted for Water (1987) at 20%		2,863
Total Water Demand - December 1987		17,180

The above service population includes 278,000 permanent residents and 50% of the average migrant worker population in 1987 or an additional 17,800 equivalent permanent residents. Peaking demands would be provided from water storage facilities in Gedaref, Abu Naga, Al Abayo, Ghubeisha, Umm Shegara, Er Rawashda and Showak.

The above demand calculation will be satisfied by the proposed improvements estimated to provide a minimum daily water supply totalling 17,600 cubic metres per day (See Section 9.4). The program supply should be available by the end of calendar 1985 even though the demand will not equal supply until two years later. A reduction in the projected population increases or a reduction in estimated per capita usage will extend available water supplies into 1988 and possibly longer.

References

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2) Meeting November 29, 1982, Gedaref North Area (Village) Council, JMM, Administrative Office-Sadiq Musa Sadi, Council Engineer-Mustapha Abass A Neima, Environmental Health Inspector-Mohammed El Jaq.

3) James M. Montgomery, Consulting Engineer, Inc. Field surveys; Gedaref, Umm Shegarah, Er Rawashda, Ghubeisha, Tawawa and Showak, November-December 1982.

4) Government of the Sudan, Ministry of National Planning, Department of Statistics, Census Division. "1982 Census Preliminary Estimates Towns and Villages, Eastern Province," January-February 1982.

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6) Meeting November 28, 1982, United Nations High Commission on Refugees (UNHCR), Gifford and Partners, JMM. UNHCR Khartoum Office Directors-Lars Johnsson, Peter Parr; Gifford and Partners-Phillip Riddel.

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CHAPTER 7

AVAILABLE WATER RESOURCES

7.1 SUMMARY OF WATER RESOURCES EVALUATION

7.1.1 General

In order to assess the availability of water supplies for the Gedaref water system, a detailed water resources evaluation was conducted as an intergal part of the project. The time frame for the project required that the water resources evaluation be limited to collection and analysis of existing data and reports. Available information which was collected included a variety of geologic and topographic maps, aerial photos, maps depicting the location of existing boreholes, climatic records, water quality information, well construction records and aquifer pump test data. Additional data on the Gedaref water resources were obtained by personal interviews, field reconnaissance and testing of existing water well facilities. A detailed description of the water resources evaluation is included in Appendix B of this report.

For purposes of the water resources investigation, an area of 5,000 square kilometres (km) was included in the evaluation. The general area of study is shown on the location map (Figure B-1) in Appendix B. The Town of Gedaref is located in the Kassala region of eastern Sudan, approximately 300 kilometres directly southeast of Khartoum.

Throughout the long history of the Gedaref region, water has been an important factor in the survival and prosperity of the local inhabitants. In comparison with many other parts of the Sudan, Gedaref is blessed with an abundance of seasonal rainfall, averaging about 600 millimetres annually. This rainfall replenishes the surface and ground water resources of the region.

7.1.2 Surface Water Resources

Surface water resources in the greater Gedaref region can be divided into two general categories. These include (1) seasonal (ephemeral) drainage systems and storage basins (haffirs) and (2) perennial river systems.

Within and immediately surrounding the Town of Gedaref there are no perennial flowing river systems. Rather, there are a series of east-west draining shallow, poorly defined surface drainage channels (wads and khors). On the western edge of Gedaref, these surface drainage channels converge to form Khor Abu Faragha. During the dry months of the year the wads and khors are devoid of moisture, however, during the summer rainy months the channels carry significant volumes of surface runoff. Throughout the region, storage ponds (haffirs) are constructed within and adjacent to the khors to store wet season runoff for later use in the drier winter months. Because of the seasonal nature of these small surface drainages, neither the khors or the haffirs respresent a viable water supply source for the Gedaref area.

In the eastern region of Sudan, near the Town of Gedaref, there are only two perennial flowing river systems. These include the Atabara River 50 kilometres directly northeast of Gedaref, and the Rahad River approximately 110 kilometres to the southwest. Because of the long distance to the Rahad River, any water supply development would currently be economically unfeasible. For this reason, no further consideration is given to the Rahad River. The Atbara River is a northwesterly flowing river which originates in the Ethopian highlands to the east of Sudan and eventually converges with the Nile River at Ed Damer approximately 425 kilometres northwest of Gedaref.

The Atbara River system carries a major portion of runoff draining from the eastern region of Sudan. Annual river flows as measured at the Kashm el Girba Dam 75 kilometres north of Showak are recorded to be 12 cubic kilometres (1.2 x 10^{10} m^3). Flow records from the dam indicate that 74 percent of the annual flow is carried during the wettest months of July through October while the remaining 26 percent, or base flow, is carried during the remaining 8 months of the year. Recorded daily flows at the dam range from 180 million/m^3 to a reported zero flow during the dryest months. Flow records maintained at the two gaging stations on the Setit and Atbara Rivers, 35 and 22 km respectively, upstream from Showak indicate minimum combined river flows of 1.7 million m^3/day. Thus, it appears there are adequate flows at the Showak intake to supply the current capacity of the Showak facilities.

Water quality data for the Atbara River is very limited. Total dissolved solids are reported to range from 100-400 mg/l, however, suspended silt loads may range to as high as 16,000 mg/l during the high runoff portions of the year. A sample of the Atbara River water collected for this study showed a TDS of 320 mg/l and total hardness of 155 mg/l (as $CaCO_3$). This analysis indicates that the water is suitable for domestic water supply purposes in accordance with the WHO Guidelines for Drinking Water Quality.

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7.1.3 Ground Water Resources

The occurrence of ground water in the Gedaref region is controlled by surface and subsurface geologic formations. In essence, the geology of the Gedaref region is defined by a stratigrafic succession of four geologic formations. These formations include the Pre-Cambrian Basement Complex, the Mesozoic Nubian Series, the Tertiary Volcanics and the Quaternary Surficial Sediments. In the Gedaref region, ground water occurs primarily in the sandstones of the Nubian Series and the Tertiary volcanic rocks.

The volcanic rocks are composed primarily of flow basalts which occur in a north-south trending band throughout the project area. The occurrence of the volcanic rocks is shown on Figure B-3 in Appendix B. The occurence of ground water in the basalt aquifer is controlled by joint and fracture patterns present in the volcanics. The degree of fracturing and thus, the permeability of the volcanics decrease rapidly with depth. Ground water storage within the basalt aquifer occurs only within the voids of the joint and fracture system and therefore, the availability of ground water storage in this aquifer is limited.

Shallow hand dug wells constructed in the volcanic rocks are common in the general area of Gedaref. In addition, some machine bored wells are known to be completed in the volcanic rocks. Quite commonly, the yields of these wells are low and occasionally completely dry up during the summer months. The water quality characteristics of the basalt aquifer are marginal to poor with TDS values ranging to 2,400 mg/l and hardness as ($CaCO_3$) ranging to 2,160 mg/l. Nitrate concentrations commonly are found to exceed WHO guidelines. For both water quality and quantity reasons, the basalt aquifer system is not considered to be a viable water supply source for use in the Gedaref water system.

The Nubian Series, commonly referred to as the Nubian Sandstone and Gedaref Formation, is a wide spread aquifer which occurs in much of the eastern Sudan area. The Nubian Series consists of a sequence of layered mudstone, sandstone and limestone which is reported to reach thicknesses of 300 m. In the Gedaref area, the Sandstone layers reach a thickness of 120 m and constitute the principle water storage and transmitting unit of the Nubian Series. Ground water contained within the Nubian Sandstone is found under confined to semi-confined aquifer conditions. Piezometric levels in the confined aquifer range from 40-70 m below ground surface, and there appears to be a relation between water levels and surface topography. Recharge to the Nubian Sandstone occurs directly from infiltration of precipitation in areas where the Nubian Series crops out and through the basalts where they overlie the

Nubian Series. Recharge to the Nubian Sandstone within the study area has been conservatively estimated at 78 x 10^6 m^3 annually.

Within the study area, more than 300 wells are reported to have been constructed within the Nubian Sandstone aquifer with reported well yields ranging from 7 to 36 m^3 per hour, depending upon well depth and design. Transmissivity values for the Nubian Sandstone vary widely with location. Tested values of transmissivity in the Gedaref region range from 5 to 150 m^3 per day. These transmissivity values are considered to be relatively low but may reflect water well construction techniques rather than the true aquifer transmitting capacity.

The quality of water contained in the Nubian Sandstone varies significantly with location. In general, Nubian ground water is considered to be good quality and suitable for domestic water supply purposes. Available analyses of Nubian ground water indicate TDS ranges from 240-2,848 mg/l with most samples falling in the 300-700 mg/l range. The water is generally hard to very hard with total hardness (as $CaCO_3$) ranging from 60 to 90 mg/l.

With the exception of certain areas where poor quality water is known to occur, the Nubian Sandstone is considered to be a feasible ground water supply source for development of supplemental water supplies for the Gedaref area.

CHAPTER 8

WATER SOURCE DEVELOPMENT ALTERNATIVES

8.1 SUMMARY

As described in earlier chapters and Appendix B of this report, two sources of water supply have been identified for use in the Gedaref water system. These include the Atbara River supply and ground water from the Nubian Sandstone. Currently, the Showak facilities are the principle source of water supply for the Town of Gedaref. This source and supply facility, while in need of improvement, appears to be the most promising long-term source of supply for Gedaref. Resulting from this finding a number of alternative intake options for the existing facilities have been analysed. The second potential water supply source is the proposed development of supplemental ground water from the Nubian Sandstone formation south and west of Gedaref. An analysis of the various water supply options is presented in the paragraphs that follow.

8.2 ATBARA/SHOWAK ALTERNATIVES

8.2.1 Relocation of River Intake

The large silt loads carried by the Atbara River and the deposition which has occured adjacent to the existing intake facilities has resulted in abandonment of the original structure. To replace the original intake, two temporary pumps and connecting pipes have been installed along the present banks of the river. The location of the intake requires continual excavation during dry season low flows to channel water from the far side of the river (east bank) to the temporary intake pumps. As many as 50 laborers are required to manually excavate this channel to the present intake. Several alternative intake options were identified in previous consultant's reports including two possible sites for relocation of the intake facilities. The identified sites were (1) at Magran near the confluence of the Setit and Atbara Rivers approximately 7 km upstream from the present intake facilities and, (2) near Umm Ud in the Kashm el Girba reservoir, a location approximately 20 km downstream from the present intake facilities.

a) Upstream River Intake: This option would require construction of an intake structure pump station and pipeline on the west bank of the Setit River near Magran at the confluence of the Setit and Atbara River. A low lift pumping station and pipeline would be required to lift the water from the river and transport it downstream to the existing treatment plant facilities. This site is apparently not hampered by the high silt deposition existing in the

Atbara river at Showak. Elevation differences between the Magran intake site and the treatment plant are minimal.

b) Downstream River Intake: This intake option considers the placement of a new river intake system approximately 20 km downstream from the existing treatment plant facilities. The intake would actually be located on the west bank of the Kashm el Girba reservoir on a mudstone promentory 2 km north of the Atbara River inlet to the reservoir. This option would require construction of an intake structure, pumping station and approximately 20 km of pipeline to lift and transport the water from the reservoir to the existing treatment plant facilities. The advantages which would result from placing the intake facilities in the reservoir include lower turbidity levels in the raw water and elimination of the silt deposition problems association with the existing intake.

8.2.2 Atbara River Diversion

This alternative is a short-term solution proposed by the UNHCR consultant to divert low flow river water from the eastern bank to the western side of the channel near the present intake facility. This proposal includes placement of gabion structures near the eastern bank of the present river channel. The gabions or training walls would deflect low flows across the present river channel to the intake pipes. There are a number of uncertainties associated with this alternative. These include (1) the permanence of the gabion structures or their ability to withstand high river flow conditions; (2) the possibility of increased silt deposition behind the gabion structures; (3) the possibility of severe bank erosion on the western shore of the river when flood flows are deflected and subsequent damage at the water treatment plant site.

8.2.3 Portable Intake System

Several schemes have been suggested for moving the present intake works to the east side of the Atbara River channel at Showak. These schemes are generally considered as short term solutions to solve the low flow intake problems. The intake options include (1) a suspended cable intake system, (2) a pier or pylon-mounted intake and, (3) a temporary flexible intake.

a) Suspended Cable Intake System: This option would require construction of a cable line across the river bed. Light weight pipe would be suspended from the cable to the intake position in the low flow channel. This system would enable repositioning the intake as river flow conditions required and eliminate the need for manual excavation as currently practiced.

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b) Pier or Pylon Mounted Intake: This option differs from the cable option in that a pier would be constructed across the river channel with a permanently installed pipeline on the pier structure. The intake would be suspended from the pier to the low flow channel.

c) Temporary Flexible Intake: This option would rely on placing an intake pipeline on the mud flats across the river bed to the low flow channel. The pipeline considered for use is light weight aluminum irrigation pipe for ease of placement and relocation.

8.2.4 Treatment Augmentation

This alternative would involve construction of large haffirs or settling ponds, upstream of the existing treatment plant. These ponds would be used as primary detention ponds to allow suspended silt to settle out prior to chemical treatment. This alternative could be used in conjunction with one of the previously discussed intake alternatives. The option would require construction of large pond structures, inlet pipe from the river intake and outlet pipes to connect the ponds with the treatment plant facility. Improvement of the river intake would be required in conjunction with this alternative.

8.2.5 Shallow Intake Wells

This alternative consists of constructing 10 to 15 shallow boreholes in a line parallel to the west bank of the Atbara River. The shallow wells would be constructed to depths of approximately 40-90 meters into the Nubian Sandstone which underlies and is recharged by the Atbara River. The wells would be equipped with submersible pumps and would be connected via a header pipe leading directly to the treatment plant facilities. Advantages of this option include development of high quality, low turbidity water which would require only chlorination and pumping to Gedaref. This option would also eliminate the problems associated with silt deposition and low river flow conditions as well as the need to upgrade and expand the existing treatment plant facilities. Use of shallow wells will require construction of a test well and several observation wells to provide necessary design information such as the number of well units, size, depth, and spacing.

8.2.6 Conclusions

The continued use of Atbara river water as the primary supply source will require improvement or replacement of the existing river intake, and expansion and upgrading of the treatment plant. The high silt deposition near the existing Showak facilities will continue to create maintenance problems for a river intake at this location. Therefore, alternatives to construct a new intake at the existing site do not appear to be feasible, long-term solutions. These alternatives include those described in Sections 8.2.2 and 8.2.3. Relocation of the river intake as described in Section 8.2.1 would require construction of a new intake, pump station and pipeline to bring water from the river to the treatment plant. The treatment plant would also require expansion and upgrading. Prior to relocating the intake sites, detailed hydrologic and engineering studies would be required to confirm the suitability of the new sites. While relocation of the intake appears to be technically feasible, the uncertainties and associated costs makes this alternative less desireable than development of shallow ground water near the Showak facilities. The treatment augmentation alternative, Section 8.2.3, would only be used in conjunction with surface river intake schemes. Therefore, if shallow ground water is developed treatment augmentation would not be required.

The exploration and testing of the shallow ground water conducted at Showak indicates a strong potential for supply development. Use of shallow ground water has a number of advantages including good quality, low turbidity, elimination of the need for treatment, continuous supply availability and proximity to the existing Showak transmission pumping facilities. Because ground water use will not require expansion and upgrading of treatment facilities, nor construction of a long transmission line, ground water development appears to be the most economically feasible alternative. Use of shallow ground water at Showak will require additional aquifer testing to provide design input for the new facilities.

8.3 GROUND WATER SUPPLY ALTERNATIVES

8.3.1 Abu Naga Well Field

The water resources evaluation (Appendix B) indicates a strong potential for development of ground water supplies from the Abu Naga well field to supplement the Atbara River supply. Development of ground water at Abu Naga will require rehabilitation of the existing wells which were constructed in 1968 and constructing two additional wells in the southern sector of the well field. Implementation of this alternative will require construction of a booster pump station near the well field and rehabilitation and construction of a new 300 mm segment of the 250 mm transmission pipeline to the Gedaref reservoir. Water from the well field would be pumped through the transmission line and blended at the reservoir with water from the Atbara River.

Although there is insufficient data to develop a safe yield for the Abu Naga well field, we feel confident that the Nubian

Sandstone can provide 3,500 to 4,500 m^3 per day with no adverse impacts to the ground water. Once the well field has been redeveloped and placed in operation, a monitoring program to measure water levels, production rates and water quality should implemented and continued to determine a long-term safe yield for the well field and adjacent aquifer.

8.3.2 Tawawa

The village of Tawawa currently relies on water carried from the Gedaref water system and a well located 2 kilometers southwest of the village. Two problems associated with the use of the well are a question of well ownership and poor to marginal water quality characteristics of the ground water at that location. Use of the existing well should be terminated and a new well constructed approximately 1-2 km northwest of the existing well (1 km west of Tawawa). This proposed location would be near the contact of the Nubian Sandstone and volcanic rocks and it is anticipated that acceptable water quantity and quality characteristics could be located. Implementation of this alternative would require construction of a test/production well and, if successful, a 1 km pipe to the storage tanks at Tawawa.

8.3.3 Umm Golga

The village of Umm Golga is located approximately 10 km west of the city of Gedaref. Four wells have been constructed near the village and are producing ground water from the Nubian Sandstone. The quality of water from these wells is generally good and meets WHO Guidelines for Drinking Water Quality. The most recently constructed wells were completed in 1982 and pump tested at rates of approximately 27 m^3 per hour. It is felt that the Nubian Sandstone in this general area exhibits suitable characteristics for ground water development from both a water quantity and quality standpoint. The development of ground water at this location would require construction of new well facilities, pumping facilities and a transmission line from the well field to the Town of Gedaref. Costs associated with developing Umm Golga exceed the available budget for the current phase of ground water augmentation for Gedaref. However, the Umm Golga area should be considered for future ground water development as Gedaref water system demands expand.

CHAPTER 9

PROPOSED WATER SYSTEM IMPROVEMENTS

The Gedaref water supply system is a reasonably simple system with a few complex interrelationships. The system relies on a single source of supply, a single transmission main and a single regulating reservoir. There are no communications between the treatment plant and the reservoir which are 68.4 kilometres apart. The service areas are scattered through a wide corridor of approximately 70 kilometres in length. The service areas contain elementary distribution networks with 4 small service storage reservoirs. The complexity of the system lies in the interdependence of the system components compounded by the sporadic nature of electric power supplies and difficulty in obtaining raw water. The two booster pumps within the distribution network in Gedaref can only operate during those periods when there is power, provided of course, that these periods coincide with the release of water from the main storage reservoir.

The entire Gedaref water supply system was reviewed and alternatives were considered to strengthen or replace each weak link in the water supply chain. The proposed improvements are believed to be the most economically and technically feasible alternatives available within the framework of the project parameters and the present funding available for water system improvements.

9.1 FIVE-YEAR PLANNING CRITERIA

Water system improvement projects are designed to meet the needs of the people for a specified number of years into the future. Although the improvements recommended in this section should last for at least an average of twenty years, service through the year 1987 was determined as the planning horizon. The five-year criteria will adequately cover the estimated time required for the design, tendering and construction phases of the proposed project. Additionally, the lack of reliable data and records relating to population trends, water production and demand requirements combine to make accurate predictions of future water needs uncertain beyond the year 1987.

An important factor which effects the useful life of a water supply system is the application of proper operation and maintenance procedures. Without them, no system can be expected to function, as planned, for very long.

Table 9.1 summarizes the planning criteria used for both the Gedaref and the Tawawa systems. As mentioned in Chapter 6, 50 lpcd (litres per capita per day) was used for direct service connections and for consumers with nearby point supplies. The calculated consumption of 35 lpcd was determined for point supplies located over 30 metres away from user housing. The present production of an over-all average of 31 lpcd provides 25 lpcd for consumers after adjustments for unaccounted for water and wastage. Consumption can be expected to increase significantly with improved supplies and continued water service

TABLE 9.1

WATER SYSTEM PLANNING CRITERIA

Item	Criteria
Design Years	
Area served	1982 populated project area
Flows	1987 projected demands
Present Population Served	
Gedaref 1982	167,000
Tawawa 1982	7,000
Others 1982	28,000
Projected Population Served	
Gedaref, December 1987	225,000
Tawawa, December 1987	12,000
Others, December 1987	41,000
Transient, December, 1987	23,000 - 48,000
Unit Demands (Average)	
Residential (with house connection or within 30 metres of supply)	50 Lcd (year 1987)
Residential (over 30 metres from supply)	35 Lcd
Commercial/Government/Institutional	10% of residential
Industrial	*
Transient	25 Lcd (year 1987)
Peaking Factors	
Maximum Pay	1.3
Peak Hour	1.5
Fire Demand	*
Future Leakage/Water Loss	20% of total demand
Storage at Main Reservoir	18 hours
Pressures (at house service)	
Minimum Static	1.40 kg/cm^2
Normal Static	2.46 kg/cm^2
Hazen-Williams Constant	
Old Pipe	100
New or A.C. Pipe	120
Pipe Depth	1.0 - 1.5 metres
Pipe Material (Recommended)	
50 mm	Polybutylene
100 mm	Galvanized steel
150 mm & above	Steel with bitumastic coating/lining
Treatment Requirements	Chlorination

* incorporated in unit demands for commercial/governmental/institutional

availability. Present demand is obviously suppressed by the availability of water service for only five hours on the average day and often for fewer hours or, sometimes, no daily water service at all.

9.2 WATER SYSTEM IMPROVEMENT ALTERNATIVES

Alternative solutions to the existing water system problems were investigated for their technical and financial feasibility. Some of the alternatives were also discussed in the Gifford and Partners' report and in the Christopher West study. The main alternatives which were considered by the study team are as follows;

9.2.1 Improvements of the Showak Intake Facilities

One problem with the Showak water treatment plant is the unreliable raw water intakes. Various different alternative were considered:

a) Do Nothing: If other problems associated with the plant can not be rectified, the improvement of the intake facilities cannot be justified as a longer term solution.

b) Reclocate the plant intake upstream: About 7 kilometres upstream from the existing plant near the village Maqran is the confluence of the Setit and Atbara rivers. Due to the converging flow from the two rivers, a deepening of the Atbara River has developed along the west bank. This could be a possible site these intake facilities but they would require a power supply, new pumping units and approximately 7,000 metres of 500 mm supply pipe.

c) Relocate the plant intake downstream: About 20 kilometres downstream, there is an outcropping of sandstone into the open waters of the Kashm el Girba reservoir. This location is also a potential site for the relocation of intake facilities. This site would require a considerably longer pipeline than the Maqran site. Raw water from this site would contain a much lower turbidity level and would be easier and cheaper to treat.

d) Modify the exisiting intake facilities: The main problems with the existing intake facilities are siltation, the tendency of the Atbara River to seek a channel through the silt near the east bank of the river, opposite the treatment plant and the disappearance of flows at the end of the dry season. Modification would therefore consist of a method, or methods, of obtaining enough raw water from across the river during periods of low flows and still provide safeguards against flood damage. Some possibilities are:

- Install a buried pipe across the river: This alternative would entail the construction of a new intake and

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laying a pipeline on the river bed. This would require diversion of the river and special construction techniques since the river bed has a silt overburden of approximately 7 metres in depth.

- Suspend an intake line across the river: This alternative is essentially the same as above but avoids the construction problems of a buried line by suspending the pipeline over the river. This approach would involve foundation problems and exposure to flood damages.

- Use of pontoons to support the intake line: During dry periods, pools are tapped to provide raw water. This alternative would involve extending the intake line across the river bed to the water's edge and adding more sections to the pump suction line as needed. Problems associated with this solution include operational problems, the possibilities of continually breaking suction head and the danger of losing the equipment from an unexpected rise in the river level.

- Construct a track-mounted intake: By placing the intake lines on a track extending into the river bed, the intake pumps can be readily moved to the waters' edge. This alternative involves operational problems and exposure to the loss of pumps or tracks in the event of an unexpected rise in the river level.

e) Modify the river flow patterns: Currently, hand dug channels divert the water to the intakes. These alternatives are various means of obtaining the same results.

- Construct a single gabion on the east bank of the river: The construction of a simple gabion in the river near the east bank of the river would divert the water flow toward the west bank and the existing intake facilities. The theory is that the currents created by such a structure would cause the river to cut through the silt, and create a channel next to the west bank. In time, the river might conceivably be trained to follow a channel on the west bank. Problems would be involved in constructing foundations to resist flood damage to the gabion. Also by directing flows toward the plant facilities the possibility of flood damage is significantly increased with possible damage to the water treatment plant.

- Construct multiple gabions: By construcing multiple gabions, the low river flows might be directed down the middle of the river bed. The opposing gabions should protect the plant facilities from flood damages. Construction problems would be encountered to prevent flood damage to the gabions. This approach would move the dry season flows closer to the plant but would not solve the problem of getting the flows next to the plant.

- Install a permanent trenching machine: If suitable foundations are constructed in the river bed, a track-mounted trenching machine could be installed. This trencher would mechanically excavate a channel to the water rather than the present hand digging process. This would save time and expedite the digging of a diversion channel from the water to the intake. This does not solve the problem, it merely speeds up the present reactive solution. This method presents operational problems and the possibility of flood damages.

9.2.2 Construct Shallow Infiltration Wells

A series of shallow infiltration wells along the west bank could be used as a raw water source, even during the dry season. The use of these shallow infiltration wells would virtually eliminate the problems associated with the existing intake facilities. The construction costs of such wells are the basic drawback to this alternative. However, the use of such wells would improve the quality of the raw water. The natural filtration would remove the silt loading which is causing major problems in the water treatment process and should negate the need for use of the mixing basin and rapid sand filters.

9.2.3 Additional Treatment Facilities

If the existing raw water surface supply is increased, improvements will be required to the treatment process. The silt content in the raw water during both dry and flood seasons chokes the filters. The filters require continual backwashing and treated water production is reduced by as much as 40%. An additional clarifier will be required to achieve settlement of the suspended solids prior to filtration. The filtration capacity must be increased by upgrading the existing filters and constructing additional filters.

9.2.4 Construct Presettlement Hafirs

The construction of presettlement hafirs, or holding ponds, was considered in lieu of an additional clarifier. This alternative will allow some of the silt to settle out of the raw surface water prior to treatment. The hafirs could be three basins, each with a capacity of about 15,000 m^3 to allow two days retention time for the fine particulate matter to settle out. The hafirs would also require the construction of transfer piping and pumping facilities.

9.2.5 Improve the Booster Pumping Facilities

Once additional raw water is obtained and treated, the next improvement alternative would be upgrading the existing high lift pumping facilities to Gedaref.

9.2.6 Implement the Phase I Brown-Boveri Recommendations

The Brown-Boveri technicians recommended the following as their Phase I improvements:

- Repair the shaft extension and replace the temporary couplings on the existing electric motors.
- Repair the third motor in Austria
- Training for one PEWC employee
- Improve substandard electrical control and safety systems.

9.2.7 Implement the Phase II Brown-Boveri Recommendations

The Brown-Boveri Phase II improvements were to install a new control panel and replace one motor. The new motor would be a high voltage (11kv) and low speed (1,000 rpm) motor. The motor would be complete with a gear box to step up to pump speed.

9.2.8 Replace the Existing Booster Pumps

An alternative that was considered involved a major change from the existing pumping scheme. The present scheme requires extremely high head pumps. An alternative would be to construct an in-line booster station along the transmission main. This station should be located as near the hydraulic mid-point as access and power supply will permit. Such a booster station would considerably reduce the pumping head requirements (for identical flows) and allow the use of smaller sized motors. The smaller motors would be less expensive and may be repaired locally.

9.2.9 Parallel the Gedaref Transmission Main

The single transmission main causes high friction losses and resultant excessive pumping heads. Further, the entire system relies on this single main for water supply. Consideration was given to a parallel main to reduce the pumping head requirements and improve the service reliability.

9.2.10 Reactivate the Abu Naga Well Field

As a means of supplementing the water supply to Gedaref from the Showak treatment plant, consideration was given to the reactivation of the existing Abu Naga well field. This alternative would include the construction and testing of additional wells. The rehabilitation of booster pumping facilities at the Abu Naga pump house will also be required.

9.2.11 Repair/Replace Abu Naga Transmission Main

If the reactivation of the Abu Naga well field proved to be a viable alternative, provisions would have to be made to convey this additional water to the main reservoir in Gedaref. Several minor decisions would have to be made under this alternative, such as repairing the existing 250 mm asbestos-cement pipe, replacing it entirely or just replacing portions of it.

9.2.12 Reactivate the Tawawa Well

This alternative assumes continual use of the existing Yugoslavian construction well which had been temporarily used by the Tawawa Refugee Settlement. Permission would have to be obtained by the Commissioner for Refugees from the Ministry of Agriculture for use of the well on a permenant basis. Water quality of this well is unsatisfactory.

9.2.13 Construct a New Well at Tawawa

With the potential political and technical (high hydrogen sulfide gas) problems of the existing well, consideration had to be given to the construction of a new well.

9.2.13 Augment Abu Naga Transmission Capability

If the reactivation and expansion of the Abu Naga well field provided to be a viable alternative, provisions would have to be made to convey the water to the main reservoir in Gedaref. An enlargement of the existing 250 mm main capacity would be required together with direct, untapped, line to the reservoir.

9.3 EVALUATION OF ALTERNATIVES

All alternatives considered as feasible are capable of being constructed within a relatively short time span which does not require a staged improvement program. In evaluating the alternatives, costs in 1982 dollars U.S. were used. A present worth evaluation of a alternatives was not needed because all alternative programs could be constructed at approximately the same time and in one stage.

The study team addressed the problem of obtaining reliable supplies of water in terms of quantity rather than quality. The basic premise being that the quality can be improved through modern technology if the quantity of water necessary is available.

9.3.1 <u>The basic parameters for this project were as follows:</u>

- To supply the expanded water demands of the existing service area through 1987.
- To provide 24 hour service to the entire service area.
- To complete the design and construction and have all facilities in service by 1987.
- To upgrade the facilities at a cost which does not exceed $6,000,000 inflated U.S. dollars.

While all of the alternatives considered were technically feasible, some of these alternatives did not meet the identified project parameters. These alternatives were eliminated from further consideration since they would not satisfy the project needs.

The first alternative to be eliminated was the construction of a parallel transmission main from Showak to Gedaref. The cost of this main alone would be approximately $8,200,000 US dollars, assuming a reasonably low installed cost of $120.00 USD per metre. Therefore, any water produced at Showak, for consumption in Gedaref, must be made to pass through the existing 500 mm steel transmission line.

The next set of alternatives to be eliminated were the relocation of the intake facilities, either upstream or downstream from Showak. These new intakes would still provide a raw water supply with a heavy silt loading. This silt would continue to bind the filters and significantly reduce the water treatment plant output.

Thus, the relocation of the intake facilities (either 7 kilometres upstream or 20 kilometres downstream) would also entail constructing additional facilities at the water treatment plant. These additional facilities would include the presettlement hafirs, or another clarifying unit, plus additional filters and associated plant piping. Also the existing filters would require upgrading.

The estimated present cost of this alternative package is approximately $3,500,000 to $4,000,000 depending upon the conditions encountered and further study. This alternative becomes cost prohibitive in comparison with the total available funding.

The elimination of other alternatives was for a variety of reasons including reliability, operational considerations and interrelationships with other componenets of the water supply system. These will be discussed in more detail in the following subsections.

9.3.2 Source of Supply

The average daily demand for the service area was estimated to be approximately 15,700 m^3/day by 1987. The water system must be capable of supplying this amount of treated water. The available raw water must be in excess of this amount to provide for water used in the treatment process.

The basic source of supply alternatives that remained for consideration were to improve the present supply at Showak to meet all the needs or a combination of improving the present supply plus augmenting this supply from localized groundwater sources.

Meeting all the water demands from Showak was eliminated since the single transmission line could not be replaced. Using the existing main to supply the entire 15,700 m^3/day would create head losses of approximately 170 metres (based upon C values of 100). This must be added to the static head of 165 metres to determine the pumping heads at the plant. Since the total dynamic lead requirement of 335 metres (476 psi) exceeds the capacity of the existing main, it was evident that a supplemental source, or sources, of water would be required.

Investigations at the Abu Naga well field indicated that the combination of constructing new wells and rehabilitation of existing well is feasible. The combination, of activties should produce a minimum of 3,800 m^3/day from the Abu Naga well field.

The use of the existing well at Tawawa should be discontinued due to both the high hydrogen sulfide content of the water and the question of the ownership of the well. The study indicates a strong probability of finding additional groundwater to supply Tawawa. The refugee settlement would be assured of a continual water supply regardless of problems affecting the Gedaref system. Any excess water produced from this source could be directed into the Gedaref system to supplement the Showak and Abu Naga supplies.

The Showak treament plant will be required to produce approximately 12,500 m^3/day. Every alternative considered to modify the existing intake facilities would still result in raw water with a high silt content. Adding to the existing supply with a few shallow wells would still not materially improve the water quality. The sedimentation and filtration capabilities of the plant would have to be increased to properly treat the increased water required.

However, through the exclusive use of shallow infiltration wells the water source requirements can be met. The intake problems will be eliminated completely. Natural filtration of the water would occur and should make any treatment, other than chlorination unnecessary. The slightly higher power costs expected with the exclusive use of these wells would be more than offset by the elimination of chemical costs and operating costs and problems associated with the existing plant.

9.3.3 Pipelines and Pumping

The existing 12 kilometres of 250 mm asbestos-cement water main from Abu Naga would have to be repaired. The total replacement of this transmission main was eliminated on a cost basis.

This main is tied into the Gedaref distribution network. If the water quality at Abu Naga is marginal this situation would lead to potential problems in Gedaref. The water from Abu Naga and Showak can be mixed at the reservoir to improve over-all quality by constructing and isolated parallel segment of line to direct this supply to the reservoir rather than into the distribution system. The mixed water can then be fed into the distribution system without cross connection.

A booster station is recommended for the Abu Naga well field. This would boost into the reservoir and would simplify operations as well as reduce the well pump head demands. The fundamental facilities for a booster station already exist and include a pump house and storage tanks.

The Brown-Boveri recommendations were eliminated as alternatives for the high service booster pumps. They would not effectively solve the existing problems and any repair work would still require expensive work outside the Sudan.

Instead, smaller high service pumps and a booster station mid-point on the transmission line are recommended. The capital investment costs for pumping equipment will be almost the same as the Brown-Boveri recommendations. Pumping cost may be slightly higher but maintenance costs should be substantially lower. The lower pumping heads will produce less stress on the

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transmission main. The mid-point booster will allow greater volumes of water to be pumped from Showak to Gedaref without the cost of replacing the existing transmission main.

9.4 PROPOSED IMPROVEMENT PRIORITY PROGRAM

The proposed improvements detailed in this section are developed to meet the water demand requirements of 17,180 m^3 per day as calculated in Chapter 6. The improvement program provides the planning year water requirements from the following sources:

Source	m^3 per day
1. Atbara River Shallow Infiltration Wells:	
For Showak-Gedaref Transmission	12,500
For Showak Village Supply	700
2. Abu Naga Well Field (minimum supply)	3,800
3. Tawawa Well	600
Total Water Supply	17,600

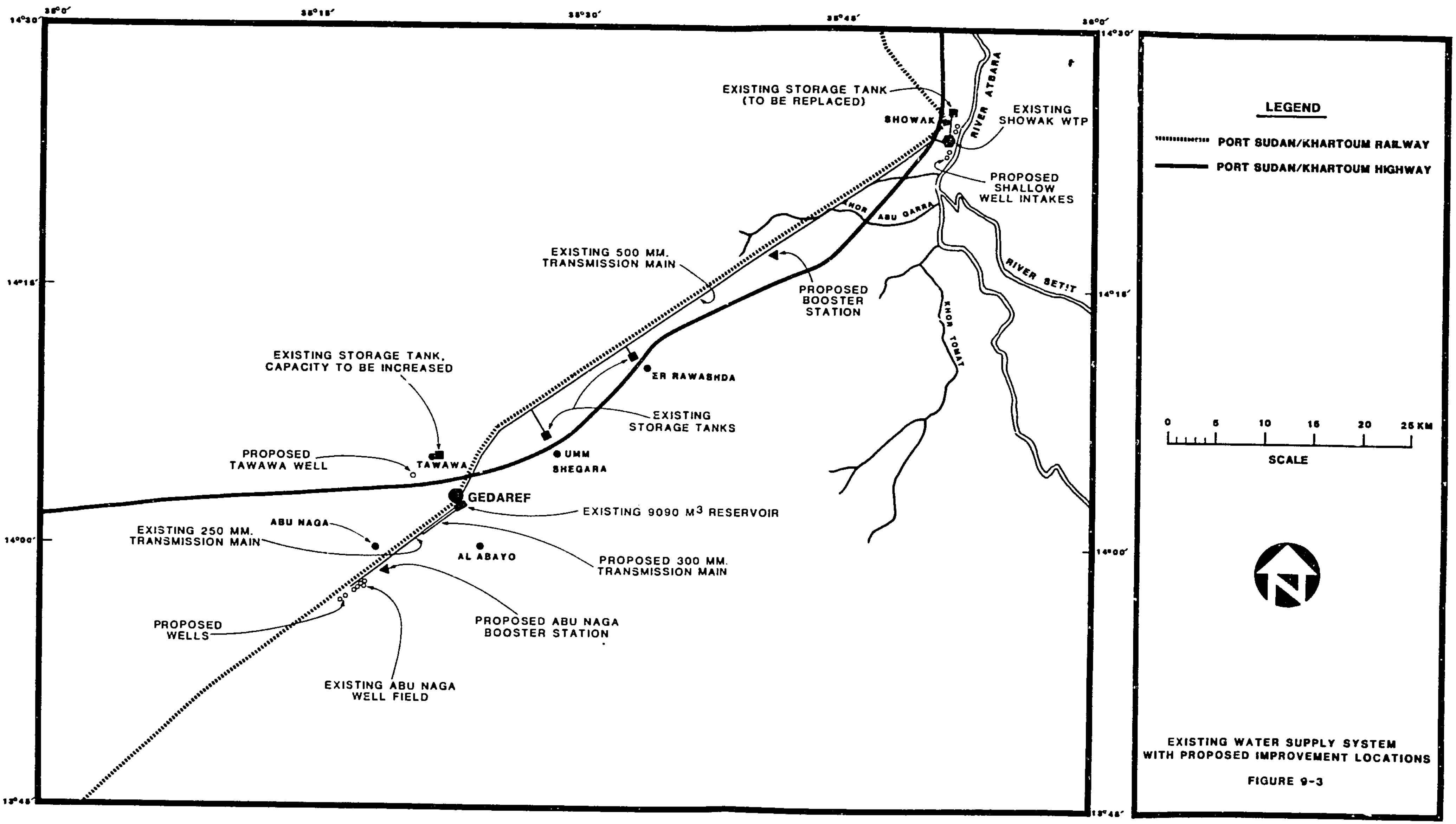
This total supply could satisfy needs after 1987 if projected population increases do not fully materialize or if per capita water usage does not equal the planning criteria and assumptions.

The following improvement program is presented and described in order of importance and priority of need rather than by improvement cost or other considerations. Figure 9-3 identifies the location of the proposed improvements.

9.4.1 Tawawa Supply and Other Improvements

The village of Tawawa is the main refugee settlement in the Gedaref area. Although it has an elevated steel tank and a 100 mm galvanized steel pipe supply line from Gedaref, there is no direct supply due to the current lack of water. The most practical improvement is to furnish Tawawa with its own independent water supply system which can be separated from the Gedaref system yet remain interconnected in order to deliver water in either direction in case of breakdowns or water outages in Tawawa or Gedaref. The Tawawa system would require the construction of a new well, a new transmission main, chlorination facilities, increased storage capacity, pumping equipment and power connections.

As mentioned in Chapter 4, the existing well is 2.0 kilometres away from the village. It has a high hydrogen sulfide gas content which would require aeration before extensive use. There are some problems associated with the wells' ownership. A new well should be constructed near the village of Tawawa to avoid the potential problems associated with the use of the existing well.



EXISTING WATER SUPPLY SYSTEM
WITH PROPOSED IMPROVEMENT LOCATIONS

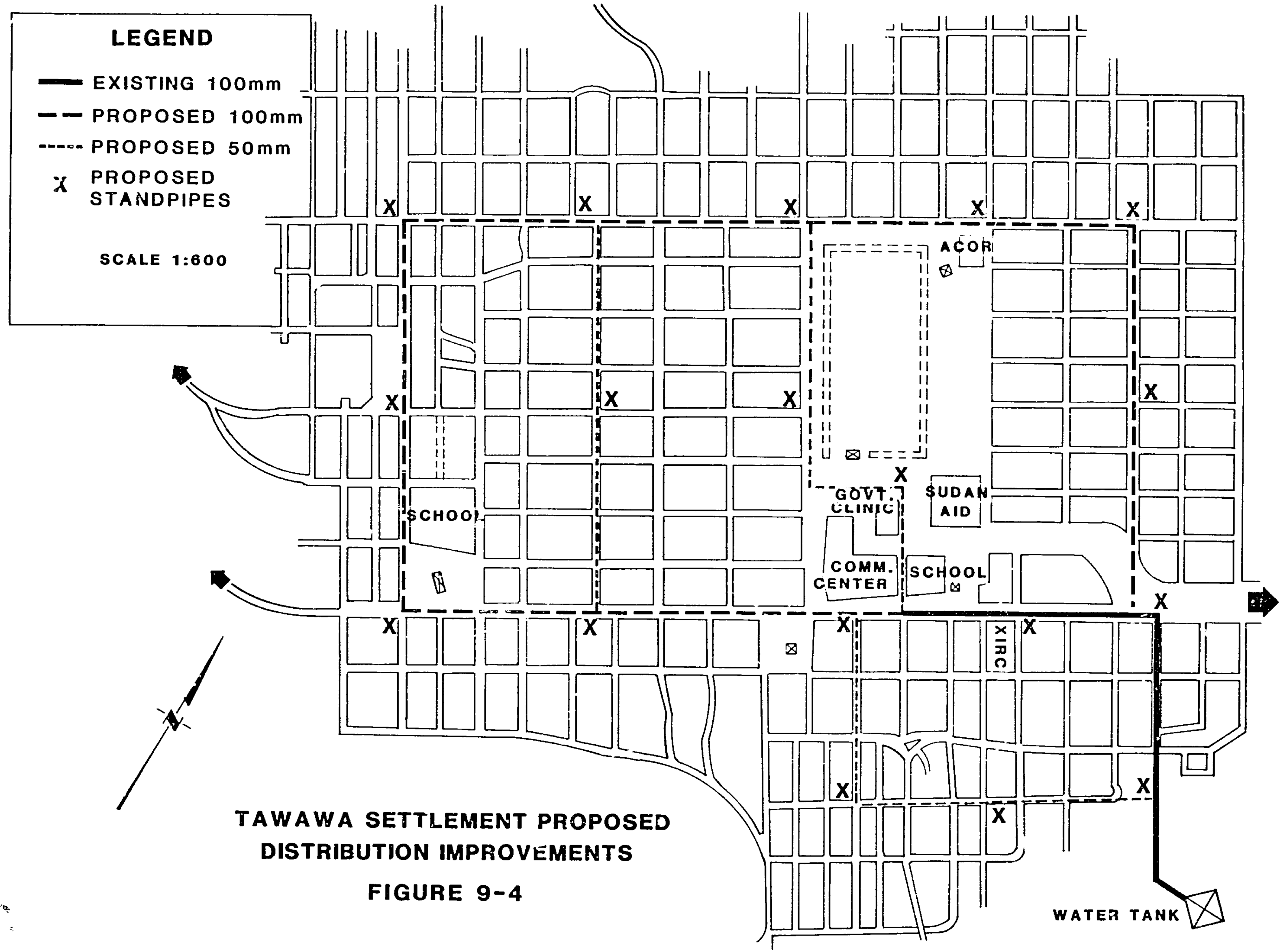
FIGURE 9-3

The proposed well should be connected directly to the elevated tank of Tawawa and equipped with a pump, an electrical control panel and a standby alternate power source. The pump cannot be sized at this time since the proposed well has yet to be drilled and tested. The pump should be a vertical turbine type with a right angle gear drive. The use of the gear drive will allow a diesel engine to be coupled to the pump. This engine will serve as a back-up pump drive during electrical interruptions or in the event of a burned out motor. Because of the unreliability of electrical service, adequate controls should include phase protectors and safe-guards against voltage or frequency fluctuations.

The existing storage tank is a Braithwaite elevated steel tank with a capacity of about 25 cubic metres (6,600 gallons). This represents less than 4 litres of storage per capita. The capacity should be increased to 70 cubic metres to provide a per capita storage capacity of 10 litres. The additional proposed storage tank can be designed and constructed to provide the required aeration if the proposed well develops water with a high gas content.

Chlorination equipment would be provided to assure the bacteriological purity of the well water supply. The chlorinator should be direct cylinder-mounted for safety and ease of maintenance. The chlorinator would be either a direct feed type at the storage reservoir, or a vacuum operated solution feed type at the well head. Either type of chlorinator is suitable for the proposed system. The final selection will depend upon the location of the proposed well, pressure heads, hours of power availability and suitable equipment housing.

Additional appurtenances recommended for the Tawawa system include a float control valve at the storage tank to prevent overflow, pressure indicators, pumping and chlorination equipment housing, a new 100 mm transmission main from the new well to the storage tank and new distribution lines. The length of the transmission main, choice of equipment and required equipment housing is dependent upon the physical location of the well. The distribution lines from the storage tank will be spread across Tawawa in a semi-grid pattern with public standpipes installed approximately every four blocks. The installation of individual house connections, as opposed to public standpipes, is considered unnecessary. Individual house connections lead to increased water demands, excess wastage and the tendency to use the water for non-consumptive purposes such as watering ornamental trees and shrubery. Separate services could serve public bath houses, public latrine facilities and other communal buildings. Figure 9-4 present the proposed distribution system additions.



TAWAWA SETTLEMENT PROPOSED DISTRIBUTION IMPROVEMENTS

FIGURE 9-4

With the installation of a separate water supply system for Tawawa, the existing 100 mm transmission line from Gedaref should be reconnected and valved off. This would be to assure a secondary source of supply if Tawawa has need and if Gedaref has excess water. Conversely, should Tawawa have excess water, it could be redirected to Gedaref proper to augment their supply.

9.4.2 Abu Naga Well Field Development

The Abu Naga well field was described in detail in Appendix B and Chapter 7. This well field served as the sole source of supply for the Gedaref area prior to the construction of the water treament plant at Showak. Since the commissioning of the treatment plant, the wells have generally been neglected and allowed to deteriorate. The result of neglecting the Abu Naga well field is the total reliance Gedaref must place on the Atbara River source and the attendant treatment, pumping and transmission facilities. The second most important improvement is to develop an additional source of supply to augment the Atbara River water and to provide for some of the needs of Gedaref, should problems occur at the Showak treatment plant.

The Abu Naga well field is the logical choice for a source of additional water supply. Lying approximately 12.0 kilometres to the southwest of Gedaref, the well field is connected to the Gedaref distribution system by means of a 250 mm asbestos-cement transmission main. This 250 mm main is broken in several locations. Of the 11 wells at Abu Naga, two have been abandoned while others are being rehabilitated by the Rural Water Administration (NAW).

The recommended improvement for Abu Naga is the complete rehabilitation of the remaining wells and the construction of two new wells. Most of the existing wells were constructed with small diameter, slotted casings and were originally tested with bailers. After the rehabilitation work is completed, proper pump tests should be conducted on these wells to determine draw downs and safe yields. Once this is accomplished, properly sized submersible pumps designed to maximize yields can be installed. The two proposed wells should be constructed with properly designed well screens for increased production. The preliminary design of the production wells is shown on Figure 9-1 and their proposed locations are shown on Figure B-4. These wells should be outfitted with properly sized submersible pump units to optimize their yields.

The Abu Naga well field should be equipped with a standby/alternative power source as a back-up to the normal power supply due to the unreliable power availability. The most feasible way of obtaining the additional power requirements is to

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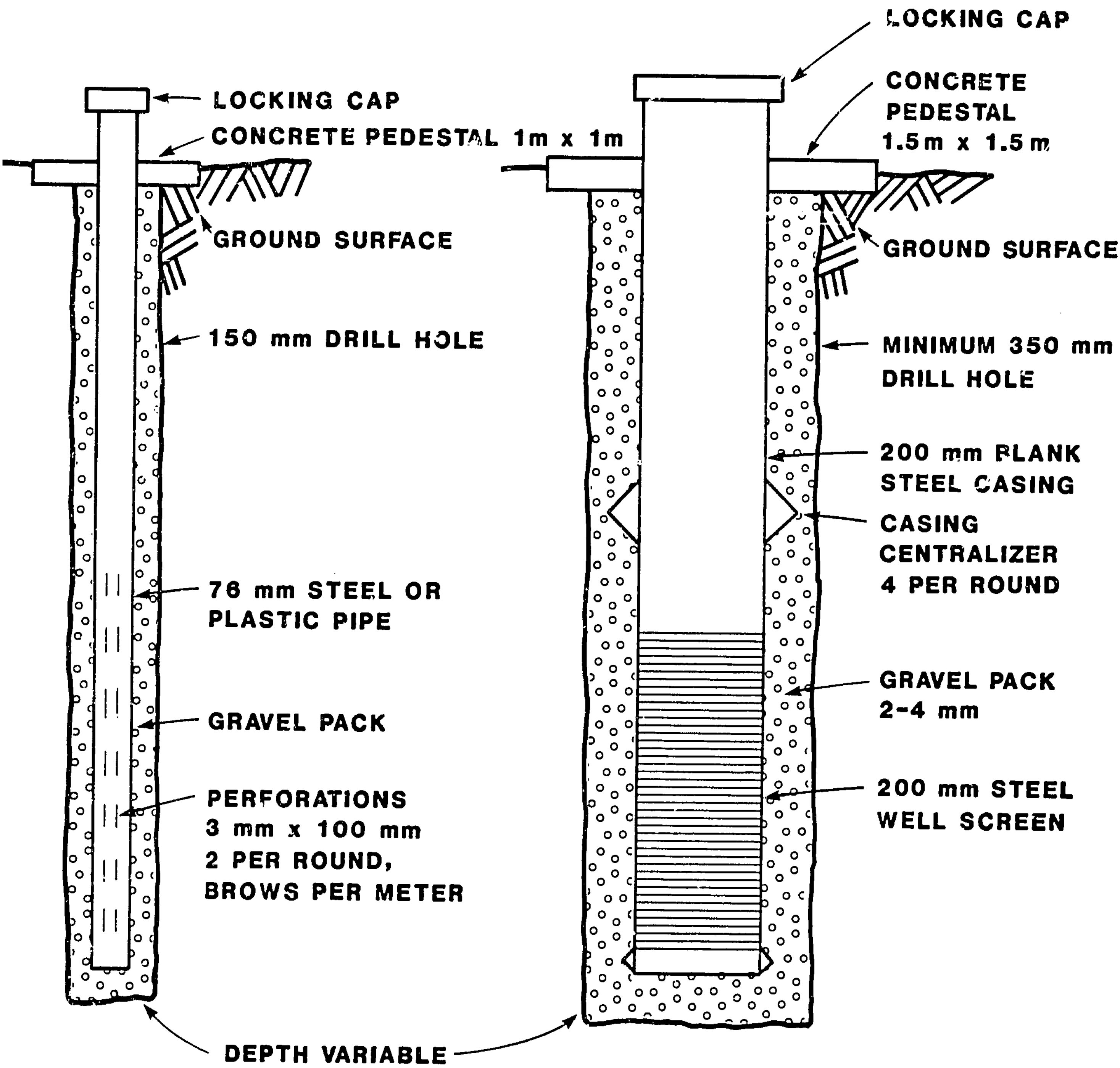

NOTE: ALL DRILLING DEPTHS AND CASING LENGTHS TO BE DETERMINED BASED ON RESULTS OF TEST DRILLING.

NOT TO SCALE

PRELIMINARY DESIGN
TEST/PRODUCTION WELL AND OBSERVATION WELL
FIGURE 9-1

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install a large diesel generator at the Abu Naga pump house. The pump house is steel frame with brick walls and a corregated steel roof. It is of approximately 12 metres by 20 metres and is structurally sound.

The generator must be sized to accomodate the horesepower requirements of the well pumps. However, these requirement will not be known until the existing and proposed wells have been pump tested and their pumps properly sized. However, each well and the proposed generator must be outfitted with control panels to protect the equipment against voltage and frequency fluctuation or the loss of a phase in the three phase supply. The pump house main control panel should be designed so that the wells could be selectively controlled. This is critical, especially during start-up, to keep the generator sizing to a minimum. Since start-up power requirements are much greater than full load running requirements, the well pumps should be energized on a staggered basis.

After the water is produced, it must be conveyed to the main population center in Gedaref. As previously mentioned, the existing 250 mm transmission line is broken in several locations. The repair of this line in situ will direct the well water into the Gedaref distribution line at a point approximately 5.25 kilometres (3.28 miles) from the reservoir site. The distribution line has numerous interconnections with the distribution network along the last 5 kilometres through town. It is recommended that the existing 250 mm transmmission main be repaired to the point of its interconnection with the distribution network and that a separate 300 mm transmission line be constructed from that point directly to the reservoir. This would allow the water from the Abu Naga well field to be directed into the reservoir where it can be mixed and controlled.

In addition to the new wells, the rehabilitation of the existing wells, back-up power source and transmission line, a booster station would be installed at the Abu Naga pump house to keep the head requirements of the well field pumps to a minimum. There are 5 existing Braithwaite elevated steel tanks near the pump house, each with dimensions of 3m x 3m x 3m. These tanks have a bottom elevation of 4.5 m and a combined capacity of about 135 m^3. By utilizing these tanks and installing a centrifugal pump to boost the water to the Gedaref reservoir, substantial savings can be realized in operation and maintenance costs.

There is a problem regarding providing housing for the well field/booster station operators. The problem is real, but it is felt that this is an internal operational problem and should not be addressed in this report.

9.4.3 Mixing and Chlorination at the Main Reservoir

The problem in Gedaref was addressed in terms of quantity as opposed to quality. There is quite a difference in taste and quality between the Abu Naga well field source and the Atbara River water. Care must be taken to assure that the two waters are thoroughly mixed prior to release into the distribution system. Several mixing alternatives were considered. It is recommended that the mixing be done as simply as possible.

The proposed method of mixing is to locate the inlet of the Abu Naga transmission main above the existing inlet of the Showak transmission main. The Abu Naga inlet should be placed above the high water level of the reservoir so that the natural fall of the incoming water will cause turbulence and effect a thorough mixing.

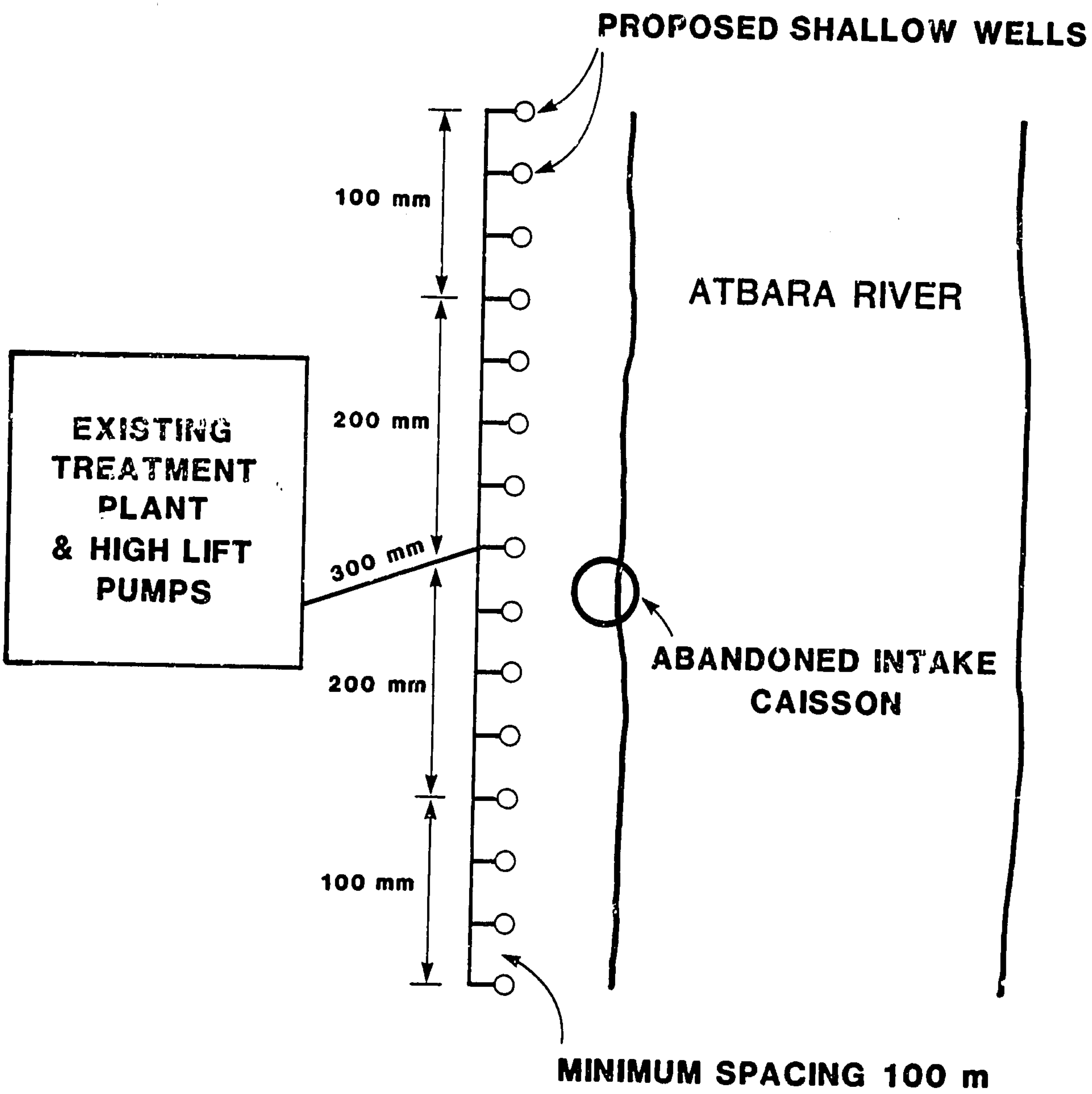
Single point chlorination at the reservoir presents a problem in obtaining proper dosages. Since the two independent sources each will have varying rates of flow, a dual chlorination system would be required. It is recommended that the existing chlorination facilities at the reservoir for the Atbara River water be renovated and that the Abu Naga water be chlorinated separately at the proposed well field booster station. Both chlorinators can be manually set and readily adjusted by the operators to match the individual supply flows.

9.4.4 Atbara River Source Improvements

The present methods of obtaining water from the Atbara River vary and are dependent upon water levels during the wet and dry seasons. It is reported that there have been dry periods with virtually no river flows. The silt loading is extremely high during the wet season and this silt causes exreme operating problems at the treatment plant.

It is recommended that a series of 10 to 15 shallow infiltration wells be constructed along the west bank of the river, spaced at least 100 m apart. A preliminary layout of the Showak wells is shown on Figure 9-2, however, the exact number of wells and their proper spacing will depend upon the yield and drawdown characteristics determined during the testing program. A testing program, as described in Section 9.7 is essential for proper well field design.

The theory for the use of shallow wells along the river bank as opposed to a direct river intake arrangement is to optimize reliability of the water source during periods of low river levels and to elimate full treatment requirements. During the flood stages, the intial rushes of water carry about 16 kilograms of silt per cubic metre of water which overloads the clarifier and the



NOT TO SCALE

SCHEMATIC LAYOUT FOR
SHOWAK SHALLOW WELL ALTERNATIVE
FIGURE 9-2

graded rapid sand filters at the treatment plant. The overloaded filters require constant backwashing which, in turn, reduces the plant capacity by 40%. The flood stage is typically about 6 m above the low water level during the dry season. The large disparity in water levels render normal intake structures impractical, especially when river bed has accumulated over of 7 m of silt over the past twelve years.

The Atbara River flows in a channel near the east bank during periods of low flow. Since the treatment plant is located on the west bank, a channel as long as 150 m must be hand dug in the silt to divert what little water is available toward the treatment plant and the intake pumps. (See cover photo).

By utilizing the shallow wells, advantage will be taken of the ground water flowing beneath the river. The water obtained would be naturally filtered, and should eliminate the need for treatment other than simple chlorination. Substantial savings would be realized in chemical requirements and plant operating costs.

The shallow wells will need to be equipped with pumping units and electrical controls. In addition, supply pipes must be provided from the wells to the clearwell at the treatment plant. The existing chlorination facilities at the plant can be modified to treat the water prior to its transmission to the Gedaref reservoir. Because the pumping units in the shallow wells will be relatively small, auxillary power can be utilized to assure 24 hour production capability.

Another major improvement at the Showak treatment plant is to replace the existing high lift pumps and 500 kva motors with smaller units. Currently, the pumps are sized to convey 420 m^3/hr at a head of 240 metres.

It is recommended that a booster station and a holding reservoir of at least 150 m^3 capacity be constructed as near the hydraulic midpoint of the existing transmission line as available electric power will allow. By using this concept, smaller motors may be used. These motors may be locally rewound and repaired and the spare parts inventory can be kept to a minimum since the pumping units at both locations will be identical. The pumps would be the centrifugal pumping variety.

With the existing low voltage, motors replaced with synchronous motors having low starting torques, standby auxillary diesel engines or generators may be employed to keep the transmission line functioning during periods of power outages. An alternate power source would also be installed at the proposed booster station.

The venturi metering device should be repaired or replaced to record the flow from the clearwell. Accurate production records can be maintained with an accurate metering device. Other mainline meters would be installed on the Showak, Er Rawashda and Umm Shegara lines to determine the amount of water ultimately reaching the Gedaref reservoir. Pressure gauges would be installed on the various pipelines to monitor flow conditions.

9.4.5 Showak Village Improvements

The only improvement necessary to get the village of Showak off the existing 500 mm transmission line is to replace the broken Harland pump and 40 Hp motor which originally supplied Showak directly from the clearwell. An additional improvement, needed at Showak is to replace the existing elevated steel tank. This tank has deteriorated to the point where there is substantial leakage along its bottom edges.

9.4.6 Metering and Waste Control

The condition of the present customer water meters creates the following adverse effects on the water supply system:

- Excessive wastage by more than one-half of the active services due to inoperative meters at the customers' services.
- Higher power and chemical costs due to treating and pumping water that is wasted.
- A reduced water supply available for basic residential needs due to wastage.
- Higher capital improvement costs due to oversizing requirements to meet wastage demands.
- A loss in water revenues for water wastage that is unmetered and therefore uncontrolled and unbilled.

Several solutions are available to control excessive customer wastage. They include:

- Equipping each water service connection with a reliable and accurate water meter.
- Establishing water rate structures that deter excessive use and waste through charges with a financial impact on family budgets.

- Installing restricted water services by using extremely small service lines, installing constricting orifices in the service line or by other physical inhibiters to the volume of flow into the customer plumbing system.

- By creating extremely low working pressures in the distribution system thus restricting the flows of water available at the customer service connections.

- By using a planned public information program to instill the need for voluntary reduction of water use and wastage.

- Levying fines or penalties for provable cases of excessive use and wastage.

Of the above solutions, only accurate water metering and reasonable water rates are considered to be the practical methods of obtaining the desired controls in Gedaref. The long-range capital costs for expanding water systems that have a large wastage factor is a significant financial burden that can easily justify the cost of installing and maintaining water meters. Operating costs are also inflated due to excessive waste and can be reduced significantly through metering and proper water rates.

The proposed improvement program includes new water meters to replace all, or most, of the present meters and a supply of meters for future water connections and for needed replacements. The program includes 10,000 residential type meters and 400 larger meters for commercial, industrial and institutional uses. It is recommended that the selection of appropriate meters consider only those meters with high reliability, accuracy and very minimal maintenance and repair requirements. It is recommended that multi-jet meters with magnetic drives and sealed registers be used in the Gedaref system. These meters meet the current AWWA standards for performance and accuracy and they are of simple design, very low in maintenance requirements, require almost no spare parts inventories or special maintenance equipment and are available at low cost. Multi-jet meters are available with magnetic shields, sealed registers and meter cases that are virtually tamper-proof. The improvement cost detailed in Section 9.5.6 is based upon current U.S. manufacturer's prices of about $24 per meter including couplings, F.O.B. factory. The larger size meters should also be of simple design and have low maintenance requirements. A fully staffed meter maintenance facility is not required if domestic meters are of the type discussed above.

9.4.7 Communications

When the main reservoir at Gedaref and the Showak treatment plant were constructed, both a radio and a direct telephone communication system were installed between the two locations. Reportedly the radio system went out of service two years after commissioning the plant and was never repaired. The telephone communications became non-operational about May 1982. These communications systems should be reactivated and modified to include the proposed booster station on the 500 mm transmission main and the Abu Naga well field booster station.

9.4.8 Other System Improvements

Because of the time constraints imposed upon the study team and lack of data, it was not possible to totally reconstruct a plan of the distribution network for Gedaref. No information was available concerning any distribtion systems within the communties of Showak, Er Rawashda or Umm Shegara. A few standpipes were noted in Umm Shegara and Er Rawashda but no individual house connections were observed. Showak most likely has a more extensive network which would have to be located in the field through the use of exploratory excavations and pipe locating equipment.

Since the information obtained to date is incomplete, it is felt that any future improvements and/or expansions to the various distribution networks (with the exception of Tawawa), should be left to the water utility to implement on an as needed basis. The costs for any such improvements could be covered in operating budgets or paid for by the beneficiaries of future extensions.

9.5 PROPOSED IMPROVEMENT COSTS

The following cost estimates for the various proposed improvements are based upon the information available at the time of the study. Several assumptions were used, such as well yields and pumping levels to obtain projected pumping requirements and costs. The actual needs and requirements can only be determined after proper testing of the proposed production wells has been conducted. The assumption was made that the funding available by the United Nations High Commissioner for Refugees for the redevelopment of the existing wells at the Abu Naga well field will be utilized for this purpose and the wells will have been rehabilitated by the time this project is implemented. It was further assumed that all the existing wells in Abu Naga will be useable and all the existing well pumps will require replacement.

The lack of solid data on the electrical power grid and individual transformer capabilities has led to assumptions of actual power requirements. This is not a major problem since the final sizing of generator sets can only be determined after wells have been tested and pumps are properly sized. Pump sizing can only be determined after accurate well testing has been completed.

All proposed improvement costs are based upon late 1982 cost data and are stated in equivalent U.S. dollars. Total estimated project construction costs are presented in Chapter 12, including a disaggregation of local cost components, escalation factors due to inflationary trends and other costs pertinent to full project implementation.

9.5.1 Tawawa Supply and Other Improvements:

Item	Description	Estimated (Equivalent US$) Current Costs
1	Construct a deep well-est. 200 m deep @ $585/m	$ 117,000
2	Construct a 100 m transmission main from the new well to storage tank est 2000 m @ $35/m	70,000
3	Install new chlorination equipment	3,500
4	Install new pump with electrical control panel-est. 20 m^3/hr @ 65 m TDH	18,000
5	Install right angle gear drive	5,000
6	Install diesel engine	5,000
7	Construct housing for pumping equipment	5,000
8	Construct additional elevated storage (45 m^3 capacity)	25,000

Proposed Water System Improvements

Item	Description	Estimated (Equivalent US$) Current Costs
9	Construct a 100 mm distribution line-est. 2,425 m @ $35/m	84,900
10	Construct a 50 mm distribution line-est. 1,680 m @ $10/m	16,800
11	Install public standpipes est. 18 @ $100 ea (with drainage)	1,800
12	Appurtenances, valves, etc.	7,700
	Total Estimated 1982 Cost	$ 359,700

9.5.2 Abu Naga Well Field Improvements:

Item	Description	Estimated (Equivalent US$) Current Costs
1	Construct 2 wells est. 200 m deep @ $585/m	$ 234,000
2	Install submersible pumps in 12 wells @ $24,000/well	288,000
3	Install a standby generator with multiple control panel	65,000
4	Restore Abu Naga booster station housing to useable condition	10,000
6	Install centrigual booster pump - est. 200 m^3/hr @ 110/m TDH	20,000
7	Install chlorination equipment	5,000
8	Install 300 mm transmission main - est. 5,500 m @ $100/m	550,000
9	Repair existing 250 mm asbestos-cement main	10,000

Item	Description	Estimated (Equivalent US$) Current Costs
10	Install est. 1500 m of 150 mm main in well field @ $45/m	67,500
11	Install est. 3,500 m of 200 mm main in well field @ $65/m	227,500
12	Appurtenances, valves, etc	23,000
13	Step up transformer	20,000
14	12 control panels-est. @ $2,000 ea	24,000
	Total Estimated 1982 Cost	$1,544,000

9.5.3 Mixing and Chlorination at the Main Reservoir:

Item	Description	Estimated (Equivalent US$) Current Costs
1	Replace existing chlorination equipment and install mixing baffles	$ 13,000
	Total Estimated 1982 Cost	$ 13,000

9.5.4 Atbara River Source Improvements:

Item	Description	Estimated (Equivalent US$) Current Costs
1	Construct 15 shallow wells-est 40 m deep @ $585/m	$ 351,000
2	Install submersible pumps in 15 wells @ $14,000/well	210,000
3	Install standby generator for wells and booster pump	110,000

Proposed Water System Improvements

Item	Description	Estimated (Equivalent US$) Current Costs
4	Install piping from shallow wells to clearwell:	
	est 2,000 m of 100 mm @ $35/m	70,000
	est 2,000 m of 200 mm @ $65/m	130,000
5	Install power lines and control panel for well field	10,000
6	Modify existing chlorination piping at treatment plant	2,000
7	Replace high lift pumps with smaller units - est. 3 pumps and motors 360 m^3/hr @ 180 TDH @ $20,000 ea	60,000
8	Booster station pumps-est. 3 pumps and motors, 360 m^3/hr @ 180 TDH @ $20,000 ea	60,000
9	Booster station pump housing	25,000
10	Booster station reservoir - 400 m^3 @ $300/$m^3$	120,000
11	Electric service to booster station	20,000
12	Auxillary power for booster station	65,000
13	Repair Venturi meter at pumping station	5,000
14	Appurtenances, valves etc.	17,000
	Total Estimated 1982 Costs	$1,255,000

9.5.5 Showak Village Improvements:

Item	Description	Estimated (Equivalent US$) Current Costs
1	Replace service pump-est. 40 m^3/hr @ 65 m TDH	$ 7,000

Item	Description	Estimated (Equivalent US$) Current Costs
2	Replace elevated steel tank ($50\ m^3$ capacity)	25,000
	Total Estimated 1982 Costs	$ 32,000

9.5.6 Metering and Waste Control:

Item	Description	Estimated (Equivalent US$) Current Costs
1	10,000 domestic water meters (5/8" x 3/4" milti-jet, magnetic drive) incl. couplings and installation	$ 400,000
2	400 1" I.D. and larger water meter at average of $80 incl. fittings and installation	32,000
	Total Estimated 1982 Costs	$ 432,000

9.5.7 Other System Improvements:

Item	Description	Estimated (Equivalent US$) Current Costs
1	Reestablish telephone communications from Showak to Gedaref	$ 7,000
2	Provide radio communications - 2 base stations and 3 remotes	43,000
	Total Estimated 1982 Costs	$ 50,000

9.5.8 Operating Materials and Equipment:

Item	Description	Estimated (Equivalent US$) Current Costs
1	Transportation Equipment - 4 units	$ 40,000
2	Tools and construction equipment	20,000
3	Replacement parts and supplies	30,000
	Total Estimated 1982 Costs	$ 90,000
9.5.9	Training Costs:	15,000
Grand Total	- Proposed Water Supply Improvements at 1982 prices	$3,790,700

9.5.10 Solid Waste Disposal Improvements:

Item	Description	Estimated (Equivalent US$) Current Costs
1	4 - 34 Hp tractors w/special 4-wheel trailers	$ 72,000
2	Bulldozer with blade	36,000
	Total Estimated 1982 Costs	$ 108,000
Total	- Water Supply and Solid Waste Improvements	$3,898,700
9.5.11	Contingency Factor at 10%:	389,900
	Totals with contingency	4,288,600

9.6 IMPROVEMENT PRIORITY AND SCHEDULING

The proposed improvements outlined in the previous section were listed in order of their importance with respect to need. Because of public pressures placed on government officials to improve the water supply to Gedaref, priority of implementation should be given to those improvements that would have maximum impact to the overall water supply situation. The following is suggested order of project implementation for the proposed improvements.

- Drill and Test Wells at Abu Naga
- Drill and Test Wells at Atbara River
- Construct the 300 mm transmission main from the existing 250 mm Abu Naga main to the Gedaref reservoir.
- Construct new well for Tawawa
- Repair the 250 mm asbestos-cement Abu Naga transmission main
- Equip the existing Abu Naga wells
- Install booster pump at Abu Naga
- Install 200 mm Tawawa Supply line to reservoir
- Replace Showak village booster and storage tank
- Construct balance of new wells in Abu Naga
- Begin water meter installations
- Construct balance of shallow wells at Atbara River
- Install Atbara River well supply lines
- Equip all wells
- Construct additional storage at Tawawa
- Construct booster station on 500 mm transmission main
- Construct Tawawa distribution lines and public standpipes
- Replace Showak booster pumps and install pumps at upstream booster station
- Implement solid waste improvement

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Due to bidding, tendering and construction contract procedures, many of the above project segments could be purchased and constructed simultaneously. Figure 9-5 sets forth our proposed project implementation scheduling. Preparation and approval scheduling was developed after consultation with USAID personnel to recognize and plan for the timing needed to process and receive governmental approvals for this project of emergency proportions.

The total local and U.S. cost components stated in Chapter 12 are escalated by stated inflationary factors several months past the scheduling shown in Figure 9-5. This was purposely done to allow for some slippage in one or several of the implementation steps.

9.7 IMPROVEMENT IMPLEMENTATION METHODOLOGY

The following is our recommended approach to realizing the satisfactory implementation of the proposed water system improvement program. The complexity and variety of system improvements will require capable technical assistance and supervision throughout the entire design, construction and start-up phases. The nature of the program also requires a two-step approach to final design and tendering because of essential information needed from the well drilling and testing program. Satisfactory project implementation will require the following essential steps and involvements.

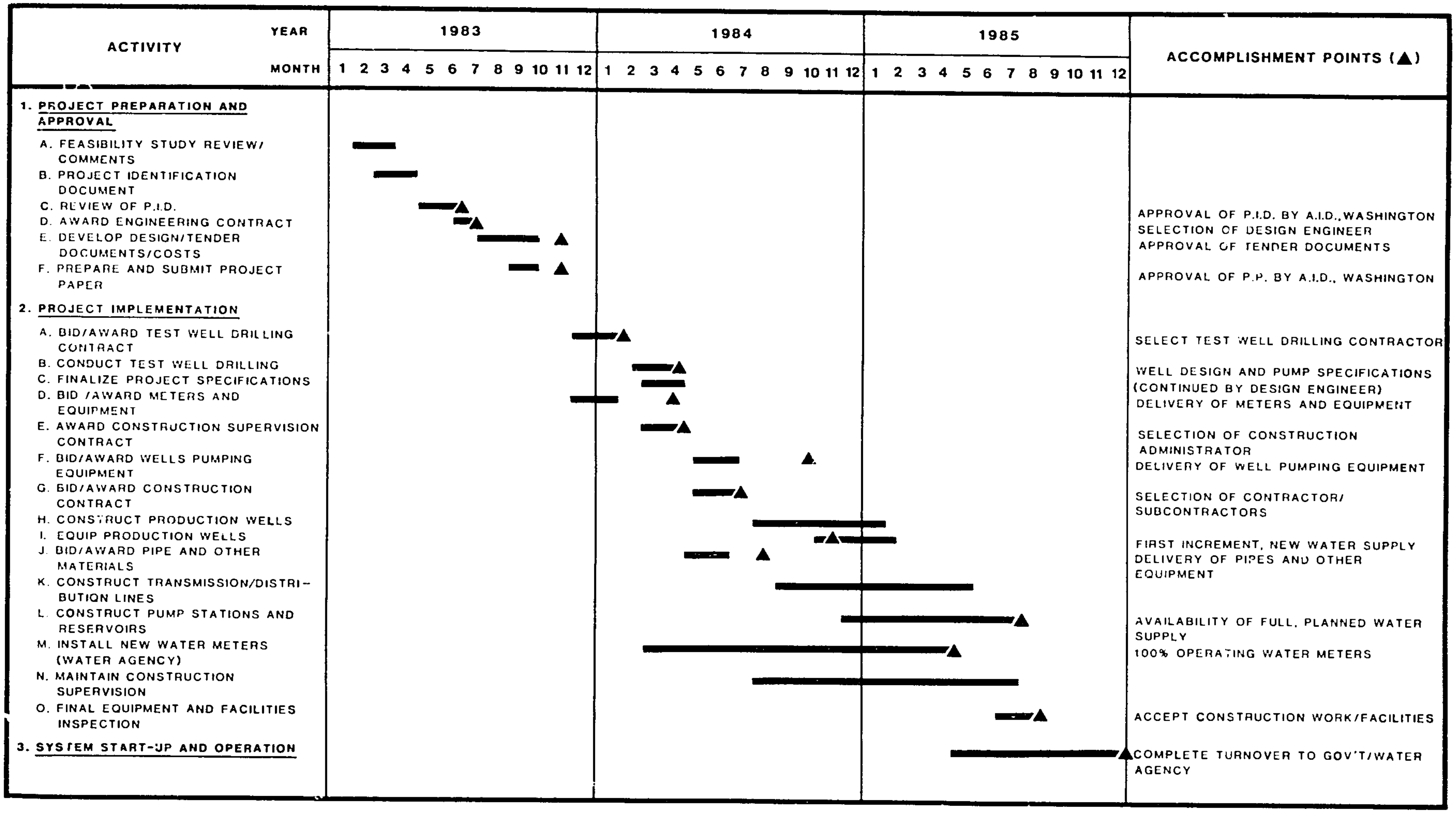
9.7.1 Intitial Design, Tender Documents and Project Paper Preparation

An engineering firm should be retained to develop final designs, specifications and tender documents for those proposed water system improvements that do not require well testing information for sizing purposes. The consultant could also assist in the preparation of the USAID project paper. Certain advantages could be realized by utilizing a firm with experience in Sudan and some familiarity with the water supply situation in eastern Sudan.

The same engineering firm should provide a hydrogeologist to oversee the test well drilling contractor and this firm should continue to complete all design work, specifications and preparation of final bidding documents. The scheduling of these activities is graphically shown on Figure 9-5. The duration of this work is estimated to be approximately five months in total.

9.7.2 Well Drilling and Testing Program

The recommended improvement alternatives include development of ground water at three separate locations for the Gedaref water service area. Because of the current insufficient data or well drilling construction practices and aquifer testing, it is essential that controlled a program of drilling and aquifer testing be conducted. This program should preceed final design



PROPOSED PROJECT IMPLEMENTATION SCHEDULE

FIGURE 9-5

of the project improvements except those not requiring sizing due to well test information. However, if project timing does not permit, the testing program can be conducted concurrently with the project design. Pumping wells constructed for testing purposes would be designed for later incorporation into the improvement project as production wells. It is recommended that drilling and testing be performed by a private drilling contractor and we recommend that this work be supervised by hydrogeologist on the design firm's staff. Specific details of the testing to be conducted are discussed below.

a) Tawawa Village: It is recommended that 1 test/production well be drilled at Tawawa approximately 1 km west of the village. The well will be drilled to a depth of approximately 200 m and constructed as shown in Figure 9-1. The recommended method of drilling is with air rotary/percussion rigs. A 100-150 mm pilot hole would be drilled and water samples collected to analyze the water quality characteristics. If the quality is suitable for drinking water supply purposes, the borehole can be reamed and casing and screen installed. Drilling depths and casing intervals will be determined by the on-site hydrogeologist. Following well construction and development, a 48 to 72 hour pumping test will be conducted. Water levels and pumping rates will be recorded throughout the test to provide design data to be used in selecting the proper sized pumping equipment.

b) Abu Naga Well Field: Two new wells are proposed for the Abu Naga well field, the locations for which are shown on Figure B-4. Drilling and testing procedures would be as described in a) above. Existing wells would be used as observation wells and would be measured during aquifer pumping tests. Estimated well depths for these wells range from 180-220 m below ground surface. The recommended well design is shown on Figure 9-1.

c) Showak Well Field: One test well and observation well have been constructed at Showak. A pumping test conducted at these wells indictes good potential for ground water development but does not provide sufficient information for design purposes. It is recommended that 1 test/production well and 4 observation wells be constructed near the existing treatment plant in accordance with the well design shown on Figure 9-1. The observation wells would be spaced around the test well both parallel and perpendicular to the river channel. One observation well would be placed between the channel and the test well and a second one on the opposite side of the test well (away from the river channel). Water level measurements would be taken in each of the observation wells during the drawdown and recovery period. Water samples would be collected and analyzed to evaluate chemical characteristics. Data obtained during the testing of these wells will provide input for the well field design including the number of wells, depths, sizes, spacing and pump specifications.

It is anticipated that the recommended drilling and testing program at the three sites could be completed in approximately 8 weeks. An apparently well-qualified drilling company with years of water well drilling experience in Sudan was contacted for information and time estimates. This particular well drilling company originates out of West Germany. It was felt that use of the NAW rigs would prove disadvantageous due to quality control problems and distinct possibilities that rigs would be transferred to other governmental work prior to completion of the entire well construction program.

9.7.3 Construction Contractors

Various options are available for awarding construction contracts. The study team was unable to review the capabilities of all local Sudanese construction firms with experience in water system installations. However, due to the mechanical and electrical complexities associated with the proposed improvements it is felt that a U.S. firm should be contracted for the prime construction responsibilities.

Therefore, our recommendations for actual construction of proposed improvements would be as follows:

a) A qualified prime contractor operating out of the U.S.A. with experience in working in North Africa.

b) Continued use of the well drilling contractor as a subcontractor for drilling and equiping all production wells. This firm could be the West German driller previously mentioned.

c) A local Sudanese subcontractor to install all water pipelines and appurtenances.

d) A local Sudanese subcontractor to provide and install surface level and elevated water storage tanks and construct new pumping stations.

e) Installation of new water meters by the Gedaref water utility under the direction of the construction supervising contractor.

9.7.4. Construction Supervision and Project Start-up

It is recommended that serious consideration be given to use of a qualified civil engineering firm for construction supervision and administration. This is important due to the hydraulic, mechanical and electrical complexities involved in this improvement program. A non-profit international organization such as CARE could be utilized if they could demonstrate availability of the needed technical personnel. The construction supervision organization should also be given the responsibility to commission and operate the improved systems, after the acceptance, for a period of not less than six months.

The above are suggested implementation methods and are not the only viable solutions available to USAID in satisfactory completing the improved water supply system.

CHAPTER 10

SOLID WASTE DISPOSAL IMPROVEMENTS

An integral part of the Contractor's scope of work is related to an evaluation of solid waste disposal facilities and development of improvement recommendations. During our inspections in the project area, we evaluated the present condition of solid waste handling and discussed the problem with local officials, including the Governor of the Eastern Region. The local officials considered solid waste disposal to be of minor importance in comparison with improving water supply reliability. They almost uniformly requested that available funds be used for water supply and not solid waste improvements. The following are our findings on this matter.

10.1 EXISTING SITUATION AND PROGRAMS

10.1.1 Evaluation of Present Problem

The study team conducted observation tours throughout the study area to measure the magnitude of solid waste disposal problems. Generally, the area was liberally scattered with solid wastes consisting mostly of cans, glass, paper and cardboard, building materials, and various unusable metal objects. Much of this material appeared to be old and in a state of natural decomposition. Animal and vegetable wastes were negligible and consisted mainly of garden clippings, tree limbs and leaves and animal droppings. Roving goats were observed scavenging through garbage heaps and drop boxes and their consumption of putrefactive wastes appeared quite thorough. The population of flies and rodents was relatively small, at least during the observation months of November and December. Several residential drop boxes were monitored and it was determined that they were never emptied during a three-week observation period. A visit to the regional capital city of Kassala revealed that solid wastes were closely controlled, the streets and surrounding area were clean and tidy and that the city managed their program without using expensive garbage trucks. Generally, the solid waste disposal conditions in Gedaref created adverse aesthetic impacts but were not considered to be significant health hazards. Health hazards could be worse in the public suq area where putrifying wastes were more prelevant.

10.1.2 Present Solid Waste Management Programs

The Public Health Inspector of Gedaref Town is responsible for the waste disposal programs for both solid waste and human waste. The solid waste division cleans the suq area daily and services to the general town are on an infrequent and unscheduled basis. The present staffing of the solid waste

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disposal division consists of the following personnel:

TABLE 10.1

GEDAREF SOLID WASTE MANAGEMENT PERSONNEL

Position	Number
Public Health Inspector	Part-Time
Supervisors	9
Sweepers	22
Slaughterhouse Cleaners	16
Burners (disposal site)	2
Drivers and Helpers	20
Present Staffing	69
Budgeted but Vacant Positions	35
Total Existing and Approved Positions	104

The majority of existing staff are occupied in cleaning the main suq area. The workers were not observed in the residential areas during field visits. Collected wastes are hauled to a site about 4 km southeast of the center of town where it is burned and infrequently backfilled. The site is located at a discontinued aggregate borrow pit and is downwind from the populated area thus causing minimal odor problems. The Town Health Inspector stated that workers are difficult to hire at the prevailing wages and that they do not stay with the job because of the upleasant nature of the work. No separate charges are levied for collection and disposal of solid waste and supporting revenues are generated though business license fees and taxes. The division has positioned 4 steel drop boxes (3 m^3 capacity) in the main suq area and has an estimated 10 boxes in various locations throughout the town. Equipment available to the solid waste disposal division is as follows:

1 Garbage Truck, rear loading, French mfgr. (presently this unit is out of service awaiting repair parts).

2 Utility Trucks

3 Small Tractors

3 Trailer Units with sides

A recent independent study of solid waste disposal needs for Gedaref recommended a program costed at about $190,000 including the provision of 4 elaborate garbage trucks. Our analysis of this study indicated that price estimates for the various equipment were quite low and costs may be understated.

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10.2 POTENTIAL BENEFITS

In Gedaref, solid waste is comprised of garbage (putrescible food waste), rubbish (combustible and non-combustible, non-putrescrible solids waste such as paper, plastics, wood, cloth, rubber, leather, metal, glass and ceramics) street and road litter and dead animals. Goats eat a portion of the putrescible waste, but their feces becomes part of the road litter. Inadequate solid waste management in Gedaref causes aesthetic offenses (visual, olfactory) nuisances and health hazards.

Benefits of solid waste management, then, will be a significant improvement in the aesthetic aspect of the town, a reduction of nuisances now created and an improvement in air quality with the elimination of trash burning. Public health is also expected to improve, but the literature provides no quantitative estimate of any solid waste/disease relationship. However, circumstantial and epidemiologic information does support a conclusion that solid wastes bear a definite relationship to certain infectious diseases. Diseases implicated are primarily those associated with fecal wastes, particularly human, which are transmitted by direct contact, indirect contact or by animal vectors. For example, changes in the prevalence of intestinal infection are well documented as fly populations rise and fall by natural cycles or man-manipulated control.

Because of the consistently high temperatures, tropical areas like Gedaref have greater potential for year round breeding of rats and flies than do temperate areas. The rainy season presents additional problems, as malaria-carrying mosquitoes can breed in rain water in cans, bottles and tires or in dirty water pools in or near dump sites.

In summary, improved solid waste management will significantly improve the aesthetics of Gedaref and will reduce the incidence of disease, particularly infectious and intestinal disease, to an unquantifiable extent.

10.3 PROPOSED IMPROVEMENTS

It is our conclusion that effective solid waste disposal programs will rely heavily on proper organization, scheduling, supervision and motivation of the divisional work force. Public education, support and assistance will be needed to make any future program really effective. We are recommending the addition of some small mobile equipment to facilitate waste collection and disposal. Garbage trucks were not considered as a viable alternative solution for this program since they are very complex machinery, are almost nonexistant throughout most of Sudan and will experience future problems due to insufficient maintenance practices and replacement parts availability. The existing disposal site appears satisfactory and well-located for future use.

Section 9.5.10 presents the costs of our recommended improvement program consisting of an additional 4 tractors and trailers plus a small bulldozer with blade for use in leveling and filling the disposal site. We also recommend the use of locally available grass market baskets for the residential storage of wastes pending collection. These baskets are large in size, inexpensive and readily available. The costs for collection baskets was not included in the proposal since it was assumed that the user would shoulder this rather insignificant cost and would therefore protect and promote a longer useful life for his containers.

CHAPTER 11

INSTITUTIONAL CONSIDERATIONS

The availability of adequate laws, organizations, staffing, and systems and procedures is paramount to the success of any large water system improvement program. A weakness in any of these institutional matters could render the improvement investment useless or could result in much reduced public benefit rather than that envisioned by the planners and government. Investments in water systems that cannot be properly operated or maintained is money lost and unrecoverable. Therefore, careful consideration must be given to the institutional capability of the operating agency before proceeding with the funding of major improvements. This chapter reviews these capabilities and highlights specific problem areas that appear relevant to reaching the goals and objectives of the proposed investment program.

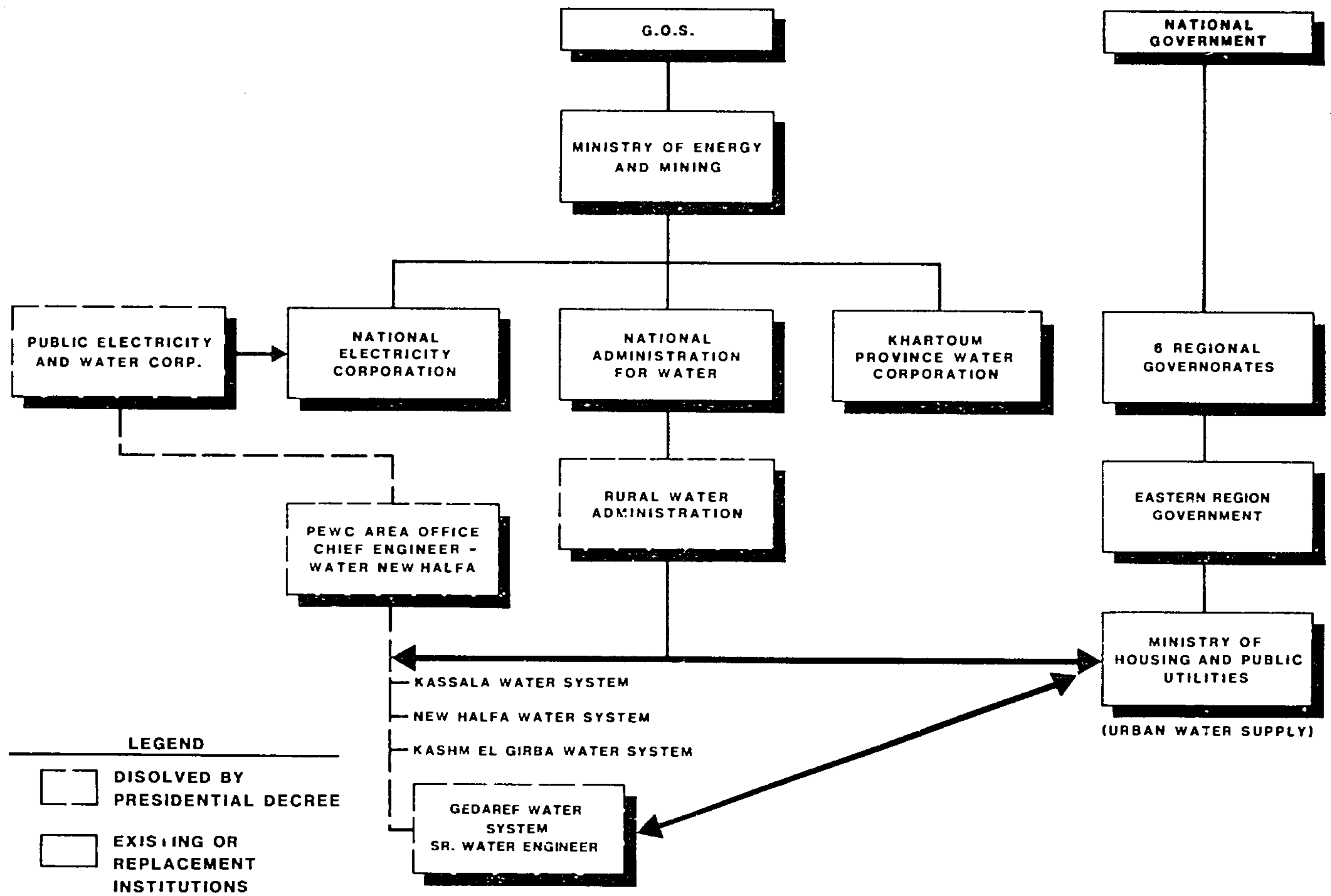
11.1 EXISTING SITUATION AND PROGRAMS

This evaluation of the existing situation centers around the national and local organization of water sector activities, the staffing and staff capabilities of the organizations and the legal aspects of providing water service. All of these conditions are critical to successful water system operation.

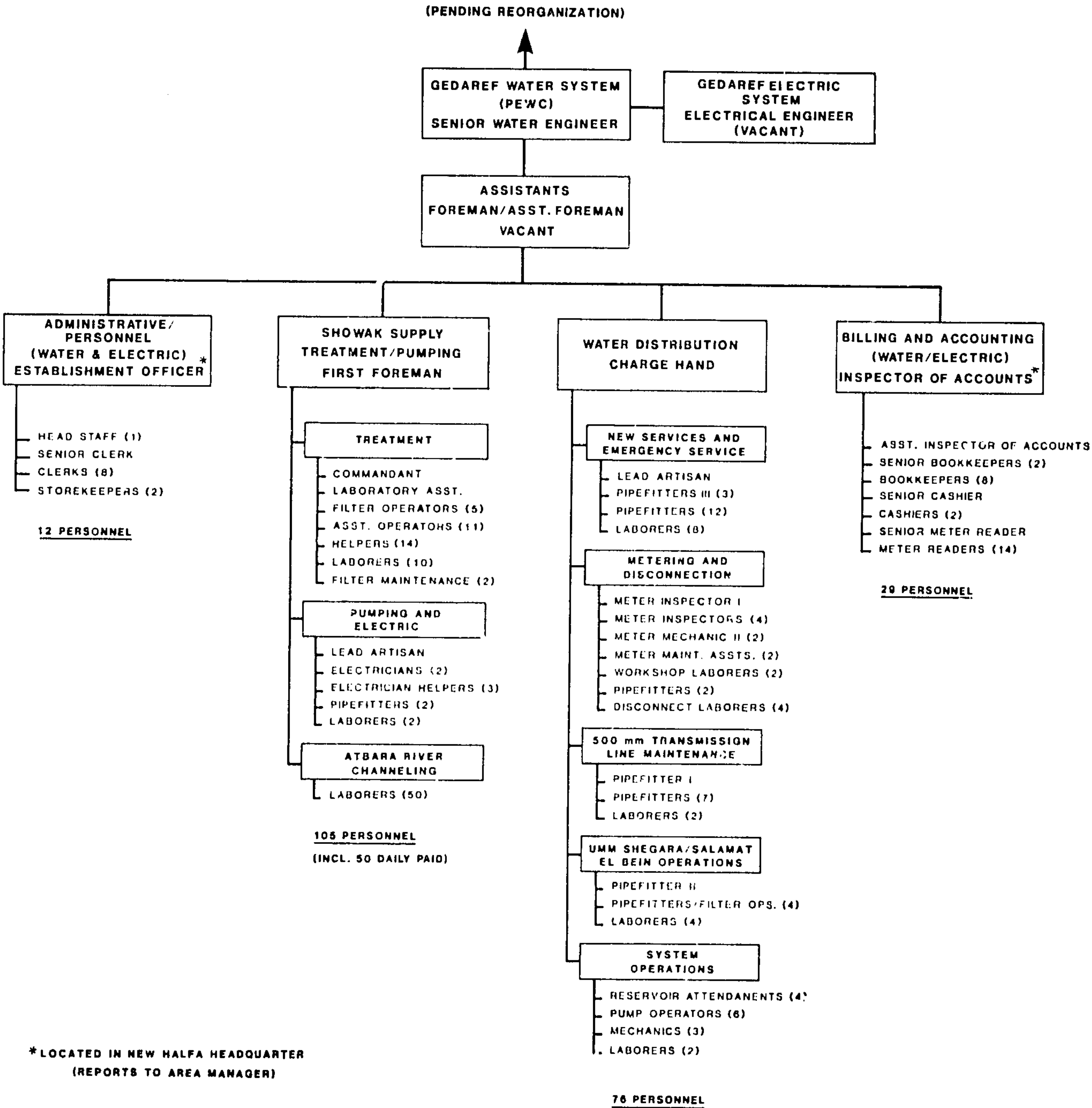
11.1.1 Organization and Legal

The present water sector organization is in a transitional stage. As part of a decentralization move by the national government, Presidential Decree No. 761 issued on November 4, 1981 dissolved the Public Electricity and Water Corporation (PEWC) and created the National Electricity Corporation. Water supply responsibilities were delegated to the Khartoum Province Water Corporation for the greater Khartoum area and to the six Regional Governorates for the operation of urban water systems previously under the aegis of the PEWC. The urban water supply responsibilities w ere to fall under the Regional Ministries for Housing and Public Utilities (RMHPU). The Rural Water Administration (RWA) was disbanded and its functions were placed under the newly-formed National Administration for Water (NAW). The responsibilities of NAW include assistance in developing supplies and drilling water wells for the urban water systems.

The Director General position at PEWC was eliminated as was the PEWC governing board. During our visits to the Eastern Region in November and December, 1982, the transition of the four PEWC water systems to the RMHPU had not taken place. The water system at Gedaref, Kashm el Girba, New Halfa and



PRESENT INSTITUTIONAL ORGANIZATION - URBAN WATER SUPPLY
FIGURE 11 - 1



GEDAREF WATER SYSTEM
ORGANIZATION AND STAFFING CHART
FIGURE 11-2

Kassala were still being operated under the direction and control of the legally non-existent PEWC Area Headquarters in New Halfa, Kassala Province. Figure 11-1 graphically depicts the present situation of potable water supply sector organization in Sudan.

The above situation creates some potentially harmful conditions to providing future water supply services. The operations of the PEWC systems and its area offices are without control and assistance from higher authority. They operate in a vacuum of almost complete automomy and meet their payrolls and local operating costs from water revenue collections deposited in the local banks. Little, or no, assistance is now available in Khartoum, and no operating or financial reports and budgets have been presented for review by higher authority for over a year. Direct control or supervision is not being exercised by the RMHPU in the Eastern Regional Government. The Minister of the RMHPH in Kassala has indicated to the study team that his control and supervision of the four urban water supplies is planned to start on July 1, 1983. If the existing situation continues into the proposed program implementation period, serious problems can develop.

The legal implications of operating water systems under organizations that have been dissolved are serious. Applicants for new water service in the four regional water systems are required to sign an agreement for water service acknowledging their compliance with the tariffs and general conditions of service in force at the time. However, the agreement form is one prepared by a predessor agency (the Central Electricity and Water Corp.) and terms and conditions of water service were not available in Gedaref, the PEWC area office in New Halfa, or evidently, anywhere in the Eastern Region. It is difficult to understand how conditions for service, or service regulations, can be administered and enforced without a copy of the legal authority to do so.

11.1.2 Staffing Levels and Training

The existing basic organizational plan of the Gedaref water utility is shown in Figure 11-2 together with details on existing positions and total staffing. Present staffing levels are as follows:

Administration, Personnel and Storekeeping	12*
Billing, Collecting and Accounting	29*
Distribution System Operation and Maintenance	76
Showak Treatment Plant and Pumping	55
Daily Paids (Mostly working on Atbara River intake channeling)	45
Ghaffirs (Guards, etc.)	30
Total (Average during year)	247

Positions marked with an asterisk (*) are dual-responsibility jobs involving work with electric customers and electric service personnel as well as water supply customers and employees. The majority of their workload is attributable to water supply functions as water customers exceed electricity connections by a ratio of 2 to 1.

The present staff levels should be satisfatory to operate the existing water facilities at the present time and into the near future. However, supervisory positions directly under the Senior Water Engineer are not filled. The responsibility for planning and supervising the activities of 246 employees rests entirely with the Senior Water Engineer and a Charge Hand, or senior foreman. This is inadequate and the consequences are evident throughout the organization. Maintenance programs are disorganized or not carried out and it is apparent that many employees are standing by awaiting direction and instructions. The reasons given to the study team for these vacancies are that qualified people are unwilling to live in Gedaref at the prevailing salary scales for these positions. Whatever the cause, it is essential that the top supervisory capabilities at the Gedaref water utility be strengthened and properly organized to promote productivity among the large staff. Improved operating systems and procedures will not be realized unless proper organizational supervision is established.

There are presently no training programs in Sudan designed for water supply sector specialities. A university-level course for sanitary engineering has been organized but attendance has been discouraging. Apparently, there are no regional water sector training programs in nearby African countries. Present staff of the Gedaref water utility has not benefited from any special training designed for water sector operations and maintenance. The accounting system and supporting chart of accounts is patterned after the uniform system of accounts that has been adopted internationally. However, the actual application of the uniform system is incomplete and non-conforming. Evidently, previous assistance was provided to Sudan in developing these accounting and recordkeeping systems for the water supply sector. Expertise of existing staff has been developed over the years through water system operating demands and improvising solutions to service problems. This system has apparently sufficed as far as providing some basic water supplies to the people in the Gedaref service area.

11.2 CAPABILITIES AND CONSTRAINTS

The Gedaref water system has been functioning for many years. The present system, installed in 1969-1971, has experienced many operational problems and was never expanded with additional improvement phases as originally envisioned. The mere fact that the service area residents are receiving some water supply is a credit to the staff of PEWC. The following is a synopsis of the study team's observations on the present system operations.

11.2.1 System Operations and Maintenance

a) Water System Operations: The lack of a communication system linking the water treatment plant at Showak to the offices in Gedaref impedes effective water system operations. The main reservoir in Gedaref has not completely filled for several years and tank overflow has not been a problem. However, with added supply and 24-hour service, overflows could occur regularly with resulting damages at the military reservation and wasted energy costs for pumping the water. A communication link between the plant and pumping station with the electric generating facility at Kashm el Girba is also needed so that pumping plant operators can determine reasons and expected duration of unscheduled power outages. Presently, plant personnel have to locate some kind of transportation and travel about 100 km round trip to the power plant to get answers on electricity availability. The work force is just about divided evenly between Gedaref and Showak and lack of ready communications separates these two groups into semi-autonomous operations with very little mutual coordination and cooperation.

b) Water System Maintenance: Maintenance of the utility plant is impeded due to the lack of repair parts and fittings, tools and special equipment and transportation facilities. Stocks of repair parts and fittings are almost non-existant and requirements are either procured from the local marketplace or by improvising with available materials. Animal leather and tire inner tubes are used to fashion gaskets for valves and fittings. Each senior pipefitter has his own large, locked tool box with his hand tools for pipeline work. The normal water system construction and maintenance equipment is not available. Several trucks and land rovers are used for both water supply and electric service purposes and breakdowns are common. The equipment at the Showak water treatment plant is without any spare parts even though parts have been ordered from Khartoum on a number of occasions. Foreign exchange is required for these purchases. The alum and lime chemical feeders are out of service and alum solution is mixed by hand. It is a credit to the plant operators that the facility is still capable of treating raw water.

The distribution system is maintained by repair crews working in 3 shifts throughout the day and night. Lack of

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sufficient supervisory level personnel affects their productivity and efficiency. The study team did not run across any repair activities after normal working hours. Reported leak repairs averaged 110 per month for 1/2" to 1-1/2" pipe and 104 per month for 1 1/2" pipe and larger during a twelve-month period. This equates to slightly over 8 leak repairs per working day. Little evidence of pipe leakage was seen by the study team during their travels around the service area.

11.2.2 Billing and Collecting

Water and electric bills are prepared when meter readers return meter books to the office. They are delivered to customers on the next reading date the following month. This creates a 30-day lag in cash flow and delays in rectifying excess usage or leakage. The 6,000 water service accounts are kept separate from the electric services in each meter reading book. There are about 120 meter books averaging 75 accounts each.

Bills and payments are entered into very cumbersome, large ledger books. Reconciliation of outstanding receivables is not accomplished and it would be extremely difficult to do so with the present system. Payment of accounts are all made to the cashiers in the Gedaref office and deposits are made daily to the local bank. The cashiers use cash registers fitted with hand cranks since power supply is not available during regular working hours.

The collection efficiency was discussed in Section 4.6.3 and a test of billings versus collections showed almost 30% as uncollected. A true and accurate accounts receivable total was not available for analysis purposes. The receivables ledger book was posted in arabic and was difficult to analyze within the limited time available.

Slightly over 1/2 of the water accounts are estimated because of faulty water meters. Estimates are prepared jointly by the Senior Water Engineer and the meter reader who is responsible for reading the account. Estimates were often for 10 m^3 per month but many were higher and one estimated account was billed for 130 m^3 monthly. At least 13% of the water revenue is not billed and is lost because of estimated accounts and inoperative meters.

11.2.3 Systems, Records and Reports

Monthly reports are prepared in Gedaref covering water treated and billed, chemical and power usage, pumping hours and basic expense and revenue data. The report for August 1982 was being completed during our visit in November. These reports are submitted to the Chief Water Engineer in New Halfa where power and chemical usage are priced and additional operating cost data is added. The reporting ends here since there is no longer anyone in Khartoum to receive and review these reports.

All disbursements including payrolls are made from the area office in New Halfa. This is about a 4-hour round trip drive from Gedaref. Local purchases can be made from a small petty cash fund in limited amounts and emergency repair materials are procured locally prior to area office approval. Deposits of revenues to the local bank cannot be withdrawn by the Gedaref staff.

The basic accounting system is an accrual system based on international water utility account numbers and classifications. However, the system is not fully implemented and financial reports are incomplete. The two storekeepers maintain a costed bin card system and use requisition and stock issue forms. The stores are very small yet costed bin cards are voluminous. Many bin cards cover issued stock and date back 10 years. The meter maintenance activities were discussed in Section 4.6.1.

A daily treatment plant log is maintained at Showak. It is entered in arabic. No accurate pipeline location maps are available and pipeline extensions and replacements are not described in work orders or other documents at the utility. Sizes, location and appurtenances of specific pipelines are stored in the memories of present and past employees.

12.2.4 Employment of Qualified Personnel

Availability of trained and experienced water supply personnel is almost non-existent throughout the Sudan labor market. The Gedaref Senior Water Engineer alleges that he cannot fill the upper supervisory positions because good people are unwilling to live in Gedaref at the salary ranges offered. The Charge Hand position that is directly under the engineer is paid a salary of Ls. 142.00 monthly. Permanent laborers receive Ls. 31.00 monthly and daily rated labor is compensated at Ls. 0.935 per day. The efficiency of the organization is obviously suffering due to vacancies in the higher supervisory positions.

11.3 INSTITUTIONAL RECOMMENDATIONS

The most critical insitutional deficiency is the transitional condition of the urban water supply systems in the Eastern Region. Even after full transfer of these systems to the Regional Ministry of Housing and Public Utilities, certain essential support activities will be missing. These technical support services are often provided by a national agency or a special board. They include:

- o Special engineering services to assist urban water systems in solving operating problems and in developing system improvements. The National Administration for Water is currently assisting urban systems with the construction and renovation of water wells.
- o Organization and presentation of special training programs designed for the water utility sector personnel.
- o The monitoring of operating costs and water service quality of the urban systems.
- o A review of water rates and budgets of the urban system.
- o Assistance in developing capital funds for water system improvement projects.
- o Some standardization and uniformity in conditions for water supply service throughout Sudan.
- o Assistance in recruitment of technical personnel for the urban systems.
- o Provision of a forum for water managers and technicians to meet and exchange ideas and discuss mutual problems.

It is felt that these important services must be provided by some organization, possibly the NAW, in order to provide good urban water services and properly maintain and safeguard the large investments in water utility plant throughout Sudan.

Besides this basic institutional consideration, other proposed improvement are listed below in their general order of priority.

11.3.1 Staffing

The two supervisory positions directly under the Senior Water Engineer should be filled with qualified people as soon as possible. This will have immediate impact on the organization of work and productivity of the rank and file employees. Special training should be provided for the top two positions in the utility as discussed in Section 11.4.

11.3.2 Water Service Regulations

Legally adopted regulations should be available to water utility personnel and its customers that clearly define the condition of service and the obligations of the applicant for water service and the customer together with the utility's responsibilities. The "General Conditions of Supply" used by the predessor agency, the Central Electricity and Water Corporation, may still be legally binding and in force but a copy of these conditions was not available for review by the study team.

11.3.3 Operating and Maintenance Supplies

An adequate inventory of repair parts and fittings should be maintained to assure proper and timely repair of water system facilities. Many mechanical and electrical items are imported and spare parts must be acquired by getting authorization to use foreign exchange. The loss of expensive mechanical and electrical equipment far outweighs the cost of purchasing needed repair parts. A budget of U.S. $30,000 plus contingency and esclation was included in the proposed improvement program to offset foreign currency requirements for replacement parts and supplies.

11.3.4 Logistic Support Equipment

Transportation equipment along with tools and construction equipment are badly needed to facilitate timely and proper repairs to essential water system components. A proposed budget of U.S. $60,000 plus contingency and escalation was included in the improvement program to accomodate these needs.

11.3.5 Communication Systems

This essential need in a scattered service area such as Gedaref is provided for in the proposed improvement program. The communications will be required as soon as the new improvements are operational to regulate water sources, determine electric supply problems and to avoid overflowing the various water storage reservoirs.

11.3.6 Internal Systems and Procedures

Many well-designed systems and procedures are essential to efficient water service activities. Some of the more critical shortcomings on adequate systems are listed for recommended improvement.

a) Engineering: Establishment of a standard work order system to cover water system improvements, extensions, replacements and betterments.

   The production and updating of a scaled map of all distribution system facilities in order to evaluate service problems and locate burried facilities.

b) Collection Enforcement: Improvement of the ratio of collected accounts to billings by strict enforcement of payment conditions and collection of all governmental accounts.

c) Billing and Posting: The provision of water bills within a few days of meter reading by employing a delivery service or use of staff messengers.

The establishment of a standard customer accounts receivable ledger card and discontinuance of existing unweildly ledger books. Possible use of the peg-board type posting system to create the bill details, the billing register and the ledger card posting in one writing. This improves accuracy and facilitates the balancing of outstanding receivables.

d) Meter Maintenance: Adoption of standard meter maintenance record card systems and inventories of un-installed water meters.

e) Customer Classification: Establish systems and procedures to classify domestic customers in the "A", "B" and "C" classes if the proposed water rate schedules are adopted. A monitoring program will be required to field check for any changes in classification usage.

f) Service Orders and Complaints: Establish the procedures to record, follow-up and summarize all water service and bill complaints.

g) Public Relations: Establish an ongoing public information program to gain public support in eliminating wastage, reporting pipe leaks and to inform the public of water supply problems and achievements of the utility.

11.4 TRAINING

There are presently no country-wide training programs for water sector employees. Also, no regional programs were located in the surrounding countries. It is recommended that the utility manager and one technician be granted a six to eight week overseas training program. This should consist of on-the-job training and observation at several well run water utilities of similar size and complexity. These utilities could be located in Europe, other parts of Africa or in the U.S.A. The proposed improvement program includes $7,500 for training each employee assuming that the training would be conducted in the U.S.A. under direct supervision of an appropriate agency or consultant.

CHAPTER 12

FINANCIAL ANALYSIS

The objective of this chapter is to evaluate the present financial condition of the Gedaref water system, determine reasonably accurate costs for implementing the proposed system improvements and to develop acceptable water rate structures to meet the forecasted revenue requirements. The key assumption used in this analysis is that sufficient improvements will be operational on or about July 1, 1985 to meet the planned water demand of the population existing at that time (see Figure 9-4).

Existing financial data on water system operations were incomplete and required augmentation by cost informatio acquired at the PEWC area office in New Halfa. Some minor cost information was unavailable to us and was not included in the following analyses. Missing information dealt with costs of office supplies, stationary and certain system repairs and replacement equipment that were financed by governmental units other than the PEWC. The PEWC area office in New Halfa (legally defunct) is financing the operations of the four water systems solely through collection of water revenues deposited into local banks. Refer to Chapter 11 for discussions on the legal status of PEWC. The unprofitable systems are being subsidized by those systems showing profit on the cash basis of accounting. Sufficient bank funds are not available for major repairs or replacements of essential equipment. Emergency repairs and replacements are financed by appealing for financial assistance from the local town councils, the Eastern Regional Government or other units of government.

12.1 IMPROVEMENT PROGRAM COST SUMMARY

The estimated costs of the proposed improvement program, totalling $4,169,800 for water supplies and $118,800 for solid waste disposal improvements, is set forth in Section 9.5. These costs are based on late 1982 prices and include a contingency factor. In order to provide the most accurate forecast of actual costs after improvements have been constructed and placed into service, adjustments were made to these costs totalling $4,288,600 based on certain assumptions and implementation schedulings. Total costs do not include any reduction for emergency improvements that may be implemented by funding through UNHCR and others. Certain elements of the $800,000 emergency program proposed by NAW in December, 1982 may negate some improvement cost should these facilities be usuable in the overall program. Potential cost reduction would come from improvement to the high lift pumping stations and renovation of Abu Naga water wells.

12.1.1 Factors Used in Developing Implementation Costs

The analysis shown in Table 12.1 develops a total, implemented program cost of $5,793,700 estimated to be all-inclusive and includes the local Sudanese Pound component. The local cost component is equivalent to U.S. dollars $1,113,600. Following are assumptions used in the Table 12.1 analysis.

a) Local Cost Component: Local costs were disaggregated by identifying project costs relating to locally provided materials and equipment, construction labor costs, and equipment installation costs. Assumptions were used in major cost categories. All pumps, motors, engines and major mechanical and electrical equipment would be imported. All pipeline materials and fittings, with the possible exception of galvanized steel pipe, would also be imported. It was determined that locally manufactured asbestos-cement pipe would be unsatisfactory for most improvement work due to the very unusual soils conditions in the area. Steel water reservoirs and foundations would be provided locally as would costs of labor and material to construct pump stations and other structures. The construction of water wells would be done by foreign firms and all costs are allocated to the dollar component. The obvious final determination of the split in costs will rely on the actual award of contracts and subcontracts for project implementation. Due to recent adjustments in the value of local currency, an exchange rate of 1.6 Sudanese Pounds to one U.S. Dollar was considered realistic.

b) Cost Escalation Due to Inflation: The summary includes an escalation of all program costs based upon the projected implemention scheduling for placement of purchase orders and awarding of construction contracts. Section 9.6 describes the scheduling of program implementation. Timing assumptions have recognized possible additional delays and "slippages" and have used a longer period of implementation than shown in Figure 9-5. Inflationary factors were established at 8 per annum on U.S. costs and 15% per annum for local currency costs. Other improvement program costs were also escalated to the time of anticipated contract finalization. Cost escalation was determined as increasing the late-1982 improvement estimates by an equivalent U.S. $744,500 and other program costs by $63,600.

12.2 WATER SYSTEM FINANCIAL REQUIREMENTS

In order to determine a reasonable picture of the Gedaref water system financial condition, it was necessary to develop a relatively complete operating statement. The reports of PEWC were incomplete in many

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TABLE 12.1

IMPROVEMENT PROGRAM COST SUMMARY

ESTIMATED IMPROVEMENT COSTS (See Section 9.5)	Total Cost (in U.S.$)	Local Cost Component [1] (in Ls.)
1. Tawawa Supply and Distribution	$ 359,700	Ls. 139,000
2. Abu Naga Well Field Supply	1,544,000	556,600
3. Improvements at Main Reservoir	13,000	4,200
4. Atbara River Supply	1,255,000	437,000
5. Showak Town System	32,000	42,200
6. Metering and Waste Control	432,000	66,600
7. Communications	50,000	11,200
8. Operating Equipment and Materials	90,000	2,600
9. Training Costs	15,000	1,600
Subtotal-Water Supply Improvements	$ 3,790,700	Ls. 1,261,000
10. Solid Waste Disposal Equipment	108,000	-
Total-Proposed Improvements - 1982 Prices	$ 3,898,700	Ls. 1,261,000
Contingencies at 10%	389,900	126,100
Total Estimated Current Improvement Cost	$ 4,288,600	Ls. 1,387,100

PROJECTED IMPROVEMENT COST ESCALATION

Calendar Year	Impacted Percentage of Total	Amount Subject to Escalation: U.S. Dollars	Amount Subject to Escalation: Sudan Pounds[1]	Escalated Cost Calculation: U.S. Dollars (at 8%)	Escalated Cost Calculation: Sudan Pounds (at 15%)
1983	100%	3,421,700	1,387,100	$ 273,700	208,100
1984	55%	2,032,500	877,300	162,600	131,600
1985	20%	768,900	366,900	61,500	55,000
Totals				$ 497,800	394,700

OTHER IMPROVEMENT PROGRAM COSTS

Item	1982 Cost	Escalation (at 8%)	Escalated Cost
1. Feasibility Studies and Related Cost	$ 137,000	$ -	$ 137,000
2. Design and Tender Documents	340,000	27,000	367,000
3. Construction Supervision	220,000	36,600	256,600
Totals	$ 697,000	$ 63,600	$ 760,600

IMPLEMENTED PROJECT COST SUMMARY

	U.S. Component	Local Currency (Ls.)	Equivalent US $ @1.6	Total Project (Equivalent US $)
Improvement Costs - 1982 Prices	$ 3,421,700	1,387,100	$ 866,900	$ 4,288,600
Cost Escalation	497,800	394,700	246,700	744,500
Other Improvement Cost	760,600	-	-	760,600
Total Estimated Program Cost	$ 4,680,100	1,781,800	$ 1,113,600	$ 5,793,700

(1) Conversion rate of $1 = 1.6 Sudanese Pounds

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standard utility expense categories. Costs were determined by developing data at the New Halfa area office and by other means. The area office contained values of the water utility plant in service but the values were stated in one lump sum for all four water systems in the Eastern Region.

12.2.1 Determination of Utility Plant Values

Table 12.2 presents an evaluation of the investments in the present operational water system. Current values were appraised and annual depreciation expense was determined based upon the estimated life expectancy of the major plant components. Projections were also made on depreciation costs of existing plant after improvements become operational and discontinued plant is retired. Table 12.2 also presents the implementation costs of proposed improvements segregated into major plant components with assigned useful life expectancies and annual depreciation expense calculations. These costs are used in later analyses and summaries.

12.2.2 Present Water System Operating Results

Based on financial reports available in Gedaref and New Halfa, a revenue and expense statement was prepared for fiscal years 1980-81 and 1981-82. The governmental accounting year begins on July 1st. Available reports were augmented with missing costs such as commercial department and administrative and general expenses. These were determined by acquiring listings of personnel involved together with their salary ranges. Other missing costs were reconstructed including fuel and miscellaneous expenses and depreciation expense. Since the dissolution of PEWC in November 1981, formal financial statement were not prepared or submitted to Khartoum.

The operating results for 1980 through 1982 are shown in Table 12.3. As discussed earlier, certain maintenance and system replacement costs were unknown since they were not processed through the accounting books of PEWC. Table 12.3 reflects a small operating profit for each year before deduction for plant depreciation expense. This added cost results in a net operating loss of Ls. 75,995 in fiscal 1980-81 and Ls. 92,229 in 1981-82. The deficit represents 16% of revenues in both fiscal years. Electric power cost represented 30% of total operating cost in 1980-81 and 37% in 1981-82. The PEWC pays itself for these power costs. The cost of water per unit sold averaged Ls. 0.27 in 80-81 and Ls. 0.24 in 81-82. This was primarily due to a reported increase of 14% in water sales.

12.2.3 Determination of Revenue Requirements

Revenue requirements were determined by projecting operating expenses and other requirements to the beginning of fiscal year

TABLE 12.2

GEDAREF WATER SYSTEM
UTILITY PLANT VALUATION AND DEPRECIATION EXPENSE CALCULATION

	Original Cost (Est.) US $	Appraised 1982 Value in US $	Ls. Equiv. @ 1.3	Est. Life (Years)	Annual Dep'n Exp. (Ls)	Monthly Dep'n (Ls)	Est. Dep'n To Date (7/82)	Net Book Value at 7/82	Annual Depreciation of Plant in Service 7/85
1. Existing System Plant Asset									
1.2 1969-71 Improvements (Additions)									
Transmission Line - 68.4 km of 20"	$ 1,800,000	$ 1,800,000	Ls 2,340,000	40	Ls 58,500	Ls 4,875	Ls 702,000	Ls 1,638,000	Ls 58,500
Treatment Plant and Pumping Station	1,200,000	600,000	780,000	25	31,200	2,600	374,400	405,600[a]	-[a]
Storage Reservoir - 9,090 m³	400,000	400,000	520,000	50	10,400	867	124,800	395,200	10,400
Distribution Systems	500,000	250,000	325,000	30	10,800	900	130,000	195,000	10,800
1.3 Other Plant Additions									
Other Distribution Network	350,000	200,000	260,000	20	13,000	1,083	-	260,000	13,000
Abu Naga Well Field and Appurtenances	250,000	100,000	130,000	10	13,000	1,083	-	130,000	13,000
Operational Water Meters (3,000)	75,000	25,000	33,000	5	6,600	550	-	33,000[b]	-[b]
Vehicles and Equipment	30,000	15,000	19,000	3	6,300	525	-	19,000[c]	-[c]
Buildings (incl.Land)	50,000	50,000	65,000	50[d]	1,300	109	13,000	52,000	1,300
Totals	$ 4,655,000	$ 3,440,000	Ls 4,472,000		Ls 151,100	Ls 12,592	Ls 1,344,200	Ls 3,127,800	Ls 107,000

a Completely Depreciated at 7/1/85

b All existing water meters retired by July, 1985

c All existing equipment retired by 7/85

d Indeterminate Life for Land - 30 years for Buildings - 50 years is weighted average

2. Proposed Improvements at July, 1985 Plant Asset	1982 Est. Cost (in US$)	Constructed Cost[e] (in US$)	Estimated Life (Years)	Annual Depreciation	Annual Depreciation[f] (Ls)
a) Production Wells	$ 1,409,000	$ 2,093,800	25	$ 83,800	Ls 134,100
b) Treatment Facilities	23,500	34,900	25	1,400	2,200
c) Pumping Facilities	335,000	497,800	40	12,400	19,800
d) Transmission	1,138,000	1,691,100	50	33,800	54,000
e) Storage Reservoirs	170,000	252,600	50	5,100	8,200
f) Distribution System	111,200	165,200	30	5,500	8,800
g) Water Meters	432,000	642,000	20	32,100	51,400
h) Transportation and Equipment	103,000	153,100	8	19,100	30,600
Totals	$ 3,721,700[g]	$ 5,530,500		$ 193,200	Ls 309,100

e Includes contingency, cost escalation and pro-rata other Improvement Program Cost (x 1.486)

f Future Conversion Factor used is Ls to U.S. $ at 1.6

g Proposed Costs of $69,000 expensed and not included together with solid waste Disp. Equip. (Table 12.1)

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TABLE 12.3

GEDAREF WATER SYSTEM

Revenue and Expense Statement - Fiscal Years 1980-1982
(From PEWC Records)

	Totals Fiscal Year 1980-1981	1981 July	Aug.	Sept.	Oct.	Nov.	Dec.	1982 Jan.	Feb.	Mar.	Apr.	May	June	Totals Fiscal Year 1981-1982
Water Production (in 1,000 m^3)	2,673.5	212.8	160.3	263.3	263.4	257.2	264.5	256.1	240.9	141.9	248.7	249.7	350.5	2,909.3
Water Sold (in 1,000 m^3)	1,602.7	193.0	147.2	158.0	164.1	203.2	197.9	206.8	181.5	163.1	218.9	200.9	203.4	2,238.0
Revenue														
Water Sales	La 431,015	43,977	32,899	38,834	40,682	48,445	44,783	47,386	49,183	48,223	53,721	45,687	47,315	541,135
Other Revenue(1)	41,010	3,626	2,500	3,020	3,626	4,220	3,626	3,413	3,519	2,955	4,616	3,626	3,626	42,373
Total Revenue	La 472,025	47,603	35,399	41,854	44,308	52,665	48,409	50,799	52,702	51,178	58,337	49,313	50,941	583,508
Expenses														
Source, Treatment and Pumping														
Labor	53,155	8,576	9,963	8,248	8,286	8,869	7,290	9,341	7,964	8,603	9,236	8,193	8,559	103,128
Electric Power	120,181	13,844	10,176	21,188	18,108	17,894	17,314	17,413	16,456	15,676	15,633	16,259	16,384	196,345
Treatment Chemicals	6,247	6,382	5,130	3,649	3,650	1,806	2,435	2,464	2,435	1,290	3,506	5,082	4,852	42,681
Materials and Supplies	347	513	88	79	72	82	27	240	42	1,002	509	217	54	2,925
Plant Maintenance	69,351													-
Fuel and Lubricants	3,778													-
	253,059	29,315	25,357	33,164	30,116	28,651	27,066	29,458	26,897	26,571	28,884	29,751	29,849	345,079
Distribution														
Labor	55,033	7,866	7,963	7,164	7,386	7,549	7,172	7,792	7,364	7,849	8,417	8,564	9,333	94,419
Maintenance Expense	44,963	1,413	1,144	1,086	673	424	2,532	507	1,746	1,920	557	840	593	13,435
Other Costs	6,605													-
	106,601	9,279	9,107	8,250	8,059	7,973	9,704	8,299	9,110	9,769	8,974	9,404	9,926	107,854
Commercial(2)														
Billing and Collecting	10,500	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505	18,060
Meter Reading	12,600	1,810	1,810	1,810	1,810	1,810	1,810	1,810	1,810	1,810	1,810	1,810	1,810	21,720
	23,100	3,315	3,315	3,315	3,315	3,315	3,315	3,315	3,315	3,315	3,315	3,315	3,315	39,780
Administrative and General(2)														
Supervision	5,010	720	720	720	720	720	720	720	720	720	720	720	720	8,640
Accounting	3,740	537	537	537	537	537	537	537	537	537	537	537	537	6,444
Personnel Administration	8,290	1,191	1,191	1,191	1,191	1,191	1,191	1,191	1,191	1,191	1,191	1,191	1,191	14,292
Storekeeping	1,420	204	204	204	204	204	204	204	204	204	204	204	204	2,448
	18,460	2,652	2,652	2,652	2,652	2,652	2,652	2,652	2,652	2,652	2,652	2,652	2,652	31,824
Total Operating Expenses	La 401,220	44,561	40,431	47,381	44,142	42,591	42,737	43,724	41,974	42,307	43,825	45,122	45,742	524,537
Net Operating Income	70,805	3,042	(5,032)	(5,527)	166	10,074	5,672	7,075	10,728	8,871	14,512	4,191	5,199	58,971
Depreciation Expense(3)	148,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	151,200
Net Income (Loss)	La (77,795)	(9,558)	(17,632)	(18,127)	(12,434)	(2,526)	(6,928)	(5,525)	(1,872)	(3,[illegible])	1,912	(8,409)	(7,401)	(92,229)
Water Revenue per cubic meter billed	La 0.269	0.228	0.223	0.246	0.248	0.238	0.226	0.229	0.271	0.296	0.245	0.227	0.233	0.242
Staffing (O&M only)														Average
Regular (including Ghaffirs)		156	156	156	168	158	159	149	155	152	152	151	151	155
Daily Rated		48	59	50	50	37	43	46	45	45	47	52	42	47
Total		204	215	206	218	195	202	195	200	197	199	203	193	202

(1) Estimated for 8 months
(2) Estimated from area office payroll records
(3) Calculated from appraised plant values

1985-1986. It was assumed that proposed improvements would be installed in sufficient completeness by around July 1, 1985 in order to provide continuous 24-hour water service to the projected service area population in 1985. Assumptions used in forecasting revenue requirement included the following:

a) Escalation due to Inflation: Since all current financial costs were stated in prices at the end of 1982, a factor of 10% was applied to labor, power cost and operating expenses for the fiscal year ending June, 1983. Subsequently, factors of 20%, 20%, 15%, 10% and 10% were applied to these costs for the five fiscal years from 1983 through 1988. (Refer to Table 12.8 for these projections). These escalation factors were the best available assumptions based on discussions with local officials and USAID, recent economic events in Sudan and general world-wide trends.

b) Other Expense Fluctuations: Personnel requirements were not changed drastically over the five-year forecasting period. It was felt that the present level of staffing should be adequate for several years with better utilization of manpower. The staff allocated to water treatment plant operations was reduced sharply in 1985 due to the start-up of the improvement program and the subsequent cut back on use of the water treatment plant. Chemical costs also reduce since alum treatment will no longer be necessary. However, projected electric power costs increase dramatically with added power demand and price escalation. During 1983-1984, power costs, estimated at Ls. 258,700, represent 34% of the costs to operate the existing system while in 1985-1986, power costs represent 63% of total operating expense (Table 12.8). The Commercial Department costs are escalated by inflationary factors plus increased staffing needed to handle the growth of active service connections. Additional distribution system maintenance costs may be required to cover pipeline leakage repairs due to higher pressures and longer service duration but it is not possible to determine these expenses with any degree of accuracy.

12.2.4 Other Revenue Requirements

Utility plant in service depreciation expense is calculated in Table 12.2 and shown as a revenue requirement in Table 12.5. Earlier discussion in this chapter described the methodology used in determining realistic depreciation cost and offsetting reserve requirements. Properly funded depreciation reserves should provide funds for future replacement of major water system components. Investment of these reserve funds in interest earning accounts should also offset inflationary trends in water system construction costs.

A further revenue requirement was calculated based upon a 6% return on utility plant investments. The calculation of this return is shown in Table 12.4 and includes both existing utility plant as well as additional plant constructed under the proposed improvement program. This is a somewhat hypothetical calculation because the net value of the existing system assumes full funding by public monies without a contribution to plant by citizens or businesses towards the cost of extending water service. Also, the proposed plant improvements are assumed to be a direct grant to the government. Surplus revenues generated by this revenue requirement would eventually create surplus cash beyond the financial needs of the utility system. Cash surpluses, if not drained off for other non-utility uses, would create political pressure for reduced water rates or rebates to existing water users. The return on investment calcualtion represents 29% of total revenue requirements in fiscal 1985-1986, 25% in 1986-1987 and 22% in fiscal 1987-1988.

12.2.5 Total Revenue Requirements

Table 12.5 illustrates the total, net revenue requirement for the fiscal years 1985 through 1988. A small adjustment was made for income from sources other than water charges. The table also presents the total revenue requirement per unit of water sold (cubic metre) ranging from Ls. 0.53 to 0.54. This is further compared with the existing quantity rate of Ls. 0.26 escalated by the inflation factors used in our analysis. This comparison shows a lower cost under existing rate for the first two years but a slightly higher cost in the third year. Therefore, the rates or tariffs required to support the new system improvements would not be disproportionate to the prevailing water rate structures.

12.3 REVENUES AND WATER RATES

Based on the previous analyses, a series of test rate structures were analyzed and tested for their ability to generate the required revenues and for their fairness, equity and anticipated political acceptance. A rate structure was chosen that is very similar in design to the present rates.

12.3.1 Description of Proposed Rate Schedule

The proposed rate schedule is simple in design and application. A uniform minimum charge is proposed allowing 8 m^3 of water consumption to every customer each month. Higher charges for larger services and meters were rejected in lieu of applying escalating consumption rate blocks. The end result is similar and the mechanics of record keeping and billing are simplified.

The basic rate of Ls. 0.50 per m^3 applies to the first 17 cubic metres over the minimum allowance accept for services classified as multiple family services. For the Class "B" or

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TABLE 12.4

GEDAREF WATER SYSTEM
CALCULATION OF NET UTILITY PLANT INVESTMENT

	Fiscal Year					
		1985-86		1986-87		1987-88
1. Existing Utility Plant in Service						
Net Book Value 7/1/82 (Table 12.2)	Ls.	3,127,800				
Less:						
Depreciation Expense 1982-1985		391,200				
Undepreciated Plant Retirement at by July 1, 1985		13,300				
Net Value - Beginning of year	Ls.	2,723,300	Ls.	2,616,300	Ls.	2,402,300
Less: Depreciation for Fiscal Year		107,000		107,000		107,000
Net Value - End of Year	Ls.	2,616,300	Ls.	2,509,300	Ls.	2,402,300
2. Proposed Plant Improvements						
Net Value - Beginning of year	Ls.	8,848,800	Ls.	8,539,700	Ls.	8,230,600
Less: Depreciation for Fiscal Year		309,100		309,100		309,100
Net Value - End of Year	Ls.	8,539,700	Ls.	8,230,600	Ls.	7,921,500
3. Combined Net Book Values	Ls.	11,156,000	Ls.	10,739,900	Ls.	10,323,800
4. Return on Investment at 6%	Ls	669,400	Ls.	644,400	Ls.	619,400

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TABLE 12.5

GEDAREF WATER SYSTEM
REVENUE REQUIREMENTS WITH IMPROVED SYSTEM

	Fiscal Year 1985-86		Fiscal Year 1986-87		Fiscal Year 1987-88	
1. Operating Expenses						
Source, Treatment and Pumping	Ls.	124,800	Ls.	138,300	Ls.	154,000
Electric Power		878,400		1,077,600		1,258,400
Distribution		211,600		232,800		256,100
Commercial		106,800		123,900		139,900
Administrative and General		62,200		73,300		80,600
Total Operating Expense		1,383,800		1,645,900		1,889,000
2. Depreciation Expense		416,100		416,100		416,100
3. Return on Investment at 6%		669,400		644,400		619,400
Total Revenue Requirements		2,469,300		2,706,400		2,924,500
4. Other Revenue (Deduct)		127,000		116,200		136,100
Net Revenue Requirements	Ls.	2,342,300	Ls.	2,590,200	Ls.	2,788,400
Rate of Annual Increase		59.7%(1)		10.6%		7.7%
Estimated Water Sales - m^3		4,400,000		4,900,000		5,200,000
Revenue Requirements per m^3	Ls.	0.53	Ls.	0.53	Ls	0.54
Existing Quantity Rate of Ls. 0.26 Escalated by Revenue Requirement Inflationary Factors	Ls.	0.47	Ls.	0.52	Ls.	0.57

(1) Based on 1984-85 Requirements of Ls 1,466,300

housing compound services, the Ls. 0.50 rate applies to the first 27 m^3 over the minimum allowance of 8 m^3. This was established based on an assumption of 5 families per compound service, an average of 5.2 persons per family and a basic water need of 45 litres per capita per day. Thus, basic needs could be met for the lowest water rate of Ls. 0.50 and excessive usage would be charged at the higher rates. For the Class "C" or public standpipe services, the Ls. 0.50 rate applies to the first 142 m^3 over the minimum allowance of 8 m^3. This was established based upon the assumption of an average of 27 families per standpipe service, an average of 5.2 persons per family and a basic water need of 35 litres per capita per day. Thus basic needs could be provided for at the lowest unit cost.

The quantity rate blocks escalate to Ls. 0.70 and 0.90 for the single family residential class and the commercial, industrial, institutional and governmental classes. This is done to offset the cost of maintaining larger services and meters, to suppress excessive usage by the more affluent and to provide a modicum of "socialized pricing" within the rate structure. Multiple family services have a maximum rate of Ls. 0.70 in order to suppress and control excessive water use and wastage. The following Table 12.6 sets forth the proposed water rate schedule to be effective about July 1, 1985.

Section 13.3.2 analyzes the ability to pay these proposed rates.

12.3.2 Projected Revenues from Proposed Rates

Table 12.7 sets forth the estimated water revenues that will be generated by the proposed water rate schedules during fiscal year 1985-1986. Information was not available on consumption patterns within customer classes for existing services and our analysis is based upon averaging techniques and the projection of assumed usages by the various user classes. Water sales are based on the planning criteria per capita use, projected population in 1985 and the expectation that program improvements will satisfy this demand on or about July 1, 1985. Total revenues are slightly understated because of averaging methods. In some cases, larger users would consume more water in higher rate brackets than shown in the analysis because others in their user class will use less than the average calculation.

An uncollectable, or bad debt, allowance of 3% of billings was deducted from net revenues which is much lower than the apparent uncollectable amounts at the present time (see Section 4.6.3). However, water utilities with strict collection enforcement programs seldom experience uncollectable amounts exceeding 0.5% of total billing. The 3% is achievable and should be realized by 1985.

TABLE 12.6

PROPOSED WATER RATE SCHEDULE
for Fiscal Year 1985-1986

	Monthly Minimum Charge	Allowance Under Minimum
1. Minimum Charges	Ls 4.00	8 m^3

2. Quantity Rates (over Minimum)

A. Class "A" Customers

1) Residential Connection to a single family residence

2) Commercial Class

3) Institutional/Government Class

4) Industrial Class

	Monthly Usage From	Monthly Usage Through	Rate per Cubic Metre
	9	25	Ls 0.50
	26	100	0.70
	Over	100	0.90
B. Class "B" Customers			
1) Residential Connections to family housing compounds (average 5 families per service)	9	35	Ls 0.50
	Over	35	0.70
C. Class "C" Customers			
Metered public standpipe services serving residential areas (Average 27 families per service)	9	150	Ls 0.50
	Over	150	0.70

TABLE 12.7

PROJECTED REVENUES FROM PROPOSED RATES
Fiscal Year 1985-1986

		Active Services	Annual Sales (in m³)
1.	PROJECTED OPERATING RESULTS (Table 12.8)	8,850	4,400,000

2. WATER SALES BY CUSTOMER CLASS

		Average Families per Service	Annual Usage per Family	Active Services	Annual Sales (in m³)
2.1	Residential Class				
	A. Single Resident Service	1	200 m^3	2,880	576,000
	B. Family Compound Services	5	80 m^3	3,800	1,520,000
	C. Public Standpipe Service	20	60 m^3	1,550	1,860,000
	Total-Residential			8,230	3,956,000

		Ave. Annual Use per Service	Active Services	Annual Sales
2.2	Commercial, Institutional and Industrial Class			
	A. Small Business and Other Users	72 m^3	150	10,800
	B. Intermediate Business and Other Users	205 m^3	115	23,600
	C. Large Business and Other Users	760 m^3	305	231,800
	D. Very Large Business and Other Users	3,550 m^3	50	177,800
	Total-Other Classes		620	444,000
2.3	Totals - All Classes		8,850	4,400,000

3. WATER REVENUES - 1985-86

Customer Type	Estimated Population	Active Services	Annual Excess	Billing Rate	Annual Revenues
All Active Services (Minimum)		8,850	-	48.00	Ls. 424,800
Class "A" Residential	15,500	2,880	104	0.50	149,760
Class "B" Residential	98,800	3,800	304	0.50	577,600
Class "C" Residential	155,500	1,550	1,104	0.50	855,600
Other Classes - Small	-	150	-	-	-
Other Classes - Intermediate	-	115	109	0.50	6,300
Other Classes - Large	-	305	204	0.50	31,100
			460	0.70	98,200
Other Classes - Very Large	-	50	204	0.50	5,100
			900	0.70	31,500
			2,350	0.90	105,740
Distribution Billing of Unused Consumption Under minimum Allowance		4,000	24	0.70	67,200
Total Water Revenue					Ls. 2,352,900
Less: Allowance for Uncollectable Accounts @ 3%					70,600
Net Water Revenue					Ls. 2,282,300

The impact of increasing or decreasing the rates for large users would be insignificant. Revenue from minimum charges and the base Ls. 0.50 rate provides 87% of total water revenue. Increased rates for large users are an attempt to recover O&M costs for larger services and meters, suppress excessive use and wastage, and to provide an element of socialized pricing within the revenue program. Other charges for service were not considered at this time as their revenue impact would be rather minor. The present charges for new service connections, reconnections to the system, etc should be increased to reflect inflationary pressures. Also, the Ls. 6.00 security deposit should be increased to guarantee payment of at least two months of normal water use for each new customer.

12.4 FINANCIAL PROJECTIONS

The results of projecting revenues from the proposed rate schedule were transferred to an operating statement to indicate the overall financial condition of the Gedaref water system after the proposed improvements are constructed. Table 12.8 shows the operating results for six years starting in fiscal year 1982-1983. After applying the new rates, net income increases sharply to Ls. 609,400 in 1985-1986, Ls. 850,100 in 86-87, and Ls. 1,094,700 in 1987-1988. Revenues were inflated by 10% in the last two years assuming adjustments to water rates equivalent to the projected 10% per annum escalation used in the analysis. The net income does not include a deduction for the return on investment shown in Table 12.4 but is more than adequate to cover this requirement. Actual return on investment would calculate at 5.5% in 1985-1986, 7.9% in 86-87, and 10.6% in the year ending 1988. As previously stated, return on investment is neither a short-term nor a long-term cash requirement and provision for this amount is water rate formulation will only tend to build large cash surpluses in the accounts of the utility.

12.5 FINANCING SOLID WASTE DISPOSAL FACILITIES

The proposed improvements to solid waste handling and disposal are presented in Chapter 10. Proposed improvements deal only with the provision of additional collection units and a bulldozer for disposal site leveling and filling. As discussed in Chapter 10, the present level of staffing of the Gedaref Town Council should be sufficient to properly handle solid wastes within the greater Gedaref area. The manpower now allocated to this task totals 69 with additional budgeted and approved positions totalling 35. Therefore, present town budgets for personnel costs should remain the same with only a small additional expediture necessary to fuel, repair and maintain the additional 4 small tractors and small bulldozer.

TABLE 12.8

GEDAREF WATER SYSTEM PROJECTED OPERATING RESULTS
Fiscal Years 1982 through 1988

	Fiscal Year (July - June)					
	1982-83	1983-84	1984-85	1985-86	1986-87	1987-88
Active Water Services	6,150	6,300	6,850	8,850	10,800	13,500
Water Production (in 1,000 m³)	2,900	2,900	3,650	5,500	6,125	6,500 (Max)
Water Sold (in 1,000 m³)	2,200	2,200	2,950	4,400	4,900	5,200
Revenues						
Water Sales (1)	Ls 595,000	714,000	1,148,000	2,282,300 (2)	2,795,900 (2)	3,263,700 (2)
Other Revenue	46,600	55,900	67,100	127,000	116,200	136,100
Total Revenue	Ls 641,600	769,900	1,215,100	2,409,300	2,912,100	3,399,800
Expenses (3)						
Source Treatment and Pumping						
Labor	113,300	136,000	163,100	93,800	103,200	113,500
Electric Power	215,600	258,700	549,200	878,400	1,077,600	1,258,400
Treatment Chemicals	47,000	56,300	67,600	16,500	19,100	22,900
Materials and Supplies	3,200	3,900	4,600	5,300	5,900	6,500
Plant Maintenance	40,000	44,000	52,800	2,000	2,200	2,400
Fuel and Lubricants	4,300	5,200	6,200	7,200	7,900	8,700
	423,400	504,100	843,500	1,003,200	1,215,900	1,412,400
Distribution						
Labor	103,800	124,600	149,500	172,000	189,200	208,100
Maintenance Expense	15,400	18,500	22,200	25,500	28,100	30,900
Fuel and Supplies	8,500	10,200	12,200	14,100	15,500	17,100
	127,700	153,300	183,900	211,600	232,800	256,100
Commercial (4)						
Billing and Collecting	19,900	23,900	33,500	48,600	56,400	63,700
Meter Reading	23,900	28,700	40,100	58,200	67,500	76,200
	43,800	52,600	73,600	106,800	123,900	139,900
Administrative and General						
Supervision	9,500	11,400	13,700	17,800	21,300	23,500
Accounting	7,100	8,500	10,200	13,300	17,300	19,000
Personnel Administration	15,700	18,800	22,600	26,000	28,600	31,400
Storekeeping/Procurement	2,700	3,200	3,900	5,100	6,100	6,700
	35,000	41,900	50,400	62,200	73300	80,600
Total Operating Expense	Ls 629,900	751,900	1,151,400	1,383,800	1,645,900	1,889,000
Net Operating Income	11,700	18,000	63,700	1,025,500	1,266,200	1,510,800
Depreciation Expense	151,200	120,000	120,000	416,100	416,100	416,100
Net Income (Loss)	Ls (139,500)	(102,000)	(56,300)	609,400	850,100	1,094,700
Revenue per cubic metre billed	Ls 0.27	0.32	0.39	0.52	0.57	0.63

Note: (1) Assuming rate increases equal to forecasted local inflation escalation factor
(2) Reflects Proposed Rate Structure effective on July 1, 1985, an uncollectable factor of 3% and 10% annual rate increase
(3) Assuming annual escalation of 10%, 20%, 20%, 15%, 10% for years ending 1983, 84, 85, 86 & 87, respectively
(4) Escalated by increased customer accounts and annual inflation factor

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CHAPTER 13

ECONOMIC ASPECTS

13.1 GENERAL

The economic assessment portion of this project analysis is included to provide an indication of the project implementation impacts on the recipient population, the local economy of the greater Gedaref area and, if applicable, the national economy. The economic assessment goes beyond the financial analysis of the project and its impact on the operating water agency in attempting to determine the net costs or benefits of the project based on project-generated impacts to all sectors of the economy and society. For such a cost/benefit analysis to produce a net "real" cost or net "real" benefit of project investments, a mass of information is required related to the following: (1) opportunity cost of capital and foreign exchange, (2) tariffs, (3) availability and price of labor, (4) cost of local and imported resource factors, (5) project recipients' incomes, (6) the social discount rate (e.g. the value society places on consuming individual economic goods now rather than in future years, and, most important, (7) data required to quantify project benefits. The streams of future costs and benefits are then discounted to their present values and compared to each other in the final step. For public utility projects such as this, data are not usually available to quantify all known benefits, thus making a quantified cost/benefit analysis inappropriate. In addition to that deficiency, much of the other data requirements for such a comparison could not be developed due to the short duration of the study assignment. Information related to shadow prices of several input factors, which was to be provided by the U.S.A.I.D. mission in Khartoum, was not yet available at the time of preparation of this report. Therefore, this analysis was limited in scope to a qualitative discussion of the "real" costs and benefits. The "economic internal rate of return" was also inappropriate for use as a measure of project economic value for the same reason, since project-generated stream of economic benefits could not be quantified.

Despite these limitations, this analysis does include an attempt to measure the economic value of the project to the operating agency based on an estimate of the would be cost of project financing through a loan from an international loaning institution at current rates, and project impacts on project recipients based on a comparison of user rates required to meet projected operating costs with estimates of ability to pay.

Economic costs and benefits of each project alternative were considered along with financial, technical, and environmental aspects in the alternatives analysis conducted in other chapters. This was done in the form of an adaptation of the financial least cost analysis to reflect differences in impacts of foreign exchange, use of scarce resources and the qualitative assessment of differences in expected levels of non-quantifiable benefits.

13.2 ECONOMIC COSTS AND BENEFITS

The approach adopted in this analysis is an attempt to indicate the social (economic) costs and benefits of this project to the Sudan as recipient of the project, and the people of the greater Gedaref area as those impacted directly.

Economic costs of project implementation would include the following factors:

1) Cost of imported materials adjusted by the shadow price of foreign exchange. Because of the Sudan's relative shortage of foreign exchange and resulting duties on imported goods, the real cost of imported materials is higher than the actual price paid for those goods. Sudanese import duties, which otherwise would have to be subtracted out are not considered here as this project is expected to be exempt due to its status as a public improvement project.

2) Cost of imported labor adjusted by the shadow price of foreign exchange. Fees paid to foreign contractors affect the national economy similarly to the purchase of imported materials.

3) Cost of local construction materials and local equipment less local purchase taxes (expected to be insignificant).

4) Cost of local labor hired for construction over a one year period. Approximately 100 positions required.

5) Loss of productivity of current water vendors which would be put out of business due to project improvements.

Economic benefits of project implementation would include the following factors:

1) Proceeds of the U.S.A.I.D. grant covering the financial (not economic) costs of purchasing imported materials and equipment, imported labor, local materials and labor.

2) Value of about 100 local one-year jobs provided, less value of the producitivity of those individuals in jobs with which they would otherwise be occupied.

3) Productivity of ex-water vendors in their new occupations.

4) Value of sale of local construction materials, less the cost of their production.

5) Increase in utility of water system users having uninterrupted supply of water, increased water supply, and improved water quality. This could be manifested in the form of less time spent by children and women in gathering water from vendors or supplemental sources, less

time storing water for those converting to direct water connections.

6) Improvement in health conditions as a result of improved water quality and improved hygienic conditions due to increased quantities of water available per family. The possibilities of this potential benefit are discussed in detail in Chapter 14.

Although the information required to perform a quantitative cost-benefit analysis and for comparison with investment in another project is not available at this time, a qualitative comparison of costs and benefits can be made. Because the project, as considered, would be funded by a grant covering all accounting costs (capital outlay) for construction of improvements, and the project-generated increase in operating expenses would be met through user fees, project economic benefits would be likely to outweigh economic costs. This conclusion is based on the assumption that the improvement of health conditions and added convenience of non-interrupted and increased supplies of water plus jobs created would outweigh any losses of productivity of locall hired laborers, loss of water vendors' productivity and net costs of foreign exchange. A comparison of the use of the projects' grant money for a different project or type of project could not be made given the time frame and scope of this study. However, such a comparison could be a topic for further consideration.

13.3 PROJECT ECONOMIC VALUATION

13.3.1 Improvement Funding

One method of imputing the value of implementation of this project would be the estimation of project financing costs assuming that the Sudanese government would desire to fund this project through sources other than a U.S.A.I.D. grant. A loan from an international loaning institution at a rate of 10 percent (reflecting recent rates) was chosen for this analysis. The loan was assumed to cover a period of 20 years with uniform annual payments. The following Table 13.1 indicates the capabilities of the proposed financial program to cover the indirect but real economic costs.

It is apparent from this summary that the proposed revenue program is satisfactory to recover all operating costs, depreciation reserves and a modest return on investment but will not generate sufficient funds to cover the hypothetical costs of loan funds for project improvements.

This is probably only proper since the water utility should not establish rates or tariffs that generate revenue far in excess of actual financial obligations. Rate structures would need to be increased by about 25% to cover these added economic costs.

TABLE 13.1

ABILITY TO RECOVER THEORETICAL LOAN
INTEREST COSTS ON PROPOSED SYSTEM IMPROVEMENTS

	Fiscal Years		
	1985-86	1986-87	1987-88
Net Operating Income (Table 12.8)	Ls 609,400	Ls 850,100	Ls1,094,700
Less: Return on Investment at 6% (Table 12.4)	669,400	644,400	619,400
Adjusted Net Income (Loss)	(60,000)	205,700	475,300
Less: Interest Cost on Uniform Loan Repayment at 10% over 20 years ($5.8 million or Ls 9.3 million)	544,900(1)	1,089,900	1,089,900
Balance of Income (Loss)	Ls(604,900)	Ls(884,200)	Ls (614,600)

(1)
Based on 1/2 year interest cost.

13.3.2 Ability to Pay

The ability of the water system users to pay the determined rates and charges for improved water service must be predicated on the following factors:

- Establishment of the low income family basic spendable monthly income.
- Determination of the volume of water consumption expected by this low income group and the subsequent water costs.
- Establishment of a maximum percent allocation of income that this group could afford to spend on water supply.
- A test of other customer classes to determine their financial ability to pay.

The proposed rates and charges are tested below based upon an assumed low income family minimum monthly income of Ls 60.00 and a maximum of 5% of this spendable income for water supplies.

		Monthly
Projected usage based upon 35 lpcd and family size of 5.2 persons		5.5 m^3
Cost per Proposed Rate Schedule effective July, 1985 (minimum charge)	Ls	4.00
Basic Minimum Income of Ls 60.00 adjusted by escalation factors used in determining rates-from January 1983 to July 1985.	Ls	95.00
Percent of Basic Minimum Income - July, 1985		4.2%

The above summary verifies that proposed water rates should be within the ability pay of the low income groups. However, if the theoretical loan service costs were included in the tariff structure, the percent of basic spendable income allocated to water supply would increase to about 5 1/4%. The water cost shown above would allow the family to use 8 m^3 even though their average estimated consumption should be only 5.5 m^3 per month. It should be noted that the families in the Tawawa refugee settlement are presently paying about Ls 12.00 per month for 10 lpcd if they are purchasing water from water trucks by the gasoline drum method. Other customer classes were evaluated and no significant adverse financial impact was apparent.

CHAPTER 14

ENVIRONMENTAL ASSESSMENT

14.1 INTRODUCTION

The purpose of this Chapter is to provide USAID with a discussion of the envisioned environmental impacts of alternative water supply improvements for the Gedaref water system and the Tawawa Refugee Settlement, Kassala Province, Democratic Republic of Sudan, and to suggest possible mitigation measures. In order to facilitate AID review, the assessment has been prepared according to and with AID Environmental Procedures published in the Federal Register, October 23, 1980.

No single Scoping Meeting was held, but interviews were conducted in early and mid-November, 1982, with USAID staff, the Gedaref Town Council, Health Officer and Hospital Director, the United Nations High Commissioner for Refugees (UNHCR), the International Rescue Committee (IRC) and the University of Khartoum. Because of the emergency nature of the project and the short time frame of this feasibility study, no Scoping Statement was submitted. The environmental factors considered by the interviewees to be of importance are listed below:

- Ground and surface water resources
- Geology, soils and topography
- Agriculture and livestock
- Public health
- Desertification
- Population growth and distribution
- Land use and infrastructure
- Water use patterns
- Antiquities
- Socio-cultural effects
- Energy requirements and availability

As a result, this assessment focuses on the analysis of the above topics. As is often the case in developing countries, available data were sparse, often difficult to obtain and contradictory among sources. The text indicates these gaps in information.

The assessment is organized as follows:

- Purpose and Need (Chapter 2 of this report)
- Summary (Chapter 1 of this report)
- Alternatives Including the Proposed Action
- Affected Environment
- Environmental Consequences

- List of Preparers

References and Bibliography are presented at the end of this chapter. Agencies and persons consulted are given in the Appendix C to this report.

14.2 AFFECTED ENVIRONMENTS

This section focuses on those aspects of the environment likely to be affected by the proposed project. For purposes of analysis, the environment is divided into its physical, biological and human components. It is understood that the three overlap, but this classification ensures a full discussion of both beneficial and adverse environmental impacts. Because of the nature of the project, a number of aspects of the existing environment are described in other chapters of this report and will be so referenced and not repeated herein.

The town of Gedaref is located approximately 421 road km southeast of Khartoum, in southern Kassala Province of eastern Sudan. Gedaref is a busy agricultural market town, the location of a Dura Mechanized Farm Scheme, livestock grazing, and fields of dura (sorghum), sim-sim (sesame) and cotton on the flat central clay plains which provide Sudan much of its food. Natural vegetation is acacia on short grass scrub or tall grass open forest.

Gedaref is also an important stop during the annual pilgrimage (hajj) route from Africa to Mecca. As a result, Gedaref contains many "east africans" from countries west of Sudan. More recently, Gedaref has received large numbers of refugees from Ethiopia, now settled in the town and in neighboring refugee settlements, placing additional pressure on limited local resources.

14.2.1 Physical Environment

The physical environment of the study area, land, water and climate (topography, geology, soils, ground and surface water quality, quantity and movement) has been described in Chapter 7 and Appendix B.

Air quality parameters are not monitored in Gedaref, but air quality is generally good with the exception of suspended particulates (primarily wind blown dust) as there are relatively few air pollutant generators, such as gasoline powered vehicles or industries, in the study area and meteorological conditions favor good mixing. Highly localized temporary air pollution "hot spots" are created, however, by open fire cooking practices, trash burning, insecticide spraying to control mosquitoes, gasoline evaporation from station pumps, drums and air siphoning, occasional pesticide spraying of neighboring agricultural areas for cotton pests, truck and vehicle traffic on the Wad Medani and Port Sudan Roads and truck stops.

Highly localized odors are generated by pesticide spraying in the agricultural fields and in buildings, by animal and human urine and feces deposited in city streets or just outside human habitation, by individual house latrines and, to a lesser extent, by decaying solid waste. Most decomposable solid waste in Gedaref is eaten by goats before it becomes odoriferous.

14.2.2 Biological Environment

The biologic environment is described in terms of regional native biota, local native biota, agriculture and livestock, and endangered species.

Regional and Local Native Biota - The biological environment of the study area has been dominated by the presence of man and his livestock for centuries, but remnants of native vegetation remain in the region. Gedaref is located in the Nile drainage basin, in an area transitional between acacia short grass scrub to the north, and more southern acacia and tall grass open forest native vegetation zones of the flat, Sudanese clay plains. These, in the state of nature, are characterized by a typical savannah mixture of grasses (primarily annual), thorny shrubs or scrub, and scattered short trees, primarily varieties of acacia. In the Gedaref area, much of this vegetation has long since been replaced by agricultural crops or destroyed by livestock grazing. The wildlife once associated with the area have been similarly removed or displaced to a large extent. Only those species able to adapt to environments created by man remain in any numbers. Apparently, in the early days of the present Gedaref town, late 18th to early 19th centuries, the area was frequented by large carnivores, and pilgrims on the route to and from Mecca were not anxious to stay there for long. The large native mammalian carnivores and herbivores of the savannah are long gone, replaced by man's camels, cattle, sheep, goats and donkeys. Small mammals, snakes, insects, scorpions and small land birds are still common, as are several types of scavenger birds. Along the Atbara River, riparian vegetation supports storks, cranes, ducks, geese and other waterfowl. The river itself contains perch, carp and many other varieties of fish. In the Rahad River drainage basin, 100 km due south of Gedaref, is the Rahad Game Reserve.

Agriculture and Livestock - Agriculture in the Gedaref area is primarily cotton, dura (sorghum) and sim-sim (sesame) mechanized dry land farming. Production of gum arabic from acacia is also important. The central clay plains region is so important to the economy of the country that one prominent geographer has ventured that, had this region been no more productive than the qoz region or the Red Sea Hills, Sudan as an organized state could not have come into being.

The heavy clay soils are not rich however, and are unfavorable for many crops. Traditional farming practice alternated agriculture with long fallow periods to allow soil replenishment. Historically, farming was accomplished with minimal clearing of acacia. Clearing of acacia without fallow period reforestation seriously depletes the soil, as the leguminous acacias have nitrogen-fixing bacteria in nodules on their roots which are important to maintaining soil fertility. With increases in human populations, fallow periods have grown shorter; the land is used continously for longer periods so that, over time, annual yields have decreased. Open grazing of cattle has also led to removal of vegetation, as have increased fuel and construction material requirements supplied by acacia wood. (Nelson, et al. 1973; El Hassan, 1981; El Tayeb, 1981).

The Mechanized Farming Corporation Project in Gedaref provides equipment and assistance to farmers developing the government-owned land. The Gedaref rain-fed mechanization scheme, part of a nation-wide project, began in the 1960's and will include about 900,000 feddans, ultimately comprising about one-third of the planned total scheme area. By the 1968-1969 crop season, about 1.3 million feddans were actually under crops in the Gedaref area and Dali and Mazmoun Districts near the rail line. The Gedaref Scheme was planted 70 percent to dura, 27 percent to sesame and three percent to cotton. (Nelson, et al., 1973).

Estimated numbers of animals in the Gedaref region in 1975 are listed below.

TABLE 14.1

ESTIMATED NUMBERS OF LIVESTOCK IN GEDAREF AREA, 1975

Animals	Numbers
Cattle	122,519
Sheep	202,170
Goats	213,102
Camels	9,196
Donkeys, horses and mules	17,870
Total	564,857

Source: Sudan National Livestock Census and T 'sources Inventory, Volume 14, 1976.

These figures are presented as background information only; the present project is not intended to provide any water for livestock.

Endangered Species - Because of the highly disturbed state of the biota, the general lack of native vegetation and wildlife due to grazing and agriculture, and the similar land use all around Gedaref, it is highly unlikely that any endangered species occur within the study area and that Gedaref would represent a critical habitat area.

In response to a request, USAID reviewed a variety of IUCN Manuals (Red Data Books) for endangered species of plants, mammals, amphibiaus, reptiles and invertebrates. The only endangered species found was Medemia argun, a palm once found along river banks, wadis and oases in Egypt and Sudan. In the Sudan it is now known from only one locality, 200 km southeast of Wadi Halfa, there are also unverified, pre-1910 records from a few other areas where it is doubtful whether it still survives. The IUCN manual (1978) also reports that this species is in cultivation in Sudan. The study area has essentially no palms except perhaps along the Atbara River, but it is highly unlikely that the species is there. In any case, all proposed water facilities can easily be relocated to avoid particular trees, so no impacts will occur.

14.2.3 Human Environment

The human environment of the study area is described in terms of population, land use and water consumption in Chapter 6, and solid waste disposal conditions in Chapter 11. Chapter 5 presents socio-cultural conditions, while Chapters 3 and 4 discuss public utilities and the existing water supply situation. Described in this section are public health and sanitation, transportation and communication, fire, police and schools, antiquities, energy sources and supplies. Institutional considerations are discussed in Chapter 11.

Public Health and Sanitation - A high incidence of disease in the study area and in east Sudan as a whole reflects difficult ecological conditions, inadequate diets and sometimes insufficient medical care. Also contributing is the continuing influx of refugees and Muslim pilgrims which increases crowding in Gedaref and may bring in non-endemic illness. Despite these factors, typhoid, plague, yellow fever, cholera and smallpox have been almost eliminated. The government considers malaria, tuberculosis and schistosomiasis (bilharzia) the country's major disease problems. These are of particular relevance to the present project as malaria and bilharzia are water related diseases, as are the widespread amebic and bacillary dysenteries. Table 14.2 presents major water and sanitation related diseases in Sudan and their mechanisms of transmission.

Bilharzia is a serious parasitic infection spread primarily through the discharge of human urine and feces into ponds, irrigation

TABLE 14.2

WATER AND SANITATION RELATED DISEASES IN SUDAN

Mechanism	Disease(s)	Prevention
Consumption of Feces-Contaminated Water	cholera, shigellosis, typhoid, dysentery, hepatitis, diarrheal diseases, giardiasis	Eliminate pollution Disinfect water supply Select clean sources
Water-washed (water scarce, costly or difficult to obtain)	skin and eye infections: trachoma, conjunctivitis, skin ulcers, scabies, relapsing fever, kala azar	Increased water availability for hygiene, hygiene education
Water based: pathogen lives in water	schistosomiasis (bilharzia) flukes and tapeworms	Control of intermediate host. Improved sanitation practices; reduce access to infested waters.
Water-related: insect vectors	malaria, filariasis, onchocerciasis, yellow fever	Insecticide spraying, anti-larval measures

Souce: Feachem, et al. 1977.

canals and show-moving streams containing the intermediate host, a species of the snail Bulinus, and subsequent skin contact with the infested waters. Permanently irrigated areas, rather than dry land farmed areas like Gedaref, are far more hospitable to bilharzia, but several hundred cases are treated at Gedaref Hospital and surrounding local dispensaries and clinics annually. The Gedaref Health Officer indicated that molluscides, used widely to control the host snail and thus interrupt the parasite life cycle, are not used in the area because they are toxic to humans. This is not the case however, molluscides can be toxic to fish which may also live in the irrigation canals and provide an important source of food. The town Health Officer in Gedaref believes infected migrant laborers from Ethiopia and West Sudan help to spread, maintain or even increase the problem.

Malaria is endemic to and widespread throughout Sudan. Virtually any standing water (ponds, hafirs, irrigation canals, latrines, garden and street puddles) provides potential habitat for larvae of the mosquito Anopheles gambiae, perhaps the most important vector in the Sudan. Thus, malaria peaks annually during and just after the rainy season (October and November in Gedaref). In western Sudan, there is a second malaria peak, December through February, associated with wheat irrigation. Malaria sites in homes in Gedaref are the latrines, primarily, and, to a much lesser extent, water jars. Reservoirs, hafirs and other standing water puddles also provide larval habitat in the study area.

Diarrheal diseases, including specific and non-specific diseases with diarrhea as a symptom, are also prevalent in Sudan. Diseases such as cholera, dysenteries, gastroenteritis, and E. coli and Rotavirus diarrhea are the most important cause of morbidity and mortality in children under five years old who represent at least 50 percent of recorded cases.

Table 14.3 shows recent numbers of water-related disease cases reported from Gedaref Hospital, regional dispensaries and dressing stations, and from the adult clinic at Tawawa Refugee Settlement (IRC 1982). Diseases of greatest frequency in Gedaref Hospital in 1980 were, in decreasing order of frequency, malaria, general digestive system disease, gastroenteritis and diarrheal disease, and bacillary and amebic dysenteries. Less frequent were schistosomiasis, typhoid and hepatitis. At the dispensaries, malaria and digestive system disease cases were most numerous, but many more cases of bacillary and amebic dysenteries were treated there than in Gedaref. For the two three-month periods at Tawawa (June - August, 1981, and August-October, 1982), gastroenteritis and diarrheal disease cases were most frequent, followed by bacillary and amebic dysenteries, with malaria as third most reported. Giardia and

TABLE 14.3

COMPARISON OF MORBIDITY AND MORTALITY FOR WATER-RELATED DISEASES AT GEDAREF HOSPITAL, TAWAWA, AND DRESSING STATIONS/DISPENSARIES

Disease	Gedaref Hospital[a] Number Treated 1980 (all ages)	Gedaref Area Dressing Stations & Dispensaries (1980)[a]			Adult Clinic Visits Tawawa Refugee Settlement	
		Total Treated (all ages)	Deaths	Referred to Hospitals	Jun-Aug[b] 1981	Aug-Oct[c] 1982
Bacillary and Amoebic Dysentery	2,578	55,881	0	14	592	596
Gastroenteritis and Diarrheal Disease	12,378	14,627	64	180	1,161	923
Schistosomiasis	474	374	0	12	69+	39
Typhoid	521	ND[d]	ND	ND	NR[e]	NR
Infectious Hepatitis	438	ND	ND	ND	138	85
Other Digestive System	20,676	340,355	0	196	UKN	UKN
Malaria	57,099[f]	303,396	34	94	41[g]	446
Giardia	ND[e]	ND	ND	ND	141	155
Onchocerciasis	ND	ND	ND	ND	156	121

[a] Translated from Arabic, Gedaref Hospital 1980 Annual Report; 20% of dispensaries outside project area.

[b] USAID, WASH Field Report No. 37, 1982.

[c] Monthly reports, IRC Adult Clinic at Tawawa.

[d] No data.

[e] Not reported.

[f] Figures for Gedaref Hospital plus three others.

[g] Two months' data.

Entamoeba histolytica were the most prevalent parasites in the camp. The camp's IRC doctor believes the fetid water present in the camp to be the single greatest obstacle to improved health (Monthly Report, October, 1982).

Historical/Cultural - Dr. Ahmed Hakim, Professor of Archaeology at the University of Khartoum Department of Archaeology, was consulted, and he subsequently stated that, while the Gedaref-Showak area had never been subject to an archaeological field study, he was sure, based on work in similar areas, that archaeological materials did exist in the area. Gedaref and Showak areas have been occupied since prehistoric times. Iron Age materials there may date from 10 B.C. to the 18th Century. The Gedaref area was also important during Islamic times as an early Moslem community settled by Arabs from Saudi Arabia and Yemen.

Farming may have disturbed as much as 90 percent of the area's archaeological materials, but the remaining 10 percent would fill an important gap in the historical picture of east Sudan.

Transportation, Communication and Energy - Gedaref, as an agricultural center and pilgrim's stop en route to Mecca, has more extensive transportation facilities than most Sudanese towns. Gedaref is served by railroad, by paved highway from Khartoum via Wad Medani and through to Kassala and Port Sudan. A small airport near Gedaref is primarily used for crop dusting planes associated with cotton agriculture in the Mechanized Farming Scheme. Gedaref has bus service to Khartoum and a system of taxis in town. A major truck stop is just outside Gedaref to the north toward Tawawa. However, roads in town are almost entirely unpaved, and few persons own cars. Transportation has been considered the chief potential obstacle to expansion of commercial production in Sudan.

Telephone service from Khartoum to Gedaref is intermittent and difficult.

Electrical energy for Gedaref is produced almost entirely by hydropower at Kashm el Girba Dam 100 km north-northeast of Gedaref on the Atbara River. The power plant supplies both irrigation and municipal power needs, but irrigation apparently takes precedence, as Gedaref Town and the Showak Water Treatment Plant 50 km south of the dam on the Atbara are without power for long periods each day.

14.3 ALTERNATIVES, INCLUDING THE PROPOSED ACTION

This section provides a comparative analysis of alternatives, including No Action, for water and solid waste management in the Gedaref town area and identifies mitigation measures. Alternatives not included in the detailed analyses are also identified.

Conceptually, the alternatives are two:

A. No Project, or continuation of the existing situation: will mean intermittent delivery of insufficient water to the Gedaref town area, and purchase of expensive, poor quality water from vendors at the refugee settlements with concomitant high incidences of disease and friction between city dwellers and refugees. Lack of effective solid waste management.

B. Upgrade existing surface supply system as well as develop local ground water sources, provide standby power, and extend existing distribution systems to ensure a continuous, reliable, adequate water supply to the Gedaref town area and Tawawa Refugee Settlement. Provision of effective solid waste management facilities and implementation scheme.

As the project is considered an emergency relief effort, the No Project Alternative is, by definition, not viable and will not be discussed further. The environmental impacts of B are overwhelmingly beneficial, and there are no significant adverse impacts. Potential minor negative impacts are discussed and tabulated in this section.

14.3.1 Water Supply Alternatives

It became clear early in planning that in order to provide adequate, reliable supplies of water to the Gedaref area, both ground and surface water sources would be involved. Therefore, alternatives are grouped into Ground Water Alternatives and Surface Supply Alternatives. Detailed descriptions of alternatives are given in Chapters 8 and 9 of this report. Impacts of providing an increased, safe, reliable water supply are shown in Table 14.4.

All water supply alternatives include the following improvements to the Showak system:

- Provision of two generators (diesel) for standby power
- Restoration of continuous chlorination of treated water at the Showak plant
- Routine chlorination at Gedaref reservoir to maintain an chlorine residual in delivered water

Surface Supply Alternatives

Alternatives considered are:

1. Showak Existing (No Project)

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TABLE 14.4
IMPACTS OF SURFACE SUPPLY INTAKE MODIFICATION ALTERNATIVES

ISSUE / ALTERNATIVE	GROUND AND SURFACE WATER RESOURCES	GEOLOGY, SOILS, TOPOGRAPHY	AGRICULTURE AND LIVESTOCK	PUBLIC HEALTH AND SAFETY	LAND USE	ANTIQUITIES	SOCIO-CULTURAL EFFECTS	ENERGY AND MATERIALS CONSUMPTION
I. No Project - Existing System.	No impact on resources. Continued problems with intake system in dry season - hand trenching of channel.	No impact.	No impact.	Continued delivery of water containing MPN 500 coliforms / 100 ml, no chlorination; intermittent deliveries prevent good hygiene.	No impact.	No impact.	No impact.	No impact.
II. Intake Relocation a. Upstream b. Downstream c. Same 1. With Pontoon 2. Cable System 3. Buried Line	No impact on resource quantity, quality. Intake relocation will reduce silt load to plant significantly, eliminate hand trenching. Possibility of facilities washed away in flood season.	No significant impacts. Buried line will require special construction techniques because of soil characteristics.	No impact.	Decreased turbidity of influent, improved plant treatment efficiency and water quality. Creation of health and safety hazards at construction site.	No impact.	Insignificant potential for impact if any excavation for structure.	Eliminates jobs of 50 workers performing hand trenching. Temporary increase in construction employment.	Consumption of energy for materials production and for pumping water into plant.
III. River Diversion a. Single Gabion b. Multiple Gabions c. Trenching Machine d. Track-Mounted Intake	Alteration of river flow and silt deposition patterns. Reduction of silt load in intake; eliminate hand trenching. Effects of flooding not clear.	Soils expansive, unstable. Structures will need support.	No impact.	Decreased influent turbidity and output quality. Creation of health and safety hazards at construction sites.	No impact.	Insignificant potential for impact if any excavation required.	Eliminates jobs of 50 workers. Temporary increase in construction jobs.	Energy consumption in construction and machine fuel for water pumping. Commitment of concrete, steel to facilities.
IV. Shallow Well Intake (Recommended Project)	No impact on surface flow. Some local lowering of groundwater level at wells. No effect of river levels	Soils expansive; to be accounted for in well construction and pipeline construction. Trench 1.0-1.5 meters deep.	No impact.	Decreased turbidity of influent, improved plant treatment efficiency and output quality. Creation of health and safety hazards at construction site.	Conversion of small areas to well sites. Not significant.	Potential for impacts due to well and pipeline excavation.	Eliminates jobs of 50 workers performing hand trenching. Short-term increase in construction jobs.	Energy consumption for well pumping and production of well and pipe materials.
V. Pretreatment Settlement in Hafirs	No impact. Place hafirs above flood stage, protect berms.	Soils clayey, suitable for berms, may need reinforcement.	Must exclude livestock to prevent contamination of hafirs.	Creation of health and safety hazards at construction site. Must exclude public to prevent spread of bilharzia and prevent hafir contamination. Hafirs are potential malaria sites. Decreased effluent turbidity.	Conversion of 11 feddans to hafirs.	Potential for impacts at hafir sites and along connecting pipelines.	Eliminates 50 jobs for hand trenching. Short-term increase in construction jobs.	Energy consumption for hafir excavation, for production of pipe materials.

2. Relocation of Intake
   - 2a. Upstream
   - 2b. Downstream
   - 2c. Same Location
     - 2c.1. Pontoon for intake line
     - 2c.2. Cable system
     - 2c.3. Buried line

3. River Diversion (training)
   - 3a. Single Gabion
   - 3b. Multiple Gabions
   - 3c. Track-mounted Trenching Machine

4. Shallow Well Intake (Recommended Alternative)

5. Pretreatment Settlement in Hafirs
   - 5a. With Upstream Intake
   - 5b. Double Pumping to Plant

Ground Water Alternatives:

Ground water alternatives are additional wells at four alternative areas:

Abu Naga Area B
Tawawa
Umm Golga (Future development)
Er Rawashda
or a combination of the above

The recommended alternative consists of:

- two additional wells at Abu Naga well field B
- a new well and additional piping at Tawawa
- paralleling the 5.5 km closest to Gedaref of the 12 km transmission main from Abu Naga, and repairing the remaining 6.5 km
- Shallow well intakes at the Showak plant

14.3.2 Impacts of All Improvements at Showak (See Table 14.5)

- The well gallery may have site-specific effects: minor removal of riparian vegetation. (Permanent, but not significant).

TABLE 14.5

IMPACTS OF PROVISION OF ADDITIONAL WATER, 24 HOURS DAILY TO STUDY AREA

ISSUE / ALTERNATIVE	GROUND AND SURFACE WATER RESOURCES (QUALITY, QUANTITY, MOVEMENT)	GEOLOGY, SOILS, TOPOGRAPHY	AGRICULTURE AND LIVESTOCK	PUBLIC HEALTH	DESERTIFICATION	POPULATION GROWTH AND DISTRIBUTION	LAND USE AND INFRASTRUCTURE	WATER USE PATTERNS	ANTIQUITIES	SOCIO-CULTURAL EFFECTS	ENERGY
No Project.	No change in delivered water quality. No effect on Atbara River flow. No change in groundwater quality or quantity regime. No change in groundwater movement.	No impact.	No impact.	Continued high incidence of intestinal disease, malaria and possibly water-washed diseases.	Population increases will increase farming pressure.	Significant growth projected	Housing for increased population converts vacant land to urban uses. Additional population increases total demand for utilities and community services: police, schools, transportation, solid waste disposal.	Continuation of present patterns - sales of water to refugees from donkey cart vendors. Hoarding of water in town during hours water is available. Insufficient water for hygiene at times.	No impact.	Continued friction between town dwellers and refugees.	No impact.
Provision of water 24 Hours Daily to Gedaref Town and Refugee Settlements	Significant improvement in turbidity and biological quality of delivered water from Showak. Increase draw from Nubian Sandstone aquifer at Showak bringing Showak Plant to design flow. No significant impact on river. Lowering of ground water levels in well field area at Abu Naga and Tawawa. Probable improvement in chemical quality of well water with sealing of wells in volcanic strata (Should be monitored over time). Limited recharge in Abu Naga area so wells must be at least 5J0 metres apart. Yield effects uncertain - need more data on basin.	Silt and clay soils expansive, facilities must be installed below zone of desiccation(depth of cracks) 1.2-2.0 metres. Soil permeability low - recharge poor. In wet season, soils become muddy, slick - travel, excavation by heavy equipment ceases. Drainage poor, puddles encourage malaria.	No impact. Livestock is not watered from town system. Agriculture is dry land farmed near Gedaref - littl- irrigation	Expected moderate to significant redurtion in intestinal disease, and possibly water-washed and water borne diseases associated with improved bacterial quality of water, improved hygiene, and shift in water sources. Increased flow to septic tanks, necessitating more frequent pumpouts to prevent failures and hand-dug well contamination. Dumping septage in khors could eventually contaminate ground water (nitrates). Increased water leakage could cause permanent puddles - malaria sites.	No impact associated with overgrazing, as water to livestock will not increase. Increased human population may place additional demands on local food sources, increasing local farming pressure but very minor.	Reduction in disease, morbidity and mortality plus in-migration to Gedaref's reliable water supply may increase population of Gedaref town slightly above projected growth	No significant addition to effects projected in absence of proposed project.	Increased per capita water use anticipated. More use for washing clothes and hygiene. Reduction in purchase of poor quality water from vendors. More gardens and other local irrigation possible. Flush toilets may replace latrines. Increased water wastage through broken distribution lines, leaky valves and faucets.	Potential for impact on archaeological materials within 2 metres of ground surface due to construction, well excavation, pipeline and pump station construction	Reduction of friction between town dwellers and refugees if all have adequate, safe water supplies. Eliminate livelihood of 200-400 water vendors	Energy consumed for well water pumping, booster pumps along transmission line.

- Energy consumption for well pumping. 8.7 million kwh/year.

- Minor potential for impacts on antiquities at well sites and along alignments of connecting pipelines.

- Commitment of concrete, steel and other materials to well equipment, pipelines, and generators. (Minor, project relatively small).

- Short-term noise generated by construction and well drilling, but there are no sensitive receptors (hospitals, schools) within earshot. (Localized and temporary).

- Creation of increased employment opportunities during the construction period. (Localized and temporary).

- Creation of temporary safety hazards on the construction site. (Average for any construction site).

- Minor emissions of air pollutants from construction vehicles. (Temporary).

- Additional traffic on the road to the Showak area created by construction vehicles. (Locally important, but temporary).

14.3.3 <u>Impacts of Improved Distribution Systems in Tawawa</u>

- A total of 2,425 m of 100 mm pipe and 1680 of 50 mm pipe plus 18 standpipes installed in Tawawa town will require trenching in the streets resulting in traffic disruption, noise, dust, and open trenches for about two months per block.

- Excess dirt will be created and have to be disposed of. Berms could be built along the khors for flood control.

- Potential for impacts on antiquities.

With the exception of antiquities, these impacts are not mitigable, but are localized and temporary.

14.3.4 <u>Impacts of Well Development at Abu Naga</u>

- Temporary increase in local employment, but workers may be from outside Gedaref area. (Benefit).

- Disruption of local traffic from the well field to the reservoir (possibly including animal migration) along the 12 km route. (Minor; road is not heavily traveled).

- Nuisance to residents - noise, dust, open trenches, health and safety hazards for about two months per residence. (Unavoidable but temporary).

- Line crosses the military reservation and will require permits.

- A hand dug trench, 1.5 m deep, has potential impacts on buried archaeological materials. (Potentially significant; on-site inspector will be required).

- Energy consumed by pumping - 23 million kwh annually. (Not mitigable, but not significant in magnitude).

- Improvement in delivered water quality because of blending Showak and Abu Naga supplies. Showak is low in carbonate, TDS and nitrates; Abu Naga is high in carbonate, also has low TDS. (Overall benefit)

14.3.5 Impacts of New Well Distribution System and Second Water Tower at Tawawa Refugee Settlement

- Provision of reliable, high quality water. (Benefit)

- Temporary increase in employment during construction. (Benefit)

- Minor potential for impacts on antiquities during excavation. (Inspector on-site during construction)

- Reduction in intestinal diseases. (Benefit)

- Commitment of materials to water tower and wells. (permanent, unavoidable, but minor)

- Energy consumption for well pumping. 131,000 kwh per year. (Minor)

- Access of each dwelling to water not more than about two blocks away. (Benefit)

14.3.6 Solid Waste Disposal Alternatives and Impacts

Solid waste alternatives, impacts and mitigation measures have been discussed in Chapter 10, and will not be repeated here.

14.4 ENVIRONMENTAL CONSEQUENCES AND MITIGATION MEASURES

Most of the impacts analyzed previously are minor, self-explanatory, require no further analysis and have been briefly described in a previous section. Those issues for which greater amplification is appropriate include the following:

- Impacts on ground waters
- Impacts on public health and water use patterns
- Impacts on antiquities
- Impact on desertification and land use
- Impact on population growth

This section includes discussion of the above issues and feasible mitigation measures for anticipated project impacts.

14.4.1 Impacts on Ground Waters

Effects of the project are described in terms of water quality and water quantity.

Water quality - The well gallery intake proposed for the Showak Water Treatment Plant will tap Nubian Sandstone aquifers recharged directly by the Atbara River. As there are no volcanics in the Showak area, the delivered water should be of good chemical quality. In addition, the elimination of a surface intake will significantly reduce the silt load and thus the turbidity of the water entering the clear well. Moreover, the well water is likely to be free of pathogens and indicators of fecal pollution such as parasites, bacteria and viruses.

Both of the new wells at Abu Naga and the new well at Tawawa will be sealed with concrete through the volcanic strata to prevent inflow of water through these layers which may to contribute to the poor chemical quality of existing wells.

Mitigation - As impacts are expected to be beneficial, no mitigation is required. Nevertheless, it is recommended that water quality from both the new and rehabilitated wells at Tawawa and Abu Naga be monitored annually to verify continued water quality.

Water Quantity - The new well gallery intake at Showak Treatment Plant will have no significant impact on ground water levels except very locally at the well field. The aquifer tapped is recharged by the Atbara River whose surface flow may almost disappear in the dry season, but whose underflow recharges the underlying Nubian Sandstone year-round.

In the Gedaref area, recharge areas are probably limited to the khors and outcrops of the volcanics and Nubian Sandstones. In order not to deplete the aquifer locally, the well field area must be expanded rather than placing new wells between existing wells. Minimum well separation proposed is 100 m.

Mitigation - In addition to well spacing, it is recommended that water levels in wells be monitored together with chemical quality. Insufficient data were available at the time this feasibility study was conducted to predict effects on safe yield of new or even existing wells, so future data will also be required.

14.4.2 Public Health and Water Use

A widely published table shows expected percent reductions in infectious diseases associated with water supplies due to water system improvements. Selected figures given in Table 14.6.

The proposed project will provide chlorinated water to Gedaref and Tawawa 24 hours a day. Estimated volume supplied would exceed present minimum (dry season) levels by 100 percent and maximum (wet season) levels by 50 percent.

Estimated present per capita water supply, at less than 10 litres per capita per day (lcd) in Tawawa, is low enough that personal hygiene may suffer (White, 1972; White, 1979). Gedaref residents receive an estimated 25 lcd. Increasing both water volume and purity is expected to reduce morbidity rates for these diseases. While the actual percentage reductions in water-associated diseases in Gedaref and Tawawa resulting from the proposed project cannot be determined, they may be similar to those shown above. The actual reduction is difficult to determine because safe water can become contaminated in unclean storage or drinking vessels, or where other sanitation practices are poor. There are not enough good data on the relationship of water improvements to reduction in water-associated disease, particularly water-borne bacterial disease. (USAID 1982).

Any reductions would represent a significant benefit to the study area population as water-associated diseases are the most prevalent cause of morbidity in Gedaref, with the exception of malaria, and the most prevalent in Tawawa.

TABLE 14.6

EXPECTED PERCENT REDUCTION IN WATER-ASSOCIATED DISEASES DUE TO WATER SYSTEM IMPROVEMENTS

Disease	Improvement Needed	Expected Percent Reduction
Cholera, typhoid	disinfection	80-90
Paratyphoid, hepatitis	disinfection	40
Enteroviruses	disinfection	10
Bacillary dysentery	disinfection greater volume available	50
Amoebic dysentery		50
Gastroenteritis		50
Skin sepsis and ulcers	greater volume available	50
Diarrhoeal diseases	disinfection, greater volume available	50

Source: Feachem, et al., "Water, Wastes and Health in Hot Climates," Longman, London & New York, 1977.

At the same time, continuous water supply increases the volume of leakage from leaking valves and faucets, broken distribution lines and other deficient points in the water system. Leaks creating permanent or long-standing puddles also create suitable habitat for mosquito larvae and, thus, may increase the incidence of malaria. Mitigation involves locating system deficiencies and repairing them or providing drainage to eliminate standing water. Implementation of mitigation measures depends on funding and degree of community awareness.

Where new water distribution systems replace the use of ditches and hafirs as domestic water supply sources, the incidence of schistosomiasis should decrease to a now unquantifiable extent. This not a significant problem at present, however.

At the same time, increased water usage may increase use of flush toilets and, in turn, individual septic tanks, necessitating regular and frequent pumpout operations to prevent failures and overflows. In the absence of adequate maintenance, overflows may result in puddles of raw sewage, creating odors and sources of malaria and hepatitis. In addition, septic tank overflows could contaminate shallow, hand dug wells. A new well requires a City permit which is granted or denied based on water quality at the time the well is dug. The permits do not record exact well locations, nor are wells that are denied permits visited to see if they have been filled in as required. Moreover, well quality is typically not monitored after the initial analysis.

Septage disposal sites should be carefully located away from the khors which are sources of recharge to the ground water basin. Land disposal of septage in recharge areas could result in increasing nitrate and dissolved solids concentration in the ground water and ultimately contaminate the wells.

Increased water supply may also result, not only in improved hygiene, but in additional horticultural irrigation as well. To the extent that standing water is created, this also could create habitat for malarial mosquito larvae.

14.4.3 Desertification and Land Use

Patterns of desertification in Sudan have resulted from increasing population and grazing and farming practices, and have been worsened by water development.

The soils are naturally low in nitrogen and organics, but were once replenished by plowing crop stubble under, by long fallow periods and by allowing reforestation of acacia, a leguminous tree whose nitrogen-fixing bacteria replenish the soil.

As a result of increasing population, the rotation of crops with fallow periods decreases from say 10-15 years to 6-10 years to meet increased food requirements. The most common food crops, sorghum, sesame and millet, deplete soil nutrients, and, typically, no fertilizer or manure is used. The soil has significantly less time to renew nutrients, so yields per feddan decrease over time. To maintain production, cultivated areas must increase, clearing yet more acacia. Seriously depleted soils support less vegetation and are more susceptible to wind and water erosion, leading to desertification. (UNU, 1978; Whitney, 1981; Pereira, 1973).

Overgrazing can also cause vegetative cover to be reduced to a point allowing significant erosion. Each herder tries to maximize his own animal numbers. Cattle and other animals are not raised for meat and not sold unless for vital minimum needs. The ever-increasing herds cause progressive range deterioration. At the same time, mechanized farming schemes have reduced available range land. Range land has also been reduced by accidental fire, usually caused by burning crop residues.

Provision of additional water without planning can increase desertification by both methods. First, providing water points accessible to livestock has been shown to cause ever-radiating overgrazed circular areas around the water point with concomitant deterioration of soil texture, soil fertility, vegetative cover and soil carrying capacity. The number of livestock continuously increases, as cattle are not routinely sold or slaughtered but amassed as signs of wealth or status.

Second, water provision can also encourage settlement growth, increasing the rate of in-migration of people and their animals, and placing increasing pressure on cultivation as described above. Continued expansion of the Gedaref Dura Mechanized Farm Scheme into the Central Butana area north of Gedaref in response to increasing population will further reduce already threatened important grazing areas (El Hassan, 1981).

The present project is intended to provide water for urban domestic supply only and not for livestock watering or agricultural irrigation. Since the distribution systems are entirely within town developments, livestock will have little or no access, and essentially all cultivation in the area is non-irrigated dry land farming. Therefore, the project will not encourage desertification through grazing practices. However, provision of a continuous supply of safe water to Gedaref cuold indirectly increase population to a small extent in the short-term by limited in-migration and in the long-term by reducing infant and child mortality from water-associated diseases. Economics, not water, will control in-migration, however, and many factors in addition to water quality affect infant and child mortality rates. In addition (as described in Chapter 6), the population of the study area is projected to increase significantly over the next five years with or without the present project, so the project's effects per se will not be readily discernible. The additional population will increase farming pressure, but the present project will not contribute significantly to the problem.

In summary, provision of a continuous, safe water supply to the study area will not contribute significantly to desertification in the area.

Mitigation - Desertification is a national concern and one which is difficult to deal with on a localized basis. Mitigative approaches must be multi-pronged and could include:

- Reforest with acacia; intercrop with acacia.
- Rotation of dura with other leguminous crops such as ground nuts and lubia to replenish soil nutrients.
- Begin use of animal manures as fertilizers to increase crop yields and maintain soil humus and nutrients.
- Allow greater grazing of harvested dura fields.
- Plant bordering windbreaks to reduce wind erosion. Suitable plants could be acacia, tamarisk or eucalyptus.
- Increase marketing of animals to increase the off-take rate and decrease pressure on vegetation.
- Increase pest and plant disease control to maximize yields.

Implementation of these measures requires development of a regional/national program which is beyond the scope of this project.

14.4.4 Impacts on Antiquities

Any excavation in the Gedaref and Showak areas has the potential for impacts on antiquities or historic materials, as this region has been occupied continuously since prehistoric times.

Mitigation - Protection of antiquities is the responsibility of the Antiquities Service Department within the Sudan Ministry of Information and Culture. Upon request, the Department will provide an inspector for the project construction site. Existing Government regulations will apply, but apparently are not routinely enforced or enforceable. Antiquities are common in Sudan but, in general, are simply paved over or destroyed by construction projects.

Dr. Ahmed Hakim at the University of Khartoum suggested that, to maximize the protection of antiquities and their scientific and educational value, government support be enlisted early in the process, begin with contacting top officials, but also develop local interest. USAID should have the Minister of the Ministry for Energy and Mining, as sponsoring ministry, contact the Minister of Information and Culture. He should, in turn, contact the Governor of the Eastern Region and the Town of Gedaref. Dr. Hakim felt that no extensive archaeological excavations were likely to be needed for the project, and that a brief "survey and salvage" evaluation and inspection of construction sites would likely suffice.

14.4.5 Impacts on Population Growth

As described previously, the population of the study area is expected to increase significantly with or without the present project so that the effects of the project alone, which are minor, will not be discernible. No mitigation is required.

However, town planning will, with or without the present project, need to plan for projected increases in demands for community goods and services: food, energy, housing, medical care, fire and police protection, solid waste management and education.

14.4.6 Adverse Effects that Cannot be Avoided Should the Proposed Action be Implemented

Abstracting from the previous discussions, unavoidable adverse impacts would be the following:

- Construction impacts: noise, dust, air pollutant emissions, traffic congestion and possible rerouting, limited access to homes and shops for periods of up to two months per block where pipelines are being installed.

- Health and safety hazards at construction sites.

- Commitment of materials, land and energy resources to materials and facilities construction and operation.

- Disturbance of antiquities within 2 m of ground surface.

- Increase in volume of water wasted through broken distrubtion lines, leaking valves and faucets.

- Local drawdown of Nubian Sandstone aquifer at Abu Naga.

- Elimination of 50 workers' jobs at hand trenching through river deposits for Showak Plant intake.

- Elimination of livelihood of 500-600 water vendors.

14.4.7 <u>The Relationship between Short-term Uses of the Environment and the Maintenance and Enhancement of Long-term Productivity</u>

This analysis is based on the principle that each generation should serve as trustee of the environment for succeeding generations, and, therefore, attention must be paid to the question of whether options for future use of the environment are being eliminated by the proposed action.

In balance, the provision of adequate, safe water supplies and solid waste management improves the environment for the future residents of the study area and reduces water associated disease.

At the same time, the project is unlikely to increase the rate or distribution of desertification or human population to a significant extent.

14.4.8 <u>Irreversible or Irretrievable Commitments of Resources Which Would be Involved in the Proposal Should it be Implemented</u>

Permanent commitments of resources include the following:

- Commitment of materials to facilities - pipelines, wells, generators, pumps, reservoirs.

- Commitment of energy to the manufacture and transport of materials, to the construction and operation and maintenance of facilities.

- Disturbance of antiquities or historical materials by excavation for water distribution lines, wells and reservoirs.

14.5 LIST OF PREPARERS

Dr. Janet Fahey - Environmental Analysis

B.A., Zoology, University of California, Los Angeles
M.A., Biology, University of California, Los Angeles
Graduate Work, Occupational and Environmental Health, School of Public Health, University of California, Los Angeles
D.Env., Environmental Science and Engineering, University of California, Los Angeles
Registered Civil Engineer in California

Dr. Fahey has over eight years of intensive experience in the direction and preparation of environmental impact reports, assessments and statements for both domestic and overseas projects, with emphasis on planning of water supply, flood control and wastewater management systems on ground and surface water resources, aquatic and terrestrial biota, antiquities, agriculture, water and land reclamation.

Mr. Robert Klein - Socio-Economic and Cultural Analysis

B.A., History/Geography, University of California, Los Angeles
M.B.A., Urban Land Economics/Urban Planning, University of California, Los Angeles

Mr. Klein has over 11 years of experience in economics and social impact assessment of large and small-scale public and private development projects, with emphasis on regional wastewater, water supply, transportation and land use planning.

Mr. Robert Ramsey - Geology, Ground and Surface Water Resources Analysis

B.S., Geology, University of Southern California
M.S., Engineering Geology, University of Southern California
Registered Geologist in California and Oregon
Engineering Geologist in Oregon
Professional Geologist in Idaho

Mr. Ramsey has over 11 years of experience with emphasis on hydrogeology, water resource development, ground water quality problems and basin management. His background encompasses planning, coordination and project control of both domestic and overseas ground water investigations, management of exploratory, production and injection well drilling programs and design of dewatering systems.

Mr. Rodney H. Emerson - Engineering Systems and Water Use Analysis

B.S., Civil Engineering, University of Florida
M.S., Geography, University of Florida
Registered Professional Engineer in New York and Florida

Mr. Emerson has 13 years of experience in civil and sanitary engineering on both domestic and international water supply projects. This experience includes water systems management, advisory services, design and construction supervision of reservoirs, water treatment plants and wells.

Mr. Eugene S. Churchill - Institutional Analysis

Business Administration, University of Michigan
Advanced Accounting, University of California

Mr. Churchill has over 22 years of experience in public utility management and operations with special emphasis on institutional organization and development. He has particular expertise in improving the organizational effectiveness and reducing the operational costs of governmental agencies, both in the United States and overseas.

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APPENDIX A

SCOPE OF WORK
GEDAREF WATER SUPPLY AND SOLID WASTE DISPOSAL
FEASIBILITY STUDY

Scope of Work - (Excerpts from A.I.D. work order No. 1 dated November 5, 1982).

1. SPECIAL STUDIES

1.1 Data Collection and Evaluation

The Contractor will collect, review and evaluate all available data and information relevant to the project. The field visits required will be carried out within the shortest practical period after Notice to Proceed, especially the investigations and collection of data needed for completion of the feasibility report.

The National Water Authority (NWA) and other involved government organizations will cooperate fully with the Contractor in this phase of the work by making available all pertinent drawings, maps, records, previous studies, policies, standards, planning and design criteria, operating records, construction costs, demographic and statistical data, etc.

The Contractor will notify USAID, in writing, if sufficient data and information is not made available to the Contractor and will summarize the effects of this deficiency on the satisfactory completion of the feasibility study.

1.2 Evaluate Existing Facilities

The Contractor will thoroughly familiarize himself with the location, size, capacity, adequacy, efficiency, dependability, and functioning of the existing water supply and solid waste disposal facilities within the Project Area.

An evaluation of relevant existing conditions of major components of the water supply and solid waste disposal systems will be undertaken. Although principally related to major components of the existing systems, this work will also cover certain minor components of the existing systems as the Contractor considers necessary. In relation to the above, field inspection will be implemented as required during the formulation of the programs to augment, confirm, and rectify significant omissions of existing as-built drawings, operating records and other data.

In the event that existing data, records, etc., are inadequate to determine capacities of the main components of the system, the Contractor will, by inspection or direct measurement, obtain these data.

The condition evaluation will be made of the water supply facilities, including treatment facilities, storage facilities, pumping stations, and, to the extent feasible, major water mains and secondary water pipelines.

For the treatment plants, pumping stations and similar facilities, surveys will be made to obtain key dimensions and to ascertain the location and type of all equipment, power supply and pump capacities. Inspections will include evaluating ability to function, assessing the condition of structures and of mechanical and electrical equipment, reviewing apparent suitability of the present design and causes of failure or nuisance. The condition evaluation and review of available engineering, construction, performance or other data will be used in estimating probable useful life. The analysis of needed improvements or renovation will take into account the possible need to change design criteria, power sources and/or equipment type. Particular attention will be given to that equipment for which spare parts are no longer readily available. Operating and supervisory personnel will be interviewed.

The Contractor will investigate and analyze the existing solid waste disposal systems to determine what additions or modifications are needed to correct deficiencies, improve public health, reduce contamination and simplify operation and control. The condition and operation of the solid waste disposal system will be studied through field investigations, review of administrative records, analysis of public health hazards and any other information source.

The results of the Existing Facilities Evaluation will be presented in the draft final report.

1.3 Population Forecasts

The Contractor will, to the extent practicable, accept and utilize the results of population studies and projections made by others. However, the Contractor will review the results of the 1976 census, recent developmental planning, and other data or information which has been developed or generated. Where more recent data so dictates in the opinion of the Contractor and upon completion of his review and subsequent evaluation of these data, the Contractor will make adjustments to the estimates of the present population and projected population at the end of the immediate improvement planning period. The basic assumption used will be explained and the rationale for selection clearly defined. These revised data may be presented both narratively and graphically. The Contractor will coordinate the analysis of investigations with the planning organizations involved, consider their view and attempt to reach agreement with such agencies on the population projections to be adopted for the development of the immediate improvement program.

1.4 Land Use Determination

The Contractor will, to the extent practicable, accept and utilize the results of any recent land use studies, including development patterns, rates of development and population densities. The Contractor will review recent development planning and other data developed. Where these more recent data so dictate in the opinion of the Contractor and upon completion of the review and evaluation of these data, the Contractor will present the basis for these revisions. The revised data will be utilized in planning the expansion and improvement of water supply and solid waste disposal facilities.

1.5 Water Requirement Calculations

The Contractor will determine the present and immediate future water requirements of the Project Area on the basis of the accepted population projections and land use development plans, the per capita water demand and variations in demand. The Contractor will analyze the present patterns of water distribution and consumption by the various classes of consumers including those which are not presently served by the water supply system. The Contractor will make projections of future demand for the study period. These projections shall be broken down into the various types of consumers, will determine the estimated hourly, daily and seasonal variations in water demand and the various pressure requirements for the different categories of consumers.

Specific criteria to be reviewed in analyzing present and the immediate future patterns of water distribution and consumption by the various classes of consumers will include, but not necesarily be limited to:

- Per capita consumption and other consumption
- Analysis of the effects of past tariff increases on demand

- Past and future growth rates of specific consumption for the various consumer groups

- Assessing suppression of demand due to non-availability of supplies or inadequate pressures

- Past and future allowances for leakage, wastage and illegal connections

- Impact of social and economic factors on specific consumption

- Estimating peak demands

- General geographic distribution of future water demand having regard for hypothetical developments of land use

- Evaluation of the reliability of demand projections considering diminishing degrees of confidence with time.

Based on the review of the various water consumption sectors and factors which influence water consumption and future demand, the results will be aggregated to derive total water demand, distributed over periods of time, according to appropriate administrative units. The Contractor will present these data both narratively and graphically, and will set forth the rationale used in making the projections. The Contractor will coordinate the analysis of water demands with the NWA.

The methodology adopted for deriving water demand projections will be set up in such a manner as to permit future periodic updating of the demand data which may be influenced by alterations in land use zoning, changes in the development schemes or variations in refugee population.

The results of the Water Demand Studies will be presented in draft final report.

1.6 Solid Waste Disposal Requirements

The Contractor will collect and review available solid waste disposal data. Projections will be made of existing and immediate future solid waste generation and the volumes requiring handling. Analyses will be conducted determining practical methods of waste collection and disposal. Waste collection, transport and disposal siting will be determined and evaluated for economic justification. Benefits and costs of waste disposal improvements will be determined.

1.7 Appropriate Technology

The Contractor will apply appropriate technology in the planning and construction of water supply and solid waste disposal improvements. Due consideration will be given to local conditions and constraints as they affect replacement parts and materials, operation and maintenance capabilities and the advantages of standardization throughout the country. Recommended technology will be reviewed with officials of the G.O.S. and USAID/Sudan.

1.8 Water Supply Criteria

The Contractor will develop water supply criteria based on consultations with appropriate officials of the G.O.S. and USAID. The criteria will include potable water quality standards, per capita water use and the levels of service to the various population segments in relation to service pressures, house connections or public standpipes and duration of services. Water supply criteria will be utilized in determining water demand projections, water treatment requirements and water systems improvements and related costs.

2. WATER SUPPLY STUDIES

2.1 Surface Water Supply

The Contractor will evalute the adequacy and suitability of existing and potential surface sources of supply based upon available data and preliminary investigations.

2.2 Groundwater Supply

As far as is known, there is no sufficient information presently available on groundwater quality and quantity, to determine the potential for its exploitation as a supplementary potable supply source within the Project Area. The Contractor will review all existing data to ascertain the availability, general quality and quantity of groundwater sources throughout the Project Area to determine the feasibility of exploiting this supply source for the purposes described above.

In the event that the Contractor, based on investigations of existing data and evaluation of the work being carried out by others, concludes that there is a reasonably good possibility of groundwater being an economical alternative source for potable uses, he will set forth his recommendations in this regard. In this event, the Contractor will provide the following:

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(i) Description of the Contractor's investigations to date including evaluations and analyses.

(ii) A separate program of physical investigations to be conducted by the Contractor or others, including as appropriate; geographical/hydrogeological surveys, geophysical tests, testing of existing wells, and/or the drilling of new test wells. This program shall include a complete description of the work, the manpower requirements, testing procedures, data to be obtained, methodology to be followed, the manner in which the tests and analyses would be carried out, a time schedule for implementation, estimated costs, etc.

The Contractor will recommend a program for utilization of the groundwater supply and outline a development scheme for its use at selected locations within the Project Area.

2.3 Water Treatment

Based upon the findings, the Contractor will develop the water treatment requirements and the conceptual physical facilities required to satisfy the approved water quality criteria.

2.4 Water Distribution Systems

The Contractor will investigate and analyze the condition and operation of existing distribution systems to determine what additions or modifications are required to correct deficiencies noted, improve the water supply service, reduce water losses, simplify control and operation of the distribution system and satisfy the determined water demands.

The Contractor will determine the condition of existing mains through examination and analysis of records of mains failures, their frequency and cause, and any other information source. The approximate magnitude and type of all water losses, including unaccounted-for losses, shall be identified. The Contractor will develop and recommend renovations, improvements and additions to the water supply system to meet the water needs as determined under this study. Determination of improvements will include pumping facilities, transmission lines, storage facilities, distribution mains, hydrants and service outlets.

3. ENVIRONMENTAL ASSESSMENT

The Contractor will prepare an environmental assessement of the water supply and waste disposal improvement program in accordance with the

Scope of Work
Gedaref Water Supply and Solid Waste Disposal
Feasibility Study

USAID Environmental Procedures. The purpose of the environmental assessment is to provide USAID and the NWA's decision makers with a comprehensive understanding of the reasonably foreseeable environmental alternatives so that the expected benefits of improvement objectives so that the expected benefits of improvement objectives can be weighed against any adverse short- or long-term impacts upon the human environment.

"Environmental Assessment" as used in this Scope of Work will not be construed to be an "Environmental Impact Statement" as defined in U.S. Government Regulations. The environmental assessment will be enbodied in a separate section of the program report. An individual or independent environmental assessment report will not be submitted.

Consideration will be given to those effects upon the environment which adversely affect such aspects of the human environment as air, water, land, flora and fauna, and socio-economic conditions. Special attention will be given, as appropriate, to problems involving solid waste, noise, hazardous substances and natural resources development, and, in addition, actions which:

- Degrade the quality of the human environment
- Curtail the range of beneficial uses of the human environment and its resources
- May have both detrimental and beneficial effects even if, on balance, the effect will be beneficial
- Have secondary effects which may be more substantial than the primary effects of the proposed action
- Are likely to have an effect on any natural or cultural heritage, archaeological or historical elements. This environmental assessment shall include, but not be limited to:

3.1 A description of the existing environment without the proposed improvements relevant to the analysis of alternatives and determinations of the environmental effects of the water supply and waste disposal feasibility report.

3.2 A description of the future environment with no action to improve the water supply and waste disposal facilities.

3.3 An environmental assessment of the alternative programs studied. The significant direct and indirect effects of each alternative program shall be determined. Long-term, irreversible and induced impacts on socio-economic conditions, public health, etc., shall be considered in the selection process.

3.4 A description of the future environment upon implementation of the water supply and waste disposal improvements proposed in the feasibility report. Direct and indirect impacts of the water supply and waste disposal feasibility report program shall be described giving special attention to unavoidable impacts and steps to mitigate adverse impacts. The significance of land use impacts shall be evaluated, based on current and projected population within the Project Area.

4. INSTITUTIONAL CONSIDERATIONS

The Contractor will evaluate the present practices and procedures being undertaken by the organizations responsible for potable water supply and solid waste disposal in the Project Area. The Contractor will identify institutional improvements needed to properly administer, manage, operate and maintain the recommended improved water supply and solid waste disposal systems.

5. PREPARATION OF FEASIBILITY STUDIES

The purpose of the technical and economic feasibility studies is to assist NWA and USAID to evaluate the advisability of undertaking the water supply and waste disposal facilities improvement program. The feasibility studies will integrate the results of the Contractor's investigations into the technical, financial, economic and other aspects of the improvement program and will be sufficiently complete to permit independent appraisal of the soundness of the improvement program on the basis of the data submitted and the assumptions used. The technical and economic feasibility studies will include but not be limited to; evaluations, analyses, and recommendations, as appropriate.

APPENDIX B

WATER RESOURCES EVALUATION

1. INTRODUCTION

To evaluate the existing and potential water source areas for the Gedaref Water System, available data were gathered from a variety of government and international agencies. Data which were obtained included geologic and topographic maps, aerial photos, maps depicting the location of existing boreholes, climatic records, water quality information, well construction records and aquifer pump tests. Additional data on the Gedaref water resources were obtained by personal interviews, field reconnaissance and testing of existing water well facilities. The results of the water resources evaluation are presented in the following pages.

1.1 Area of Investigation

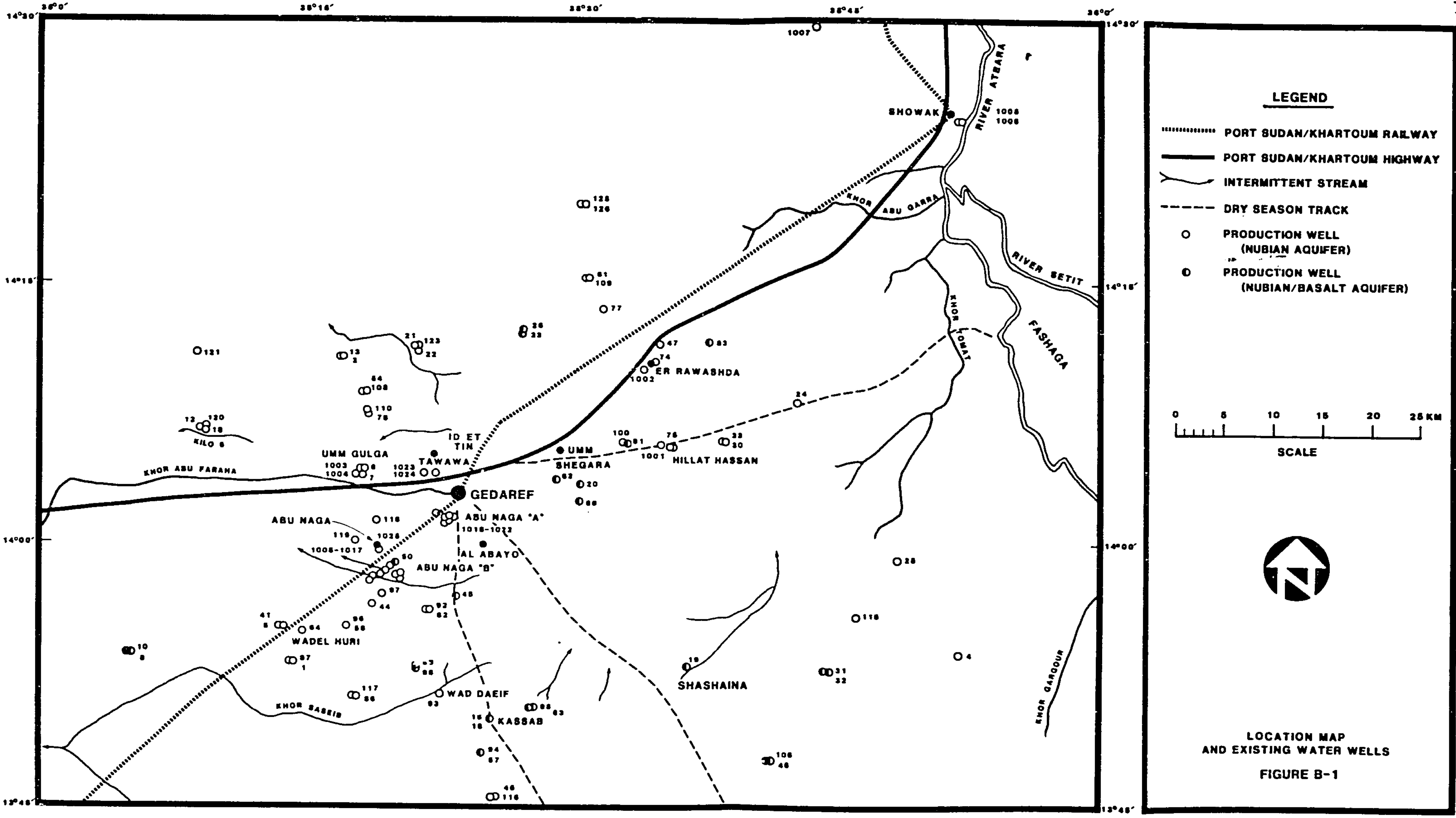
The town of Gedaref is located within the Kassala Province of Eastern Sudan at the approximate geographic coordinates of 14° 02' north latitude and 35° 24' east longitude. For purposes of the water resources investigation, an area of approximately 5,000 square kilometers was evaluated. The general area of investigation is shown on the location map (Figure B-1).

Gedaref sits astride a low north-south trending ridge which creates a surface drainage divide on the high plateau between the Atbara River to the east and the Rahad River to the west. The elevation of Gedaref is about 600 meters (1,978 feet) above mean sea level. The existing water source area is located at Showak, 64 kilometers to the northeast at an elevation of 510 meters (1,673 feet) above mean sea level.

Topography within the City of Gedaref can be described as mild with gentle hills increasing in elevation towards the northeast. Ground-surface elevations within the city range from approximately 590 to 625 meters above sea level.

1.2 Previous Investigations

The population of Gedaref has experienced a dramatic growth rate during recent years. As a consequence, the City's water supply needs have attracted the attention of many government agencies and international organizations. This has resulted in numerous water resource and supply studies for Gedaref and the adjacent areas. A listing of those studies is included in the references.



LOCATION MAP AND EXISTING WATER WELLS

FIGURE B-1

2. SURFACE HYDROLOGIC FEATURES

The Gedaref area lies within the semi-arid, rolling high plains or plateau region of eastern Sudan. Throughout the long history of this region, water has been an important factor in the survival and prosperity of the local inhabitants. Because of the relative abundance of seasonal rainfall, the Gedaref region has developed into the major durra producing center of the country.

2.1 Precipitation and Weather Patterns

The importance of rainfall to the Gedaref region has resulted in a long record of climatological observations. Precipitation measurements have been maintained on a continuous basis since 1931 at Gedaref and Wad El Huri, some 25 kilometers to the southwest. In addition, the Gedaref climatological station has maintained records on temperature and relative humidity over the same period.

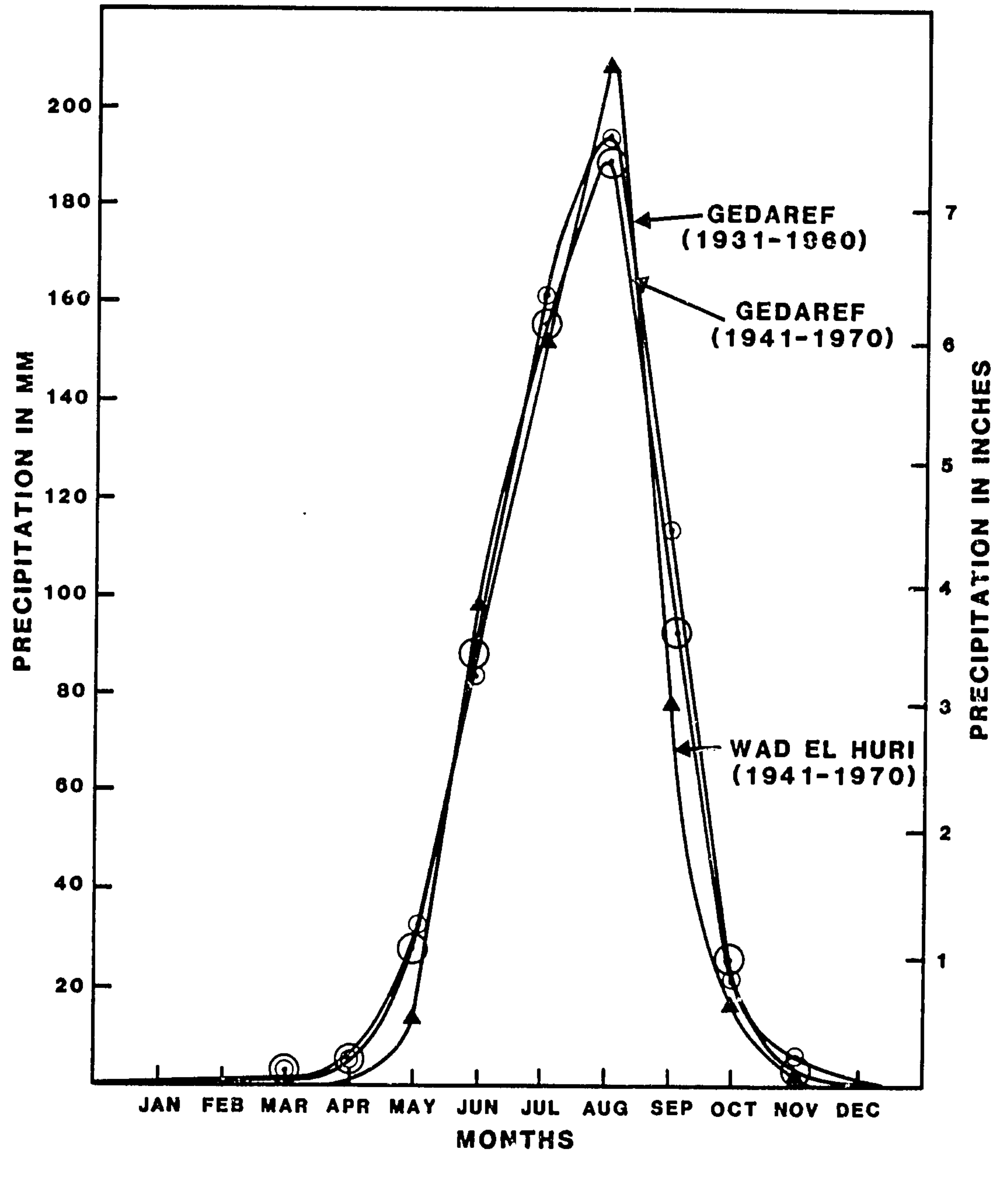
Rainfall records for Gedaref during the period 1921 to 1970 show a long-term average precipitation of approximately 600 mm (Table B-1). These data are depicted on Figure B-2 and show a local climate characterized by one wet season and a prolonged dry season. During the dry winter months, between November and April, less than 10 mm of moisture reaches Gedaref. Between the wet summer months of June to September, approximately 90 percent of the total annual precipitation is recorded. Much of this precipitation occurs in short-duration, high-intensity storms which cause severe flooding and damage to Gedaref.

Mean temperatures vary considerably between the summer and winter months. The cool winter season is characterized by mean temperatures ranging from 62^o-75^oF, while the hot, moist summer months exhibit mean temperatures ranging from 87^o to 104^oF. Relative humidity ranges from 21 percent in the dry winter months to 79 percent in the wet summer months.

2.2 Surface Drainage Systems

In the greater Gedaref region, surface drainage can be divided into two general systems. These are; 1) seasonal or ephemeral drainage courses (wads or khors) and 2) perennially flowing drainage courses.

In the immediate vicinity of Gedaref there are no perennial flowing surface sources of water. Surface drainage is contained within the wads and khors, a series of shallow, poorly defined channels. These channels pass through the City from the north and east to form Khor Abu Faragha on the western edge of Gedaref. During much of the year the wads and khors are devoid of moisture. However, during the summer rainy months, the channels carry significant volumes of surface runoff. Severe flooding of the khors and adjacent lowlands is an annual event and usually brings heavy damage to areas along the channels.



MEAN MONTHLY PRECIPITATION
GEDAREF AREA
(1931-1970)
FIGURE B-2

TABLE B-1

RAINFALL DATA FOR THE GEDAREF AREA

Location	Period of Record	Month												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Gedaref	1931-1960	0	0	1	4	31	84	161	193	113	22	5	0	614
Gedaref	1941-1970	TR	TR	1	4	27	86	154	188	92	24	3	0	579
Wad El Huri	1941-1970	0	TR	TR	5	13	98	157	208	78	16	1	0	576

NOTES:

1. All measurements in millimeters
2. Data from Sudan Meteorological Department
3. Geographic - Coordinates of Gedaref Lat. 14° 02' N, Long. 35° 24' E.
4. Gedaref Elevation 600 M.
5. Geographic coordinates of Wad El Huri Lat. 13° 56' N, Long. 35° 14' E.

As mentioned earlier, Gedaref lies on a topographic ridge which creates a water divide along a general north-south axis. Khors flowing to the east drain into the Atbara River, some 50 kilometers northeast of Gedaref. Khors and wads draining toward the west contribute to the Rahad River located approximately 110 kilometers southwest of Gedaref. The Rahad River is outside the current study area and will not be discussed further in this report.

The Atbara River system is a northwest flowing perennial river which eventually converges with the Nile River near Ed Damer 425 kilometers northwest of Gedaref. Near Showak, 60 kilometers northeast of Gedaref, as shown on Figure B-1, the Setit River converges and joins with the Atbara. The existing Showak intake facility is approximately 5 kilometers downstream from the confluence of these rivers.

The Atbara River system and the Blue Nile are the two primary rivers draining Eastern Sudan and the Ethiopian Plateau area to the east. Surface runoff from these two sources constitutes 66 percent of the total runoff in Sudan. The Atbara River carries an annual flow of 12 cubic kilometers, as measured at the Kashm el Girba Dam some 75 kilometers north of Showak.

River flows in the Atbara reflect the climatic extremes shown on Figure B-2. In addition to the high river levels which occur between July and October, the river is subject to occasional flash floods during (Kashm) the normally drier months of the year. Approximately 74 percent of the annual Atbara flow is carried during the wettest months of July through October; the remaining 26 percent, or base flow, is carried during the other 8 months of the year. Daily flows at Kashm el Girba Dam range from 180 million cubic meters during August, to reported zero flow during the driest months. Minimum combined low season flows at two gaging stations on the Setit and Atbara Rivers, 35 and 22 km, respectively, upstream from Showak are 1.7 million m^3/day. Thus, it appears there are adequate flows in the Atbara River at Showak to supply current capacity of the Showak facilities.

2.2 Spring Sources

Several small springs are reported to exist in the Gedaref area. These springs are related to the volcanic outcrops and occur only during the rainy months when rainfall recharges the near surface voids and fracture systems. Because of their small volume and seasonal nature, these springs will not be considered further in this report.

2.4 Surface Water Quality

Water quality data on the ephemeral surface drainages in the Gedaref area are currently unavailable. However, from a water quality standpoint, the surface runoff is probably low in total dissolved solids as it is derived directly from runoff of precipitation within the Gedaref watershed.

The water quality of the Atbara River is generally considered to be good with total dissolved solids in the 100 to 400 range. The Atbara River water carries a high suspended solids load derived from erosion along the Ethiopian highlands. Average silt loads measured at the Kashm El Girba Reservoir are 45 million m^3/yr. Suspended silt carried in the river water ranges to a maximum of 6,000 ppm. While average silt load is about 6,000 ppm.

At the time of this investigation, no complete chemical and physical water analysis for the Atbara River source was available. For this reason, three samples were collected to analyze water quality characteristics of raw, treated and delivered water supplies. The results of these analyses are shown in Table B-2. At the time of sampling, the raw river water had a total dissolved solids content of 320 milligrams per liter (mg/l) and a total hardness (as $CaCO_3$) of 155 mg/l. Although the water is slightly alkaline and hard, it meets the World Health Organization (WHO) Guidelines for Drinking Water Quality (Table B-3). As noted in Table B-2, the river water contains a fluoride content of 0.5 mg/l which provides natural fluoridation to the inhabitants of Gedaref.

3. GEOLOGY

The general geologic conditions of the Gedaref area are discussed in the following paragraphs with special emphasis being given to the formations which bear a direct relation to the availability of ground-water resources of the area. The geologic map, Figure B-3, depicts the major geologic features of the study area.

In essence, the geology of the Gedaref area is defined by a stratigraphic succession of four geologic formations. Starting in order of the oldest, the four formations are listed below and described in the following paragraphs.

- Pre-Cambrain Basement Complex
- Mesozoic Nubian Series
- Tertiary Volcanic Rocks
- Pleistocene Surficial Deposits

3.1 Pre-Cambrian Basement Complex

Basement complex rocks of Pre-Cambrian age underly the entire study area at depths ranging from 0-350 m below ground surface. Bedrock in the form of inselburgs and jebels (mountains) crop out in the plateau area to the west of Gedaref. The bedrock complex consists of metamorphosed rocks which have been intruded and deformed by basic

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TABLE B-2

ATBARA RIVER WATER QUALITY[a]

Constituent[b]	Sample Location: Raw Water	Treatment Plant	Gedaref Distribution System
Lab Number	1201/82/83	1201/82/83	1200/82/83
Sample Date	Dec. 18, 1982	Dec. 18, 1982	Dec. 18, 1982
Appearance	Turbid	Turbid	Clear
Odor	Unobjectionable	Unobjectionable	Unobjectionable
Taste	Unobjectionable	Unobjectionable	Unobjectionable
Color	Nil	Nil	Nil
Conductivity umho	395	420	430
pH	8.6	7.5	7.5
TDS	320	360	340
Total Hardness ($CaCO_3$)	155	160	175
Total Alkalinity ($CaCO_3$)	170	130	150
Excess Alkalinity ($CaCO_3$)	15	Nil	Nil
Calcium	35	45	45
Magnesium	15	10	15
Chloride	20	15	15
Sulphate	40	90	60
Nitrate (as NO_3)	Nil	Nil	Nil
Nitrates (as NO_2)	Nil	Nil	Nil
Fluoride	0.5	0.5	0.5
Ammonia (as N)	Nil	Nil	Nil
Albuminoid Nitrogen (as N)	0.39	0.39	Nil
Arsenic	Nil	Nil	Nil
Lead	Nil	Nil	Nil
Sodium	20	20	20
Potassium	5	5	5

[a]All analyses conducted by the Sudan Ministry of Health - Chemical Laboratory

[b]All constituents reported in mg/l, unless otherwise noted

TABLE B-3

WORLD HEALTH ORGANIZATION

GUIDELINES FOR DRINKING WATER QUALITY*

AESTHETIC QUALITY	mg/l
Aluminum	0.2
Chloride	250
Copper	1.0
Hardness (as $CaCO_3$)	500
Iron	0.3
Manganese	0.1
Sodium	200
Sulphate	400
Total Dissolved Solids	1,000
Zinc	5.0
Color	15 True Color Units (TCU)
Taste and Odor	Not offensive
Turbidity	5 Nephelometric Turbidity Units (NTU)
pH	6.5 -8.5

INORGANIC CONSTITUENTS OF HEALTH SIGNIFICANCE	mg/l
Arsenic	0.05
Cadmium	0.005
Chromium	0.05
Cyanide	0.1
Fluoride	1.5
Lead	0.05
Mercury	0.001
Nitrate (as N)	10
Selenium	0.01

ORGANIC CONSTITUENTS OF HEALTH SIGNIFICANCE	mg/l	
Benzene	10	
Chlorinated Alkanes and Alkenes		
Carbon Tetrachloride	3	(T)
1, 2 - Dichloroethane	10	
1, 1 - Dichloroethylene	0.3	
Tetrachloroethylene	10	(T)
Trichloroethylene	30	(T)
Chlorophenols		
Pentachlorophenol	10	
2, 4, 6 Trichlorophenol (Odor threshold 0.0 mg/l)	10	

TABLE B-3
(Continued)

WORLD HEALTH ORGANIZATION

GUIDELINES FOR DRINKING WATER QUALITY*

ORGANIC CONSTITUENTS OF HEALTH SIGNIFICANCE,	(Continued)mg/l
Polynuclear Aromatic Hydrocarbons	
Benzo (a) pyrene	0.01
Trihalomethanes	
Chloroform	30
Pesticides	
Aldrin/Dieldrin	0.03
Chloridan	0.3
2, 4D	100
DDT	1
Heptachlor and Heptachlor Epoxide	0.1
Hexachlorobenzene	0.01
Lundane	3.0
Methoxcylore	30
Radioactive Materials	
Gross Alpha Activity (Bq/l)	0.1
Gross Beta Activity (Bq/l)	1

BACTERIOLOGICAL QUALITY	No. per 100 ml
Treated Water Entering Distribution System	0 Fecal Coliform 0 Coliform Organisms
Untreated Water Entering Distribtuion System	0 Fecal Coliform 3 Coliform Organisms per one sample 0 Coliform Organisms per two consecutive samples
Water in Distribution System	0 Fecal Coliform 3 Coliform Organisms per sample 0 Coliform Organisms per two consecutive samples

*All values presented are guidelines established by the United Nations World Health Organization (1982).

(T) Tentative guideline value.

and granitic igneous rocks. The metamorphic complexes consist predominantly of shists and phyllites. The igneous instrusives consist of gabbros, andesites and lighter grained granitic rocks. The basement complex rocks are largely an impermeable nonwater bearing group and thus, will not be discussed further in this report.

3.2 Mesozoic Nubian Series

The geologic map, Figure B-3, shows the distribution of the Nubian Formation in the vicinity of Gedaref. In most locations, the Nubian is not exposed directly to the surface but is overlain either by the volcanics or a thin veneer of dark clay soil. The Nubian Formation consists of an interbedded sequence of mudstone, sandstone and minor limestone layers with major lithological variations being common. The formation, also termed the Nubian Sandstone and Gedaref Formation, is the principal water-bearing unit in the study area.

Boreholes constructed into the Nubian have penetrated thicknesses of more than 300 m (1,000 ft). In the immediate vicinity of Gedaref, the Nubian ranges from about 150-190 m (500-600 ft) in thickness. The Nubian sediments thin toward the west, pinching out entirely some 40 kilometers west of Gedaref. Mudstone, which comprises up to 70 percent of the total Nubian Series, is massive, hard, noncalcarious and varies in both color and texture. The sandstone layers range from loosely consolidated to well compacted and cemented. Grain size distributions range from uniform fine-grained to coarse-grained and even occasional congomeratic layers.

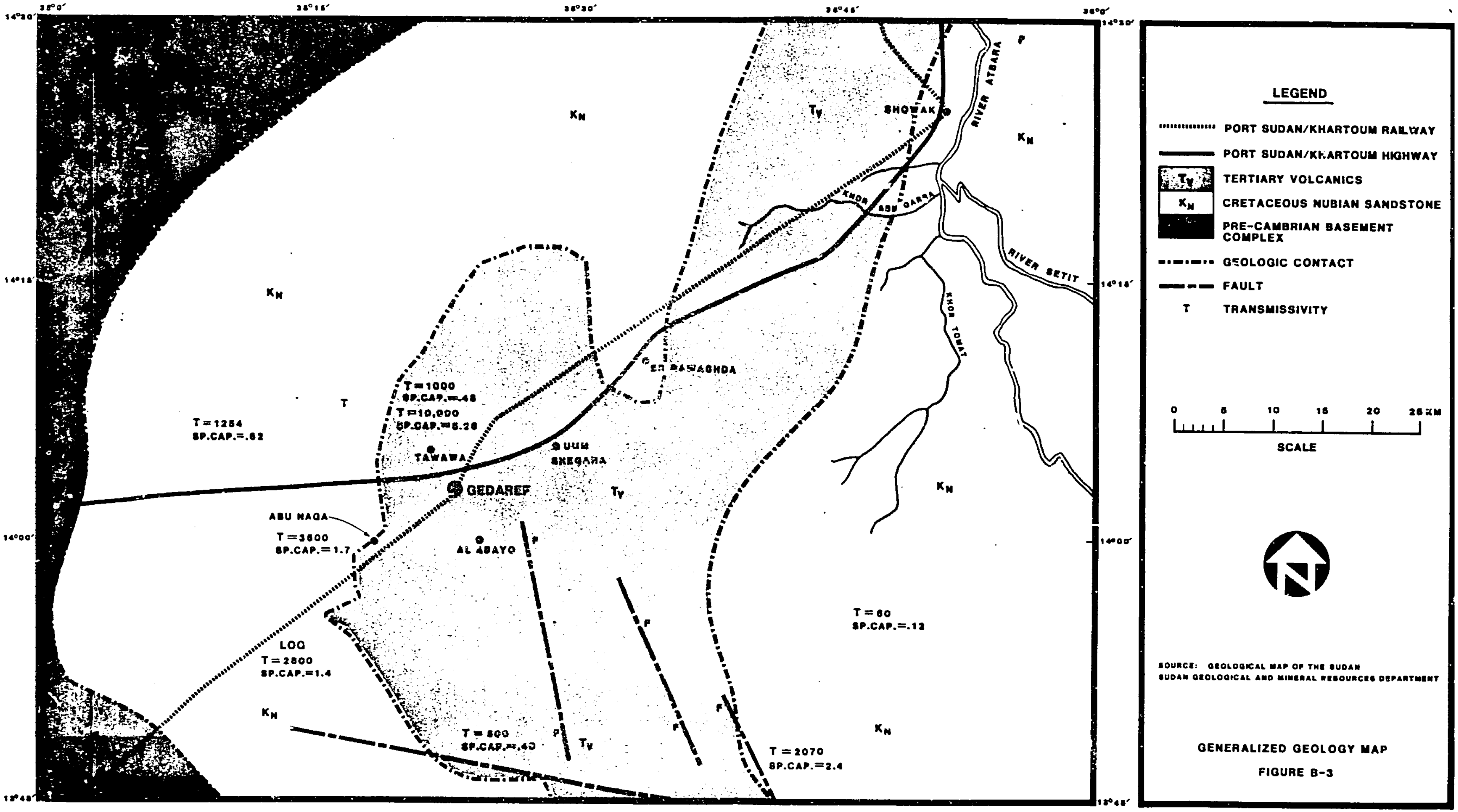
3.3 Tertiary Volcanic Rocks

As shown on Figure B-3, the volcanic deposits occur in a north-south trending band throughout the area of investigation. The volcanics are composed predominantly of amydoloidal olivine basalt which ranges in thickness up to several hundred feet. It is thickest along the central area of outcrop and thins to both the west and east. The basalts range in color from light to dark grey and brown to red. Where exposed, the outcrops are weathered and exhibit deep fracture patterns which may extend several tens of meters below ground surface.

The volcanic deposits were formed contemporaneous with the Ethiopian Plateau Volcanic Series and were deposited as extensive lava and fissure flows. Beneath Gedaref, boreholes have penetrated as much as 120 m (400 ft) of the volcanic deposits.

3.4 Pleistocene Surficial Deposits

With the exception of isolated peaks, much of the surface in and adjacent to Gedaref is covered by dark black soil which consists predominantly of silt and clay. This material is commonly referred to as "cotton soil" and is derived from the decomposition of the volcanic rocks underlying the central portion of the study area. These soils range in thickness from less than a meter near volcanic outcrops to as



GENERALIZED GEOLOGY MAP

FIGURE B-3

much as 10 meters west of Gedaref. The clayey soil is expansive and when dry, develops desiccation cracks which may extend up to 3 meters below the surface.

4. HYDROGEOLOGIC FEATURES

Ground water in the vicinity of Gedaref exists in both near surface unconfined and deeper confined aquifer systems. These aquifer systems have characteristics which are individual to each and are discussed separately below.

4.1 Unconfined Basalt Aquifer System

Within the study area, the basalt aquifer system occurs in a north-south trending band which centers on Gedaref. (Figure B-3) The occurrence of ground water in this formation is controlled by fracture and joint patterns which are visible in surface exposures. The degree of fracturing, and thus the permeability, of the volcanics decreases rapidly with depth. The near surface fracture system channels infiltrating precipitation which provides direct recharge to the basalt aquifer. As a result of the limited storage capacity in the fractures and the seasonal nature of recharge, ground-water levels in the basalt experience significant fluctuations between wet and dry seasons.

Wells constructed in the basalt aquifer are of the shallow hand-dug and machine-drilled types. Numerous hand-dug wells have been excavated into the shallow weathered zone of the basalt within the Gedaref area. These wells yield appreciable quantities of water during the summer months but experience diminishing yields as the drier winter months approach. The second type of wells are constructed by drilling several hundred feet into the volcanic rocks. Several such wells have been constructed in the Gedaref area. Yields of these boreholes are generally less than 4.5 m^3/hr.

Resulting from the relatively low yield derived from wells constructed in the basalt aquifer and because of characteristically marginal to poor water quality, the unconfined basalt aquifer system is not considered to be a suitable or potential water resource for the City of Gedaref.

4.2 Confined Nubian Sandstone Aquifer

The Nubian Sandstone underlies the basalt at depth beneath Gedaref and is exposed at ground surface to both the east and west of the City. As described previously, the Nubian Formation is composed of alternating layers of mudstone and fine- to coarse-grained sandstone. The sandstone comprises 30 - 40 percent of the total thickness and is the principal water storage and transmitting unit of the Nubian Series. Within the study area, as many as 300 boreholes are known to penetrate and withdraw ground water from this formation. It is, therefore, the principal aquifer system in the Gedaref region.

Ground water contained within the Nubian Formation is under confined to semi-confined aquifer conditions. While no flowing artesian wells are known to exist within the study area, piezometric levels of Nubian wells exhibit static pressure heads of 40 - 100 m. Depending upon location, piezometric levels range between 40 to 70 m below ground surface. Ground-water level measurements of Nubian wells, recorded at the time of construction, indicate a general correlation between piezometric levels and surface topography. That is to say, a general north-south ground-water divide occurs in the Gedaref area. The gradient and direction of movement of ground water is to the southwest and northeast from this ground-water divide.

In areas where the Nubian Series crops out, recharge may occur directly from infiltration of precipitation. However, piezometric levels suggest that the primary source of recharge to the Nubian aquifer is derived from the volcanic rocks where they overlie the Nubian Formation. Using a very rough hydrologic comparison with other well studied semi-arid regions, an estimate of annual recharge may be determined by using a factor of 5 percent of total precipitation. Applying this factor to the 2,600 km^2 volcanic outcrop area, shown on Figure B-3, provides a conservative annual recharge estimate of 78 x 10^6 m^3 to the Nubian Sandstone in the study area.

During recent years, many new wells have been constructed in the Nubian Sandstone to provide rural villages with good quality dependable water supplies. Under the auspicies of the Rural Water Corporation (RWC), many of these wells have been pump tested to develop information on the Nubian aquifer conditions and water quality characteristics. Pumping tests and water level observations are generally conducted only in the production well, but nevertheless, give a reasonable estimate of well yield, specific capacity and aquifer transmissivity. From a review of several aquifer tests in the vicinity of Gedaref, well yields can be expected to range from about 7-36 m^3/hr depending upon well depth and design. Specific capacity[a] of wells are generally low, ranging from 0.3 to 3.9 meters cubed per hour per meter of drawdown (m^3/hr/m).

The transmissivity[b] of the Nubian Sandstone varies widely with location. This condition results from several factors including the number and thickness of sandstone lenses, grain size, and degree of cementation, well depth and design and most importantly, well construction and development techniques. Given these constraints, an analysis of aquifer pumping tests reveals transmissivities of the Nubian Sandstone ranging from about 5 to 150 m^2/day. These transmissivity values are considered to be relatively low and may reflect well construction techniques.

[a] Specific capacity, for purposes of this report, is defined as cubic meters of water per hour divided by meters of drawdown (m^3/hr/m).

[b] Transmissivity is defined as the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient, herein stated as meters squared per day (m^2/day).

4.3 Existing Ground Water Resource Development

Currently, the principal source of water supply for the City of Gedaref is derived from the Atbara River via the Showak treatment plant and pumping facilities. Ground water is now being used to a limited degree to provide supplemental supplies to Gedaref and villages such as Tawawa and Abu Naga. A discussion of the existing ground-water development is presented in the following paragraphs.

4.4 Abu Naga Well Field

Prior to construction of the Showak facilities, Gedaref's water needs were supplied by ground water from the Abu Naga well field located approximately 10 km southwest of the City (Figure B-4). The well field consists of 11 wells which reportedly produced a total of 1,900 m^3/day or the equivalent of 172 m^3/day per well. When in operation, the wells pump into the Abu Naga pump and storage compound, from where the water was boosted to the town for distribution and use. When originally tested, each of the wells was pumped at 545 m^3/day. Thus, it appears that the well field was never utilized to its full tested capacity. In 1972, when the Showak facilities were completed, use of the Abu Naga well field was discontinued. In the years that followed, most of the pumping equipment from the wells and booster station was removed. Resulting from the abandonment and neglect, the well bores were subsequently vandalized and filled with stones and miscellaneous debris.

Since 1980, the Rural Water Corporation has undertaken a program to clean out and rehabilitate the wells. At the time of this writing, six wells have been redeveloped and tested for yield, drawdown and recovery. Data and results of these tests are discussed in the section on Ground-Water Resource Development and Potential. Two of the 11 wells have been equipped with submersible pumps rated at about 22.7 m^3/hr. Water from these pumps is pumped to the Abu Naga storage tanks where it is distributed to local water vendors or "donkey boys."

4.5 Tawawa Refugee Settlement

The refugee settlement at Tawawa is located approximately 5 km west of Gedaref. Although the village is connected to the Gedaref distribution system via a 4-inch line, the line is damaged and is not providing any water to the village. Tawawa is currently being supplied by water trucks provided by UNHCR and private vendors. Water is supplied from the Gedaref reservoir and by ground water from one well located approximately 2 km southwest of the village. The well was originally drilled for use in construction of the Port Sudan Highway. Through the efforts of UNHCR and the Sudan Committee for Refugees, the well was tested and equipped for supplying Tawawa village.

5. GROUND-WATER QUALITY

A complete evaluation of ground-water quality within the study area is limited by the availability of chemical analyses and both the time and special distribution of samples. A large number of wells have been sampled, the analyses for which span a period of 24 years. Several organizations have been involved in sample collection and analysis with little or no control over sampling and analytical techniques. Thus, the description of ground-water quality must rely on a limited data base which is questionable at best.

5.1 Unconfined Basalt Aquifer System

The quality of water in the basalt aquifer is generally considered to be marginal to poor. Water samples exhibit significant variations with both location and the season in which samples are collected. During and immediately following the rainy months, the quality of shallow ground water is at its best. As the dry season approaches and water levels drop, the quality deteriorates. This is especially true in the shallow hand-dug wells.

Table B-4 shows the water quality characteristics from several wells sampled in the Gedaref area in spring 1977 and 1979. As can be seen, total dissolved solids (TDS) range from 320 - 2,400 mg/l, hardness (as $CaCO_3$) from 255 to 2,160 mg/l and nitrates from 0 to 870 mg/l. Only 6 of the 26 samples are considered suitable for drinking water purposes as defined by World Health Organization, Guidelines for Drinking Water Quality (Table B-3).

Although there is considerable variation, ground water in the unconfined basalt aquifer is generally of the calcium/magnesium-bicarbonate type, hard to very hard, and is considered to be unsuitable for domestic water supply purposes from both quality and quantity standpoints.

5.2 Confined Nubian Sandstone Aquifer

The quality of water contained in the Nubian Sandstone varies significantly with location. In general, Nubian ground water is considered to be good quality and suitable for domestic water supply purposes. Table B-5 lists 41 analyses of well waters sampled from the Nubian Sandstone between 1968 - 1979. Of the samples analyzed, TDS ranged from 240 to 2,848 with most samples falling in the 300 -700 range. The water is generally hard to very hard with total hardness (as $CaCO_3$) ranging from 60 - 900 mg/l. Nitrates (as NO_3) are generally well below WHO guidelines, except where both the Nubian and Basalt aquifer are taped. Of the 41 samples analyzed, 9 samples exceeded WHO drinking water quality guidelines for total dissolved solids and/or hardness.

Localized pockets of poor quality water are known to exist in the Nubian aquifer. The best documented example of this is near Abu Naga well field. Abu Naga Well Field "A" was constructed with five

TABLE B-4

GROUND-WATER QUALITY ANALYSES

UNCONFINED BASALT AQUIFER

Sample Location	Date	Color	Turb	Odor	Taste	E.C.	TDS	pH	T.H.	T.A.	E.A.	CA	Mg	Cl	SO_4	NO_3	NO_2	F	N	Remarks
El Sadf (N.E.)	5/3/77	Nil	Nil	U	U	2700	1840	7.3	1680	280	Nil	195	290	350	140	870	0.66	0.7	Nil	Unfit
El Teim Middle (1)	5/3/77	Nil	Nil	U	U	750	480	7.7	410	280	Nil	60	65	70	80	145	2.63	0.1	0.18	Unfit
El Teim West (2)	5/3/77	Nil	Nil	U	Saline	1800	1320	7.8	1160	380	Nil	155	185	200	270	330	1.6	0.1	Nil	Unfit
El Teim (3)	5/4/77	Nil	Nil	U	U	950	840	7.8	675	260	Nil	95	105	10	150	330	0.104	0.8	Nil	Unfit
El Teim (4)	5/4/77	Nil	Nil	U	U	900	600	8.1	505	540	40	75	80	70	105	Nil	Nil	0.8	1.79	Unfit
El Teim (5)	5/4/77	Nil	Nil	U	U	1600	1400	7.7	940	220	Nil	175	220	170	150	Nil	2.6	0.9	Nil	Unfit
El Teim East (6)	5/5/77	Nil	Nil	U	U	1900	1800	7.1	1100	250	Nil	210	140	190	80	730	2.63	0.7	Nil	Unfit
El Teim (7)	5/7/77	Nil	Nil	U	U	1800	1680	7.1	1100	230	Nil	195	150	190	105	590	0.66	0.65	Nil	Unfit
Hilat El Malik (West)	5/17/77	Nil	Nil	U	U	500	400	7.6	255	280	25	50	30	30	25	20	0.33	0.6	Nil	
Hilat El Malik (West)	5/7/77	Nil	Nil	U	U	500	440	7.6	270	330	60	55	30	30	25	Nil	Nil	0.5	3.6	
Toroma (N.E.)	5/7/77	Nil	Nil	U	U	450	320	7.7	290	280	Nil	50	40	30	35	4.1	0.2	0.55	Nil	
Toroma Health	5/7/77	Nil	Nil	U	U	2400	1520	7.5	1200	360	Nil	120	220	280	80	730	0.052	0.5	Nil	Unfit
El Sadf (North)	4/27/77	Nil	Nil	U	Saline	2800	2400	7.7	2160	330	Nil	165	405	380	130	870	3.96	0.95	Nil	Unfit
Khor Abu Farga (N)	4/27/77	Nil	Nil	U	U	1650	1000	7.9	1280	300	Nil	115	240	170	50	470	2.63	0.95	Nil	Unfit
Khor Abu Farga (S)	4/27/77	Nil	Nil	U	Saline	2700	2240	7.8	2080	300	Nil	190	385	325	105	730	0.33	0.4	Nil	Unfit
El Sadf (N.W.)	4/27/77	Nil	Nil	U	Saline	1700	1280	8.0	1480	280	Nil	150	265	220	65	510	2.63	0.9	Nil	Unfit
El Sadf (North)	4/26/77	Nil	Nil	U	U	700	520	7.4	485	270	Nil	65	80	55	50	110	0.19	0.35	Nil	Unfit

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TABLE B-4
(Continued)

GROUND-WATER QUALITY ANALYSES
UNCONFINED BASALT AQUIFER

Sample Location	Date	Color	Turb	Odor	Taste	E.C.	TDS	pH	T.H.	T.A.	E.A.	CA	Mg	Cl	SO_4	NO_3	NO_2	F	N	Remarks
Abayo Village (N.E.)	4/26/77	Nil	Nil	U	Saline	2400	2000	7.1	1860	280	Nil	175	345	336	105	730	0.82	0.45	Nil	Unfit
Abayo Village (N.E.)	4/26/77	Nil	Nil	U	U	600	400	7.3	390	270	Nil	60	60	50	50	9.0	0.52	0.2	Nil	Unfit
Hilat El Agib (S.W.)	4/26/77	Nil	Nil	U	U	475	360	7.4	370	330	Nil	45	60	30	50	25	0.07	0.3	Nil	
Abayo Village (West)	4/25/77	Nil	Nil	U	Saline	2100	2000	7.4	1780	240	Nil	225	290	210	125	775	1.3	0.45	Nil	Unfit
Abayo Village (Middle)	4/26/77	Nil	Nil	U	Saline	1300	1120	7.8	770	200	Nil	155	90	120	80	365	0.98	0.45	Nil	Unfit
Khor Magadim (S)	4/25/77	Nil	Nil	U	U	1200	880	7.7	710	280	Nil	190	55	110	40	330	0.26	0.6	Nil	Unfit
Khor Magadim (S)	4/25/77	Nil	Nil	U	U	1130	425	7.7	300	Nil	55	40	55	25	6.5	0.02	0.5	0.09	0.06	
Khor Serraf (3538)	1979	-	-	-	-	1100	870	8.6	408	750	363	61	62	70	16	240		1.6	0.96	Unfit
Khor Serraf (3534)	1979	-	-	-	-	1400	920	8.0	330	690	380	25	65	105	50	12.5	-	1.4		

Notes: U = Unobjectionable

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TABLE B-5

CHEMICAL ANALYSES OF GROUND WATER FROM THE NUBIAN SANDSTONE

Nat'l No.	Serial No.	Location	E.C.	pH	TDS	TH	TA	EA	Ca	Mg	Cl	SO_4	NO_3	NO_2	F	AMM as N	Na	K	Remarks
4272	98	Kabaros	810	8.0	520	250	320	75	40	35	50	40	-	-	1.8		55	5	Nubian
1846	31	Shoikhoin	1150	7.1	700	510	430		135	40	125	165	5	-	0.28	0.08	130		Nubian
1846	31	Shoikoin	900	8.4	560	310	280	-	40	50	110	80		0.48		95			Nubian
5408	117	Saseib	530	7.8	360	195	310	120	40	25	25	25	-	-	0.4		35	10	Nubian
5405	116	El Mahal	800	8.0	520	325	400	80	40	55	30	40			1.2		60	10	Nubian
1777	25	Umm Sunta	1500	8.3	1280	240	250	10	50	25	270	225	3.4				295		Nubian
3015	54	Umm Khanger	610	8.1	400	290	280		70	25	30	25	20	0.45	0.5				Nubian
3527	74	Er Rawashda	800	8.1	580	355	370	35	55	50	45	40		0.35	1.3				Nubian
2001	35	El Tamargo	350	8.4	240	100	150	55	25	10	35	-			0.92		65		Nubian
5401	115	El Gamman	960	8.1	875	280	490	215	55	35	55	230			2.6			30	Nubian
4269	95	Gennen	1100	8.0	680	350	430	85	25	70	70	20			2.5		105	35	Nubian/Basalt
4268	94	Wad El-Halangi	1390	8.0	760	370	340		50	60	90	25	200		2.5		105	35	Nubian/Basalt
4267	93	Wad Daief	1040	8.0	640	440	400		65	70	65	25	125		0.6	0.09	55	10	Nubian/Basalt
4271	97	Obu Urief	920	7.0	570														Nubian
2490	45	Ghiroigana	1100	8.3	770	215	630	440	25	35	65	40			0.88	0.2			Nubian/Basalt
1439	15	Kassah	900	8.3	560	252	450	210	48	32	52	19	0.8		1.6		136		Nubian/Basalt
3111	58	Suffara	1100	8.1	682	430			70	60	100	80	0.025		1.1				Nubian/Basalt
3112	59	Kabaros	900	8.2	558	300			45	50	50	35			30				Nubian/Basal
4280		Tawawa	-	7.5	940	505	700	210	85	70	95	65	Nil	Nil	3.0	Nil	-	-	Sampled 2/19/82
4280		Tawawa	-	72	1320	615	1060	470	100	90	85	130	Nil	Nil	2.1	Nil	-	-	Sampled 2/25/82

TABLE 5
(Continued)

CHEMICAL ANALYSES OF GROUND WATER FROM THE NUBIAN SANDSTONE

Nat'l No.	Location	Sample Depth	Sample Date	Odor	pH	TDS	TH	TA	EA	Ca	Mg	Cl	SO_4	NO_3	NO_2	F	N	Na	K	Remarks
Abu Naga Well Field																				
974	Basin A #4	803	1968	Nil	8.2	2840	610	2500	2025	72	105	68	48	-	-	1.36	1			Nubian
971	Basin A #	-	1968	Nil	7.3	2480	840	2300	1548	112	136	80	29	-	-	1.96	-			Nubian
475	Basin A #3	810	1968	Nil	7.0	310	60	130	80	20	5	65	-	-	-	0.1	-			Nubian
921	Basin A #2	393	1968	Nil	8.2	2650	740	2400	1802	104	117	64	38	-	-	1.4	0.5			Nubian
544	Basin A #1	-	1968	Nil	8.2	2848	900	1802	900	84	168	80	48	-	-	0.8	-			Nubian
1101	Basin A #5	420	1968	Nil	8.2	600	244	310	70	42	34	80	10	-	-	0.32	Tr			Nubian
1120	Basin A #	-	1968	Obj	8.2	2700	820	2630	1810	208	73	150	38	-	-	5.2	-			Nubian
1427	Basin B #2	300	1968	H_2SO_4	8.1	500	170	310	148	22	27	28	62	-	-	0.32	0.22			Nubian
1447	Basin B #3	300	1968	Nil	8.3	460	316	310	Nil	48	47	32	62			0.22	4.4			Nubian
1457	Basin B #1	350	1968	Nil	8.1	490	230	350	127	30	129	22	78	-	-	Nil	1.32			Nubian
1486	Basin B #6	300	1968	Nil	8.8	440	188	370	193	6	42	44	29	-	-	2	0.5			Nubian
1487	Basin B #4	330	1968	Nil	8.3	540	234	350	123	33	37	48	29	-	-	1.5	0.75			Nubian
1491	Basin B #5	320	1968	Nil	8.3	468	220	340	127	28	36	48	19	-	-	2.0	1.0			Nubian

TABLE B-5
(Continued)
CHEMICAL ANALYSES OF GROUND WATER FROM THE NUBIAN SANDSTONE

Nat'l No.	Serial No.	Location	E.C.	pH	TDS	TH	TA	EA	Ca	Mg	Cl	SO_4	NO_3	NO_2	F	AMM as N	Na	K	Remarks
3110	57	Wad El Halongi	950	8.2	589	245			40	35	65	75	Nil		2.9				Nubian/Basalt
3994	86	Saseib	970	8.0	560	360	360		65	50	90	65			1.1		65	10	Nubian
4308	106	Umm Sawani	750	8.0	500	230	290	65	30	35	15	90			3.9		85	35	Nubian
3996	87	Kamadeib	800	8.0	440	320	260		50	50	95	40			2.2		50	15	Nubian
4270	96	Soffara	980	7.0	607														Nubian
9021		Umm Gorgour		8.5	1300	330	800	495	35	60	125	90	Nil	0.03	4.2	0.72	-	-	Sampled by RWC 7/4/82
9019		Umm Golga 1		8.4	680	360	450	95	50	60	120	40	Nil	0.08	0.9	Nil	-	-	Sampled by RWC 6/20/82
9020		Umm Golga 2		-	480	440	560	125	90	50	120	Nil	Nil	1.8	Nil	-	-	-	Sampled by RWC 6/24/82
703	6	Umm Golga 2a		7.9	700	412	100	-	58	65	100	40	1.2	Nil	1.2	-	-	-	RWC 1958
706	7	Umm Golga 2b		7.1	780	550	543	-	80	85	110	40	0.72	-	1.6	-	-	-	RWC 1958

Note: Except where noted, data from Ground-water Investigation of El Gedaref, 1979, by the Sudanese Rural Water Corporation and TNO Consultants, Netherlands wells located about 6 km south of Gedaref. This well field was abandoned upon completion due to excessive levels of dissolved minerals. Total dissolved solids averaged about 2,500 mg/l and hardness ranged from 600 - 900 mg/l. It is thought that these boreholes tapped water only from the Nubian sandstone, but it is possible they received water from the overlying volcanics. In contrast, Abu Naga Well Field B is located about 13 km south of Gedaref and yields water of good chemical quality with total dissolved solids ranging from 400 - 550 mg/l. Hardness is also much lower, ranging from 170-316 mg/l.

6. GROUND-WATER RESOURCE DEVELOPMENT POTENTIAL

Five potential ground-water source areas for development of supplemental supplies to the Gedaref water system were identified in the course of this evaluation. The source areas are all located outside the town and would develop ground water from the Nubian Sandstone. The areas are as follows:

- Abu Naga
- Tawawa
- Showak
- Umm Golga

An analysis of each of the potential ground-water production areas is presented in the following pages.

6.1 Abu Naga Well Field

As discussed previously, the Rural Water Corporation is conducting a program to rehabilitate, redevelop and equip the existing wells at Abu Naga well field. A summary of available data from original well drilling records and aquifer tests conducted at the completion of redevelopment is listed in Table B-6. Review of these data provides insight into the development potential of Abu Naga well field. Referring these data to the Abu Naga location map, Figure B-4, reveals the wide variations of hydrogeologic characteristics which occur within the Nubian Sandstone. As can be seen, the transmissivities, specific capacities and well yields are significantly higher in the southernmost wells. In particular, Wells Nos. 9, 10, and 11 are the most productive and have potential for increased yield up to 40 m^3/hr each. These data further indicate that expansion of the well field is physically feasible to the south of Well No. 11.

The aquifer pumping tests performed on the Abu Naga wells confirmed that ground water occurs under confined to semi-confined conditions. Specific capacities of the wells range from .25 m^3/hr/m in the northern wells to 4.2 m^3/hr/m in the southern wells. Transmissivities

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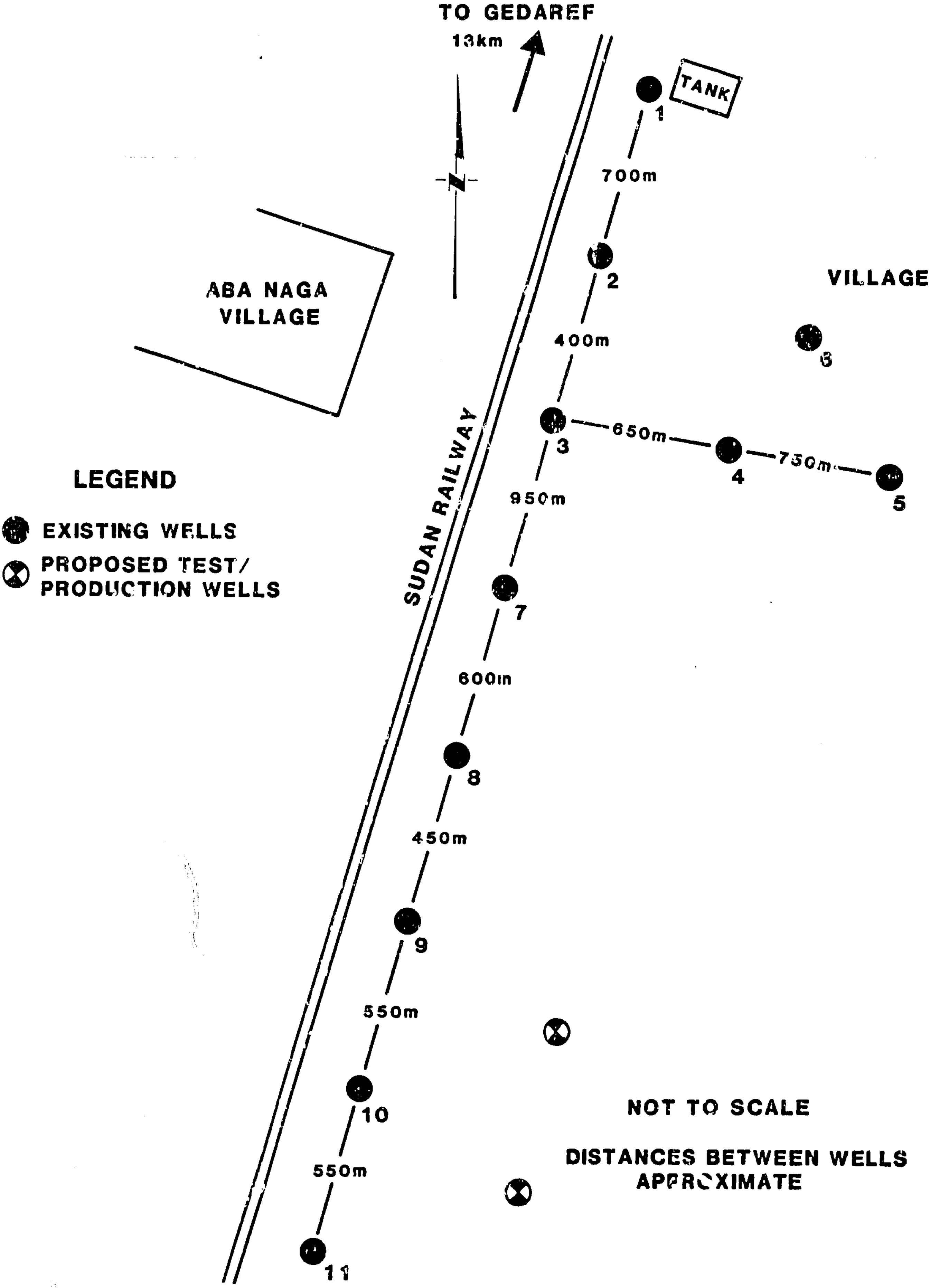

EXISTING ABU NAGA WELL FIELD
FIGURE B-4

TABLE B-6

SUMMARY OF WELL DRILLING DATA

ABU NAGA WELL FIELD

Well Designation	National No.	Date Drilled	Depth (m)	Date Tested	Static Water Level (m)	Pumping Rate (m^3/hr)	Maximum Pumping Level (m)	Maximum Drawdown (m)	Specific Capacity (m^3/hr/m)	Trans-missivity (m^2/day)	Maximum Potential Yield (m^3/hr)	Well Status /Remarks
Well No. 1	1457	1968			Dry	-	-	-	-	-	-	Abandoned
Well No. 2	1427	1968			Dry	-	-	-	-	-	-	Filled w/Debris
Well No. 3	1447	1968	204	11/11/82	55.67	6.54	81.85	26.18	0.25	5.0	6.5	Equipped w/Pump
Well No. 4	1487	1968	221									Equipped w/Pump
Well No. 5	1491	1968	190.5									
Well No. 6	1486	1968	240	10/28/82	48.75	16.36	67.91	19.16	0.85	24.0	20	Equipped w/Pump
Well No. 7		196[illegible]										Filled w/Debris
Well No. 8		1968										Filled w/Debris
Well No. 9		1968	180	11/1/82	42.73	13.10	48.44	5.71	2.30	60.0	40.00	Pump Setting 54 m
Well No. 10	2408		222	10/29/82	46.32	11.44	50.68	4.36	2.63	58.0	40.00	
Well No. 11	2409	1968	208	11/29/82	43.00	26.16	49.20	6.20	4.22	122.0	40.00	Pump Setting 81 m

showed a similar pattern with values ranging from 5 to 122 m^2/day. Comparing the most recent test (1982) for Well No. 3 with the original pump test (1968) shows a significant reduction in both specific capacity and transmissivity. These reductions appear to be a function of well deterioration which may have been caused by clogging of the screens from both chemical incrustation and debris dropped into the well. It is, therefore, possible that further redevelopment, including acid treatment, could improve the yield characteristics of the northern wells.

Recent aquifer recovery tests, which followed short-term (10-hour) pump tests, showed full recovery in the southern wells (Nos. 9, 10, 11). Longer term tests, lasting from 48 - 72 hours should be conducted, however, to confirm the availability of sufficient recharge to the aquifer.

Currently, there is insufficient data available to calculate an estimate of the safe yield for the Abu Naga well field. However, comparing pump tests, original construction records and precipitation data suggests that the well field can sustain at least 3,500 to 4,000 m^3/day. Once the well field has been redeveloped and placed in operation, a monitoring program to measure water levels, production rates and water quality should be implemented to facilitate estimation of a long-term safe yield.

6.2 Tawawa

Two wells are known to exist near Tawawa village. One well (National No. 3533) supplies water to the Pilot Irrigation Farm, and the second well (National No. 4280) provides intermittant supplies to Tawawa. Both wells develop water from the Nubian Sandstone at depths from 132 - 258 m below ground surface. Near the wells, the Nubian aquifer is overlain by 48 - 62 m of basalt belonging to the Tertiary Volcanics. The piezometric levels in both wells are about 43 m below ground surface. In April 1982, the UNHCR conducted a 5-day pump test on the well supplying Tawawa (No. 4230). The well was tested at 14.5 m^3/hr with a measured drawdown at 12 m. This equates to a specific capacity of 1.2 m^3/hr/m. and an estimated transmissivity of 32 m^2/day.

From the above information, it is evident that the Tawawa supply well can yield at least 20 to 25 m^3/hr. However, because of the question of well ownership and water quality problems associated with the well, a new well for Tawawa may be advisable. A new well could be located approximately 1 km west of the existing well. Properly designed and constructed, this new well could be expected to yield 20 to 40 m^3/hr.

6.3 Showak

Recently, considerable attention has been given to developing ground water near the Showak refugee settlement. To study the feasibility of utilizing ground water, the RWC drilled two test wells adjacent to the

Showak treatment plant. These wells were tested on 2/27/82 with the following results:

	Pumping Well	Observation Well (10.14 m from pumped well)
Static Water Level	4.43 m	4.39 m
Pumping Rate	21.82/m^3/hr	-
Pumping Level	9.72 m	6.35 m
Drawdown	5.29 m	1.46 m
Specific Capacity	4.12 m^3/m/m	-
Transmissivity	35 m^2/day	212 m^2/day

The test well was drilled to a depth of 89 m into the Nubian Sandstone which crops out adjacent to the Atbara River. The results of the pump test indicate that the Nubian Sandstone near the treatment plant has good production potential and is apparently recharged from the Atbara River. Wells constructed adjacent to the river to develop only the shallow sands and gravels could be expected to yield 40 to 50 m^3/hr. It is also possible that wells constructed to greater depths may tap deeper Nubian Sandstone lenses which could supply even higher yielding wells.

The available information on the ground-water conditions along the Atbara River near Showak indicates that ground water can be developed as an alternative supply source for the Showak treatment and pumping facilities. This source has the advantage of high water quality with low suspended solids and turbidity and would not be subject to flow interruptions during winter low flow conditions of the Atbara River. Development of this source will, however, require construction and testing of at least one additional test well and several piezometers to provide design information on the number, depth and spacing of production wells. This test drilling could be conducted prior to or during the design stage and should be directed by an expatriate hydrogeologist.

To further explore the ground-water potential, the NAW is conducting geophysical surveys along the west bank of the Atbara River to both the north and south of the treatment plant. Results of these surveys should be available in early 1983 and will provide additional information on the extent of the shallow aquifer near Showak.

6.4 Umm Golga

The village of Um Golga is located near the Khartoum-Port Sudan Highway, approximately 10 km west of Gedaref. The village has four wells which provide ground water as the principal source of supply. Two wells (National No. 703 and 706) were constructed in 1957 and currently yield about 5 m^3/ hr each. In 1982 two additional wells were constructed. The wells were drilled and subsequently tested by the RWC to determine yield and drawdown characteristics. Results of the drilling and testing of the new wells are shown below:

	Umm Golga I (National No. 9019)	Umm Golga II (National No. 9020)
Total Well Depth	159 m	139 m
Screen Setting	58-68.6 m	59.5-68.6 m
	111-117 m	79-90 m 94.5-99 m
	137-154 m	111-120 m
Static Water Level	43.5 m	45.1 m
Pumping Rate	27.27 m^3/hr	27.27 m^3/hr
Pumping Water Level	55.0 m	67.0 m
Drawdown	11.5 m	23.95 m
Specific Capacity	2.37 m^3/hr/m	1.14 m^3/hr/m
Transmissivity	82 m^2/day	51 m^3/day

The data listed above indicate that the Nubian Sandstone in the vicinity of Umm Golga is productive and has good potential for additional ground-water development. Recovery tests show complete aquifer recovery indicating ample recharge. It is currently not anticipated that Gedaref will need to develop additional ground-water resources outside the Abu Naga, Tawawa area. Nevertheless, the Umm Golga area does appear to have potential for additional ground-water development and should be listed as a potential area for future development.

APPENDIX C

AGENCIES AND PERSONS CONTACTED

The following agencies and persons were contacted during the conduct of the feasibility study. Valuable information, assistance and cooperation were supplied by those listed below.

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT - SUDAN

Mr. A. Mudge, Mission Director
Jerry Weaver, Refugee Officer
Mrs. Joan F. Kontos, Assistant Refugee Officer
Lynn C. Sheldon, Chief Engineer
Steven P. Mintz, Project Operations Officer
Jack Faircloth, Management Officer
David Gephart, STC Engineer

AGENCY FOR INTERNATIONAL DEVELOPMENT - WASHINGTON, D.C.

Albert Printz, Environmental Coordinator

COMMISSIONER FOR REFUGEES - SUDAN

Abdel Migid Bashir Elahmadi, Commissioner

NATIONAL ADMINISTRATION FOR WATER

Khair Alla Mahgoub, Director General

PUBLIC ELECTRICITY AND WATER CORPORATION (dissolved)

Hassan Abd el Rahman, Area Chief Water Engineer - New Halfa
Sayed Burhan Mohd, Water Engineer - Gedaref

RURAL WATER ADMINISTRATION (NAW) - (dissolved)

Mohammed Hussein, Executive Director - Gedaref/Kassala

GEDAREF LOCAL GOVERNMENT

Isseh Din Mohamed Ahmed, Executive Director, Gedaref Area Councils
Gedaref Town Council Members
Bashir M. Ahmed Ossman, Town Planner-Gedaref
Md. Awad Hassan Malik, Abayo North Village Council
Md. Abdel Moneim, Gedaref North Area Council

Appendix C

GEDAREF INSTITUTIONS

Dr. Nabil Aziz, Deputy Director, Gedaref Municipal Hospital
Dr. Babi Kir Ahmed, Director, Gedaref Veterinary Center

REGIONAL GOVERNMENT - KASSALA

His Excellency Hannid Ali Shash, Governor, Eastern Region
Sayed O Haj Ibrahim Musa, Minister for Housing and Public Utilities
Mahajub Osheik, Economics Div., Ministry of Finance
Mustafa Bashir, Chairman, Social Services Committee
Mohamed Soghair, Assistant Commissioner

REFUGEE SETTLEMENTS ADMINISTRATION - SHOWAK (C.R.S.)

Al Tiraifi Younis, Deputy General, Project Manager

DEPARTMENT OF STATISTICS - KHARTOUM

Dr. Muhammed Farah, Director, Population Census Division
Md. Ahmed Abd El Gadir - Supervisor of Mapping

UNITED NATIONS HIGH COMMISSIONER FOR REFUGEES

Robert J. Muller, Representative, Khartoum
Karen Abu-Zied, Khartoum
Peter Parr, Director, Gedaref
Gary Shook, Environmental Health Officer, Gedaref

INTERNATIONAL RESCUE COMMITTEE

Tom Fellows, Director, Gedaref
Dr. James Tidwell, Medical Officer, Tawawa
Guian Heintzen, Khartoum

CARE - Khartoum

Stanley Dunn, Director

UNIVERSITY OF KHARTOUM

Dr. Ahmed Hakim, Professor of Archeology
Dr. Mahmoun El Khalifa, Chairman, Institute of Environmental Studies
Dr. Yagoub Abdalla Mohamed, Professor of Arts
Dr. Bashir M. El Hassan, Faculty of Engineering

Christpher West, Consulting Hydrogeologist, U.K.

Gifford and Partners, Consulting Engineers, U.K.