DEMOCRATIC REPUBLIC OF SUDAN
WORLD BANK
REHABILITATION PROJECT MANAGEMENT UNIT

THE SUDAN GEZIRA REHABILITATION PROJECT
TECHNICAL ASSISTANCE TO SUDAN GEZIRA BOARD

FINAL REPORT
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INTERNATIONAL IRRIGATION MANAGEMENT INSTITUTE

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FOREWORD

The Sudan Gezira Scheme stands in the cross-roads faced with stagnant or decline in productivity of major crops and a network of distribution systems and regulatory structures which have shown increasingly low levels of performance.

The full benefit from the rehabilitation of the scheme which is nearing completion cannot be obtained until water management both at the system as at well as at the farm level is significantly improved.

This report, based on the technical assistance provided to Sudan Gezira Board by the International Irrigation Management Institute, identified the strengths and weaknesses of the irrigated agricultural system of the Gezira scheme and made specific recommendations for improving productivity.

It is hoped that the SGB administration will implement the recommendations, in a phased way, to optimize agricultural productivity of the scheme.

Nanda Abeywickrema
Director, International Cooperation
International Irrigation Management Institute

PREFACE

This final report is the outcome of the technical assistance provided by the International Irrigation Management Institute, from mid-August, 1990 through June, 1993, to the Sudan Gezira Board for the establishment of a Water Management Advisory Unit to enable it to improve onfarm water management of the Gezira scheme for increasing agricultural production. The original TA was approved for two years but later extended to December, 1992. The Head of IIMI's Sudan country program who was the Senior Water Management Advisor during the extended phase informed the donor and national partners that for administrative purposes the project will terminate at the end of December but the program will be continued to the end of June, 1993. The first draft of the report was submitted to Sudan Gezira Board and Rehabilitation Project Management Unit in early August of 1992. The major recommendations of the report were discussed in a workshop held at Gezira Board on 6 August, 1992 which was participated by senior officials of Gezira Board (including the Managing Director), Ministry of Irrigation and Agricultural Research Corporation.

At the time the technical assistance project was being implemented the Government was planning to affect significant changes in operational as well as organizational aspects of the Sudan Gezira Board. In 1993 operation and maintenance of canals from minors downward have been revested in the Ministry of Irrigation (from Sudan Gezira Board). In the same year the management of the SGB has been sized down drastically with the elimination of the positions of Managing Director and Deputy Managing Director. It is too early to predict what impact the reorganization will have on the strengthening and operation of the Water Management Advisory Unit. Whatever the arrangements I am convinced that the recommendations made both for the strengthening and operation of the WMAU shall have to be followed up to achieve the desired objectives for which it was established.

To make the Water Management Advisory Unit an effective unit the Gezira Board shall have to make determined effort to recruit second technical staff with required academic qualifications without further delay.

K. Azharul Haq
Senior Water Management Advisor

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The successful completion of the technical assistance project was possible due to effective support provided by the management and professional staff of the Sudan Gezira Board (SGB), Rehabilitation Project Management Unit (RPMU), Ministry of Irrigation (MOI) and Agricultural Research Corporation (ARC).

I am thankful to Mr. Izzeldin O. el Mekki, Managing Director of SGB, Mr Abdulla Mohammed El Zubeir and Mr. Gasim Osman, Executive Director and Engineering Advisor respectively of RPMU, Dr. Ahmed Adam and Mr. Bedawi Elfadi El Monshid, First Under Secretary and Under Secretary respectively of the MOI for their constant assistance and guidance. Mr. Mekki took special interest in establishment and operation of the Water Management Advisory Unit (WMAU).

The professional and technical staff of SGB, MOI and ARC deserves special citation. I will be failing in my duties if I dot recognize individual contributions made by Dr. Gamar El Din El Khatib, Manager, WMAU, SGB, Dr. Omar Abdel Wahab Abdalla, Manager, Pilot Farm, Mr. Galal H. Osman, Director, Agricultural Administration, SGB (1990-91), Mr. Ahmed Badwi Mohammad Saleh, Director, Agricultural Administration, SGB (1991-92), Dr. Ahmed Hussein Salih, Hydraulic Research Station (HRS), MOI, and Dr. Ahmed Ali Salih, Soil Physicist, ARC towards the fullfilment of the objectives of the technical assistance project.

I am specially grateful to Dr. M.S. Shafique, Head, IIMI/Sudan for his total and continued support during the implementation of the Technical Assistance Project.

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The World Bank deserves special thanks for their generous funding for the technical assistance project.

K. Azharul Haq
Senior Water Management Advisor

EXECUTIVE SUMMARY

Built between the twenties and sixties Gezira scheme of Sudan is the largest irrigation system in the world under single centralized management. This 0.8 million ha scheme started experiencing continuous decline in agricultural production from the mid-seventies. Recognizing the severity of the problem the Government of Sudan sought financial assistance from the World Bank for rehabilitation of the Gezira irrigation scheme. During the appraisal for rehabilitation it was, however, recognized that along with restoring the hardware of the system (dams, hydraulic structures, water supply and disposal systems) improvements in "software" (on-farm water management) was also equally important if the declining productivity trend had to be arrested or even reversed to maintain sustainable production. The Staff Appraisal Report, therefore, recommended that a new unit named Water Management Advisory Unit be established within the agricultural administration of the Gezira scheme to improve farm productivity and the International Irrigation Management Institute was entrusted with the responsibility of helping establish the WMAU through a technical assistance program.

During the 2 year technical assistance project (August 1990 through July 1992) present status and performance of the major components of the irrigated agricultural system was assessed by literature review, extensively touring the scheme, personnel communication with tenants as well as professionals from various government agencies, conducting selective experiment etc. The components included water storage, diversion, control and regulation, distribution and disposal and various aspects of crop production system. At the same time the Water Management Advisory Unit (WMAU) was established to address issues constraining agricultural productivity.

The WMAU has established but there was enormous difficulty in staffing the unit. The manager of the unit had a basic degree in entomology and naturally was not the most suitable professional to lead the unit as he had neither the academic background nor the field experience for the purpose. Within these limitations he tried to do everything in his capacity to help with the establishment and functioning of the unit. During the entire two year period no other full time technical or support staff was assigned to the unit. During the second year three technical staff were assigned on part time basis.

This report makes appropriate recommendation for further strengthening the WMAU through man power development (training both local and abroad), procurement of equipment for laboratory, field research and agro-meteorological station.

While assessing the present status of the irrigation agricultural systems of the scheme it was observed that performance of the distribution system has deteriorated due to the problems of aquatic weed, growth, sedimentation and changes in canal cross-sections.

The flow monitoring, measuring and regulating structures have also deteriorated to a point where it is increasingly becoming difficult to control and regulate flow causing severe disparity in water supplied between head and tail areas. At the same time localized flooding is increasingly becoming a common phenomenon within the scheme.

For the purpose of this report performance of canals were assessed from minors to Abu Sittas, the operational jurisdiction of the Gezira Board. It was observed that performance of all types of canals have deteriorated. As a result farmers are increasingly resorting to water piracy through the construction of "Nachus" (extra field outlets). The Night Storage Systems constructed within the minors have also lost their significance as tenants are increasingly breaching the NSS to make up for inadequate water supply.

Assessment of the crop production system indicated that yields of major crops have shown erratic trends. As a declared government policy of attaining self sufficiency in cereal production, cotton the major export crop, is being increasingly moved to rainfed areas.

Water indents prepared by the SGB inspectors continue to be based 5000 m^3/day for every crop and every season. This encourages water wastage in growing low water demanding crops like wheat grown during the cooler months. Soil moisture depletion profiles computed for both cotton and wheat in 1991-92 season indicated that subsequent irrigation were applied well before the available soil moisture was depleted to the permissible levels.

It was also observed that the planned cropped for a particular growing season was determined more or less on a adhoc basis rather than considering the available water supply. This resulted in planting of low acreage in the good water year and expanded average in a low flow year.

Irrigation frequency (No. of irrigation) more or less followed the recommendation. There were, however significant difference in the duration of irrigation which resulted in significantly higher depth of irrigation application, in certain "Numbers" the application exceeded recommendation by more than 300 percent.

Irrespective of significantly higher yields of all the majors crops, average water use efficiency (WUE) figures continue to remain low at below 30% of recommended values.

Based on the assessment of the irrigation agricultural production systems of the Gezira scheme a number of recommendations have been formulated to optimize production per unit of water as well as per unit of land.

Major recommendations in the on-farm water management area includes relocation of Abu Ashreen, supplying water to Abu Ashreeen on both sides of the minors, strategies for irrigation of highlands within the "Howashas" adoption of modified furrow irrigation to row crops, use of dead storage, practicing flow control and regulation by observing existing conditions rather than using design manuals, preparing water indents for specific corps and specific season, supervision of night storage system, conjunctive use and management of surface and ground water etc.

On the crop production aspects recommendations include emphasis in planting and harvesting within recommended dates, improving plant densities (planting optimum number of plants/unit area), increasing organic matter content of soils which inturn will improve soil structure, water holding capacity etc., increasing cropping intensity by supplementing surface water by ground water etc.

Involvement of tenants in the operation and maintenance of the system below Abu Ashreen level and creating awareness among the farmers about the importance of proper water management are also important recommendations.

1.0 INTRODUCTION

1.1 General

In the recent years the Gezira scheme of Sudan has shown definite signs of deterioration not only in its hard ware department but the yields, production and nearly all efficiency parameters have either stagnated or showed declining trend. Built between 1920's and 1960's the first phase of rehabilitation was completed in early 80's. The second phase of rehabilitation started in the year 1988 and was expected to be completed in six years.

To improve the on farm water management of the Gezira scheme IDA requested International Irrigation Management Institute (IIMI) to provide the services of a Senior Water Management Advisor (SWMA) to establish a Water Management Advisory Unit (WMAU) within the Agricultural Administration of the Sudan Gezira Board (SGB).

1.2 Scope of Technical Assistance

For providing Technical assistance negotiations were initiated between Rehabilitation Project Management Unit (RPMU) and International Irrigation Management Institute (IIMI) in early 1987 and it was agreed that a Senior Water Management Advisor (SWMA) will on board by october, 1988. Copy of the agreement is presented in Appendix-I. The SWMA, however, was placed at SGB in august, 1990 with the following terms of reference:

" The Senior Water Management Advisor will be the principal advisor on water management to the Agricultural Manager of the SGB, who is also a member of the Steering Committee of the Pilot Farms. In this capacity he will:

a. Advise the SGB on the exploration of technical and managerial issues of irrigation by means of problem identification and analysis at field and sub-system levels,

b. Translate results from problem identification and analysis into programs for research or programs for remedial action;

c. Pay particular attention to planning and progress being made on the Pilot Farms and, working through the Agricultural Manager, SGB, provide advise to the Steering Committee, the Management Committee and the Project Manager.

d. Advise SGB on the development of the Water Management Advisory Unit foreseen in the IDA appraisal report on the Gezira Rehabilitation Project, bearing in mind the progress made by the Pilot Farms as well as the Rehabilitation Project as such;

e. Make recommendations on type and content of training needed for the proposed SGB field staff of the Water Management Advisory unit;

f. Organize short workshops or seminars geared exclusively to specific issues in irrigation management and jointly attended by staff of SGB, MOI, Universities and other relevant institutions;

g. Advise on the drafting of revised operating rules or procedures, to the extent that this may appear necessary in relation to specific components of the system; in this he will pay special attention to the process of introducing such revised rules and making them functional, including the related requirements of information flows within the system;

h. Liaise with national and international organizations active in the field of irrigation water management research for the benefit of the system;

i. Promote and arrange the linkage of the activities carried out in Sudan with similar activities undertaken in countries participating in IIMI's international irrigation management research and development network."

2.0 BACKGROUND

Sudan is the largest country in Africa with a land area of about 2.5 million square kilometer. Little over 4 percent i.e about 25 million feddans (10.50 million ha) is presently cultivated. The present population is approximately 26 million and the growth rate has been estimated at just over 3% per anum. Of the total cultivated area 11.16 million fd (4.69 ha), 11.66 million fd (4.90 ha) and 3.20 million fd (1.34 million ha) are grown respectively in mechanized rainfed, traditional and irrigated sub-sectors.

2.1 The Agriculture Sector

Sudan is basically an agricultural country with over 80% of its population directly or indirectly dependent on income and employment from agriculture. With 36%, agriculture is the largest contributor to GDP. Agriculture also accounts for more than 60% of the country's export earnings.

Major crops are Dura (sorghum), wheat, sesame, millet, cotton, groundnut and water mellon. During the current year,1992 the country experienced bumper harvest of wheat, an increase of nearly 100% over 1991. As a result the country was left with substantial amount of surplus wheat. Cotton production also increased by over 25%.

According to available statistics, the 1991 output of wheat from irrigated areas was also a record 5,50,000 tons, following record plantings, compared with 409,000 tons in 1990. But because of substantial drop in the production of sorghum crop harvested in late 1990 (1,502,000 tons), aggregate cereal production in 1991 was still well below requirements.

The government is now in the process of putting into practice its radical agricultural policy change in expanding the production of food crops in irrigated areas at the expense of commercial crops including cotton, whose production is now being partly transferred to the rainfed areas. As per plan of the Ministry of Agriculture over 18.57 mn fd (7.30 mn ha) of food crops was planted in the 1991-92 season, of which 4.37 mn fd (1.70 mn ha) is in the irrigated sector and 14.2 mn acres in the rainfed areas. In order to encourage food production the previous policy of compulsory purchase of wheat and has been dropped. The government, however will continue to guarantee minimum prices to producers.

Other important crops are cotton, Dura and sugarcane. In the 1990-91 season 461,700 fd (194,000 ha) was planted to cotton and the production was estimated around 410,000 bales (of 237.6 kg. each). In 1991-92 season cotton area decreased to around 428,400 fd (180,000 ha) and the estimated production fell slightly to 400,000 bales. In 1990-91 crop season Dura (Sorghum) acreage fell from 3801,000 fd (1,597,058 ha) to 2,925,000 fd (1,228,900 ha) with a slight reduction in total out put from 1,536,000 tons to 1,502,000 tons. But both the figures are well below the bumper production of 4,425,000 ton obtained in 1988-89 crop season. Unlike wheat, Dura is mainly a rain fed crop and both the acreage and production is highly dependent on amount and distribution of rainfall.Sugar production in 1990-91 was estimated at 432,000 tons, nearly 11.5% increase over 1989-90. The country's total sugar consumption requirement is around 385,000 tons. Therefore, Sudan enjoyed self-sufficiency for the second consecutive year and the shortages may now be a thing of the past.

2.2 Irrigation Sub-sector

The importance of irrigated subsector in the Sudanese economy is well established. Presently the irrigation subsector commands approximately 1.80 m ha (18%) of the 10m ha of cropped land but contributes some 50% to the total production. The irrigation schemes of the country is shown in Fig. 1.

The first large-scale gravity irrigation system in Sudan was started in 1925 at Gezira, primarily to grow cotton as an export crop. There are now five major irrigation schemes namely: Gezira-Managil (0.90 mn ha), New Halfa (0.17 mn ha), Rahad (0.13 mn ha) and the Blue and White Nile Pump schemes covering (0.30 mn ha). During the decade, 1970-1980, the irrigated sub sector accounted for nearly 50% of the export earnings(Staff Appraisal Report, 1983).

Any further expansion of the irrigated agriculture will be extremely difficult and is constrained by the following two major factors:

1. Limited potential for further development of available surface water resources.

2. Difficulty in obtaining adequate financing for new projects.

Irrigated agriculture in Sudan is primarily dependent on the Nile waters. The Nile waters was divided between Sudan and Egypt in 1959 by the " Full Utilization of the Nile Waters agreement". As per agreement Sudan acquired 18.5 billion m^3 (milliard) of the average annual discharge of 84 billion m^3 measured at Aswan. Sudan has already developed over 80% of its share of 18.5 milliard.

Until early 1992 the GOS did not accept recommendations of international monetary agencies like the International monetary fund and the World Bank on certain structural adjustments and other policy reforms including devaluation of the Sudanese Pound. This created serious differences between the international monetary agencies and the GOS and as a result the IMF, in early 1991 was inclined to declare Sudan as "Non-cooperative country".

The GOS, however, in february 1992 devalued the currency from LS 12.5 to a US dollar to LS 90. At the same time the GOS also decided to ensure a more prominent role of the private sector in the economy including agriculture. These policy changes improved relation between the international lending agencies and the GOS and it is expected that in the very near future funding will be available for new projects especially in the irrigated subsector.

2.3 The Gezira Scheme

The Gezira scheme is the largest, oldest and the most important agricultural scheme in Sudan. It is also the largest farm in the world irrigated from the one source and operated under a single management. It constitutes 12% of the total cultivated area in the country and 50% of the irrigated sector. Gezira makes major contribution to national economy by producing 75% of the country's principal cash crop, cotton, 12% of sorghum (dura), 60% of ground nuts and 85% of wheat. It also accounts for about 50% of the total foreign exchange earnings (The Gezira Scheme- Past, Present and Future, Sudan Gezira Board, 1991-92).

2.31 Project Area: Located at the triangular area between the White and the Blue Nile rivers the Gezira irrigation scheme (Fig. 2), at the present time commands an area of about 0.9 million ha (2.1 million feddans). The scheme is divided roughly into two equal halves: the area served by the Gezira main canal and the Managil extension developed during the mid-sixties. The principal features of the scheme area are a level and nearly uniform topography , low percolation and water holding clay soils, centralized control of farming operations by the Sudan Gezira Board, almost uniform farm size distributed among 102,000 tenants and a prescribed cropping pattern of cotton, groundnut and sorghum in summer and wheat in winter. The most dominant feature of the Gezira plain, however, is the flatness of topography which has a slope of 5 cm/km northwards.

The Gezira scheme was initiated in the year 1911 as a pilot project with an area of 250 fd (105 ha) for growing cotton. Successful growing of cotton led to expansion of the area over the subsequent years. Around the same time it was also decided to construct a dam at Sennar on Blue Nile for major expansion of the project. With the completion of the Sennar dam in 1926, 300,000 fd (1,26,050 ha) were brought under irrigation. With subsequent extensions carried out the command area increased steadily and by late 1950's the nearly 1 million fd (0.42 million ha) were brought under irrigation.

Further major expansion of the project was started in the year 1957 to bring another 0.80 million fd (0.34 million ha) under irrigation and with further small extensions the irrigated area was increased to 0.90 mn fd (0.38 mn ha). This new area is known as Managil extension.

From mid-seventies, after nearly 50 years of operation the Gezira scheme started experiencing continuous decline in agricultural production. This resulted in reduction of export earnings by about 50% during the 1979-81 period compared with 1972-74(Staff Appraisal Report, World Bank, 1983). A number of factors have contributed to such decline. The important ones are:

1. Maintenance of the existing irrigation schemes were neglected in favor of new construction.

2. Crop diversification and intensification carried out in the early seventies was not matched by required improvement in the delivery of inputs and management.

3. The government policy to held producer prices of cotton low with the twin objectives of financing new investments and maximize short term revenue, cotton became an economically unattractive crop and as a result farmers devoted more attention to other crops. A decline of cotton prices in the international market around the same time together with reduced import led to shortages of foreign exchange and the agricultural corporations were unable to cover maintenance costs, replace equipment, buy spare parts and inputs.

4. The flight of skilled manpower as well as young unskilled tenants from the project area to the neighboring oil producing countries further compounded the problem.

Recognizing the severity of the problem the Government of Sudan requested World Bank assistance for financing the rehabilitation of the Gezira irrigation scheme. The bank responded favorably and a group of consultants were engaged with financial assistance from Kuwait Fund and IDA for the preparation of the project.The project was appraised by an IDA appraisal mission fielded in May/June 1982 and a follow up mission in october the same year. Implementation of the project started in the year 1983. The principal objectives of the $300 million rehabilitation project are(Gezira Rehabilitation Project: Staff Appraisal Report. May 1983):

1. Rehabilitation of the irrigation and drainage systems and infrastructures.

2. Better land preparation and improved input delivery systems, strengthened management and appropriate producer incentives to increase production and productivity of the principal crops grown in the scheme.

3. Restore financial solvency of SGB through adoption and enforcement of cost recovery policies. This in turn will result in a substantial increase in the government's foreign exchange earnings and revenues, largely from increased cotton exports.

4. Undertake studies and trials for upgrading technology and restructuring institutional arrangements thus setting the stage for further modernization of the scheme.

The Staff Appraisal Report recognized that on-farm water management throughout the scheme was very poor and recommended the establishment of a Water Management Advisory Unit(WMAU) within the SGB for maximizing benefits from irrigation. It also recommended 24-man months of technical assistance to help establish the WMAU. Based on this the Rehabilitation Project Management Unit(RPMU) entered into an agreement with International Irrigation Management Institute(IIMI) for providing technical assistance. As per agreement IIMI, in august, 1990, assigned a Senior Water Management Advisor (SWMA) to assist SGB with the establishment of the WMAU.

2.32 Management and Operation of the Scheme: The Gezira scheme is primarily operated by two ministries- the Ministry of Agriculture (MOA) and the Ministry of Irrigation and Water Resources (MOI) and the farmers (tenants). The responsibilities of the MOI include water storage, diversion and distribution upto the "Minor" and repair and maintenance of the whole system including the "Minors". The MOA through the SGB utilizes the water for crop production purposes. Operation of "Minors" and "Abu Ashireens" and on-farm water management are also the responsibility of the SGB. The Government has, however, has decided to make the MOI responsible for distribution of water upto the "Abu Ashireen" level and the decision has already been implemented.

For operation and management of the scheme, the MOI is organized into two Directorates- one for the Gezira and the other for the Managil extension. The Directorates are further subdivided into seven Divisions, 23 subdivisions and 56 sections. Each Division is headed by a Divisional Engineer, Subdivision by an Assistant Divisional Engineer (ADE) and the Section by an Assistant Engineer. Each Subdivision commands, on an average, an area of around 90,000 fd (37,800 ha). At the Subdivision level the ADE is assisted by a Senior Assistant Engineer, three Assistant Engineers each heading a Section several other technical and non-technical support staff. The total number of MOI staff directly involved in the management of the scheme is around 3,200. Of these 3,111 or 97% is non-technical support staff including over 2800 skilled laborers.
It should be noted here that two semi-autonomous bodies, the Earth Moving Corporation (EMC) and the Irrigation Works Corporation (IWC) are responsible for the maintenance of canals, drains, roads and hydraulic structures. These corporations work as contractors to the MOI for maintenance work of the Gezira scheme.

The ADE is responsible for control, monitoring and supply of water as per indent submitted by the SGB. Maintenance work is generally carried out under the direction of the Assistant Engineers and Technical Assistants.

The Sudan Gezira board, a semi-autonomous corporation, is responsible for the management of the agricultural production system in the scheme. In addition to the operation of the "Minors" and "Abu Ashreens" and on-farm water management, the Board is also responsible land preparation, crop planting (cotton and Wheat), procurement, distribution and application of fertilizer, application of pesticide, seed multiplication and distribution, harvesting (wheat only) and ginning of cotton. It is also responsible for the maintenance of infrastructures including the ginneries and the 1050 km long light railway network used for transporting agricultural produce (especially cotton) and agricultural inputs, mostly fertilizer.

For agricultural production purpose the whole scheme is divided into Gezira and Managil extension each headed by a Deputy Director/Manager responsible to the Director/Manager of Agriculture who is located at the Gezira Board Head Quarters in Barakat. The scheme is further subdivided into 14 Groups, seven each in Gezira and Managil and 107 Blocks. Each Group consists of 6 to 9 Blocks and is headed by a Group Inspector assisted by a Assistant Group Inspector. The block is supervised by the Block Inspector who is helped by several Inspectors (3 to 4). One of them acts as the deputy to the Block Inspector and is designated as Second Inspector. The responsibility of the Block Inspector includes supervision of different agricultural operations and preparation and submission of water indent to the ADE of MOI.

The Board of Directors holds full responsibility to determine and execute policies and undertakings of the scheme within the framework of policy directives issued by the Government. The Managing Director is the chief executive and works on behalf of the Board. The Board of Directors consists of a Chairman (the Minister of Agriculture and Natural Resources) and 23 members representing the Gezira Board, the relevant Organizations (Ministries and Corporations), Tenants, Employees etc.

In the discharge of responsibilities the Managing Director is assisted by a Deputy Managing Director and four main executive Directorates- Agriculture, Engineering, Finance and Administrative Affairs each headed by a Director. Each Directorate is sub-divided into specialized departments. The newly established Water Management unit is under the administrative control of the Director of Agriculture. In addition, there are other departments that are directly responsible to the M.D. These include Department of Information and Public Relations, Planning and Socio-economic Research Unit, Training Unit etc.

The SGB employs nearly 2800 permanent staff and over 100,000 permanent laborers. In addition around 600,000 seasonal staff and laborers are also employed of which 500,000 are employed for picking cotton.

The third component of the management system is the tenant-farmers. Farmers do not own their land and hence are tenants. The command area of the scheme is divided into 102,000 tenancies of 40 or 20 fd (16.8 or 8.4 ha) divided into four equal rotation plots called "Hawashas". Except for cotton and wheat, tenants are responsible for all agricultural operations for all the crops grown in the scheme. These operations, however, are closely monitored by the SGB inspectors to ensure timeliness and quality. For cotton and wheat which can be called "state crops" tenants supply labor (family or hired), tend the crops, apply irrigation water, pick seed cotton and transport them to the collection centers. Production of wheat is fully mechanized and except for a small amount for family consumption the entire harvest is taken by the government right from the field. From 1991-92 season, however, the government has started to deregulate the cultivation of wheat and by the next season it will be tenants own crop.

Over the years, like the scheme itself tenants crop husbandry has also deteriorated. Increased cost of production, reduced net return, increased dependence on hired local and migrant labor (upto 85%), reluctance of the new educated generation to pursue farming as a career, migration of skilled labor force to neighboring oil producing countries etc. have contributed to such decline. It is now estimated that over 50% of the tenants are no longer involved in farming and the ones who are still around have a second job (Plusquellec, 1990).

2.33 The Climate: Most of the large irrigation schemes of the country including the Gezira scheme are located in central part of the country between 100 mm and 500 mm isohytes. The climate of the Gezira scheme area is semi-arid characterized by low average annual rainfall and occasional cycles of drought of moderate to severe intensity. The short rainy season spans from july to september and accounts for 85% of the annual rainfall. The mean annual rainfall varies from around 400 mm in the south near Sennar to about 200 mm in the north near Khartoum and fluctuates considerably from year to year. There are two other seasons that are quite distinct: a cool dry winter from november to february and a hot summer from april to june. March and october are transitional months. Mean maximum and minimum temperatures are 33° C and 41° C and 14° C and 25° C in january and june respectively. The relative humidity varies from 20% in dry months to 70% in the wet months. In the month of december the minimum temperature may go down to less than 10°C while the maximum may exceed 46°C in april/may. The E_o (Penman) at Wad Medani varies from 5.5 mm per day in december to 9 mm per day in june. The scheme area experiences moderate to strong wind-run through out the year with an average 190 km/day (2.2 m/sec) in october to 390 km/day (4.5 m/sec) in june/july. As the project area is surrounded by dry uncropped lands such strong winds in hot months transport advective energy and can contribute to higher evapo- transpiration. Weather related data is presented in Table 1.

Under the technical assistance the Senior Water Management Advisor's assignment covered two crop seasons, 1990-91 and 1991-92. Both the seasons experienced near extreme weather conditions (Table 2). The 1990-91 season received less than average rainfall, higher average temperatures and high average wind-runs during the rainy season which is the major crop growing season. The wheat season (Nov-April) was characterized by hot spells during the crop establishment and early vegetative growth stage and during the reproductive stage. This period also experienced severe water shortages due to low rainfall season and as result some of the tail end ares could not be supplied with irrigation and a total of about 40,000 fd (17,000 ha) of wheat was completely lost.

In contrast, the 1991-92 crop season was extremely favorable both water and weatherwise. A good rainfall in the project area as well as in the catchment of the Blue Nile coupled with the reduction in area of cotton, wheat and groundnut, the of the crop season received adequate water except in some isolated pockets. This coupled with better crop husbandry and over all management yield of major crops, especially of cotton and wheat increased substantially over those obtained in 1990-91 season. The wheat growing season, climatewise, was near perfect.

2.34 Soils: In the Gezira scheme the soil order is described as vertisol series Suleimi containing 50-60 percent clay. Organic matter content is low (0.4%) and showing signs of further decline. Available water is 23% (by volume) with the field capacity(FC) at around 45% and the permanent wilting point(PWP) at 22%. Between field capacity and PWP the soil can hold between 180-240 mm of water per meter depth of soil. Bulk density of the soil is 1.22 gm/cm^3. Permeability is very low and the basic infiltration rate ranges from 3-5 mm/hr. The exchangeable sodium (ESP) ranges from 5.6 to 25 percent and the electric conductivity varies from 0.70 to 4.4 mmohs/cm.

The soils are fairly uniform , cracks severely when dry, self-mulching and have loose granular structure. In certain areas of the scheme the top soil is underlain by an impermeable clay layer, hard pan, at depths ranging from 15 to 25 cm. This impedes root development, reduces infiltration rate as well as soil water reservoir. It also prevents ground water buildup thus reducing chances of water logging in the long run.

Despite over 65 years of irrigation soils have not developed any serious problems. Though there are some saline pockets the scheme is generally free from salinity. Even in pockets with visible salinity effect on crop yield has so far been minimal.

2.35 Water Storage, Diversion and Distribution: Except for some pocket areas where irrigation water is pumped the Gezira scheme is principally fed by gravity. The Sennar dam regulates the flow of the Blue Nile and feeds the Gezira scheme. The river is well known for its marked seasonal and annual variation in flow. Its average annual discharge has been estimated at 50 billion m^3 and contributes about 68% to the yield of the combined flow of Blue and White Nile. The seasonal variation in discharge ranges from over 900 million m^3 per day at peak of high flood (in august) to 100 million m^3 per day in the lean period (march/april) of a low water year. Water demand in the scheme is maximum during july to november. During this period 20 to 30 million m^3 per day is supplied to the system. Lowest water demand occurs between march and may when 1.5 to 3 million m^3 per day is diverted which is primarily used for domestic purpose (Table.3). When constructed the Sennar dam had storage capacity of just over 900 million m^3 which by 1986 was reduced by 300 million m^3 due largely to siltation.

To serve as a back up storage for Sennar dam, Roseires dam was constructed on the Blue Nile in the year 1966 approximately 250 km. upstream of Sennar. The total storage capacity of the reservoir was 3,000 million m^3 and live storage was 2,400 million m^3. The dam provides water during the low flow months and generates hydropower. The storage capacity of the Roseires dam has, over the years, reduced significantly and presently it can barely meet the irrigation demand.

The distribution system of the Gezira scheme includes the following:

1. The main, branch and major canals: Two main canals have total length of 260 km and a combined capacity of 354 m^3/sec near the headwork. The Gezira main canal and the Managil main canal has conveyance capacity of 168 m^3/sec and 186 m^3 respectively which reduces to 10 m^3/sec at the tail end. There are 11 branch canals with carrying capacity ranging from 25 to 120 m^3/sec depending on the service area. Major canals numbers 107 with capacities ranging from 1.5 to 15 m^3/sec depending on the command area.

The main, branch and main canals are carrier canals aligned on ridges and elevated lands so as to take maximum advantage for the gravity flow. These canals flow continuously day and night throughout the growing season.

3. Minor Canals: The minor canals are a unique feature of the Gezira irrigation system. There are 1,498 minor canals with carrying capacity ranging from 0.5 to 1.5 m^3/sec. The minor canals generally take off from the majors though a few draw directly from main or branch canals. One major may feed a substantial number of minors, often on both sides, but mostly on one side only. The standard distance between two successive minors is 1,420 meters.

The minor canals are designed to ensure full supply level between 20 cm and 40 cm above the adjacent land , by means of regulators at required intervals, each consisting of a sluice gate and a steel pipe embedded in earthen dike across the channel, throughout their lengths. The minors have a duel function of both conveyance and storage, conveying water during the day time and storing at night. They are, therefore, over dimensioned in relation to their carrying capacity to act as night storage reservoirs. The dimension of the cross section vary from a bed width of 4 to 6 meters and a depth of 1.30 to 0.80 meters towards the down stream. Though the minors were originally designed as regime channels, the night storage concept was introduced in the in mid 1920's as the tenants were opposed to night irrigation.

Like most of the other canals in the system the length of the minor canals also varies according to their service area. Some of them are over 20 km long. Minor canals are also divided into reaches of 1 to 4 km depending on the slope of the terrain. At every reach a cross regulator has been provided consisting of a over flow weir and a steel sluice gate. The crest of the weir is set to a calculated height (16 to 20 cm) above the normal full supply level at that point. By night both field outlet pipes (FOP) and regulator sluices are closed completely and the discharge entering the canal head raises the level in the first reach to some 30 cm above the full supply level. At this height the discharge spills over the weir into the next reach thus filling up the canal reach after reach to the desired level. The field outlet pipes are opened in the morning to draw off the stored water while at the same time regulator sluices are opened in succession from the tail upwards.

4. Water courses i.e "Abu Ashreens": The "Abu Ashreens" are laid out at a standard distance of 292 meters which includes 12 meters for the channel and the inspection road. Each "Abu Ashreen" is designed to serve a standard rectangular unit of 38 ha (90 fd) measuring 1400 m

GROUP AND BLOCK DIVISION

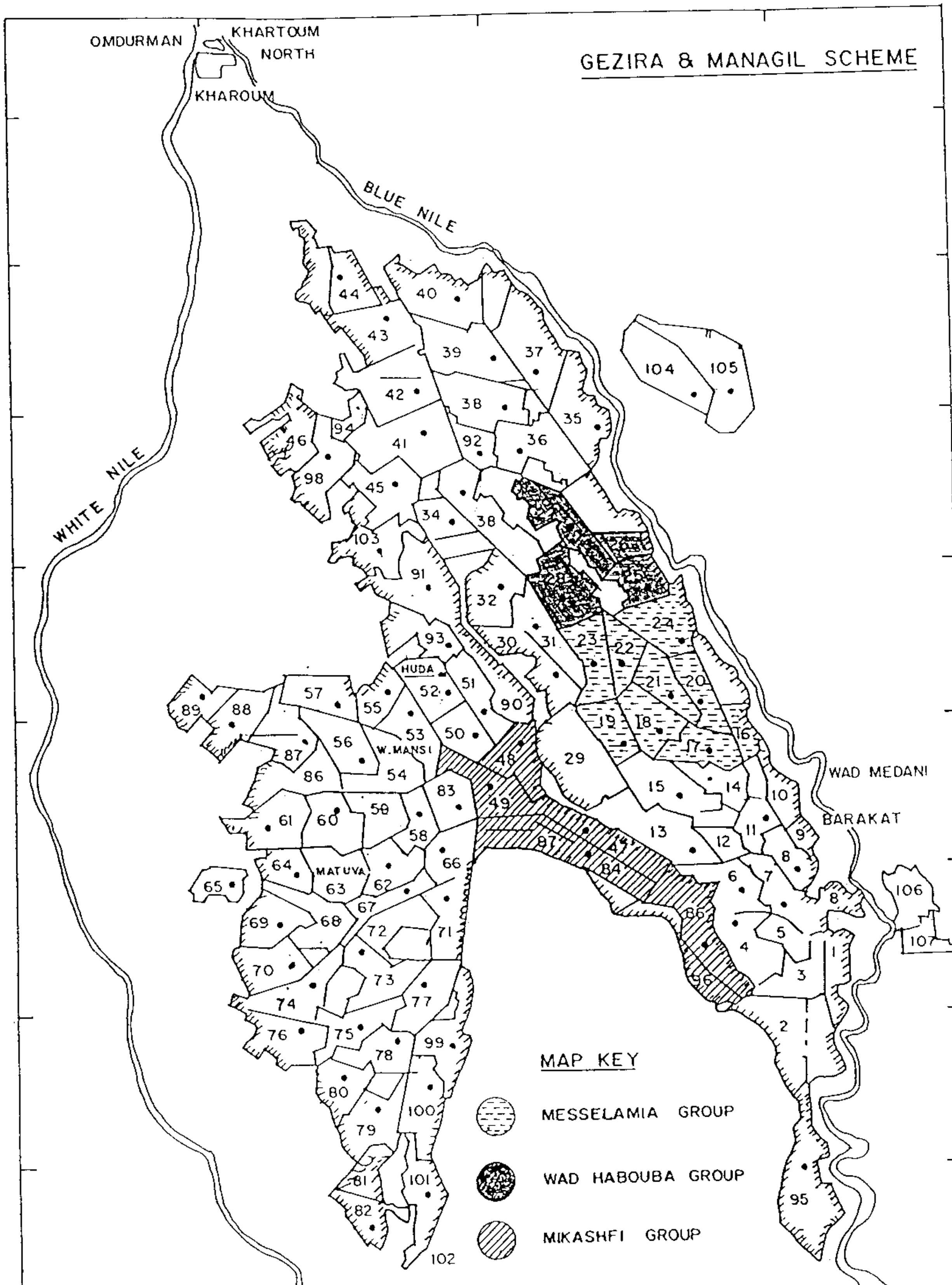
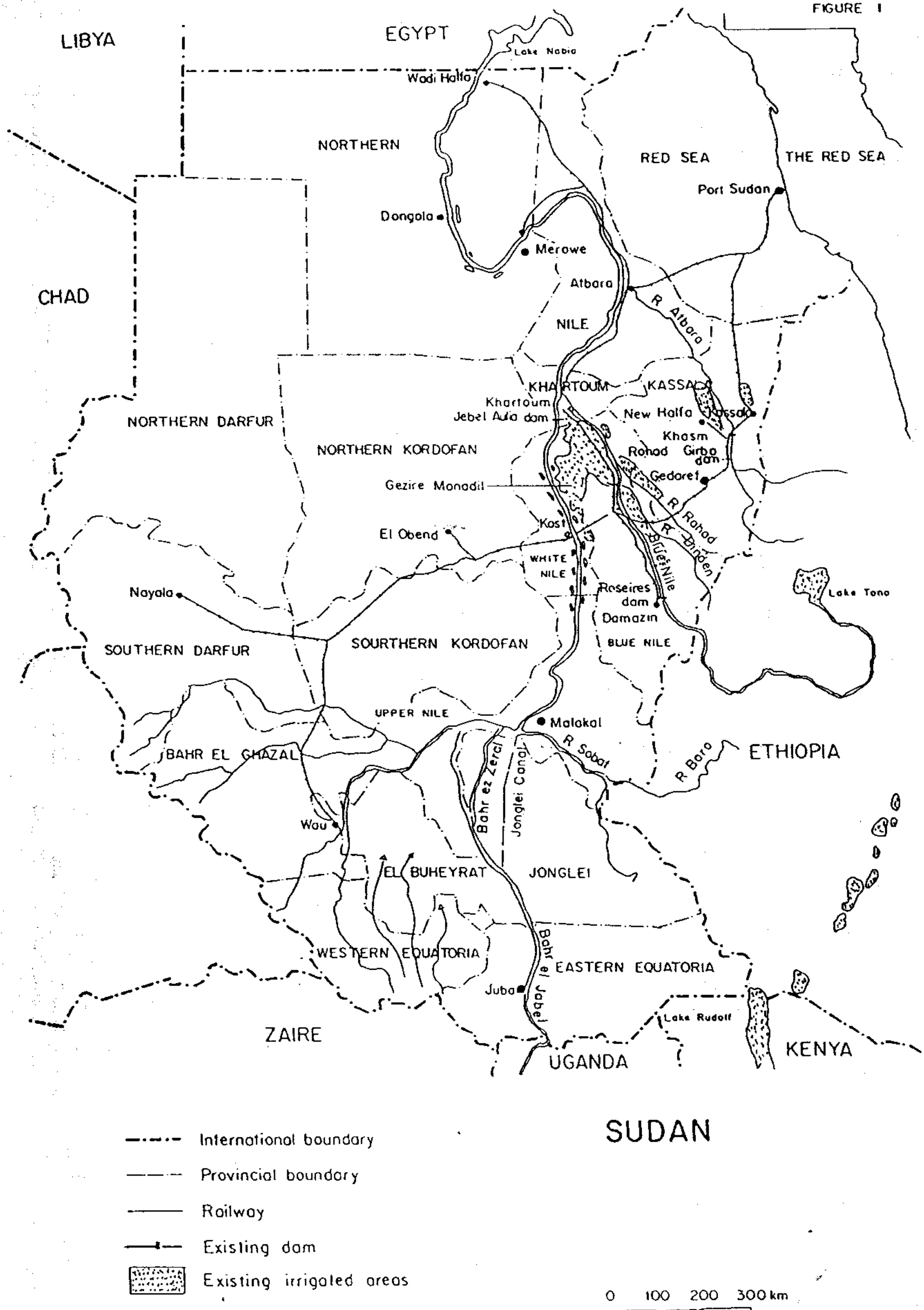
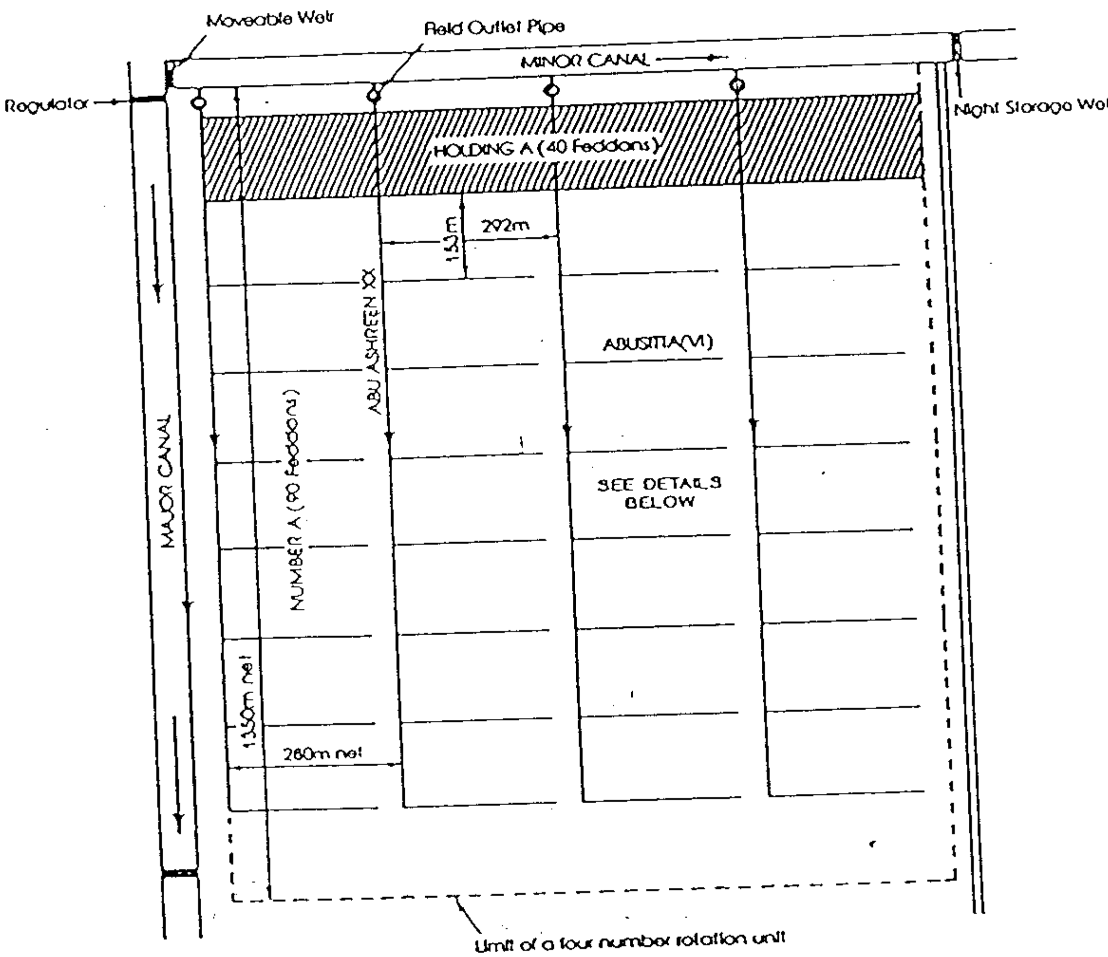


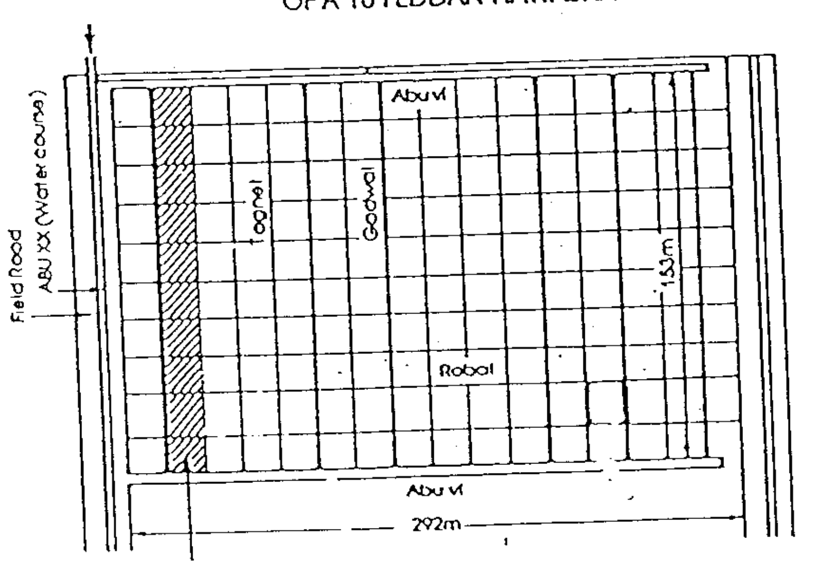
FIGURE 1


LIBYA
EGYPT
Lake Nubia
Wadi Halfa
NORTHERN
RED SEA
THE RED SEA
Port Sudan
Dongola
Merowe
CHAD
Atbara
NILE
R. Atbara
KHARTOUM
KASSALA
Khartoum
Jebel Aulia dam
New Halfa
Kassala
NORTHERN DARFUR
NORTHERN KORDOFAN
Khasm
Rahad
Girba dam
Gedaref
Gezira Managil
R. Rahad
Kosti
R. Dinder
El Obeid
WHITE NILE
Blue Nile
Nayala
Roseires dam
Damazin
Lake Tana
SOUTHERN DARFUR
SOURTHERN KORDOFAN
BLUE NILE
UPPER NILE
Malakal
R. Sobat
ETHIOPIA
BAHR EL GHAZAL
R. Baro
Bahr ez Zeraf
Jonglei Canal
Wau
EL BUHEYRAT
JONGLEI
Bahr el Jabel
WESTERN EQUATORIA
EASTERN EQUATORIA
Juba
Lake Rudolf
ZAIRE
UGANDA
KENYA
SUDAN
International boundary
Provincial boundary
Railway
Existing dam
Existing irrigated areas
0 100 200 300 km

SUDAN
GEZIRA IRRIGATION SCHEDULE
Typical Field Layout



ORIGINAL DETAILED FIELD LAYOUT OF A 10 FEDDAN HAWASHA



SOURCE:World Bank Tech. Paper No.120

FIG 4: ORGANIGRAM OF PROPOSED WMAU

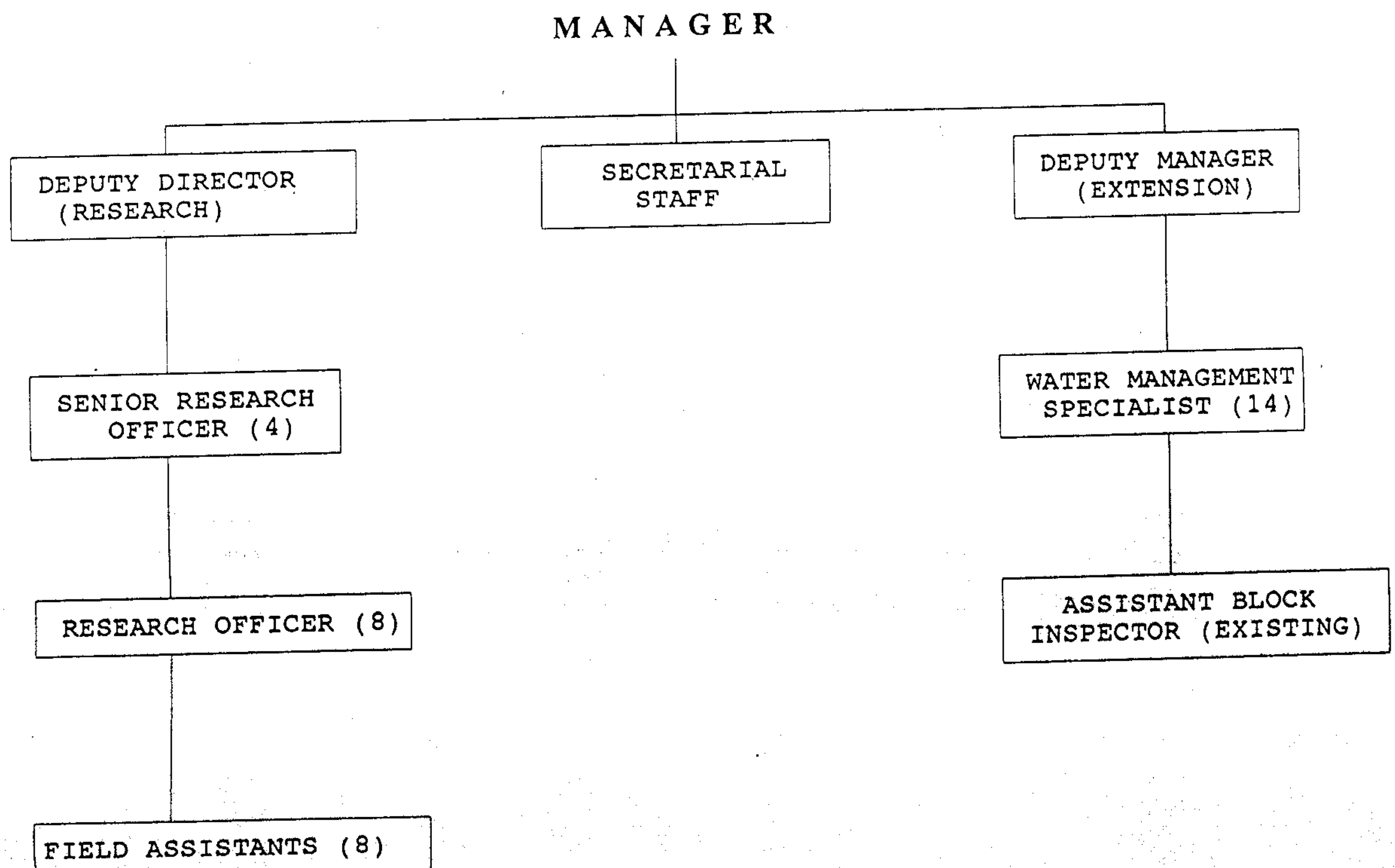
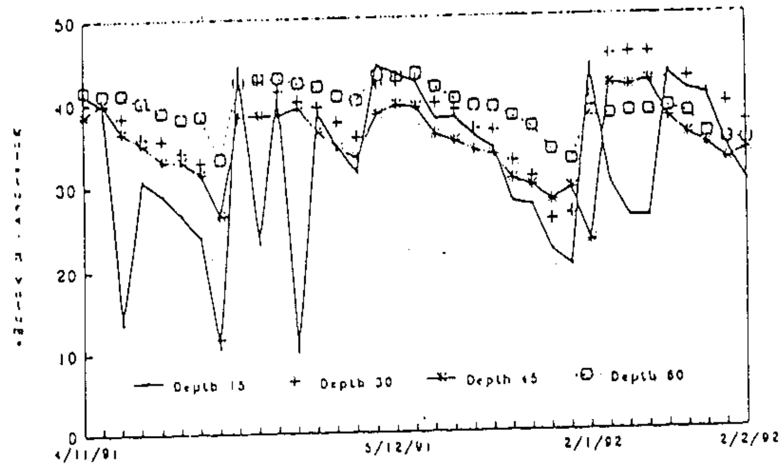
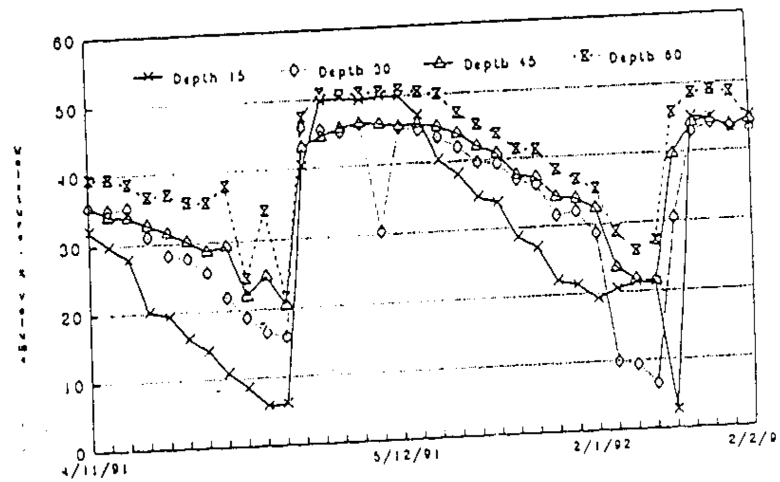


Figure 5

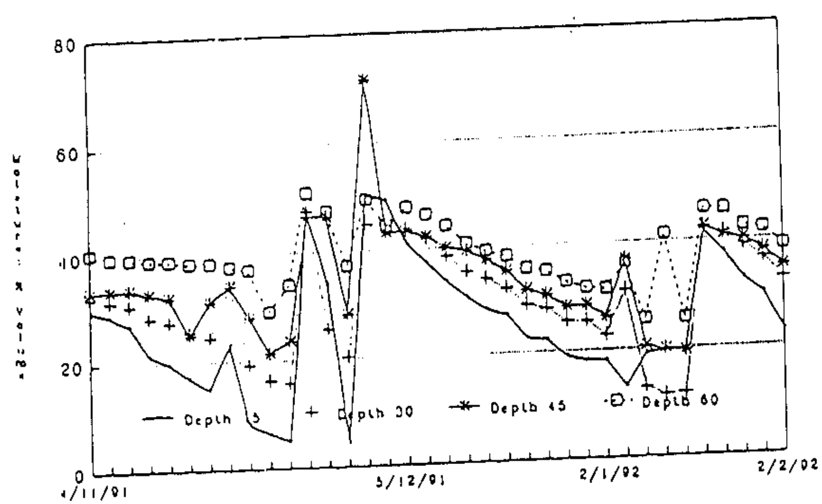
Soil- Water Depletion Profile
Minor: Ibrahim, Number 7.
Hawasha 1, Location 1, Crop: Cotton



Soil- Water Depletion Profile
Minor: Ibrahim, Number 7.
Hawasha 1, Location 2, Crop: Cotton



Minor: Ibrahim, Number 7.
Hawasha 1, Location 3, Crop: Cotton



Soil- Water Depletion Profile
Minor: Ibrahim, Number 7.
Hawasha 1, Location 4, Crop: Cotton

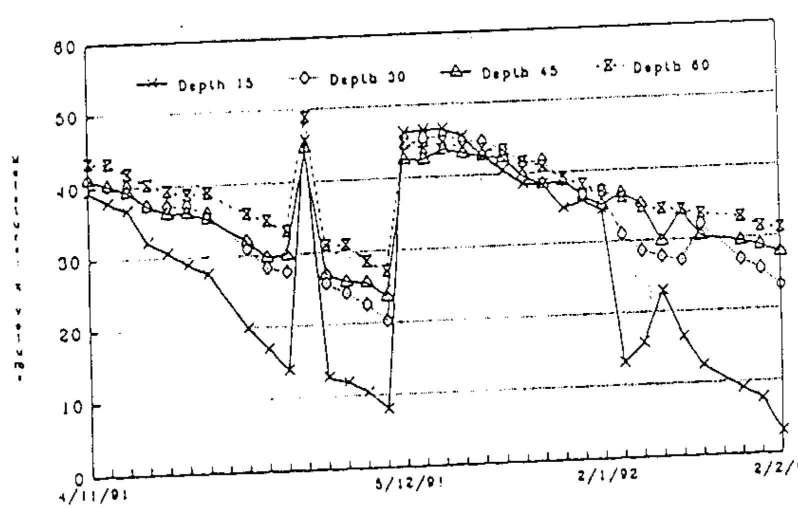
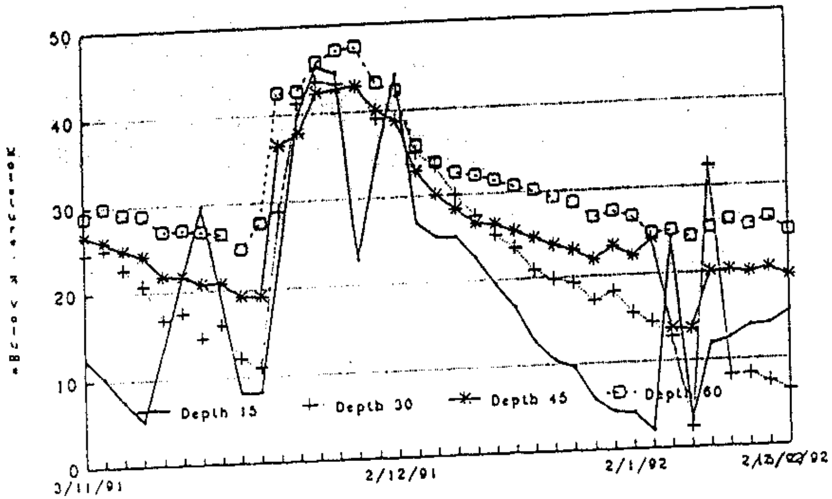
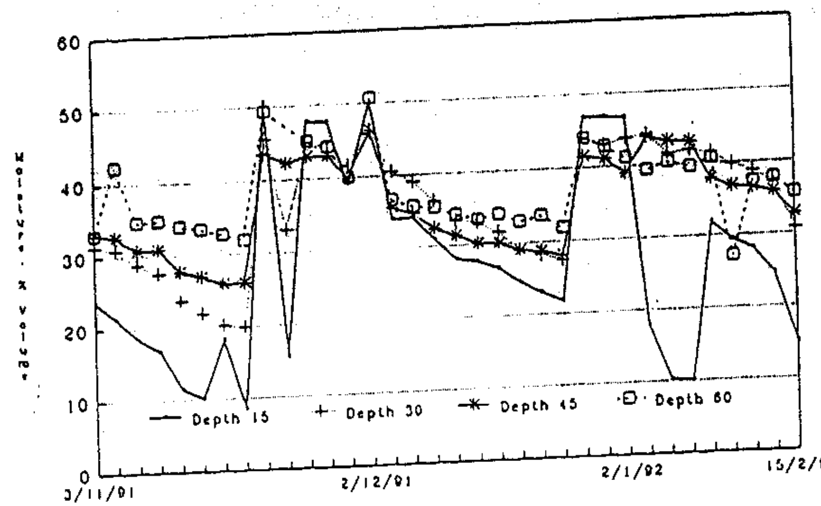


Figure 5 (cont)

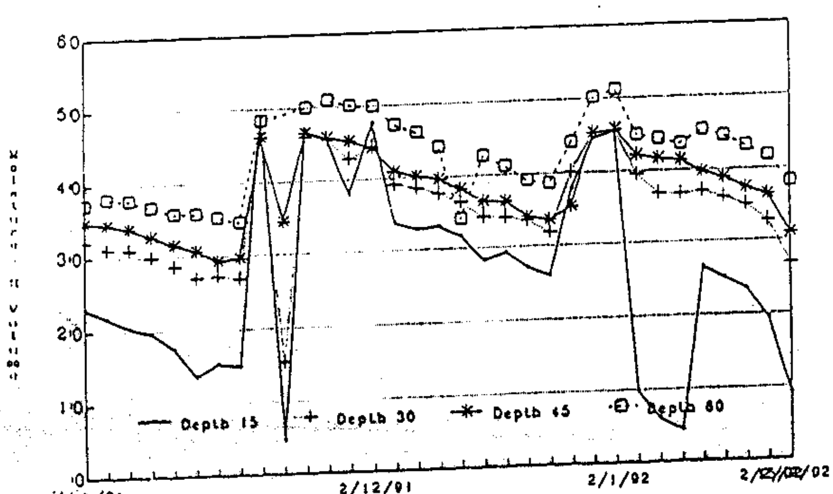
Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasba 1, Location 1, Crop: Cotton



Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasba 1, Location 2, Crop: Cotton



Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasba 1, Location 3, Crop: Cotton



Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasba 1, Location 4, Crop: Cotton

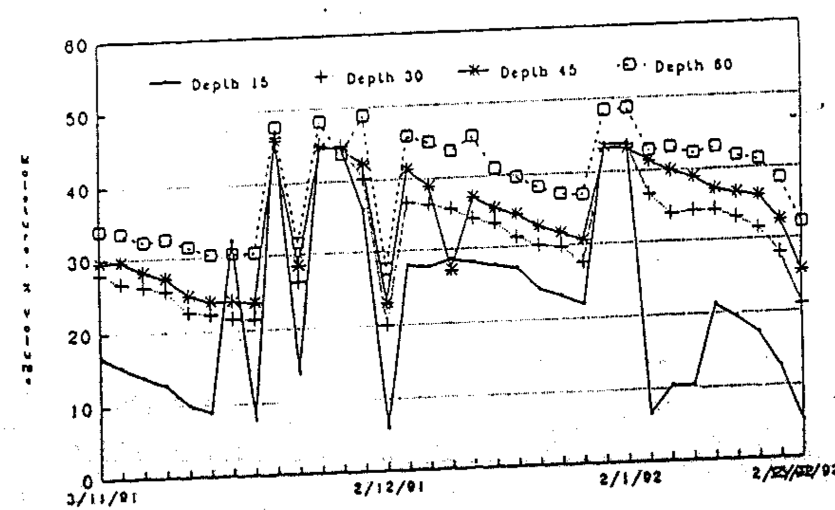
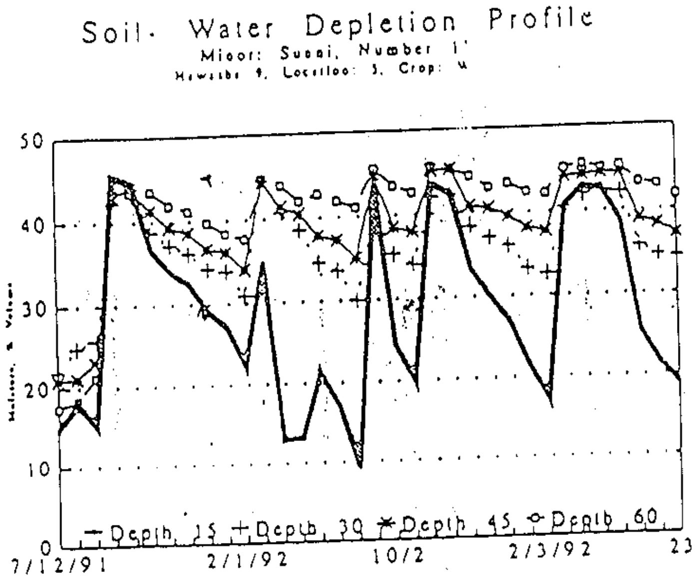
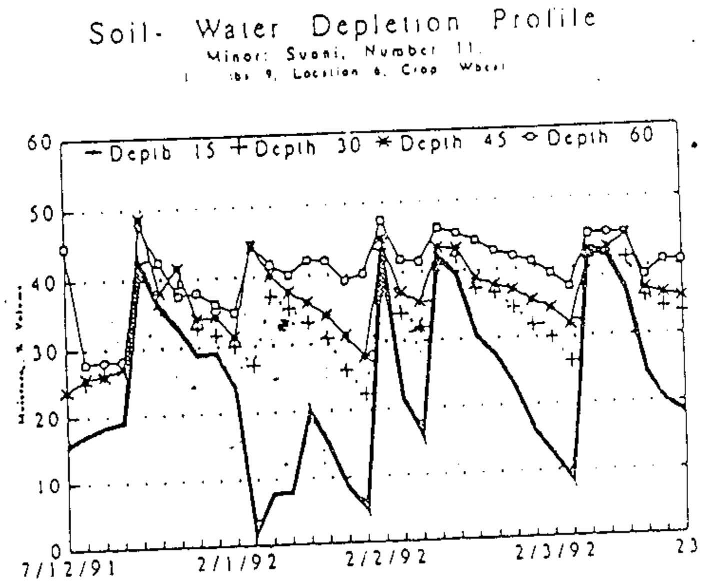


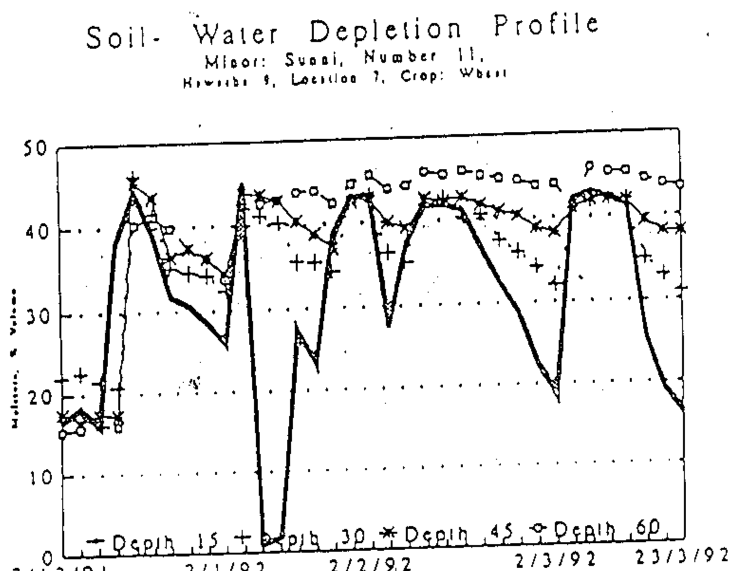
Figure 6



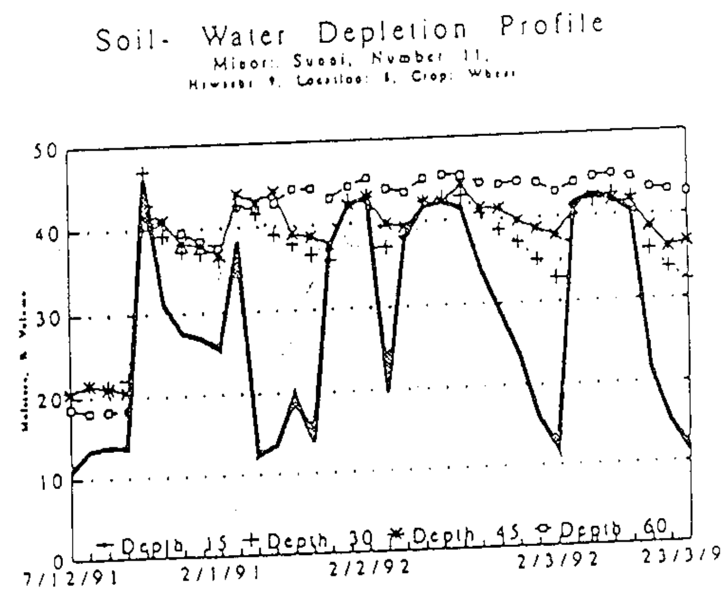
Soil- Water Depletion Profile
Minor: Suani, Number 1
50
40
30
20
10
0
7/12/91
2/1/92
10/2
2/3/92
23
Depth 15 + Depth 30 * Depth 45 ○ Depth 60



Soil- Water Depletion Profile
Minor: Suani, Number 11,
Location 6, Crop: Wheat
60
50
40
30
20
10
0
Depth 15 + Depth 30 * Depth 45 ○ Depth 60
7/12/91
2/1/92
2/2/92
2/3/92
23

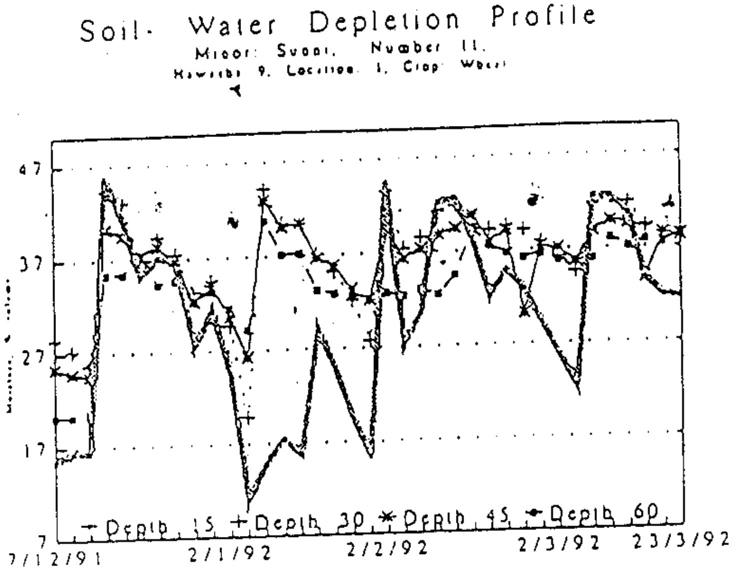


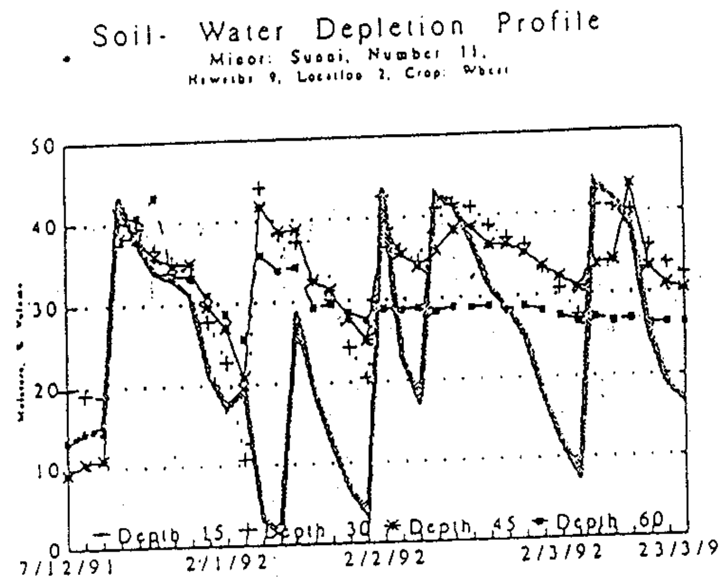
Soil- Water Depletion Profile
Minor: Suani, Number 11,
Hawasha 9, Location 7, Crop: Wheat
50
40
30
20
10
0
Depth 15 + Depth 30 * Depth 45 ○ Depth 60
7/12/91
2/1/92
2/2/92
2/3/92
23/3/92

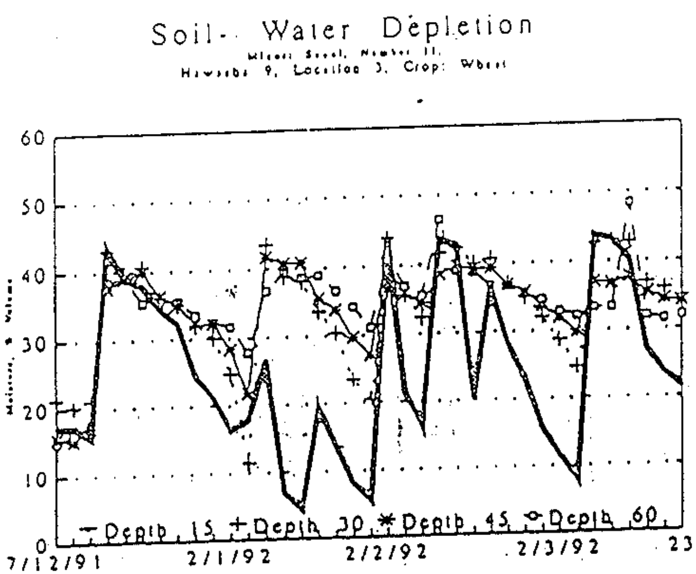


Soil- Water Depletion Profile
Minor: Suani, Number 11,
Hawasha 9, Location 8, Crop: Wheat
50
40
30
20
10
0
Depth 15 + Depth 30 * Depth 45 ○ Depth 60
7/12/91
2/1/91
2/2/92
2/3/92
23/3/92

Figure 6 (contd)







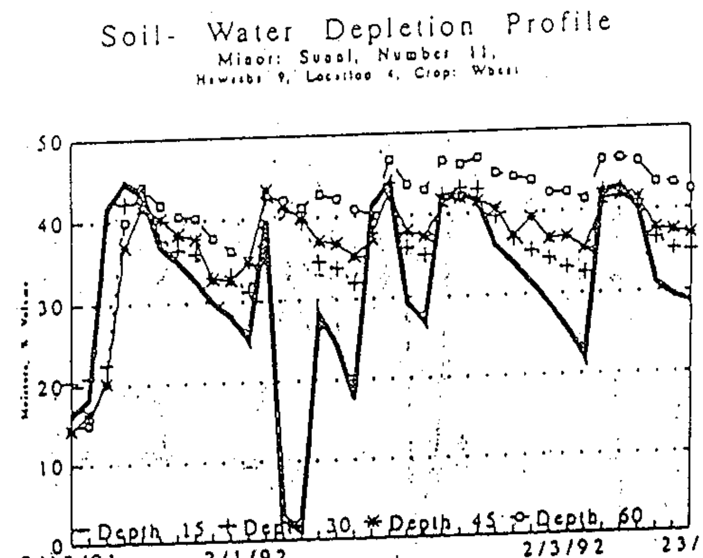
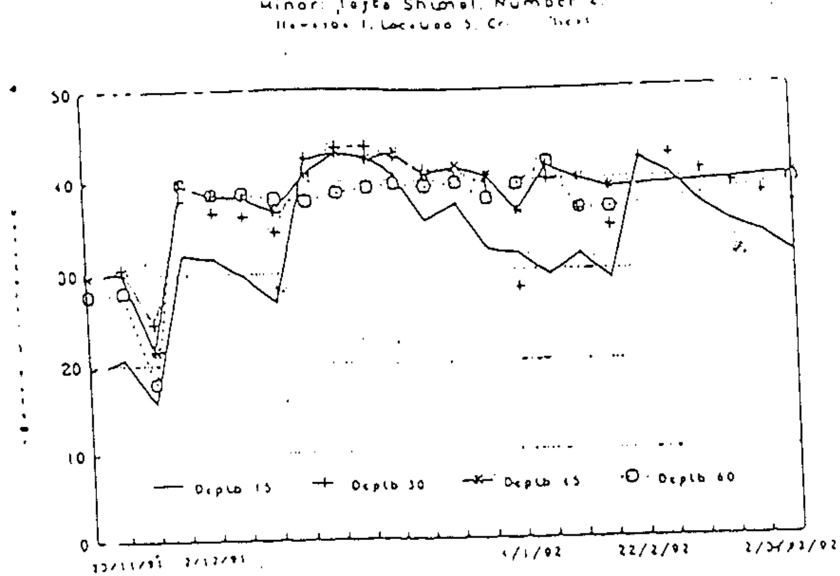
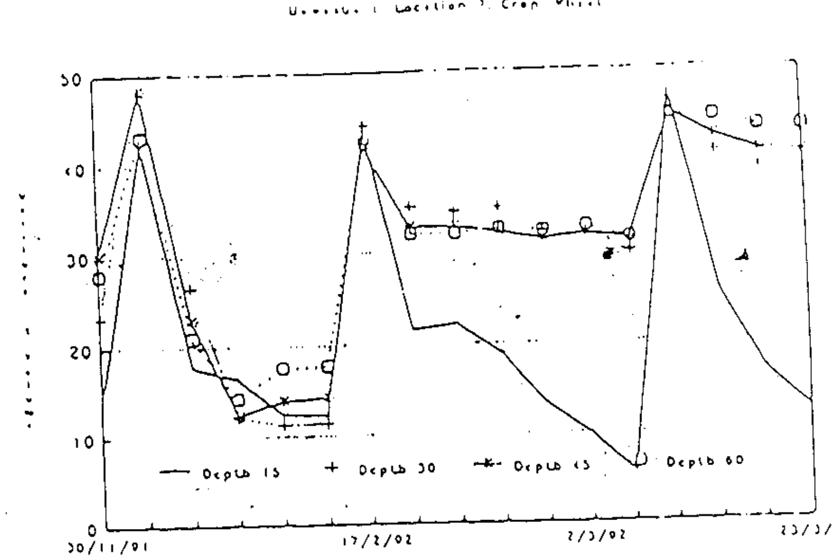


Figure 6 (contd)

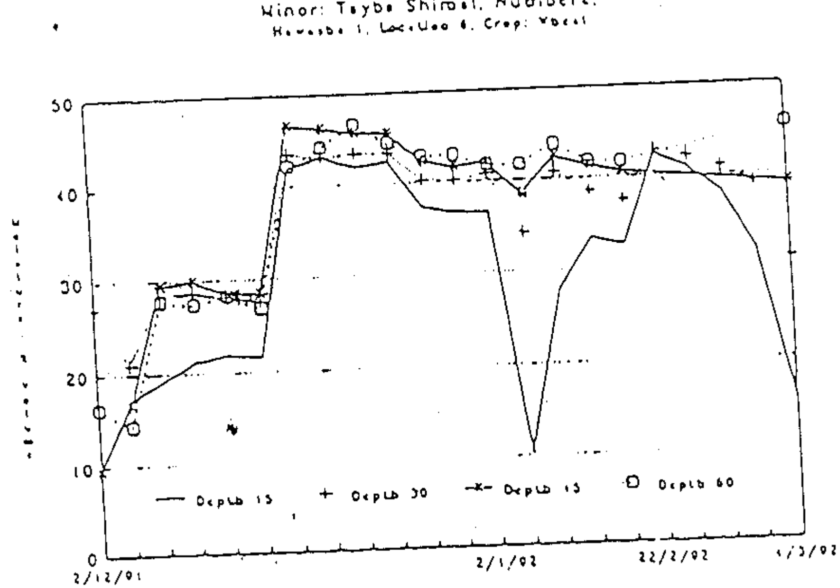
Soil- Water Depletion Profile



Soil- Water Depletion Profile



Soil- water Depletion Profile



Soil- Water Depletion Profile

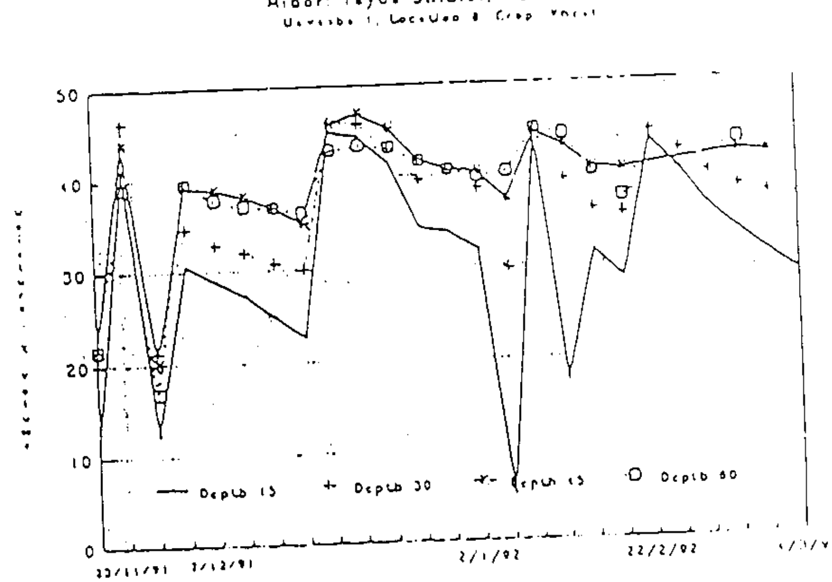
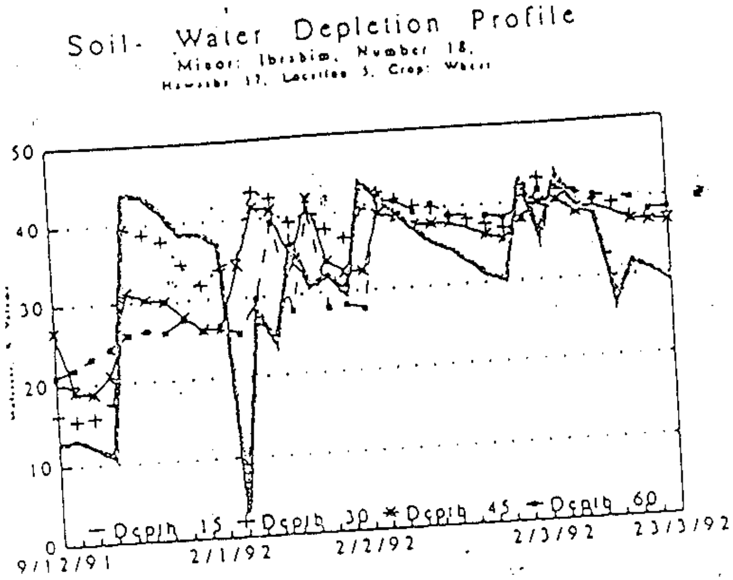
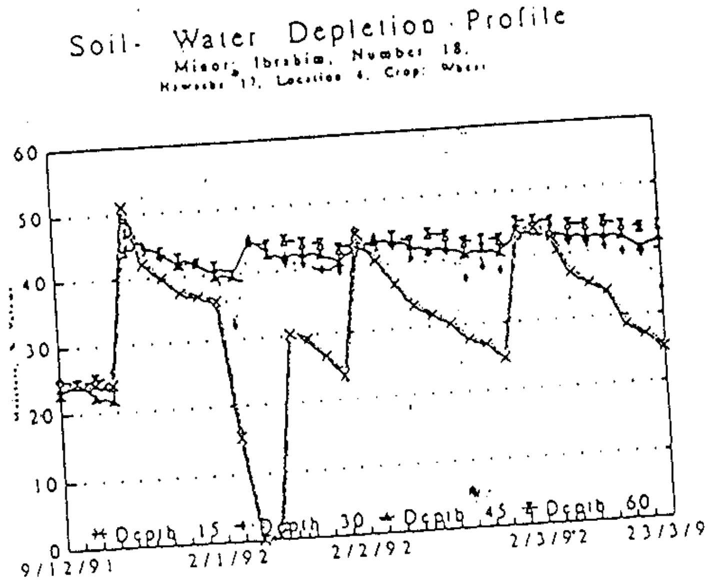
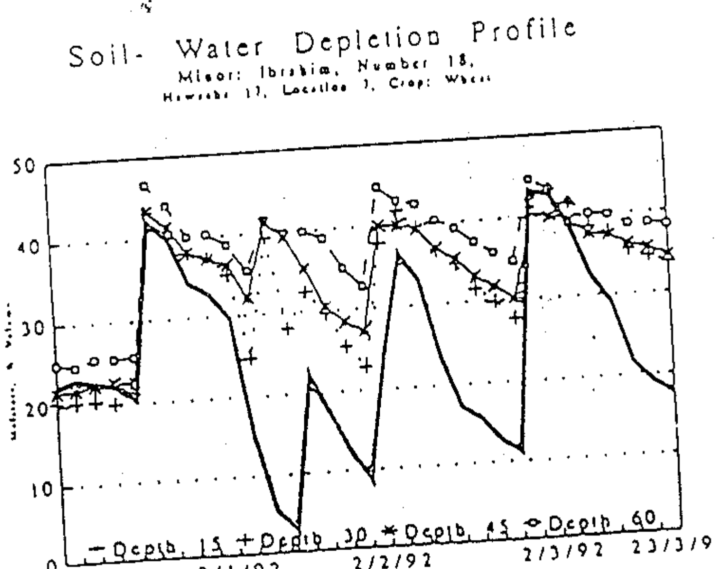


Figure 6 (contd)







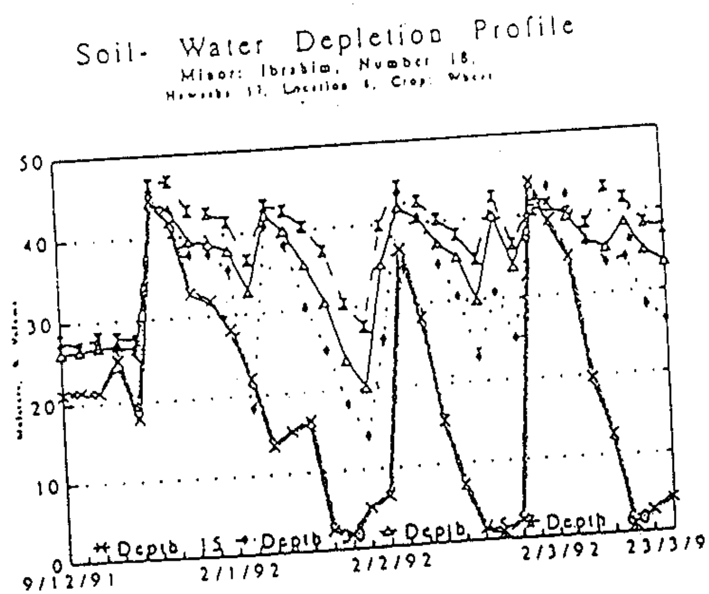
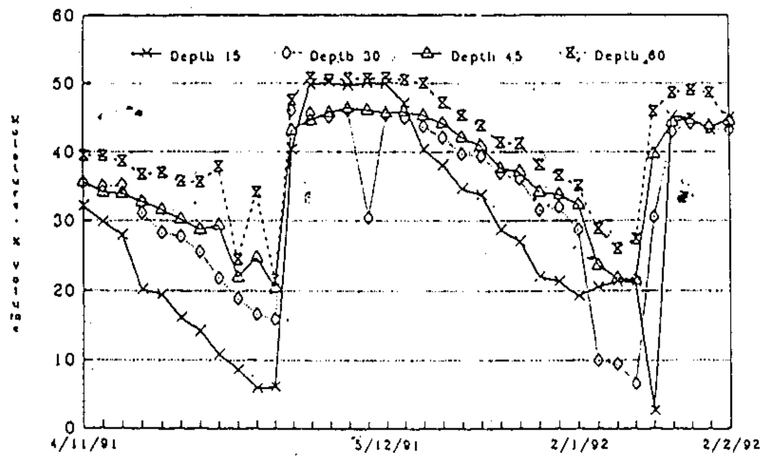
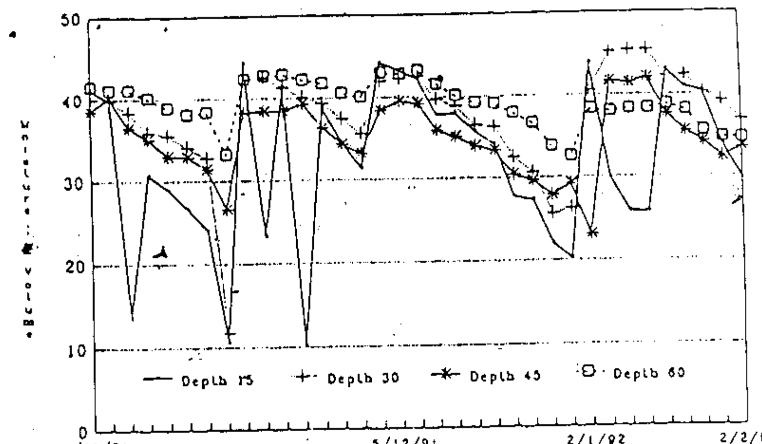


Figure 6 (contd)

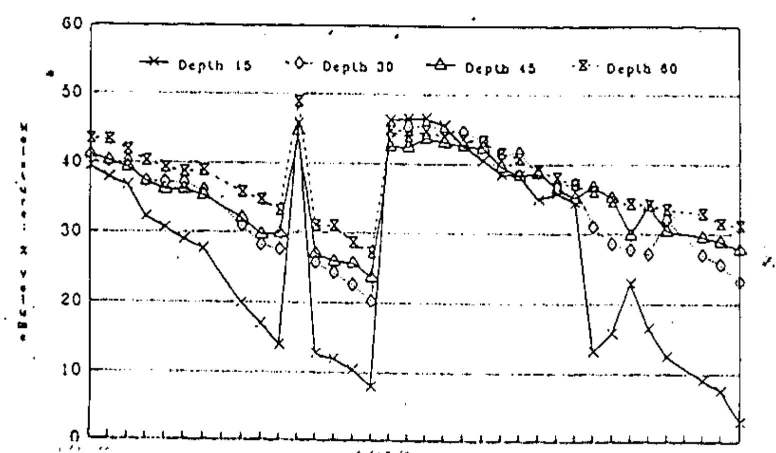
Soil- Water Depletion Profile
Minor: Ibrahim, Number 7,
Hawasha 1, Location 2, Crop: Cotton



Soil- Water Depletion Profile
Minor: Ibrahim, Number 7,
Hawasha 1, Location 1, Crop: Cotton



Soil- Water Depletion Profile
Minor: Ibrahim, Number 7,
Hawasha 1, Location 4, Crop: Cotton



Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasha 1 Location 2, Crop: Cotton

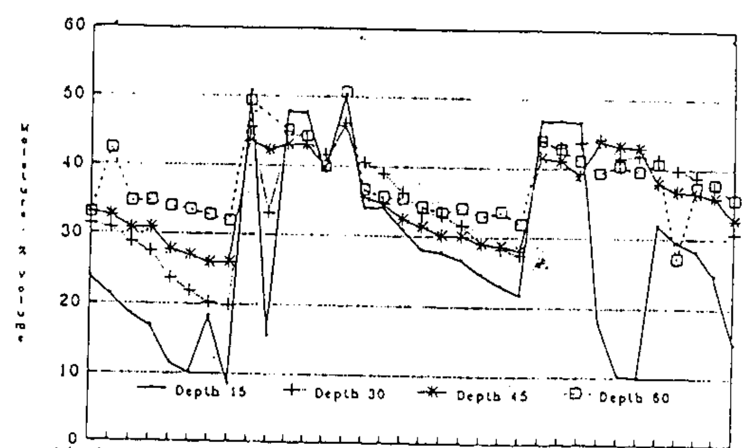
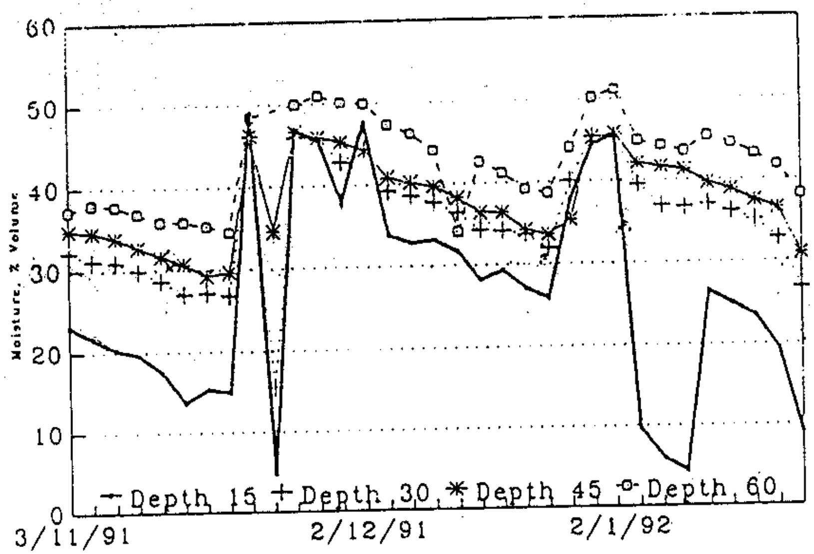
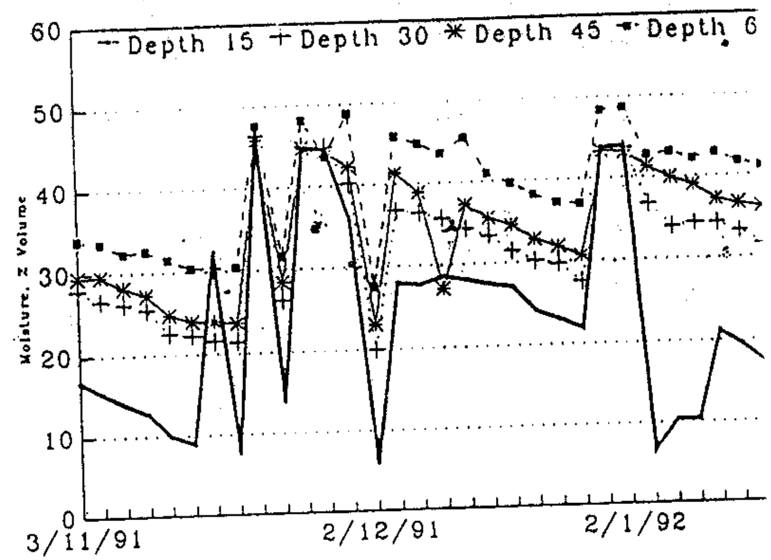


Figure 6 (contd)

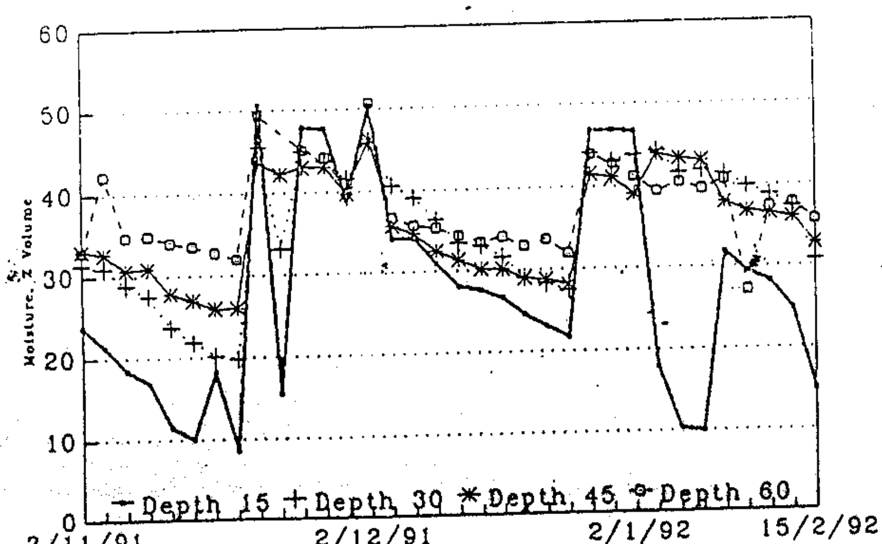
Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasha 1, Location 3, Crop: Cotton



Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasha 1, Location 4, Crop: Cotton



Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasha 1, Location 2, Crop: Cotton



Soil- Water Depletion Profile
Minor: Sunni, Number 12,
Hawasha 1, Location 1, Crop: Cotton

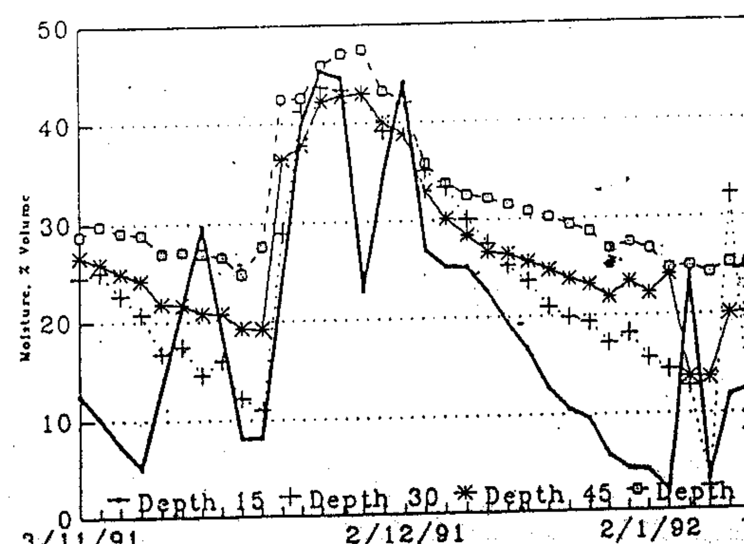
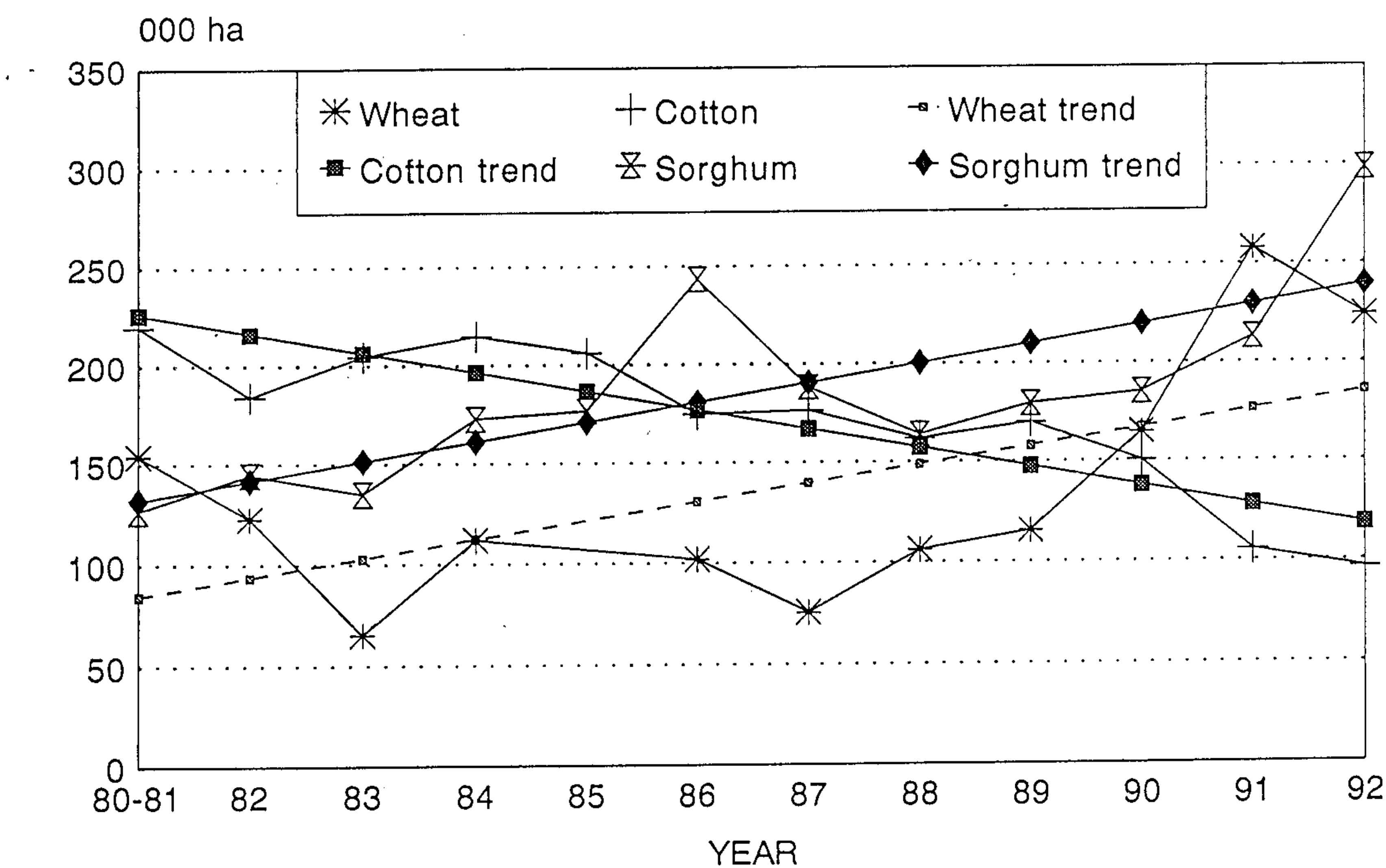
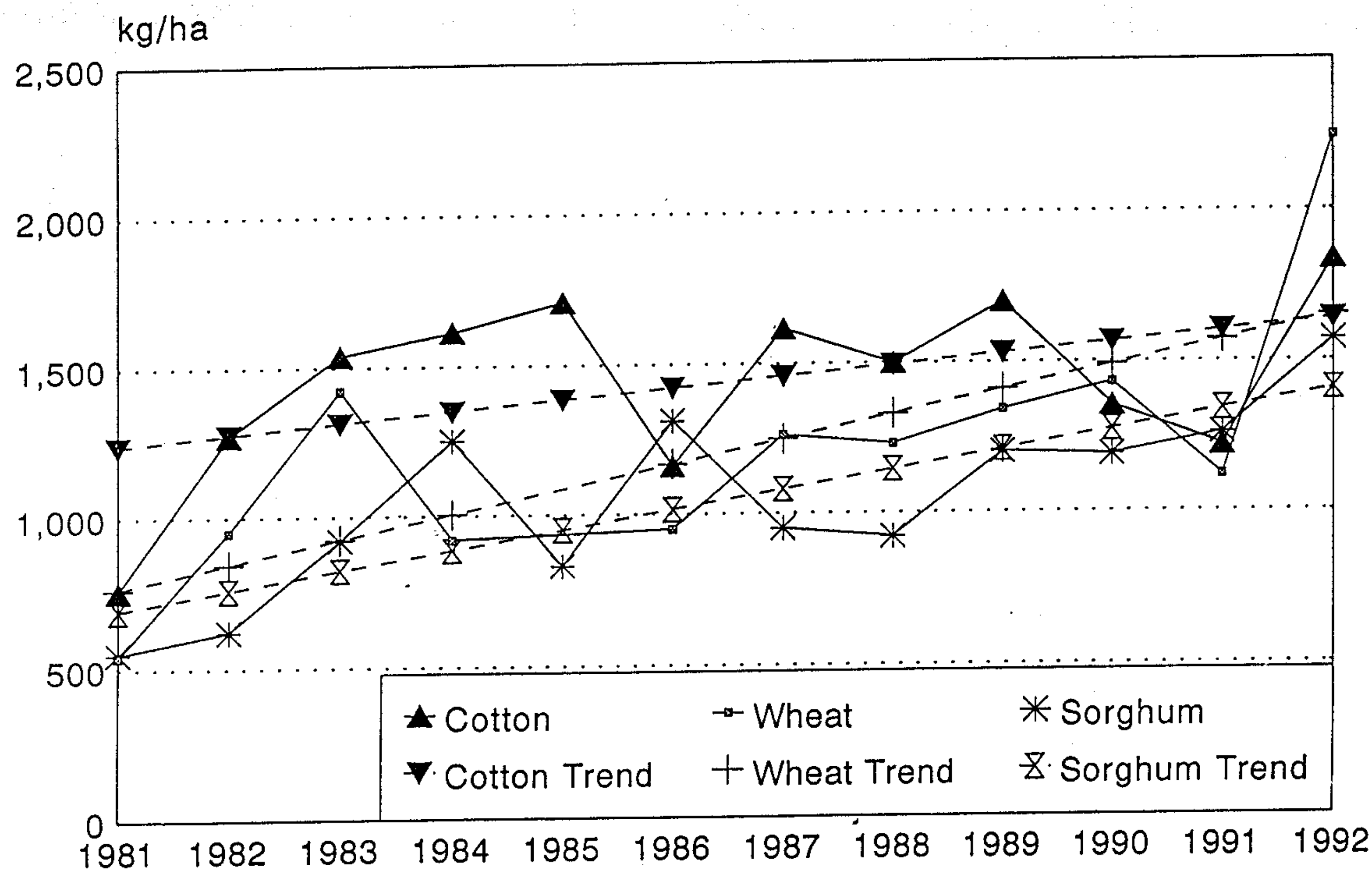


Fig 7: Trend in Wheat and Cotton acreage in the Gezira Scheme



No Wheat was planted in 1984-85 season due to shortage of water

Fig 8: Yield Trends for Cotton, Wheat and Sorghum



No wheat was planted in 1984/85 due to shortage of water x 280 m, locally known as "Number". The "Abu Ashreens" are usually 1400 m long and has carrying capacity of 116 l/sec. In the original design the "Abu Ashireens" had a bed width of 1.00 m, depth of 0.40 m and command of 0.20 m. Water is admitted into the water courses from the minors through 35 cm diameter and 12 m long steel pipes fitted with sliding valves on the upstream end. Due to the damages caused to these steel pipes and high cost of procurement and maintenance the MOI, very recently, has started to replace them with concrete pipes of similar conveyance capacity. There are 29,000 "Abu Ashreens" in the scheme.

5. 5. Field channels i.e "Abu Sittas": The "Abu Sittas" take off from the "Abu Ashreens" and deliver water to 18 plots of 2.10 ha(5 fd) each. These channels were designed to irrigate 4.20 ha (10 fd) "hawashas" at the standard spacing of 150 meters along the "Abu Ashreen". At present there are over 400,000 field channels in the scheme with an average carrying capacity ranging from 25 to 50 l/sec.

2.36 Flow Regulation: The flow in the irrigation system is controlled by two main classes of regulator gates --the vertical lifting sluice gate and the movable weir.The system of water control is influenced by the discharge characteristics of the regulator gates. flow through the sluice gates is determined by computing the head difference between the upstream and down stream levels. The control structures maintain a constant upstream level and gate opening is changed manually.

The Butcher's movable weirs are a class of very important hydraulic structures in the Gezira scheme. These are commonly used as head and cross regulators on major canals and as intake structures at the minor canals and has a discharge capacity of upto 5 m^3/sec. The other two flow regulating devices, the night storage weir and the field outlet pipes have been described earlier.

2.37 Drainage System: The nature of the soil and absence of high water table required no on farm drainage facilities and hence none was provided. The only need for drainage was to deal with the surface runoff from rainfall and/or excess irrigation water diverted into the canal systems.

The present drainage system consists of 1500 km major drains and about 6000 km minor drains. Minor drains run parallel to the minors and discharge into the majors or collector drains which generally follow the lines of natural drainage and lead the runoff water to outfalls. Disposal of runoff from Abu Ashreens is seldom a serious a major problem. At time of heavy showers a large part of the total area is either fallow or has not yet been planted. A large part of the heavy showers falling on the dry cracked fields is readily absorbed by the soil. Because of the presence of the tagnets each plot retains some of the unabsorbed rainfall and often causes localized water logging.

The major drains ideally outfall beyond the cultivation boundaries to natural drainage systems and on to the Blue or White Nile. However, in most of the Gezira this does not happen. Several drains terminate into large local depressions and so drainage water either has to be pumped into nearby canals or is allowed to pond up and evaporate.

2.38 Crop Production Systems: Although Gezira scheme commands an area of around 0.9 million ha yet at any given time of the year the cropped area seldom exceeds 0.69 million ha because as a part of the rotational system of cropping 25% of the cultivable land is fallowed every year. The principal crops grown in the Gezira scheme are cotton, sorghum, wheat, groundnuts and vegetables.

From the establishment of the Gezira scheme in 1925, a wide variety of rotations were introduced. Table 4. shows the different types of rotations practiced over the years. Until 1985, a four-course rotation, including a fallow in the Gezira and a three course rotation without fallow was followed. In 1985 cropping intensity in the Managil extension was reduced by introducing fallow in the rotation and the entire scheme had identical rotation. Soon after a 5-course rotation was introduced in Barakat block of the Gezira area of the scheme. The new rotation included fodder primarily to increase animal feed availability which is in short supply.

One of the main objectives of the crop rotation is to maintain or even improve soil fertility. Incidence of pests and diseases are also reduced by such rotation. The rotations, however, have not produced desired increase in yields especially those of cotton. In fact yield of cotton have reduced drastically even though cotton is planted after fallow. Yield of other major crops also either declined or showed erratic trend. Yield has largely been attributed to introduction of cereals in rotation and exclusion of Lubia, a nitrgen fixing legume.

Crop season in the Gezira scheme begins from the month of may with planting of groundnuts towards the end of the month. This is followed by sorghum which is planted between early june and mid-july. Both medium and long staple cotton are grown in the scheme. Planting of cotton starts from mid-july and ends in the third week of august. Wheat is planted between early november and mid-december.

In 1975-76 the MOI and the SGB entered into an agreement for implementation of the agricultural intensification and diversification program (AIDP). For effective implementation the program fixed dates for sowing and last irrigation for different crops as follows:

CROP	**SOWING DATES**		**DATE OF LAST IRRIGATION**
	Start	**End**	
Cotton MS	15/07	15/08	15 - 28/02
Cotton ELS	21/07	21/08	31/03
Dura	21/06	15/07	20/10
Wheat	21/10	20/11	28/02
Groundnuts	01/06	30/06	30/10

Implementation of the program helped increase cropping intensity from 50% to 75% in the Gezira and from 66% to 100% in the Managil extension. Efficient management of the AIDP was dependent on efficient flow distribution and regulation as well as strict adherence to programs of land preparation, sowing dates, cropped areas, dates of first and last irrigation, and correct indenting followed by good supervision and efficient on-farm water control (Abdu,K.M., 1992).

2.39 On-Farm Water Management: Generally speaking, Minor canal, in the Gezira scheme is the interface between the MOI and the SGB. This is the transition zone where the responsibility of distribution changes from MOI to SGB. The Block Inspectors compute the volume(m^3/day) of water require for each Minor and submit indent for water delivery to the ADE at the Minor intake.

The procedure for preparation of indents dates back to 1925. The handbooks, prepared in 1925 and 1934 (Gezira Canal Regulation hand book, 1934) on water control stipulated many regulations governing the procedures to be followed in good water control and efficient distribution. At the beginning these precise instructions on all aspects of quantitative preparation, recording, implementation and distribution of water indents were practiced efficiently. The preparation of the indent, however was not an easy process and needed knowledge, among others, of crop water requirements, soil properties as well as those on local conditions and working of the canal system (Griffin, 1932).

The intensification and diversification which introduced overlapping of crops resulted in increase in operating FOPs. This together with changes in practices of water delivery within the "Hawasha" including increase in the number of "Abu Sittas" and defacto practice of continuous irrigation by tenants (by abandoning the night storage system) has made the indenting system more or less academic. The indenting system now involves demanding water at the rate of 5000 m^3 per"Number" per day (12 hrs) irrespective of the types of crop, their growth stages, and growing seasons. It should also noted that when indenting system was introduced cotton was the only major crop in the Gezira scheme. At the time whole indenting system was based on an average water duty of 950 m^3/ha (400 m^3/fd) At present cotton ranks a distant third to sorghum (Dura) and wheat in the number of hectares planted.

In the Gezira scheme fixed interval-fixed depth (volume) rotational system of water delivery is practiced where canals receive water by turns and the farmers in the command of each canal also receive by turns when it is available in the canal. The system operates on a fixed irrigation interval of 14 days and fixed supply of 5000 m^3 per day (12 hours). This fixed depth-fixed interval scheduling usually results in inefficient irrigation during the germination and crop establishment stages when the roots are shallow and water use is low and during the late growth stages when water use also is low. This may result in reduced yield due to water logging in the heavy clay soil of the scheme.

The Minors are operated in such a way so that water is allocated to 9 "Numbers" simultaneously. The "Abu Ashreens" are, therefore designed to supply 5000 m^3 in a 12 hour-day so that a "Number" can be irrigated in 7 days. The usual practice is to apply water to half the "Number" at for 3.5 days so that the whole area can be irrigated in 7 days. It is recommended that the downstream half should be irrigated first but in the prevailing practice the upstream half gets the preference.

The field irrigation system has been designed to serve the standard "Number". A typical lay out of water delivery system of a "Number" is shown in Fig.4. From the Minor water is supplied to the "Abu Ashireen" though the FOP. SGB appointed "Ghaffirs" operate the FOPs as per prescribed rotation. But the responsibility is increasingly being taken over by the tenants. Officially management of water by the tenants begins from the "Abu Ashireen".

The "Number" is subdivided into 18 "Hawashas" having equal areas of 2.10 ha (5 fd) and each "Hawasha" is served by an "Abu Sitta". Each "Number", therefore, irrigated by a total of 18 "Abu sittas". But the tenants usually build an extra "Abu Sitta" in the last "Hawasha" probably to ensure its proper share of water. It also observed that some times tenants construct "Abu Sittas" to serve 1.05 ha (2.5 fd). An example is "Number-18" of Ibrahim Minor in the 1991-92 wheat season.

Water scheduling of the Gezira calls for irrigating half the "Number" at a time and as such half the "Abu Sittas" (9 to 10) operates simultaneously. To divert water from the "Abu Ashireen" to the "Abu Sittas" tenants construct earthen closures across the "Abu Ashireen" by excavating earth usually from within the "Abu Ashireen". After few irrigations at the inlet to "Abu Sittas" mini lakes are formed with areas ranging from 6 to 8 square meters and depths varying from 1 to 1.5 m. These areas are significant contributors to the dead storage in the canals.

Each "Hawasha" is further subdivided into seven "Angayas" with an area of 0.30 ha (0.70 fd) each. Irrigation water to each "Angaya" is delivered through a small plot channel called "Gadwal" having an average carrying capacity of 7 l/sec. A narrow field divider (dyke) called "Tagnet" divides the "Angaya" into two equal halves and as such each "Angaya" is served by two "Gadwals".

Cotton and sorghum (Dura) are irrigated by furrow method while wheat is irrigated in basins. For cotton furrows are spaced 0.80 m apart and 20 m lengths are irrigated from the "Gadwals". For Dura furrow lengths are same as those in cotton. For wheat each "Angaya" is divided into 6 basins of equal size of 25 m * 20 m (each "Hawasha" into 42 basins). It was observed that furrow irrigation is not really practiced in its true sense rather furrows are used to flood the whole cropped area. For wheat normal practice is to irrigate until 2 to 3 cm of water stands in the basin.

3.0 ESTABLISHMENT OF WATER MANAGEMENT ADVISORY UNIT (WMAU)

One of the principal tasks of the technical assistance was to help set up a WMAU to help SGB improve the on farm water management of the schemes. This section describes the progress achieved, problems faced and a set of recommendations to make the WMAU more effective so that it can play its due role in improving on farm irrigation management with the over all objective of agricultural productivity of the scheme.

3.1 Personnel recruitment: The Staff Appraisal report indicates that during negotiations with the World Bank on funding for rehabilitation of the Gezira scheme the GOS assured that the Water management Advisory Unit(WMAU) will be established under the Agricultural Administration "no later than december 31, 1983". The agreement also called for assignment of field irrigation engineers/water management specialists at the Group level. The principal responsibilities of the WMAU were to:

i) Train and organize the farmers in irrigation management and, where extension pilot works are established, to act as subject matter specialists.

ii) Provide technical inputs on crop irrigation planning and preparation of water indents, and monitoring the delivery of water to "numbers".

iii) Ensure group action by farmers and upkeep of field channels according to prescribed rules; and

iv) Conduct engineering surveys and designs for maintenance of Abu Ashreens, land levelling and field drainage as required.

Recommendations were also made to recruit graduates from faculty of Agriculture of the University of Khartoum and qualified and experienced SGB field inspectors to fill up the newly created posts. Provision was also made to provide Technical assistance (24 man-months) and overseas training (42 man-months) to establish the unit.

The establishment of the WMAU, however, got off to a slow start. The unit was formally established in june, 1990 with the appointment of the Manager, Water Management Unit.
The IIMI also suggested that to maximize utilization of the services of the SWMA, counterpart staff, both technical and support personnel, should be in place before the arrival of the SWMA(Abernethy, 1988). Except for the Manager, WMAU no other counterpart or support personnel were assigned to the SWMA until mid-1991 except for a part-time typist. Towards the end of 1991 three mid-level technical personnel were assigned to the WMAU to work with the SWMA on part-time basis. Except for the Inspector of the Pilot Farm, the other two personnel, agricultural engineers from the Engineering Directorate could not be utilized to the full potential due to lack of equipment and other logistical support. As recommended in Appraisal Report no specialists were appointed at the Group level till to-date to conduct the on-farm water management work. The appointments have been delayed among other things by a ban by the

government on new recruitment. Full time secondment from within the SGB was also not possible because the newly established WMAU could not offer logistical support such as vehicles, housing (especially at Barakat) etc. for the seconded staff.

3.2 Training and Man Power Development: For staff training and development provision for upto 42 man-months of training abroad was made. This, as far as records indicate, has not been utilized for this specific purpose. In the budget for the technical assistance $20,000 was allocated for international travel by SGB staff. This amount was later revised to $ 30,000 and the following three specific activities were supported:

1. A three-week study tour to irrigation projects in Pakistan and Bangladesh by three senior SGB staff members (Director Agricultural Administration, Manager, Water Management Advisory Unit and the Manager, Pilot Farms).

2. A three-week on-farm water management training program for three mid-level SGB management personnel at the Water Management Training Institute at Lahore, Pakistan.

3. A one week study tour of selected irrigation projects in Pakistan by the present Director of Agricultural Administration. The present Director took over charge from the previous Director in july, 1991.

Though the terms of reference of the SWMA called for making "recommendations on the type and content of training needed for the proposed SGB field staff of the Water Management Advisory unit" it was recognized that this activity had to be expanded to actually conducting training for selected SGB field staff especially those engaged in the agricultural production management. It was also recognized that even when the water management specialists are located at the Group level, the Field Inspectors (Group Inspectors, Assistant Group Inspectors, Block Inspectors, Assistant Block Inspectors etc.) will continue to play important roles in irrigation water management. Two courses were designed for the purpose: A water management awareness course for the senior management personnel and two week intensive course for mid-level management personnel. Course description and curriculum are presented in Appendix II and III.

To conduct in-country training program there was no budget provision in the Technical assistance project. Considering the importance of the training to its field staff the SGB authorities allocated funds for conducting one such training. Participated by 31 trainees including one from Ministry of Irrigation (three persons were nominated by the MOI but only one showed up) the two week course was conducted from may 16, 1992 to may 28, 1992. SGB participants consisted of Assistant Group Inspectors and Block Inspectors. List of participants is presented in Appendix IV.

In addition to those from SGB, 3 resource persons each from Agricultural Research Corporation and Ministry of irrigation were invited to deliver lectures on specific topics dealing with irrigation management problems of the Gezira scheme in general and issues related to on-farm water management in particular. Of the total 70 hours of lectures the SWMA was involved in conducting 55 hrs. The course was a blend of theory, field work and problem oriented lessons related to the operation and management of the Gezira irrigation scheme with especial emphasis on on-farm water management.

The course was very well recieved both by the participants and the management. An independent and comprehensive evaluation conducted by the Training Unit of Gezira Board indicated that without exception every participant considered the course as one of the best they have ever attended. The participants are now impressing upon the Gezira authority to conduct this course on a regular basis so that most of the field staff can take advantage of this. A copy of the evaluation form is presented in Appendix IV.

The pre and post evaluation of the course indicated significant increase in knowledge of the participants in understanding the water management issues and logical and methodical approach to address them. Pre and post evaluation questionnaire are presented in APPENDIX V and VI.

3.3 Equipment for Field Research: As the WMAU has been very recently established it does not have any equipment whatsoever to conduct field research. Under the Technical assistance program an amount of $ 33,000 was allocated for the procurement of vehicle and equipment including a 4-wheel drive vehicle. The cost of the vehicle accounted for more than 72% of the budget and the rest was spent in procuring office equipment such as a desk top computer, one photocopy machine and a english type writer.

A large number of field research equipment were procured under the Gezira Rehabilitation project specially on the Pilot Farm account. But none of these ended up with the SGB because SGB did not have the capability to use those. But with the establishment of the Water Management Advisory Unit the capability has been created but there is no way to retrieve those equipment. Field research conducted during the residence of the SWMA had to be carried out by borrowing equipment from Agricultural Research Corporation, Hydraulic Research Station (HRS) and the University of Gezira. These were probably the same equipment procured through the Pilot Farm budget of the SGB.

3.4 Laboratory Facilities and Equipment: For an effective water management program it is essential that the Water Management Advisory Unit has its own well equipped laboratory. No provision exits in the project document for establishment of such a laboratory.

3.5 Building Research Capability Within WMAU: In addition to its responsibility to address on-farm water management issues, the WMAU shall have to develop capability to generate data that is not available off-the-shelf. Conducting applied research in the farmers field to test new and promising technology will also be a major undertaking of the unit.

At the present time water management research is not well organized and is fragmented. The ARC, the HRS and the universities are all engaged in some form of water management research. The WMAU shall have to synthesize these for appropriate application in the Gezira scheme. The WMAU should also perform the role of coordinator of water management research.

3.6 Establishment of Meteorological Station: Climatic data on time and space distribution of precipitation, solar radiation, temperature and wind are necessary to determine crop irrigation requirements and even determining what crops are suitable to a given set of conditions. It is ,therefore, of paramount importance to have access to adequate and reliable data for developing and implementing an effective water management program.

3.7 Recommendations: Based on the above discussion the following recommendations are made to make the newly established WMAU into an effective unit to achieve its objectives.

1. Strengthening of Water Management Advisory Unit:

As stipulated in the project document water management specialists should be recruited and/or seconded to the WMAU for assignment at the Group level. It may not be possible to place specialists to all the fourteen Groups simultaneously. It is, therefore, recommended that the three professionals that were assigned to the WMAU on a part-time basis should immediately be assigned on full time basis for appointment as water management specialist at the group level. Another SGB staff member is about to complete M.S degree in irrigation from Gezira university who should also be assigned to a Group. Assignment of the specialists at the Group level should be done in phases and be completed by the 1995-96 crop season. The specialists should have a bachelors degree in Agricultural Engineering/Irrigation Engineering/Civil Engineering/Agronomy/Soil Science and preferably some advanced degree/training in water management. In fact all the personnel of the WMAU Including the Manager should preferably have above mentioned qualification.

For reasons mentioned earlier a research wing should be created within the WMAU. The head of the unit should have the status of a Deputy Manager and report to the Manager, WMAU. This person should have an advanced degree, preferably, Ph.D in irrigation water management and demonstrated ability conduct research and interpret results for adoption.

Considering the importance of water in land-abundant and water-scarce agricultural scenario the SGB authority should consider to upgrade the WMAU into a full Directorate probably towards the end of the decade. It may be pointed out that the Managing Director of the SGB, on more than one occasion, has indicated SGB's willingness to upgrade the unit into a Directorate.

It also recommended that the WMAU be organized as per the organigram presented in Fig. 4. It is proposed that the WMAU be headed by a Manager and assisted by a two Deputy Managers, one for extension and the other for research. Deputy Manager research may be assisted by 4 senior research officers and 8 research officers. Research staff should be multidisciplinary unit comprising of professionals from engineering, agriculture and socio-economic disciplines. The extension wing should be staffed by professionals designated as water management specialists and located at Group level. Block level water management activities should be responsibility of the assistant Block Inspectors.

2. Training and Manpower Development:

A good and effective water management program requires that technical personnel responsible for design and management of the program and the farmer who ultimately uses it on his farm be properly trained. Training and manpower development should be the main thrust for the next five years. Training should be arranged for personnel of the Water Management Advisory unit as well field staff responsible for production management. At some stage farmers have to be trained as well so that he can monitor and if necessary participate in management interventions to improve water management at his farm. Following different types of training are proposed:

TRAINING ABROAD: Technical personnel from the WMAU should be sent abroad both for:

1. Long term training leading to advanced degrees (M.S and Ph.D).

2. Short term on-the-job type training of duration ranging from 1 to 6 months.

3. Study tour to countries having similarity in agro-ecological systems.

Personnel from the proposed research cell of the WMAU should be sent for higher studies leading to M.S and Ph.D. degrees. The advanced degree programs should be designed in such a way so that the participants can attend theoretical courses in countries that have strong water management programs but the thesis research should principally be done at the Gezira project. Some of the Group based specialists will also benefit from advanced degrees.

Short term training programs will be primarily for training of the trainers. The specialists of the WMAU will qualify for such training. These persons, after being trained will conduct in-country training programs for SGB field staff. The Water Management Training Institute located in Lahore, Pakistan has been identified as an appropriate institution for sending participants. Participants can also be sent to other countries that have strong water management training programs. Such trainees on return will become trainers for training locally SGB field staff. As has been mentioned earlier three SGB staff members have already completed a 3-week water management training from Pakistan.

Senior management personnel of the SGB including those from the WMAU will immensely benefit from visiting irrigated agricultural projects in countries having some what similar agro-ecological countries. Countries most suitable, among others, include Egypt, Syria, Pakistan, India etc.

In-Country Training: In-country training should be designed and conducted for management and production personnel of different levels as well as tenants.

An awareness type trainning course should be designed for the senior staff members, Group Inspectors and above, to provide them with an over view of the on-farm water management issues and their role in helping address such issues. Duration of such courses should not exceed two days and involve lectures followed by intensive discussion. A sample course outline for the purpose is presented in APPENDIX II. Technical training will be for the field staff including Assistant Group Inspectors.

As has been mentioned earlier the SGB field staff (those other than WMAU staff) will remain involved in addressing on farm water management issues. It has been recognized that their knowledge on on-farm water management needs refreshing and upgrading. One such training conducted by the WMAU amply demonstrated the need for organizing more such training courses so that in turn all the Field Inspectors can be trained over the next five years. Field engineers from MOI and field staff from other Agricultural Corporations may also be invited to attend such courses. Such courses should be 4 to 6 weeks in duration.

Materials presented in the first training course can form the nucleus of the curriculum. Subsequent courses should be further upgraded by incorporating more problem oriented lectures to be delivered by senior SGB, ARC, HRS, MOI and university of Gezira personnel. The course should also be modified to include extensive hands-on field training. At least 50% of the time should be allocated for field exercise. Classroom instructions should also be supported by classroom exercises, slide shows, video-presentations and training bulletins.

It is also recommended that inter-project visits by field staff be highly encouraged. This will help in exchanging experience as well as evaluating comparative strengths and weaknesses of the watermanagement aspects of different projects.

Training of the tenants should also be strong component of the training program. The training of both the technical personnel and tenant levels can essentially cover the same subjects, but the tenant training will on a more basic level. It should also provide him with enough fundamentals so that he can monitor his system well and make changes in timing, duration, flow rates, and other operational characteristics as and when the need arise.The logic for having similar course for the technical personnel and farmers can be questioned. But it should recognised that to every tenant his "Hawasha" is a micro-Gezira scheme, the "Abu Ashreen" being his Blue Nile, the dike he constructs across the "Abu Ashireen" is his sennar dam, "Abu Sitta" his main canal and so on. A good understanding of the system will, therefore, immensely benefit him and the Gezira scheme as a whole. In the field-days organized by SGB for the farmers importance of on-farm water management should be an important issue for deliberation.

3. Equipment for Field Resarch: To monitor and regulate flow in the Minors, "Abu Ashreens", "Abu sittas" and within the "Hawashas" the WMAU needs to be adequately equipped. The technicians and technical staff of the WMAU should be properly trained in their operation and maintenance. The list of equipment should include the following:

Name of the Equipment	Quantity
Current meter (0.5 to 1.5 m^3/sec)	2
Continuous water level recorders	10
Vane flow meters (80 to 150 l/sec)	4
Parshall Flume (30 to 60 l/sec)	10
Cut-throat Flume (20 to 40 l/sec)	6
Neutron Probe	2
Access tube for Neutron probe (120 cm long)	100
Double ring infiltrometer	2

4. Laboratory Equipment: The preparation and execution of a on-farm water management program requires location specific extensive but accurate data on soil water holding capacity, depth of different soil layers and the infiltration characteristics of the soil. Knowledge of soil texture, structure and organic matter content is helpful to determine wheather improvements in water holding capacities, intake rates etc can be made. It is , therefore, recommended that two adequately equipped laboratory be established, one for Gezira and the other for Managil extension. It is also recommended that following basic equipment be procured which should be upgraded as and when necessary:

Name of the equipment	Quantity
Drying oven	2
Electronic balance (+ 0.1 gm)	2
Soil auger	4
Soil sampling tube	4 Desiccator 4
Soil sample containers	10 doz.
Tensiometers	2 doz.
Gypsum block	6
Pressure plate	2
Other standard accessories for the laboratories	

5. Agro-meteorological stations: Atmosphere in which the plant grows determines how much water the plant needs to grow and produce at its potential. The rate of plant transpiration and evaporation from the soil and plant surfaces is influenced by the energy status of its surrounding atmosphere and is dependent on weather parameters like solar radiation, temperature, humidity and wind run. In addition precipitation which enters the soil serves as source of water and influence crop water use. Considering the importance of weather parameters on irrigation scheduling it is recommended that two properly equipped agro-meteorological stations be setup, one each at Gezira and Managil extension. Stations should preferably be located in or near the cropped area and standard precautions should be taken in locating and installing the equipment. The following equipments are essential part of the Agro-met. stations:

Parameter	Name of the equipment	Quantity
Rainfall	Rain Gauze	1 doz
Temperature		
T_{max}	Mercury thermometer	6
T_{min}	Alcohol thermometer	6
Rel. Humidity	Sling Psychrometer	2
Solar radiation	Pyranometer	2
Wind run	Anemometer	2
Evaporation	Class-A Evaporation pan	2

It may be argued that it is not necessary to establish a Met. station in Gezira as there is a government weather station at Wad Medani. But there are two distinct advantages of having such station. First, being located in or close to the crop fields these stations will produce more representative data and second the stations will work as mutual checks for maintaining acceptable quality of the data.

4.0 STATUS OF IRRIGATED AGRICULTURE AND SUGGESTED IMPROVEMENTS

4.1 Present Status of the Distribution System: The Gezira scheme has been in operation for over 65 years. Naturally the canals and regulators can not be expected to operate according to their designed specification. Performance of the canals have deteriorated due to silt deposition(over 8 million tons of silt enters the Gezira scheme every year, of which 65 percent is admitted between july and september), aquatic weed growth and changes in cross section of the canals. Silt and weed problems are more acute in the Majors and Minors due primarily to reduction in velocity and the night storage system accelerates the deposition.

4.1.1 Sedimentation: A Number of studies have been conducted on sediment load, particle size distribution and its deposition characteristics. Due to lack of adequate instrumentation and trained personnel earlier estimate of annual silt deposition varied from 4 to over 10 million m^3 (Plusquellec, 1990). Collaborative studies conducted by Hydraulic Research Station (HRS) with Hydraulic Research Ltd. (HR) U.K indicated that nearly 6 million tones of sediment enters the system between july and november and silt and clay particles constitutes over 95% of the sediment (Hydraulic Research Lt.1989). The study also found that of the total sediment load brought into the system 60 percent (30% each) were deposited in the Major and Minor canals and another 30 percent were passed on to the channels and fields beyond them and rest 10 percent settled in Main canals. A more recent study (Sir M Mcdonald & Partners Ltd, 1992) approximated sediment deposition as 14%, 22% and 33% in the Main, Major, and Minor canals respectively and the rest 31 percent is carried beyond. The largest portion of the maintenance work involves silt clearance which has progressively increased from an average of 4.2 million m^3 in 1977 to 6.2 million m^3 in 1983. It has been projected that over 10 million m^3 shall have to be removed by mid-nineties.

4.1.2 Aquatic weeds: The growth of aquatic weed in the Gezira canal systems is another important contributor to the performance deterioration of the distribution system. Weed growth in the canals in general reduces velocity by obstructing flow and thus induces increased sediment deposition. They also increase water level in the canals reducing the gradient which results in reduced flow into the canals. The period from january to april is considered main weed growing season. This is the time when the system draws clear (relatively sediment free) water and allows enough sunshine to penetrate and help weed growth. During the period july to september the heavy sediment load prevents penetration of sunlight through the water inhibiting weed growth. Manual, mechanical, chemical and biological methods as well as some combination of the above methods have been practiced with varied degree of success.Generally speaking the standard of weed control in the Gezira scheme is far from desirable.

4.1.3 Canal Deterioration: The third important factor is the change in cross section of the canals. The desiltig of the canals, at present, is carried out mostly by the judgement of the dragline and hydraulic excavator operators. No doubt there are experienced operators who can do the job reasonably well but again there are others who are not very well experienced and their judgement logically will not be of the required standard. Excavation will, therefore, be either too much or too little causing changes in the canal cross section resulting in changes in carrying capacity.

4.14 Present status of hydraulic structures: The flow monitoring, measuring and regulating structures have also deteriorated to a point where it is increasingly becoming difficult to regulate the flow. A study conducted by Salam et. el. (1988) on the performance of hydraulic structures indicated that most of the structures were performing well beyond their designed specification. Of the three intakes of major canals studied one was delivering 44 percent less water than required(Kab El Gidad Major intake), the Gamusia Major intake was supplying upto 13 percent more water and the Zananda Major intake was supplying, more or less the designed discharge. Studies conducted by Gasser and Ahmed (1980), Gasser (1983), Ahmed et. el (1986) that measuring and regulating flow in Main, Branch and Major canals have become difficult and the delivery is not consistent with demand. A more recent study conducted jointly by HRS and HR (1991) reported that cross regulators in Zananda major was set at values significantly different from those authorized. This may result in average potential errors in discharge from -28 percent to + 55 percent.

Other smaller but equally important structures like the Butcher's Movable weirs(BMW), Night storage weirs and the Field Outlet Pipes(FOP) have also registered significant decline in their performance. Of the eight BMWs evaluated by Ahmed et el(1989) for their performance 75 percent was conveying less water than the designed capacity. Due to sedimentation, weed growth and deterioration of the structures, flow measurements through them have become quite erroneous and measured values vary widely and error sometimes reaches 50 percent. Limited data available on the performance of the NSWs indicates that they are performing better than most other hydraulic structures. Any serious discrepancy in their performance can be attributed to manipulation by the tenants.

The FOPs were originally designed to deliver 10,000 m^3 per day (24 hrs). After the introduction of the night storage system they deliver 5000 m^3 per irrigation day (12 hrs) at 15 cm head. FOPs are probably the most neglected structures in the whole system. The opening and closing of the FOPs are controlled by a long operating handle hinged to a plate which moves in an arc to about 10^0 from fully open to fully closed position. Most of these devices have disappeared and closing and opening of the FOPs are affected by mud-sacks. The operation of the FOPs have also been taken over (informally) by the tenants from the SGB "Ghafirs".

Recognizing the severity of the problem the Government of Sudan requested assistance from the World Bank for financing the rehabilitation and modernization of the irrigation delivery system including rehabilitation of the Sennar dam.

In the rehabilitation project adequate funding was provided for upgrading the water delivery system. Canal regulators and structures were to be repaired or replaced as the case may be. As most of the regulators were in working condition the major emphasis of the project was on repair of damaged and worn out structures and to carry out overdue maintenance. Some required replacements were also recommended which included 16 roller sluice gates on main canal cross and head regulators and 66 on branch and major canals, 680 steel pipes and 475 regulator doors for the night storage weirs and pipe regulators on the minor canals and installation of vertical slide gates at all 29,000 FOPs.

The project also provides for maintenance of the canals including annual maintenance of canal banks and drains, weed removal but excludes silt removal which is being satisfactorily being done by the EMC with GOS financing.

To restore the drainage systems to original design standards the project includes removal of an estimated 3.0 million m^3 of silt from the major drains, construction of 190 km of new drain and rehabilitation of 4,000 km of silted up minor drains to their design sections. Five new drainage pumping station will replace the old ones which are out of operation. Two new siphons and six hundred road crossings along the major drains are also to be installed.

Major repair and maintenance of Sennar dam is also being undertaken. The work includes repair of gates, overhauling of cranes, and upgrading of mechanical and workshop facilities.

4.2 Performance of canals: For the purpose of this report on farm water management practices are being addressed from the operation of the system from minor canals and below from where responsibility of the SGB begins (this was valid upto end of 1991-92 crop season which also the year of termination of the SWMA's assistance to (SGB). The maintenance is of the minors is the responsibility of the MOI.

4.2.1 Performance of the minors: Due lack of equipment and technical man power parameters related to the performance of the minnors could not be measured. The following analysis is, therefore, based on studies conducted by other researchers and observation of the system operation.

As has been mentioned earlier minors in the Gezira scheme are the most important hydraulic structures because they serve the duel purpose of both storage and conveyance. Hydraulic Research Ltd.(1991) reported that the water levels were significantly above the full supply level in six of the nine intensively monitored minor canals. This was primarily caused by raised bed level due mostly to siltation and raised water levels at the head of the minor canals. The study also indicated that on the average the water requirement exceeded canal capacity. Indents and authorized releases generally remained at or below the design canal capacity with few exception where authorized releases exceeded design capacity.Peak actual releases, however, exceeded canal design capacity in all the canals studied. The study also indicated that indents generated for the minor canals were not always available and no information on indents were available for major canals, the main canal and the Managil branch canals.

On adequacy the study found that the minor canals monitored generally received adequate supplies to meet requirements. The minor canals were over supplied 62% of the time and under supplied 27% of the time. No minor, however, was significantly under supplied. There was, however, no clear trend with respect to location of minor canals along the supplying major canal but variation was between minors of different major canals.

The findings of the HR Ltd. is based on six minor canals and one should be very careful in drawing conclusions for the whole scheme. It should be remembered that the scheme has 1,498 minors and maintinance of the required flow in every canal is extremely difficult. It was observed during the tour of various parts of the scheme that even in the Pilot farm area minors go totally dry when they are supposed to be delivering. In the wheat season of 1991-92, 40,000 fd (17,000 ha) could not be harvested because the minors were not receiving the required supply. Again there were areas where water was running off after over topping the canals. It is, therefore essential that before the minors are restored to their original design specifications which is in progress under Gezira Rehabilitation Project the canals be more closely monitored and flow regulated as per prevailing flow condition rather than operating the gates as dictated by the manual.

The NSS system for all practical purposes are not operating and tenants have resorted to night irrigation. It will be extremely difficult to reinstitute NSS as the tenants have discovered flexibility that continuous irrigation system offers. Again the original design was based on continuous irrigation and NSS was introduced for social rather than technical reasons. In addition, with the increase in distributive inequity tenants will resort to ways and means to irrigate their crops experiecing stress whenever they will have access to water.

It is, therefore, recommended that the NSS system be abandoned in favor of continuous flow, initially in a pilot area to scientifically to demonstrate advantage it offers over the NSS system. Evaluation should include studies to investigate if part of the sediment that settles in the minors (as well as those settling in the majors due to velocity reduction caused by NSWs) can be guided on to the field. The sediment settling in the Abu Ashreens will be easier to handle when compared to minors and the amount entering the Abu Sittas and the Hawashas can be spread over the field during land preparation. Some might argue that this will increase elevation of the field and interfere with proper water distribution. It should be noted that estimated 20% of the 10 million cubic meter of silt (annual deposit) is expected to increase the level of the field by only 0.00021 mm per year.

4.2.2 Abu Ashreens: Measurement of flow at the farm gate (at FOP) is probably the most important factor for making proper on-farm water management decisions. This also is probably the least investigated parameter in the distribution system of the Gezira scheme. Like the minors the Abu Ashreens also suffers from the twin problems of weed growth and sedimentation. As a result the available head has been reduced with consequent reduction in flow. The operation of these channels have been effectively taken over by the tenants. Most of them have become grossly over-dimentioned especially in areas where Abu Sittas take off. The present practice adopted by the tenants to irrigate high lands by increasing the water level above the recommended level by constructing cross dams reduces hydraulic gradient thus causing reduction in delivery and depending on the reduced gradient loss of water can be significant.
Ahmed et el (1988) reported that the measured discharge through the FOPs were far less than the 5000 m^3 per 12 hrs with variation of upto 60%. They also found that the morning discharges were higher than the afternoon ones. This is expected because of additional head created due to night storage. Discharge through an Abu Ashreen measured in the pilot farm area also indicated lower discharge by about 22 percent (Haq, 1990).

Due to reduction in head between Abu Ashreens and Abu Sittas and significant change in cross-section especially in areas near the off-take of the Abu Sittas where tenants excavate the Abu Ashreen to construct cross dams as well as to shut off Abu Sittas a sizeable amount of water is left as dead storage and is lost through evaporation.

During 1991-92 crop season volume of dead storage was quantified in three Abu Ashreens of the Pilot Farm (Tayba Shimal: Number 2; Sunni: Number 11 and Ibrahim: Number 18). After irrigation was over i,e after water ceased to flow into Abu Sittas volume of water left in the Abu Ashreens were measured and their "Abu Sitttas". At every 200 m length of these channels a 15 m section was diked and the volume of water was measured by buckets. It was observed that the volume of dead storage ranged from 800 m^3 to 1200 m^3. This water can be effectively used for irrigation by lifting the water from the channel by appropriate pumps.

In 1990-91 crop season presence of large number of "Nachus" (unauthorized Abu Sittas constructed by the tenants from the Abu Ashreen of adjacent Number) was observed through out the scheme including the Pilot Farm area. The number of such "Nachus" is an indicator of status of the water supply in a particular area of scheme, large numbers indicating serious shortage of water. In 1991-92 crop season number of Nachus reduced greatly indicating adequate water supply.

Like most of the distribution system in the scheme maintenance of the Abu Ashreens were not upto the desired level. To improve the situation it is strongly recommended that tenants be actively involved in the maintenance of the Abu Ashreens. Each tenant may be made responsible to maintain his section of the channel. For maintaining proper section, reference sections may constructed by brick lining 1 m section of the channel every 200 m.

It was also observed that, contrary to the established rules, tenants have started to serve one Abu Ashreen from two minors. But this is a very interesting management concept. By the present practice of irrigating the tail end of the Number at the end of the rotation appears to deprive those farmers their due share of water. From experience the tenants realized that to irrigate their Hawashas adequately an alternative is to irrigate the tail end of the Number from the next minor. This practice was observed in Number 11 of Sunni minor where tenants were irrigating 25% of the area from Ibrahim minor. It will not be surprising if this concept spreads to other areas as well. It is, therefore recommended that pilot studies be initiated to investigate the technical feasibility of using two minors to supply one Abu Ashreen. The argument against this recommendation is that the topography of the land which slopes in one direction may not permit this. But it should be remembered that the Nachus are also constructed against the slope and seems to be working pretty well. The existing NSS system also provides an opportunity to study this mode of management. The night storage increases water level in the minors above the day time operating head based on which the system is designed. It provides an opportunity to investigate the possibility of irrigating part of the Number from one minor (downstream one)during the morning hours and the other part from the designated minor after the level in the minors have dropped to their normal operating head.

4.2.3 Abu Sittas: Tenants are effectively involved from this point of the distribution system both for operation and maintenance. There are on the average 19 Abu Sittas in every standard Number of 90 fd (38 ha). Tenants in the recent years, however have started to construct more with a view to irrigate their fields quickly. One such example is Number 18 of Ibrahim minor where some Abu Sittas were constructed to serve 2.5 fd (1.05 ha) rather than commonly practiced 5 fd (2.10 ha). Abu Sittas come in all shapes and sizes and some of them are as big as Abu Ashreens in cross-section. It was observed that the Abu Sittas were deeper than required and retains sizeable volume of water as dead storage which is lost due to evaporation. A small amount is expected to move into the Hawashas by seepage. Very little information is available off the shelf on the performance of these field channels and this is an area where the WMU of SGB should under take studies to improve performance. It has been mentioned earlier the off takes of the Abu Sittas from the Abu Ashreens turns into a mini-lake due reasons described before. It is recommended the Unit also pay adequate attention to developing/adopting low cost and easy to operate structures. One such structure "Nacca" developed in Pakistan (at Water Development Board's Mona Project) has been very successfully adopted by the farmers there. This was observed by the SGB delegation when visiting Pakistan in 1991. These structures may be tried out here for their adoptability. The SGB field Inspectors should also supervise construction of Abu Sittas, Gadwals etc to ensure that these are properly constructed and advise tenants on their proper operation and maintenance.

4.3 Evaluation of crop production systems and onfarm water management practices:

4.3.1 Cropped Area: Data on target and actual planted area as well as long term trend for wheat, cotton and Dura from 1980-81 through 1991-92 crop seasons are presented in Table 8 and Fig. 7 repectively. No wheat was planted in 1984-85 season due to very low flow in the Blue Nile.

From the base year 1980-81 the wheat acreage dropped by 27% in 1981-82. Over the next decade through ups and downs the coverage peaked in 1990-91 to 6,13,305 fd (2,57,700 ha) an increase of 67% over the base year when 3,66,737 fd (1,54,100 ha) were planted. This significant increase was a result of the Governments policy to attain self-sufficiency in food grains at the shortest possible time.

During the reporting period the actual planted area for wheat ranged from just over 100% in 1990-91 to 77% in 1982-83 of the target.. It may be pointed out that in 1990-91 the actual planted area was nearly 40,000 fd (17,000 ha) more than those shown in the tables. crops in these areas were destroyed due to shortage of irrigation water and hence could not be harvested. This, however was not reflected in the estimates. This experience led to the reduction in wheat area by over 80,000 fd (33,600 ha) or 14% in 1991-92. For the whole period from 1980-81 to 1991-92 the average achievement in cropacerage was 90% of the target which can be considered as very satisfactory (SGB Socio-economic Unit). Similar trends were also observed in the in the 15 wheat Numbers monitored in Messelmia, Wad Habouba and Mikashfi Groups.The Hydraulic Research Ltd., however, reported 71 and 83 percent achievement in 1988-89 and 1989-90 seasons respectively.

For the same period cotton acreage decreased from 5,22,060 fd (219,350 ha) in 1980-81 to 215,503 fd (90,550 ha) in 1991-92 season a 60% decline. Though cotton area showed general decline during the whole period the most significant reduction (40%) took place between 1989-90 through 1991-92 due primarily to governments declared policy to move cotton, partly, to rainfed area and increase cereal acreage in the irrigated schemes. More dramatic was the decrease in ELS cotton area which dropped from 437,127 fd (183,667 ha) to 52,946 fd (22,246 ha) a 88% decline. The major reason for this is attributed to very high irrigation requirement of this 9-month duration crop. It should be noted that unlike wheat, reduction in cotton area did not result in significant loss of income as there was significant increase in Dura and groundnuts.

Area planted to Dura has more than doubled from 3,00,832 fd (126,400 ha) in 1980-81 to 709,640 fd (298,170 ha) in 1991-92. The reasons for such increase have been described earlier. It is interesting to note that for over ten years tenants have been planting more areas to Dura than those recommended by the SGB. Starting with a modest increase of slightly over 1% in 1980-81 (this probably was the year when tenants probed SGB's determination to keep within the prescribed target) the SGB projection was exceeded by nearly 70% during the last crop season. This is a determined departure from the centralized-guided agriculture followed in the scheme. It is surprising as to why SGB was projecting such a small area for Dura when the target was successively being exceeded by over 50% from 1985-86 to 1991-92 with the exception of 1988-89 season when the target was overhauled by 35%. Tenants prefer Dura for the following reasons:

1. It is the principal staple and very well adapted to local growing conditions. In fact Dura appears to have originated from this area over 5000 years ago (Doorenbos et. el.1979).

2. It is a short duration crop, can tolerate mild to moderate drought, and 40-60% of its irrigation requirement can be met from precipitation of a normal year and the crop season matches with high river flow.

3. It is widely used in social and religious functions.

4.3.2 Planting Dates: Over the last decade, with recommendation from ARC, planting dates for wheat have considerably changed from the those in the agreement. The recommended optimum dates, at present is from last week of october to end of november. Planting upto mid-december, however, is acceptable. During 1990-91 and 1991-92, 71 wheat Numbers monitored (17 from Pilot Farm, 27 each from Mikashfi and Wad Habouba) indicated that over 95% area was planted during the recommended period. Planting dates ranged from october 30 to december 10 (Table.5). Hydraulic Research Ltd monitored wheat planting during 1988-89 and 1989-90. They observed that the start of planting of wheat was delayed in both seasons by about three weeks. Planting was more or less completed within the recommended period at the head of the scheme but in 1988-89 extended for further three weeks in tail minors. The following season, however, planting did not extend beyond one week after the close of the official dates.

During 1991-92 cotton, in general, was planted within or near the optimum range in the Numbers monitored (Table.6). 25% of the Numbers were planted two weeks before the recommended date. Only four Numbers were planted after the cut-off date. The planting date spread was from 05-07-91 to 28-07-92. In 1988-89 planting occurred upto two weeks before the official dates in minors in the head of the scheme where as in the tail of the scheme planting was extended by upto two weeks beyond the end of the official period where as in 1989-90 the spread was much reduced (Hydraulic Research Ltd., 1991).

The planting of Dura (sorghum) extended well beyond the recommended dates in most of the Numbers. In 1991-92 season planting of dura actually started around the end of the recommended range and continued into the second week of August (Table 7). Similar results were also reported by Hydraulic Research Ltd.

Principal reasons for early or late planting are timing and amount of rainfall/availability of irrigation water (especially digging of the Abu Ashreens on time), land preparation, availability of inputs etc.

4.3.3 Water Application and Soil Moisture depletion: Of the three major crops, Dura and cotton are irrigated by furrows and wheat in basins. It has been estimated that the water application efficiency in the Gezira scheme is around 75% (Plusquellec, 1990).

Moisture depletion profiles for both cotton and wheat for 1991-92 crop season were determined by using neutron scattering method from four depths of the root zone (15 cm, 30 cm, 45 cm and 60 cm). For cotton, depletion profiles were computed from eight locations from two Numbers i,e Number 12 of Sunni Minor and Number 7 of Ibrahim Minor. For wheat, profiles were computed from 27 locations from three Hawashas: Hawasha No.1 from Number 2 of Tayba Shimal minor; Hawasha No.9 from Number 11 of Sunni minor and Hawasha No.17 from Number 18 of Ibrahim minor all located in the Pilot farm. Plots of the wetting and depletion characteristics for cotton and wheat are presented in Fig. 5 and 6 respectively.

It was observed that except for the upper 15 cm depth both the crops,generally, received adequate moisture during the entire period of monitoring. The upper 15 cm depth is not critical except during the early part of the vegetative growth period when moisture content in this area was also within the available zone. There are some instances, however, when the moisture level went below the PWP (22% by volume) during the early vegetative phase of growth. For the other three depths where most of the effective roots are located, soil moisture was, in most of the cases well above the PWP. This is indicative of the fact that irrigation was applied well before the soil reservoir was depleted to the allowable limit. In other words the irrigation interval could have been extended by between 5 to 8 days during the season. It should, however, remembered that the 1991-92 had an extended winter season with the average temperature 3 to 4° below normal. It is, therefore, advisable to repeat the experiment during the next two seasons to confirm the possibility of extending the irrigation interval especially during the wheat season which incidentaly is also the low flow months. The data also indicate that moisture distribution in different areas of the Hawashas were more less uniform with very few locations showing variation in the excess of recommended 20%. Such uniformity is probably due to application of water well before the depletion of the soil water reservoir to the allowable limit which resulted in filling up of the reservoir quicker than previous years and the tenants were allowing water to flow for increased number of hours based on previous experience and this helped water to flow to hard to reach ares of the fields.

4.3.4 Irrigation Frequency and Duration: Data on irrigation frequency and duration for cotton, Dura and wheat are presented in Tables 9 thruogh 14.

In most of the Numbers monitored wheat received 7 irrigations except in Numbers 2 of Ibrahim, 3 of Sunni, and 10 of Hieloat which received 6 irrigations each and Number 23 of Elwalie which received 8 irrigations. In the Pilot farm area the irrigation interval ranged from 12 to 21 days and the total number of days of water application ranged from 44 to 88 days. In the Wad

Habouba and Mikashfi Groups irrigation interval ranged from 10 to 17 and 7 to 28 days respectively. Total number of water application days ranged from 64 to 73 and 46 to 58 days respectively in Wad Habouba and Mikashfi Groups. As per recommendation water should have been applied for 49 days during the growing period.

Most of the cotton Numbers also received 12 irrigations (including rainfall- each significant rainfall was considered as one irrigation). Three Numbers, Sunni-4, Sunni-8 and Ibrahim-8 recieved 11, 10 and 11 irrigations respaetively. Irrigation interval ranged from 12 to 25 and 12 to 24 days respectively in the Pilot farm and Mikashfi Groups respectively. Total number of irrigation days ranged from 71 to 145 and 60 to 83 respectively in Pilot farm, Wad Habouba and Mikashfi Groups respectively for Numbers having an area of between 29 and 39 ha.

Frequency of irrigation for Dura ranged from 7 to 8, 5 to 7 and 2 to 4 (excluding rainfall) in the Pilot farm, Wad Habouba and Mikashfi Groups respectively. The irrigation interval ranged from 7 to 20, 5 to 21 and 13 to 26 in Pilot farm, Mikashfi and Wad Habouba Groups respectively. Total number of days of water application ranged from 36 to 80, 60 to 68 and 21 to 67 days in Pilot farm, Wad Habouba and Mikashfi Groups respectively.

4.3.5 Crop Yields: Average yields of major crops have generally been low in the Gezira scheme. Decade of the eighties showed significant fluctuation in yield per unit area (Table 8).

From a low 0.21 t/fd (0.48 t/ha) in the bench mark year wheat yields peaked to 0.94 t/fd (2.24 t/ha) in 1991-92 an increase of over 350%. It has already been mentioned that this year was extremely favorable for wheat growth. A long and cold winter coupled with favorable water supply situation resulting from adequate rainfall in the catchment as well as 13% reduction in area over the previous year combined to set up for the bumper harvest. Even this all time high yield of 0.94 t/fd (2.24 t/ha) is almost a third of the potential yield of 2.80 t/fd (6.67 t/ha) obtained at the research farms (Ishag and Ageeb, 1987). For irrigated wheat a 1.70 to 2.50 t/fd (4.00 to 6.00 t/ha) is considered a good yield (FAO Technical Report No.33).

Like wheat, cotton also went through the fluctuating cycles of high and low yields with 1991-92 season producing an all time high yield of 5.62 k/fd (0.80 t/ha; 1 kantar per feddan = 141 kg/ha), an increase of 52% over last year and 143% increase over the bench mark year. The potential yield obtained in the research farms of 13.30 k/fd (1.88 t/ha) continued to remain well above the average yield obtained by the tenants and with cotton it was higher by 137%. A good yield of a 160 to 180 day cotton crop under irrigation is 0.60 t/fd (1.40 t/ha) to 0.75 t/fd (1.75 t/ha). Unless otherwise mentioned cotton yields have been expressed in terms of lint per unit area (lint constitutes 35% of seed cotton).

Like the two other major crops, wheat and cotton, Dura also registered significant yield increase in 1991-92 season. The increase, however, was less spectacular than other two crops and limited to around 25% over 1990-91. This is due to the fact that unlike wheat and cotton, a large area is planted to traditional varieties. The overall increase over the reporting period was 186%. Ishag and Ageeb (1987) estimated potential yield of Dura in the experimental field as 3 t/fd (7.14 t/ha) which seems quite high. Doorebos et el.(1979) reported that 1.50 to 2.10 t/fd (3.5 to 5 t/ha) can be considered as good yield for irrigated Dura.

4.3.6 Crop Water Requirements and Actual Application: Estimated crop water requirements for major crops in the Gezira scheme is presented in Table 15. These fall within the range recommended by the FAO (Cotton: 700-1300 mm; Dura; 450-650; wheat: 450-650 mm; Irrigation and Drainage Paper No. 33).

In 1990-91 average depth of application for wheat ranged from 667 mm to 993 mm (Haq,K.A.,1991). In the 1991-92 data collected from the 55 Numbers showed that the range was between 661mm to 1380 mm (TABLE. 12). Upper limit of the actual application, therefore, exceeded the recommended application depth by over 100% which is very significant. Even the lower limit is 11 mm above the recommended upper limit.

Actual depth of irrigation application for cotton and Dura were computed in 1991-92 season only. Water application for cotton ranged from 798 to 1908 mm (TABLE. 13). Average irrigation water application (depth added by rainfall excluded) was highest in the Pilot farm area (1622 mm) followed by the Mikashfi (1026 mm) Group. This follows the universal head-tail syndrome where tail always receives minimum water even when both the head and tail areas applied significantly higrer amount of water thn recommended.

Estimated depth of water application for Dura had a very wide variation, especially in Mikashfi Group and Pilot Farm where the minimum and maximum application ranged from 278 to 886 mm and 692 to 1101 mm and the average depth of application was 993 and 514 respectively for Pilot Farm and Mkashfi Group (TABLE 14). In Wad Habouba Group the spread was 776 to 1152 mm with 898 mm as the average. Except for Mikashfi Group where the average applied amount matched closely with the recommended amount (TABLE 15), in the other two study areas the applied amount was significantly higher than those recommended.

All the application depths have been computed without accounting for the rainfall. With rainfall the average application for cotton and dura will increase by 99, 92 and 163 mm respectively for Pilot Farm, Wad Habouba and Mikashfi Groups respectively thus decreasing the WUE further.

4.3.7 Water Use Efficiency: Water use efficiency (kg of produce/cubic meter of water) varied widely for all the three majors crops in all the areas monitored. Computed values for WUE for different crops are presented in Tables 12 through 14. For wheat the WUE ranged from 0.41 to 0.17, 0.10 to 0.11 and 0.46 to 0.10 in Pilot farm, Wad Habouba and Mikashfi Groups respectively. The average values were 0.24, 0.28 and 0.105 respectively. In 1990-91 season the WUE ranged from 0.14 to 0.39 in the selected areas of the Pilot farm (Haq, 1991) and with a substantial increase in yield (t/ha) the corresponding increase in WUE was insignificant and continues to remain at a value less than half those recommended for irrigated wheat (0.80 to 1.00). Ratio of the average values of potential and actual WUE for wheat is 0.24.

For cotton the computed values ranged from 0.10 to 0.17 and 0.10 to 0.20 in the Pilot farm and Mikashfi Group respectively with an average of 0.13 and 0.17. The recommended range is 0.40 to 0.60. The ratio of actual and potential is 0.30.

Calculated WUE values for Dura ranged from 0.20 to 0.25, 0.09 to 0.33 and 0.105 to 0.53 in Pilot farm, Wad Habouba and Mikashfi Groups respectively with 0.24, 0.24 and 0.32 as average values respectively, the ratio being 0.34.

Though WUE values for all the three crops remains significantly low the study found that cotton and dura utilized the irrigation water more effectively than wheat. To improve the WUE, for all the crops discussed above, irrigation application should be matched more precisely with the actual requirements and/or yields shall have to be increased substantially.

4.4 Recommendations

Based on the above discussion and analysis the following recommendations are made to improve the over all performance of irrigated agriculture:

1. Crop acreage should be planned on the basis of the dependable water supply from the reservoirs. This can be estimated from historical stream flow data. For the wheat season peak water demand should be used for estimating areas.

2. Flow control and regulation should be strengthened by recalibrating structures especially those at majors and below. Studies conducted by other researchers indicate that though total volume of water entering the system is adequate to meet the crop water requirements yet serious distributive inequity exists between different areas of the scheme as well as in different "Numbers" of the same area with the tail ends being universally deprived of their fair share.

3. Due to siltation, weed growth and malfunctioning hydraulic structures the conveyance characteristics of the canals have changed from those of the original design. Till these are restored, the system should be operated not by the strict design specification but by the actual conveyance condition. That means personnel responsible should supervise the water distribution system more closely and intensively and regulate flow as per existing conditions which may demand operation of the structures in ways significantly different than those prescribed in the text books. Water flowing well over/under the regulator and over topping of the canal banks are increasingly becoming common in the scheme. At the present time the only way to avoid this is to keep an eye on the situation and regulate the flow accordingly.

4. Though conveyance loss in the scheme is very low (< 10%), yet significant amount of water is lost due to dead storage and over topping of the canals. Dead storage losses quantified in the "Abu Ashreens" and "Abu Sittas" of three "Numbers" in the pilot farm indicated loss of 1000 to 1200 m^3 per irrigation per number. Effective ways including manual pumping of water should be adopted to use this water. If 75% of the 29000 "Numbers" are cropped and an average of 8 irrigations are applied a total volume of 210 million m^3 of water will be lost through dead storage

which is equivalent to 40% the average monthly supply during january when water requirement for wheat is the maximum and constitutes about 3.4% of the average annual release of 6100 million m^3 of the entire system.

5. Water management within the "Hawasha" is far from desirable. Two types of edge effects have been observed both contributing to yield reduction. The high lands within the Hawasha estimated to be 5% suffers from water stress and the low lands and furrow ends from water logging.

To irrigate high lands near the edges of the Abu Ashreens the tenants raise the water level above the "free board" by constructing cross dams on the Abu Ashreens. This practice reduces the gradient between the minor and Abu Ashreen and reduces flow and depending on the duration of high-land-irrigation, tenants may loose a substantial amount of their share of water. High lands should preferably be irrigated by (a) using the water from the dead storage of Abu Ashreens and Abu Sittas, (b) constructing deeper furrows for row crops and deeper corrugations for small grains (like wheat). For wheat, after the first irrigation, the 42 standard basins should be re-adjusted or fine tuned following the wetting pattern of the land or the contour.

Over/under irrigation results from lack of knowledge about the cut-off time. Tenants use their judgement to turn off irrigation. Some guide lines should be provided to the tenants on duration of irrigation. They should be made aware that over irrigation is often more harmful than under irrigation.

6. To save irrigation water row crops (cotton, dura, onion etc) may be irrigated by alternate furrows i,e every furrow should service two rows. Alternately if existing method of furrow irrigation is used alternate furrows should be irrigated every time water is applied. It is estimated that upto 30% water can be saved by this without sacrificing the yield. In the 1990-91 crop season yield trials on cotton were conducted in the Pilot farm by using 'one furrow service two rows' method. There was no significant difference in yield as compared to conventional furrow method. The study unfortunately did not consider water as a variable.

7. Limited study conducted in june, 1992 in collaboration with ARC on moisture distribution from "naked" furrows (uncropped) indicated that moisture distribution is some what uniform up to about 1.5 m on both sides of the furrow when water is allowed to infiltrate for nearly 24 hrs. This opens up the possibility of irrigating upto three rows between furrows. Further studies are needed to confirm this. If successful this expected to reduce volume of water required as wellas weed growth as wetted area will be reduced.

8. Furrow irrigation practiced in the scheme in reality is controlled flood irrigation. Because the field is normally flooded by introducing the water through the furrow. This exposes the plant to prolonged and undesirable water logged condition. This is especially injurious when the crop is in early stages of vegetative growth. Furrow irrigation in its true form should be practiced except when fertilizer is applied on the ridges.

9. The soils of the Gezira scheme like all heavy soils having low intake rates require that they be irrigated in the shortest possible time. But the present Abu Sittas takes too much time to convey water along its entire length of 280 m and thus contributes to low application efficiency. It is, therefore, recommended that pilot studies be conducted by relocating the Abu Ashreens through the middle of the Number. This will reduce length of the Abu Sitta by 50% and irrigation can be completed in shorter duration. For this no new Abu Ashreens needs to be constructed. Half the area of the Numbers on either side of the Abu Ashreen will constitute the new Number. This new arrangement is also expected to discourage construction of "Nacus" (unauthorized Abu Sitta) by the tenants. Some people will argue that the slope of the Gezira may not permit this practice. But the very existence of large number of "Nacus" nulls this hypothesis. Also the slope is so small (5 to 10 cm per kilometer) which can be adjusted without making major investment.

10. Investigations should also be made to assess the possibility of conveying water from the minor to Abu Ashreens on both sides. This is being practiced in certain areas of the scheme where slope is favorable. As has been mentioned earlier the gentle slope of the scheme may not prove to be a major constraint. During the 1991-92 crop season tenants of Number 12 of Sunni minor were in fact drawing water both from Sunni and Ibrahim minor. One third of the area was being supplied from the unauthorized Ibrahim minor.

Normally such arrangements will require resectioning of the minor. But in the Gezira scheme minors also act as night storage reservoir and hence is expected to accommodate the increased volume without much difficulty. Also if night irrigation which already is being practiced by the tenants is formalized the minors will be able to to carry required capacity to serve both sides.

11. Night storage system (NSS) introduced over half a century ago seems to have lost its relevance and tenants in many areas of the scheme is irrigating their hawashas at night. The practice should be encouraged and at the same be institutionalized. This will have following advantages:

1. The increased volume will increase the velocity resulting in decreased deposition of silts in the minors which at present accepts over 30% of the sediment entering the system. The sediment will be transferred to the Abu Ashreens and will be easier to manage if the responsibility of the maintenance of the Abu Ashreens are transferred to the tenants and each tenant is asked to maintain his portion of the canal. Some researchers have expressed concern that sediment diverted to the Abu Ashreens may increase the elevation. But the 10 million m^3 of sediment entering the system every year will increase the field levels by about 1 mm in 10 years.

2. Night storage weirs will no longer be required. This will also reduce sediment deposition in majors which also gets 30% of the sediments carried into the system. Repair and maintenance of these structures will also be eliminated as these will no longer exist.

It may be pointed here that NSS was introduced exclusively for social reasons rather than technical reasons.

12. Fertilizer (N) uptake has been reported to be very low (< 30%). In China around 70 % of the applied nitrogen is productively used. Studies on fertilizer-Water-crop inter-relations should be initiated to improve fertilizer efficiency. Deep placement of fertilizer is being talked about as a way to improve fertilizer uptake. But studies conducted at IRRI and some other institutes demonstrated no decisive advantage of deep placement.

13. During the 1991-92 crop season data collected from the study areas indicated that though the average plant density was near optimum, the variation was highly significant. This was especially true for wheat. Plant count from three Numbers of the pilot farm indicated that average density for wheat were 522, 490 and 648 per m^2 respectively in Sunni minor (Number 11), Ibrahim minor (Number 18) and Tayba Shimal minor (Number 2). For the same Numbers the maximum and minimum densities were 284 and 828, 252 and 808 and 412 and 928 plants per m^2 respectively. This type density distribution decreases yield in areas that are over crowded and also in the sparsely populated areas. Improper adjustment of the seeder and lack of experience on the part of the operator are two major contributing factors. It was also observed that 3 to 5% areas of these Numbers did not have any plants at all. It has been recommended that agronomists from ARC and SGB investigate and identify exact causes for the above mentioned situations and recommend remedial measures.

14. Nearly a third of the scheme area is fallowed every year to improve soil fertility to increase crop yields especially those of cotton. But the decline in cotton yield over the years have negated this hypothesis. It now appears that if water is made available cropping intensity can be increased to 100% without further sacrificing yield. This was supported by most of the field staff. It is, therefore, strongly recommended that potential for conjunctively using surface and ground water be pilot tested for technical feasibility, economic viability and farmers acceptance.

15. Distributive inequity was also observed at the micro-level i,e at the Hawasha level. Soil moisture content in different parts of the same Hawasha varied more than the recommended 20% which demonstrates need for better distribution by improving levellig and control of water delivery.

16. Water depletion profiles computed for the cotton and wheat indicated that moisture content in the effective root zone was much higher than the allowable depletion limit before the next irrigation was applied. This indicates possibility of extension of the irrigation interval.

17. The Gezira soil is low in organic matter content (0.35 to 0.40). Higher organic matter content is expected to improve soil structure, water holding capacity, infiltration rates etc. in addition to supplying nitrogen. In the early days when chemical fertilizers were non-existent nitrogen fixation by leguminous crop (dolicos lablab) and fallows in the rotation were the only ways to ensure high soil fertility levels and ensured availability of essential nutrient for cotton (Burhan and Mansi, 1967). At the present time despite heavy fertilization of the crops in the intensified

rotation--3N as urea for cotton, 2N for Dura and 2N for wheat yield of all the crops either continued to decline or showed no definite trend of increase. It is ,therefore, becoming increasingly important to restart use of organic manure.

There are several cheap and abundant sources of organic matter such as agricultural residue, animal manure (it is estimated that there are over 1.2 million animals in the scheme area and another 2 million graze through the scheme every year). The third one is growing of green manure crop during the lean season.

As has been mentioned earlier experiments have already been initiated for composting cotton residue. It will take several years before scientists can make recommendations on the amount needed per unit area (tons/fd), optimal size of the pit that can be easily constructed and maintained by the tenants, number of crops one application of OM will sustain and the extent of possible reduction in the application of chemical fertilizers.

Raising a green manure crop during the fallow rotation offers a good potential for organic manuring. The best time for planting the crop would be just after the first significant rainfall of the season (> 15 mm) and biomass should be incorporated after 40-45 days. In the rice growing areas of south and south east Asia rice crop preceded by a green manure crop increased yield across the board by about 1 ton/ha and at the same time reduced the application of chemical fertilizer (N) by 50%. In the process a total of 15 t/ ha of green biomass was incorporated in the soil. Studies should, therefore be initiated to select suitable green manure crop(s) and the amount of biomass to be incorporated (t/ha) for increased, sustainable and economically attractive yield. In selecting green manure crops researchers should shop around to ascertain as to what kind of materials are available off-the-shelf that has more relevance to the conditions here. Some new varieties of cow peas developed at the International Institute for Tropical Agriculture (IITA) can be used for green manuring after the crops have been harvested. These are said to be good as cattle feed as well.

Determined efforts must also be made to effectively use the animal manure for improving soil fertility and soil characteristics including those effecting water movement through soil. A good starting point would be to encourage farmers to use animal manure who very soon will be growing 50,000 fd (21000 ha) of citrus. Later the practice could be transferred to field crops.

Though organic manuring is not generally practiced in the Gezira scheme yet some of progressive farmers, ones producing the highest yields, are using all kinds of organic residues including animal blood.

18. Studies conducted during 1990-91 and 1991-92 found that Water use efficiency (kg/m^3 of water) for all the major crops, cotton, wheat and Dura, are very low as compared to the recommended ones. In 1990-91 water use efficiency (WUE) in three selected number ranged from 0.14 to 0.39 as against recommended 0.80 to 1.00. In 1991-92 season, data collected from 27 "Numbers" of the Mikashfi Group indicated that even with a 35% increase in wheat yield over 1990-91 the WUE efficiency continued to remain low and ranged from 0.12 to 0.45.

19. It was also observed that, in 1991-92 crops, especially wheat was left unharvested after the crop was ready for harvest and the optimum harvest time was exceeded by a minimum of 31 days and maximum of 52 days. This was also true in 1990-91 season even in the pilot farm. To reduce shattering losses it has been recommended that timeliness in the harvest be ensured.

20. At present the SGB is responsible for operation and maintenance of FOPS and Abu Ashreens. Like most of the distribution system these have also departed significantly from their designed specifications. It is strongly recommended that farmers be increasingly involved in the operation and maintenance of the FOPs and Abu Ashreens. FOPs should be calibrated in such a way so that farmers are able to quantify the volume of water entering into their systems. For easy maintenance of the Abu Ashreens by the tenants brick lined reference sections should be constructed every 200 meters for two meter lengths through out the entire length of the Abu Ashreens.

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Table 1. Meteorological data for Wad Medani

	Period	J	F	M	A	M	J	J	A	S	O	N	D	Yearly
Rainfall, average (mm)	1941-75	-	-	-	1.0	15.0	27.0	110.0	131.0	52.0	17.0	-	-	354.0
Rainfall, average (mm)	1971-80	-	-	-	3.0	13.0	27.0	94.0	96.0	57.0	8.0	1.0	-	299.0
Rainfall, average (mm)	1981-90	-	-	-	-	18.0	25.7	54.0	95.0	51.7	11.8	3.2	-	259.4
Temperature (degree C)														
mean max.	1941-75	33.4	35.1	38.3	40.8	41.4	39.6	35.8	33.4	35.2	37.8	36.5	33.6	36.7
mean min.	1941-75	14.0	15.2	18.3	21.2	24.0	24.7	22.8	22.0	21.8	21.6	18.0	14.5	19.9
average (max. + min)\2	1941-75	23.7	25.1	28.3	31.0	32.7	32.1	29.3	29.3	28.5	29.7	27.2	24.1	28.3
Temperature (degree C)														
mean max.	1981-90	32.8	34.2	38.0	40.9	41.7	40.2	37.3	36.4	36.4	38.7	36.8	34.0	37.3
mean min.	1981-90	14.3	15.8	19.4	21.5	24.7	25.4	24.0	23.3	22.7	22.7	18.8	16.3	20.7
average (max. + min)/2	1981-90	23.6	25.3	28.7	31.2	33.2	32.8	30.7	30.0	29.6	30.7	27.8	25.2	29.0
Relative humidity mean (%)														
06.00 GMT*	1941-70	38.0	29.0	22.0	18.0	30.0	48.0	68.0	79.0	72.0	52.0	37.0	40.0	44.0
12.00 GMT	1941-70	18.0	13.0	10.0	9.0	15.0	23.0	39.0	51.0	42.0	27.0	19.0	19.0	24.0
18.00 GMT	1941-70	30.0	22.0	16.0	15.0	23.0	35.0	55.0	69.0	62.0	45.0	34.0	33.0	37.0
wind speed, mean (m/s)	1941-70	3.6	4.0	3.6	3.1	3.6	4.5	4.5	4.0	3.1	2.2	3.1	4.0	3.6
Evaporation, Eo (Penman) (mm)	1957-68	177.0	189.0	247.0	256.0	280.0	282.0	244.0	206.0	206.0	204.0	180.0	171.0	2632.0

Source: Agro-climatological study in the Arab Countries (1976), except for evaporation data which were supplied by the Gezira Research Station (GRS)

GMT = Greenwich Mean Time

Table 2 : Weather Data : 1990-91 and 1991-92 Crop Seasons

	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Max Temp. 10 Avg (81-90)	40.20	37.30	36.40	36.40	38.70	36.80	34.00	32.80	34.20	38.00	40.90	41.70
Avg max temp (89-90)	41.10	37.70	37.20	38.0	38.90	37.50	32.30	33.40	33.40	31.90	35.90	41.90
Avg max temp (90/91)	41.80	38.10	39.80	39.00	39.60	38.90	37.40	32.10	34.30	37.90	42.20	43.10
Avg max temp (91/92)	41.20	37.50	35.20	38.30	38.20	37.10	32.50	30.70	30.40	38.00	42.20	41.70
Min Temp 10 Avg (81-90)	25.40	24.00	23.30	22.70	22.70	18.80	16.30	14.30	15.80	19.40	21.50	24.70
Avg min temp (89-90)	25.8	24.2	23.5	23.1	23.20	19.40	14.40	15.20	14.20	15.20	22.80	24.60
Avg min temp (90-91)	25.70	24.10	24.40	23.50	23.30	20.80	19.20	13.70	15.60	17.90	24.10	24.80
Avg min temp (91-92)	26.00	24.40	22.70	22.70	21.30	18.00	13.30	12.10	11.80	18.50	24.10	26.90
Rainfall 10 Yr avg (81-90)	25.70	54.00	95.00	51.70	11.80	3.20						18.00
Rainfall (90-91)	7.70	38.90	0.30	27.60	40.90						1.30	
Rainfall (91-92)		40.20	56.20	51.40	44.40							

Source: Wad Medani Meteorological Station

TABLE 3: MONTHLY DIVERSION OF WATER (MILLION M^3) AT SENNAR (1987-1992)

MONTH	1987	1988	1989	1990	1991	1992
January	506.6	541.1	565.9	690.2	648.6	634.4
February	391.8	498.6	493.6	534.1	553.5	557.9
March	280.2	304.0	361.1	266.6	218.6	390.1
April	34.6	59.9	75.5	62.2	57.5	65.7
May	53.5	66.6	66.8	94.4	67.7	68.4
June	199.8	270.0	187.9	238.2	150.8	231.0
July	622.9	530.0	487.7	594.8	668.0	-
August	520.0	482.3	568.9	739.1	628.8	-
September	694.5	502.8	525.2	800.8	827.9	-
October	924.9	811.1	895.0	893.2	923.4	-
November	851.0	759.6	869.0	863.7	788.3	-
December	672.8	780.0	797.7	818.6	797.1	-
TOTAL	5752.6	5606.1	5892.3	6596.0	6330.3	1947.5

Source: Ministry of Irrigation, Wad Medeni

Table 4 : History of Crop Rotations (1925 - to date)

Season	Details of the Rotation	
1925-1930	Cotton Dura/Lubia-Fallow-Cotton-Dura/Lubia-Fallow	(6-course)
1931-1932	Cotton-Fallow-Fallow-Cotton-Fallow-Fallow	(6-course)
1933-1960	Cotton-Fallow-Dura-Lubia/Fallow-Fallow-Cotton-Fallow-Fallow	(8-course)
1961-1974	Cotton-Wheat-Fallow-Cotton-Lubia-Groundnuts-Dura/Phillipesara-Fallow	(8-course)
1975-to date	Cotton-Wheat-Groundnuts/Dura/Vegetables-Fallow	(4-course)
1986 (barakat-block)	Cotton-Wheat-Groundnuts/Dura/Vegetables-Fodder-Fallow	(5-course)

Source : Ishag et.el

Table 5. Agronomic Practices and their impact on Wheat Yield

Serial NO.	Location	Number	Date of Sowing	Date of Harvest	Field Durati (Days)	Yield t/ha
1	Tayba Shimal (Tayba)	2	06.11.91	08.04.92	154	3.09
2	Tayba Shimal (Tayba)	6	04.11.91	01.04.92	147	3.33
3	Ibrahim (Tayba)	2	21.11.91	16.04.92	147	1.95
4	Ibrahim (Tayba)	12	19.11.91	21.04.92	154	2.09
5	Ibrahim (Tayba)	17	07.11.91	10.04.92	155	2.36
6	Sunni (Tayba)	3	28.11.91	15.04.92	139	2.14
7	Sunni (Tayba)	11	04.11.91	08.04.92	156	2.62
8	Sunni (Tayba)	14	06.11.91	10.04.92	156	2.48
9	Saadiya (Huda)	1	02.11.91	10.04.92	159	1.93
10	Saadiya (Huda)	7	20.11.91	10.04.92	141	0.98
11	Saadiya (Huda)	10	26.11.91	10.04.92	135	1.38
12	Kareima (Huda)	1	12.11.91	12.04.92	151	1.48
13	Om Husan (Huda)	1	03.11.91	16.04.92	163	1.36
14	Om Husan (Huda)	7	08.11.91	16.04.92	159	1.09
15	Om Husan (Huda)	12	05.11.91	16.04.92	162	1.09
16	Garash (A.Gani)	1	24.11.91	29.04.92	156	2.33
17	Garash (A.Gani)	7	25.11.91	29.04.92	155	1.93
18	Garash (A.Gani)	10	26.11.91	28.04.92	153	1.81
19	Hamdnall (A.Gani)	1	30.10.91	04.04.92	157	2.55
20	Hamdnall (A.Gani)	7	06.11.91	05.04.92	150	2.71
21	Hamdnall (A.Gani)	9	07.11.91	05.04.92	149	2.52
22	Abdalla Yousif(A.Gani)	7	02.11.91	10.04.92	159	2.59
23	Abdalla Yousif(A.Gani)	21	30.11.91	16.04.92	137	2.57
24	Abdalla Yousif(A.Gani)	31	30.11.91	16.04.92	137	3.19
25	Garab (Abrag)	39	15.11.91	17.04.92	153	2.19
26	Garab (Abrag)	36	13.11.91	17.04.92	155	2.31
27	Garab (Abrag)	33	10.11.91	15.04.92	156	1.81
28	Garab (Abrag)	7	04.11.91	05.04.92	152	2.64
29	Garab (Abrag)	10	05.11.91	05.04.92	151	2.64
30	Garab (Abrag)	63	20.11.91	20.04.92	151	2.64
31	Garab (Abrag)	1	01.11.91	20.04.92	151	1.55
32	Garab (Abrag)	54	20.11.91	05.04.92	155	2.50
33	UmSayala(Istrahna)	3	20.11.91	20.03.92	121	0.98
34	Elwalie(Istrahna)	23	01.11.91	01.03.92	121	0.92
35	Hieloat(Istrahna)	10	15.11.91	15.03.92	121	0.83

Table 6 : Agronomic Practices and Their Impact on Cotton Yield

	Location	Number	Date of Sowing	Date of Harvesting	Field Duration (Days)	Yield T/ha
1	Tyba Shimal	3	05.07.91	23.12.91	170	2.46
2	Tyba Shimal	9	08.07.91	12.12.91	156	2.00
3	Sunni	4	15.07.91	08.12.91	145	1.83
4	Sunni	8	14.07.91	27.12.91	165	2.17
5	Sunni	12	20.07.91	30.12.91	162	2.26
6	Ibrahim	8	28.07.91	19.01.91	174	1.57
7	Ibrahim	14	15.07.91	28.12.91	165	2.31
8	Gorash (A/Gani)	2	08.07.91	21.12.91	165	1.91
9	Gorash (A/Gani)	5	10.07.91	22.12.91	164	1.83
10	Gorash (A/Gani)	11	15.07.91	22.12.91	159	1.30
11	Adb alla yousif (A/G)	2	16.07.91	24.12.91	160	1.63
12	Adb alla yousif (A/G)	11	18.07.91	24.12.91	158	1.57
13	Hamadnalla (A/G)	2	16.07.91	24.12.91	160	1.97
14	Hamadnalla (A/G)	11	13.07.91	20.12.91	161	1.57
15	Adb alla yousif (A/G)	25	21.07.91	27.12.91	158	1.57
16	Hamadnalla (A/G)	5	16.07.91	23.12.91	159	1.63
17	Om Husan (Huda)	13	27.07.91	25.12.91	150	1.37
18	Om Husan (Huda)	5	22.07.91	22.12.91	152	1.57
19	Om Husan (Huda)	2	20.07.91	22.12.91	154	1.97
20	Kariema	12	18.7.91	22.12.91	156	1.14
21	Kariema (Huda)	5	15.7.91	22.12.91	159	1.71
22	Saadiya (Huda)	10	15.7.91	20.12.91	157	1.43
23	Saadiya (Huda)	2	10.7.91	21.12.91	163	2.17
24	Kariema (Huda)	2	17.7.91	22.12.91	157	1.37

Note:

1. Harvest date indicated is the date of 1st picking. Cotton is generally picked 3 times and after each picking irrigation is applied. Two to three weeks gap between picking is a usual practice.
2. Yields are in seed cotton.

Table 7: Agronomic Practices and Their Impact on Sorghum (Dura) Yield

SERIAL NO.	LOCATION	NUMBER	Date of Sowing	Date of Harvest	Field Duration (Days)	Yield T/ha
1	Tayba Shimal (Tayba)	4	15.7.91	20.11.91	127	1.48
2	Tayba Shimal (Tayba	8	15.7.91	15.11.91	122	3.57
3	Ibrahim (Tayba)	9	17.7.91	14.11.91	119	2.19
4	Ibrahim (Tayba)	16	2.8.91	28.11.91	117	1.95
5	Sunni (Tayba)	13	29.7.91	20.11.91	113	2.19
6	Sunni (Tayba)	9	12.7.91	18.11.91	128	2.62
7	Saadiya (Huda)	3	27.7.91	30.10.91	95	1.67
8	Saadiya (Huda)	5	15.7.91	30.10.91	107	1.20
9	Kareima (Huda)	17	18.6.91	01.11.91	104	0.71
10	Om Husan (Huda)	10	15.6.91	21.10.91	127	0.95
11	Om Husan (Huda)	3	05.7.91	24.10.91	110	1.19
12	Garash (A.Gani)	3	30.7.91	31.10.91	93	1.67
13	Garash (A.Gani)	6	28.6.91	15.10.91	108	1.79
14	Garash (A.Gani)	13	20.6.91	15.10.91	111	2.62
15	Hamdnalla (A.Gani)	10	25.7.91	29.10.91	96	1.43
16	Hamdnalla (A.Gani)	6	20.7.91	26.1091	92	1.67
17	Hamdnalla (A.Gani)	3	30.7.91	31.10.91	93	1.90
18	Abdalla Yousif(A.Gani)	26	25.7.91	29.10.91	96	1.19
19	Abdalla Yousif(A.Gani)	13	15.7.91	20.10.91	97	1.43
20	Abdalla Yousif(A.Gani)	3	20.7.91	26.10.91	97	1.90
21	Gorab (Abrag)	6	19.6.91	10.10.91	112	2.86
22	Gorab (Abrag)	14	19.6.91	11.10.91	113	3.33
23	Gorab (Abrag)	26	01.7.91	16.10.91	106	2.14
24	Gorab (Abrag)	29	25.6.91	16.10.91	113	1.90
25	Gorab (Abrag)	34	02.7.91	20.10.91	109	1.79
26	Gorab (Abrag)	41	28.6.91	19.10.91	112	1.90
27	Gorab (Abrag)	50	10.7.91	10.11.91	123	0.71
28	UmSayala (Istrahna)	5	10.7.91	01.12.91	142	0.75
29	Hieloat (Istrahna)	7	15.7.91	01.12.91	137	0.7
30	Elwalie (Istrahna)	17	20.7.91	30.11.91	132	2.33
31	Hieloat (Istrahna)	27	25.7.91	02.12.91	128	2.57
32	Gadelalian (Dolga)	12	10.7.91	01.12.91	142	2.8

Table 8 : Proposed and Actual Area (fd) Under Wheat, Dura and Cotton In Gezira Scheme

	Wheat			Sorghum (Dura)			Cotton		
Season	Proposed	Actual	Yield (t/fd)	Proposed	Actual	Yield (t/fd)	Proposed	Actual	Yield (k/fd)
1980/81	407644	366737	0.28	297685	300832	0.23	522060	610000	2.31
1981/82	296548	267863	0.33	307897	343899	0.26	438606	610000	3.88
1982/83	203087	155538	0.60	303397	320940	0.39	486606	610000	4.70
1983/84	297625	265824	0.39	324980	410791	0.53	510575	610000	4.93
1984/85*	-	-	-	301122	420068	0.35	490207	610000	5.22
1985/86	275033	242497	0.40	345863	578753	0.55	415879	610000	3.45
1986/87	221806	179869	0.44	291629	448005	0.40	419458	610000	4.93
1987/88	271499	252313	0.47	262421	390295	0.38	385069	610000	4.57
1988/89	308293	274247	0.56	315681	426810	0.50	404505	610000	5.20
1989/90	396424	392297	0.66	283045	440953	0.49	357983	391799	4.14
1990/91	613132	613305	0.44	282419	506577	0.53	251047	258831	3.70
1991/92	543327	532813	0.44	420767	709640	0.66	215503	229440	5.62

*No wheat was grown in 1984-85 season due to low flow in the river.

1 ha = 2.38 fd.

1 Kantar per feddan = 141 kg/ha

Table 9 : Date of First and Last Irrigation, Irrigation Frequency and Interval (1991-92): Wheat

SERIAL NO.	LOCATION	NUMBER	DATE OF FIRST IRRIGATION	IRRIGATION INTERVAL (DAYS)						
				2ND	3RD	4TH	5TH	6TH	7TH	8TH
1	Tayba Shimal (Tayba)	2	11.15.91	14	16	16	15	14	16	-
2	Tayba Shimal (Tayba)	6	11.18.91	18	14	16	15	14	12	-
3	Ibrahim (Tayba)	2	11.28.91	13	12	14	14	15	-	-
4	Ibrahim (Tayba)	12	11.23.91	13	14	14	15	16	12	-
5	Ibrahim (Tayba)	17	11.17.91	21	14	15	13	16	14	-
6	Sunni (Tayba)	3	12.02.91	16	15	12	14	14	-	-
7	Sunni (Tayba)	11	11.14.91	13	13	11	13	14	14	-
8	Sunni (Tayba)	14	11.17.91	12	12	14	16	11	14	-
9	Saadiya (Huda)	1	11.08.91	28	15	15	15	15	13	-
10	Saadiya (Huda)	7	11.22.91	14	17	16	17	18	19	-
11	Saadiya (Huda)	10	12.01.91	18	15	16	16	16	17	-
12	Kareima (Huda)	1	11.20.91	18	7	15	14	14	18	-
13	Om Husan (Huda)	1	11.21.91	18	14	14	17	15	14	-
14	Om Husan (Huda)	7	11.14.91	17	17	15	16	13	16	-
15	Om Husan (Huda)	12	11.16.91	17	15	17	15	16	15	-
16	Garash (A.Gani)	1	11.29.91	18	15	14	13	14	14	-
17	Garash (A.Gani)	7	12.01.91	18	14	14	15	14	14	-
18	Garash (A.Gani)	10	12.03.91	18	14	14	13	14	15	-
19	Hamdnall (A.Gani)	1	11.17.91	18	15	14	14	16	-	-
20	Hamdnall (A.Gani)	7	11.10.91	18	16	14	17	17	16	-
21	Hamdnall (A.Gani)	9	11.20.91	18	15	15	14	14	16	-
22	Abdalla Yousif(A.Gani)	7	11.14.91	19	14	16	14	16	14	-
23	Abdalla Yousif(A.Gani)	21	11.03.91	21	13	15	14	14	17	-
24	Abdalla Yousif(A.Gani)	31	12.05.91	18	14	14	14	13	14	-
25	Garab (Abrag)	54	11.22.91	18	17	16	15	17	14	-
26	Garab (Abrag)	39	11.20.91	20	14	15	14	15	16	-
27	Garab (Abrag)	36	11.17.91	19	16	16	15	15	15	-
28	Garab (Abrag)	33	11.15.91	18	14	17	15	17	16	-
29	Garab (Abrag)	7	11.12.91	18	14	16	16	14	16	-
30	Garab (Abrag)	10	11.15.91	19	14	16	15	16	15	-
31	Garab (Abrag)	58	11.25.91	16	16	14	15	16	16	-
32	Garab (Abrag)	63	11.29.91	11	15	16	14	15	16	-
33	UmSayala (Istrahna)	3	11.20.91	15	15	10	16	15	16	-
34	Elwalie (Istrahna)	23	11.01.91	14	15	12	14	15	10	16
35	Hieloat (Istrahna)	10	11.15.91	14	17	14	16	15	-	-

Table 10 : Date of First and Last Irrigation, Irrigation Frequency and Interval (1991-1992) - Cotton

	Location	Number	1st Irrig Date	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
1	TS	3	08/7/91	14	14	25	15	15	14	15	15	15	13	23
2	TS	9	10/7/91	15	15	14	14	16	14	15	15	14	15	14
3	Sunni	4	18/7/91	15	14	16	15	14	13	16	17	16	13	-
4	Sunni	8	17/7/91	18	16	15	15	17	14	15	14	17	-	-
5	Sunni	12	23/7/91	17	14	17	13	14	15	16	15	13	13	15
6	Ibrahim	8	02/8/91	18	18	18	16	12	22	18	18	16	20	
7	Ibrahim	14	17/7/91	16	15	17	16	13	15	16	14	14	15	22
8	Gorash (A/Gani)	2	05/7/91	Rain	Rain	Rain	14	14	15	14	14	15	14	16
9	Gorash (A/Gani)	5	08/7/91	Rain	Rain	Rain	14	16	14	15	14	14	13	16
10	Gorash (A/Gani)	11	12/7/91	Rain	Rain	Rain	14	16	15	14	14	15	16	15
11	Adb alla yousif	2	14/7/91	Rain	Rain	Rain	14	13	14	15	14	16	15	15
12	Adb alla yousif	11	15/7/91	Rain	Rain	Rain	14	14	14	15	15	15	14	15
13	Hamadnalla	2	14/7/91	Rain	Rain	Rain	15	14	14	14	15	14	14	12
14	Hamadnalla	11	12/7/91	Rain	Rain	Rain	14	14	14	14	14	14	14	14
15	Adb alla yousif	25	18/7/91	Rain	Rain	Rain	14	14	16	14	15	14	15	16
16	Hamadnalla	5	15/7/91	Rain	Rain	Rain	14	14	14	15	14	14	14	15
17	Om Husan (Huda)	13	27/7/91	Rain	Rain	Rain	14	13	14	16	14	14	17	16
18	Om Husan (Huda)	5	20/7/91	Rain	Rain	Rain	14	15	14	14	14	14	14	15
19	Om Husan (Huda)	2	18/7/91	Rain	Rain	Rain	14	14	14	14	14	14	15	17
20	Kariema (Huda)	12	14/7/91	Rain	Rain	Rain	14	14	14	15	14	14	14	15
21	Kariema (Huda)	5	15/7/91	Rain	Rain	Rain	24	12	14	14	15	15	15	15
22	Saadiya (Huda)	10	15/7/91	Rain	Rain	Rain	15	14	14	14	14	14	13	14
23	Saadiya (Huda)	2	08/7/91	Rain	Rain	Rain	16	14	15	14	16	16	16	15
24	Kariema (Huda)	2	15/7/91	Rain	Rain	Rain	15	13	14	15	14	14	15	15

TABLE 11 : DATE OF FIRST AND LAST IRRIGATION, IRRIGATION FREQUENCY AND INTERVAL (1991-92) SORGHUM (DURA)

SERIAL NO.	LOCATION	NUMBER	DATE OF FIRST IRRIGATION	IRRIGATION INTERVAL (DAYS)						
				2ND	3RD	4TH	5TH	6TH	7TH	8TH
1	Tayba Shimal (Tayba)	4	5.8.91	12	15	11	12	11	7	-
2	Tayba Shimal (Tayba)	8	20.7.91	14	11	11	11	12	14	13
3	Ibrahim (Tayba)	9	22.7.91	12	13	16	12	17	13	-
4	Ibrahim (Tayba)	16	9.8.92	14	13	12	15	17	13	-
5	Sunni (Tayba)	9	20.7.91	15	15	13	14	15	13	20
6	Sunni (Tayba)	13	5.8.91	12	16	13	16	12	15	-
7	Saadiya (Huda)	3	27.7.91	11	Rain	Rain	9	-	-	-
8	Saadiya (Huda)	5	28.7.91	16	Rain	Rain	5	-	-	-
9	Kareima (Huda)	17	24.6.91	11	9	Rain	Rain	21	-	-
10	Om Husan (Huda)	10	20.6.91	11	8	Rain	Rain	11	-	-
11	Om Husan (Huda)	3	13.7.91	10	Rain	Rain	11		-	-
12	Garash (A.Gani)	3	2.8.91	15	Rain	Rain	8	12	-	-
13	Garash (A.Gani)	6	1.7.91	10	Rain	Rain	10	12	-	-
14	Garash (A.Gani)	13	8.7.91	12	Rain	Rain	9	13	-	-
15	Hamdnalla (A.Gani)	10	27.7.91	14	Rain	Rain	11	9	-	-
16	Hamdnalla (A.Gani)	6	27.7.91	19	Rain	Rain	9	10	-	-
17	Hamdnalla (A.Gani)	3	2.8.91	15	Rain	Rain	8	12	-	-
18	Abdalla Yousif(A.Gani)	26	27.7.91	13	Rain	Rain	13	11	-	-
19	Abdalla Yousif(A.Gani)	13	16.7.91	9	Rain	Rain	12	11	-	-
20	Abdalla Yousif(A.Gani)	3	25.7.91	11	Rain	Rain	11	10	-	-
21	Garab (Abrag)	6	22.6.91	18	Rain	Rain	10	13	-	-
22	Garab (Abrag)	14	27.6.91	13	Rain	Rain	10	-	-	-
23	Garab (Abrag)	26	5.7.91	11	7	Rain	11	9	-	-
24	Garab (Abrag)	29	2.7.91	10	13	Rain	11	8	-	-
25	Garab (Abrag)	34	5.7.91	10	8	Rain	11	7	-	-
26	Garab (Abrag)	41	1.7.91	14	Rain	14	21	18	-	-
27	Garab (Abrag)	50	15.7.91	21	Rain	15	15	-		
28	UmSayala (Istrahna)	5	10.7.91	12	19	15	16	15	20	-
29	Hieloat (Istrahna)	7	15.7.91	16	-	-	24	-	-	-
30	Elwalie (Istrahna)	17	25.7.91	-	-	-	16	15	16	-
31	Hieloat (Istrahna)	27	25.7.91	15	-	-	-	15	17	13
32	Gadelalian (Dolga)	12	10.7.91	15	-	-	-	26	20	-

Table 12 : Irrigation Frequency, Irrigation Days, Depth of Application and Wue : Wheat

SERIAL NO.	LOCATION	NUMBER	AREA (HA)	NO. OF IRRIGATION	DAYS OF IRRIGATION	DEPTH APPLIED (MM)	WUE (KG/M3)
1	Tayba Shimal (Tayba)	2	29	7	44	759	0.41
2	Tayba Shimal (Tayba)	6	29	7	66	1138	0.30
3	Ibrahim (Tayba)	2	32	6	73	1141	0.17
4	Ibrahim (Tayba)	12	38	7	80	1053	0.20
5	Ibrahim (Tayba)	17	34	7	88	1294	0.18
6	Sunni (Tayba)	3	38	6	80	1053	0.20
7	Sunni (Tayba)	11	38	7	78	1026	0.25
8	Sunni (Tayba)	14	38	7	77	1013	0.24
9	Saadiya (Huda)	1	37	7	65	868	0.22
10	Saadiya (Huda)	7	28	7	56	987	0.10
11	Saadiya (Huda)	10	19	7	53	1204	0.26
12	Saadiya (Huda)	1	36	7	56	771	0.19
13	Om Husan (Huda)	1	38	7	57	754	0.18
14	Om Husan (Huda)	7	38	7	58	767	0.14
15	Om Husan (Huda)	12	38	7	57	754	0.15
16	Gorash (AbdelGani)	1	37	7	52	703	0.33
17	Gorash (AbdelGani)	7	38	7	50	661	0.29
18	Gorash (AbdelGani)	10	38	7	50	661	0.27
19	Hamdnall (Abdel)	1	28	6	46	811	0.31
20	Hamdnall (Abdel)	7	38	7	57	754	0.36
21	Hamdnall (AbdelGani)	9	13	7	55	784	0.32
22	Abdalla Yousif	7	38	7	55	727	0.36
23	Abdalla Yousif	21	38	7	53	794	0.37
24	Abdalla Yousif	31	38	7	53	701	0.46
25	Gorab (Abrag)	54	35	7	56	808	0.30
26	Gorab (Abrag)	39	38	7	55	714	0.30
27	Gorab (Abrag)	36	38	7	58	754	0.30
28	Gorab (Abrag)	33	38	7	56	741	0.24
29	Gorab (Abrag)	7	38	7	55	714	0.36
30	Gorab (Abrag)	10	38	7	55	727	0.36
31	Gorab (Abrag)	58	38	7	55	727	0.36
32	Gorab (Abrag)	63	21	7	50	1380	0.13
33	UmSayala	3	38	7	65	855	0.11
34	Elwalie	23	38	8	73	965	0.10
35	Hieloat	10	38	6	64	842	0.10

Table 13 : Irrigation Frequencies, Irrigation Days, Depth of Application, Crop Yield (Cotton) & Wue

	Location	Number	Area/Ha	No. of Irrigation	Days of Irrigation	Depth Applied/mm	Yield Ta/Ha	WUE Kg/m3
1	Tyba Shimal	3	29	12	87	1500	2.46	0.17
2	Tyba Shimal	9	29	12	71	1224	2.00	0.16
3	Sunni	4	34	11	115	1690	1.83	0.11
4	Sunni	8	38	10	118	1552	2.17	0.12
5	Sunni	12	38	12	142	1868	2.26	0.12
6	Ibrahim	8	38	11	123	1618	1.57	0.10
7	Ibrahim	14	38	12	145	1908	2.31	0.12
8	Gorash (A/Gani)	2	38	9	79	1040	1.91	0.18
9	Gorash (A/Gani)	5	38	9	78	1026	1.83	0.18
10	Gorash (A/Gani)	11	38	9	71	934	1.30	0.14
11	Adb alla yousif	2	38	9	76	1000	1.63	0.16
12	Adb alla yousif	11	38	9	76	1000	1.57	0.15
13	Hamadnalla (A/G)	2	28	9	55	982	1.97	0.20
14	Hamadnalla (A/G)	11	13	9	31	1192	1.57	0.13
15	Adb alla yousif	25	30	9	60	992	1.57	0.16
16	Hamadnalla (A/G)	5	36	9	76	1055	1.63	0.15
17	Om Husan (Huda)	13	38	9	81	1065	1.37	0.13
18	Om Husan (Huda)	5	38	9	80	1058	1.57	0.15
19	Om Husan (Huda)	2	38	9	78	1032	1.97	0.19
20	Kariema (Huda)	12	19	9	41	1080	1.14	0.10
21	Kariema (Huda)	5	19	9	42	798	1.71	0.16
22	Saadiya (Huda)	10	19	9	41	1078	1.43	0.13
23	Saadiya (Huda)	2	37	9	83	1123	2.17	0.19
24	Kariema (Huda)	2	37	9	74	998	1.37	0.14

TABLE 14: IRRIGATION FREQUENCY, IRRIGATION DAYS, DEPTH OF APPLICATION AND WUE: SORGHUM (DURA)

LOCATION	NO.	AREA HA	NO. OF IRRIGATION	DAYS OF IRRIGATION	DEPTH APPLIED/mm	WUE Kg/m3
1 Tyba Shimal	4	13	7	36	692	0.22
2 Tyba Shimal	8	34	8	63	1017	0.33
3 Ibrahim	9	17	7	37	1101	0.20
4 Ibrahim	16	38	7	74	978	0.20
5 Sunni (Tayba)	13	19	7	40	1058	0.22
6 Sunni (Tayba)	9	38	8	80	1052	0.25
7 Saadiya (Huda)	3	19	2	23	615	0.27
8 Saadiya (Huda)	5	21	2	21	500	0.24
9 Kariema (Huda)	17	38	3	41	548	0.13
10 Om Husan (Huda)	10	38	3	30	397	0.24
11 Om Husan (Huda)	3	38	2	21	278	0.43
12 Gorash (A/Gani)	3	38	3	32	423	0.39
13 Gorash (A/Gani)	6	38	3	34	450	0.40
14 Gorash (A/Gani)	13					
15 Hamadnalla (A/G)	10	38	3	34	635	0.32
16 Hamadnalla (A/G)	6	38	3	38	602	0.33
17 Hamadnalla (A/G)	3	38	3	35	426	0.41
18 Adb alla yousif	26	38	3	37	489	0.24
19 Adb alla yousif	13	38	3	32	423	0.37
20 Adb alla yousif	3	38	3	32	423	0.45
21 Gorab (Abrag)	6	38	3	41	542	0.53
22 Gorab (Abrag)	14	38	2	23	304	0.10
23 Gorab (Abrag)	26	38	4	38	502	0.43
24 Gorab (Abrag)	29	38	4	42	555	0.34
25 Gorab (Abrag)	34	38	4	36	476	0.38
26 Gorab (Abrag)	41	38	4	67	886	0.21
27 Gorab (Abrag)	50	38	4	61	807	0.10
28 Umsayala (Istrahnna)	5	38	7	66	1152	0.20
29 Hieloat (Istrahna)	7	38	5	60	790	0.09
30 Wali (Istrahna)	17	38	5	68	895	0.26
31 Hieloat (Istrahna)	27	38	6	59	776	0.33
32 Gadelaliem (Dolga)	12	38	5	67	882	0.32

Table 15 : Monthly Crop - Water Requirement in the Gezira Scheme in m3/ha

	COTTON	COTTON	WHEAT	GROUND-NUT	SORGHUM
January	724	150	799	0	0
February	150	0	23	0	0
March	105	0	0	0	0
April	0	0	0	0	0
May	0	0	0	0	0
June	0	0	0	1.207	806
July	200	200	0	700	598
August	565	576	0	868	910
September	548	753	0	924	936
October	884	1.016	257	404	435
November	889	915	657	0	0
December	822	569	737	0	0
Total	4,887	4,179	2,473	4,103	3,685
M3/ha	12,678	10,447	6,388	9,722	8,759
Mm	(1270)	(1045)	(640)	(972)	(876)

Source: Gezira Rehabilitation Project, Staff Appraisal Report

Note: 1. Crop requirements are at field outlet pipe taking into account the staggered planting dates and requirements for initial irrigation.

2. Crop requirements are calculated using the crop factor based on GRS field measurements (GRS 1979) and the Penman EO at Wad Medani.

3. FAO recommendation for wheat: 450-650 mm.

AGREEMENT BETWEEN RPMU AND IIMI

Between the Sudan Gezira Rehabilitation Project Management Unit (hereinafter called RPMU of the one part and the International Irrigation management Institute (hereinafter called IIMI) of the second part.

WHEREAS

a) the Government of Sudan, and IIMI on 2nd February 1989 entered into a Memorandum of Agreement (MOA) to provide for collaborative activities for mutual benefit in the field of irrigation management.

b) the MOA by Article 3:1 provides for further expansion of such collaborative activities with other agencies.

c) the RPMU, inspired by common interests and objectives, and in recognition of complementarily of mutual concerns in irrigation management in general and water management in particular, has sought IIMI's expertise to collaborate with it in the latter field.

d) the World Bank has indicated its willingness to sponsor and finance the recruitment of a Senior Water Management Adviser (SWMA) by IIMI to assist in this endeavor, whose costs (Schedule I) will be met under its Technical Assistance program as part of the Gezira Rehabilitation Program.

e) the Technical Assistance will be carried out by IIMI in collaboration with the Sudan Gezira Board (hereinafter called SGB).

NOW THEREFORE, the parties hereto agree as follows:

Article I

OBJECTIVES

In order to achieve the stated objectives, both parties have agreed to;

A) to collaborate on research projects and/or field evaluation of irrigation management techniques,

B) to exchange scientific literature, information and research methodologies, and

C) specifically, to recruit a Senior Water Management Adviser to the SGB under the Gezira Rehabilitation Project, to implement the agreed program of work.

The program of work covers:

a) the provision of advice on Water Management aspects of the experiments being conducted at the Pilot Farm and on the utilization and implementation of the results of the experiments.

b) the establishment of Water Management Advisory Unit to be created under the Gezira Rehabilitation Program.

The parties agree to implement the Technical Assistance in accordance with the provisions of this agreement and as outlined above.

Article II

RESPONSIBILITIES OF IIMI

to achieve the above objectives, subject to personnel and budgetary limitations, IIMI undertakes to:

A) provide the services of its internationally recruited staff, as to be mutually agreed on and to provide other services from within or other research institutions to collaborate with SGB in agreed ongoing programs,

B) recruit a mutually acceptable resident international irrigation specialist (Schedule II) as the Senior Water Management Adviser on water management to the Agricultural Manager of the SGB and who will

   a) advise the SGB on the identification of the technical and managerial issues relevant to irrigation:

   b) translate the results of problem identification and analysis into research and remedial action programs:

   c) closely attend to the planning and progress being made on the Pilot Farm and, working through the Agricultural Manager, SGB, provide advice to the Steering Committee, and the Project Manage;

   d) advise SGB on the further development of the Water Management Advisory Unit;

e) make recommendations on the type and content of training needed or the SGB field staff of the Water management Advisory Unit;

f) organize short workshops or seminar orient toward issues in irrigation management to be jointly attended by staff SGB, MOI, Universities and other relevant institutions.

g) advise on drafting revised operating rules and procedures to the extent that is necessary in relation to specific components to the system:

h) liaise with the national and international organizations active in the field of irrigation management research for the benefit of the system;

i) promote and arrange the linkages between activities carried out in Sudan and similar activities undertaken in countries participating in IIMI's international irrigation management research and development network.

Article III

RESPONSIBILITIES OF RPMU

RPMU shall, to support the proposed program of work, arrange for the provision by SGB of,

A) competent counterpart staff in respect to the Pilot Farm and Water Management Advisory Unit to be recruited by mutual agreement between the parties

B) adequate office accommodation for the SWMA and staff, and

C) support staff for secretarial and allied functions of the SWMA.

Article IV

TERMS AND CONDITIONS OF ASSIGNMENT

A) The SWMA appointed by IIMI will enjoy all the privileges available to IIMI staff as provided for in Article 6 of the existing MOA with the Government of Sudan.

B) The period of assignment of SWMA will be two years in the first instance, which can be extended for another year if parties so agreed.

Article V

ARRANGEMENTS FOR IMPLEMENTATION

To provide for the smooth integration of IIMI activities with those of SGB, the following arrangements will be adopted.

The adviser will conduct all operational matters through the Director of Agriculture, SGB. His immediate counterparts will be the Manager, Pilot Farm and Head of the Water Management Advisory Unit.

In view of the need to review periodically (as may be determined by mutual consent) the progress of such collaborative activities and approach such activities on a programmatic basis, the work plans as may be jointly developed as agreed under the program has to be forwarded to the Steering Committee of the Pilot Farm as set for the RPMU/SGB for discussion and review.

In view of the further need to insure consistent approach and general conformity with IIMI's overall program in Sudan, the Head of Sudan Field Operations will be co-opted as a member of the Steering Committee of the Pilot Farm.

Article VI

WORK PLANS

This Agreement will be supplemented with the work plans to be developed jointly, covering the more specific activities to be carried out under the cooperative program and setting forth the proposed contributions of each party. These work plans may originate from either party but require mutual agreement for implementation.

Article VII

FUNDING AND ACCOUNTABILITY

A) The RPMU shall make available funds, inn accordance with terms and conditions hereinafter set forth, for the recruitment and employment of the Senior Water Management Adviser, as outlined in Schedule I.

B) All the items of expenditure under the program to be financed by the RPMU will be considered as foreign currency expenditure in United States Dollars except items of expenditure in Schedule I which are considered as Local Costs or as otherwise agreed to between IIMI and RPMU.

C) Except as RPMU and IIMI agree, and subject to the agreement of the World Bank, IIMI will receive an initial advance payment as per Schedule No. II.

Thereafter the funds shall be drawn down quarterly by IIMI on the basis of the work actually performed under the contract.

D) At the end of each quarter, IIMI shall make a written application for drawdown of allocated RPMU funds, setting out work performed and specific items of expenditure for which the requested funds will be used.

E) The RPMU will make prompt remittance on request by IIMI, to ensure the continuity and smooth implementation of the agreed program.

F) Other than in the initial application for a drawdown, IIMI will, when submitting claims, provide proper and satisfactory evidence payments made in the previous quarter, that correspond to the activities agreed to by the two parties.

G) At the termination of the program, IIMI will forward a consolidated statement of accounts to the RPMU, showing the application of funds for the entire duration of the project.

H) If, for any reason, the parties agree to terminate the program before the completion of the assignment of the SWMA, the RPMU will undertake to meet all the commitments and expenses connected of work actually performed under the contract.

Article VIII

SERVICES, PROCUREMENT AND CUSTODY OF EQUIPMENT

A) The nature of the equipment, supplies, services and other items of expenditure to be financed from funds made available by RPMU will be determined by agreement between RPMU and IIMI.

B) IIMI shall make satisfactory arrangements for insurance of the equipment and vehicle procured with funds provided by RPMU. Should be in accordance with the "Guidelines for Procurement" under World Bank loans & IDA Credit.

C) At the termination of the project, all the equipment and vehicles procured under the funds provided by RPMU shall revert to the SGB.

Article IX

RESEARCH RESULTS AND FINDINGS

A) Benefits such as improved irrigation technologies and irrigation instrumentation designs, techniques and water management systems accruing and arising from this cooperative venture may be used by one or both parties, with due recognition of each party'[s contribution.

B) Research findings will be published in the public interest when both parties consider this desirable.

C) Publications may be joint or separate, as shall be determined in each case. In the case of failure to agree on the method of publication, except for annual reports, the party desirous of publishing the findings separately may do so three months of date of receipt of any manuscript by the other party and after due consideration of the comments and suggestions offered by the other party.

D) Either party publishing research findings will give credit to the other party's contribution but shall, at the same time, bė entirely responsible for the conclusions and interpretations reported therein.

Article X

OTHER PROVISIONS

A) The officials responsible for the implementation of this agreement shall be

a) for IIMI, the Director General of IIMI, or any other officer duly authorized by him in writing; and

b) for RPMU, the Executive Director or any other officer duly authorized by him in writing.

B) The English language is the ruling language of this contract.

Article XI

AMENDMENTS

The parties to this agreement by mutual consent and due notice may modify the provisions of this Agreement.

Article XII

DATE OF EFFECTIVENESS

This agreement will be effective from the date of signature until the program of work proposed for the SWMA is completed or until such time as either party serve notice on the other of its intention to terminate this Agreement, in which event, six calendar months will be provided to the other party for disengagement from the activities and, for IIMI's case, departure.

Article XII

LAWS OF SUDAN

This contract shall be governed, construed and interpreted in accordance to Sudanese law.

Article XIV

ARBITRATION

A) Any dispute or difference arising out of or in connection with this contract shall be settled amicably between the parties.

B) In case settlement cannot be reached, the dispute or difference shall be referred to an arbitration tribunal to be constituted as follows:

a) Either party shall within thirty days of receiving a notice in writing by the other party appoint an arbitrator. Both arbitrators within thirty days of appointment of the second arbitrator agree on a person to act as an umpire. If within the specified period either party fails to appoint an arbitrator or the two arbitrators fail to agree on a person to at as an umpire, the second arbitrator or, as the case may be, the umpire shall be appointed by the Chief Justice of the Sudan.

b) The award of the arbitration tribunal shall be final and binding upon both parties.

c) Each party shall bear the costs of its arbitrator and the cost of the umpire shall be borne by the party against whom the award is made.

d) The work for the procurement of services under this contract shall continue during the arbitration proceedings.

e) The arbitration shall take place in Khartoum and shall be conducted in accordance with the UNCIIRAL Rules of Arbitration.

Article XV

VALIDATION

In witness to which the authorized agents have signed this Agreement in five originals in the English language this 14th day of June 1990.

Sgd.	Sgd.
Name: Abdulla Mohamed El Zubier	Name: M.S. Shafique
Title: Executive Director	Title: Head, Sudan Field Operations
for	
The Rehabilitation Project Management Unit	The International Irrigation Management Institute (IIMI)

Schedule I

SENIOR WATER MANAGEMENT ADVISER - SUDAN GEZIRA BOARD

Budget * 24 person months

	in LS' 000 Local Costs**	in US $' 000 Foreign Cost
Salary*** + Ben. Inc. : Housing, vehicle main., Post Allowance, etc.	360.00	220.00
IIMI Staff Time (International Consultants - 3 person - 10 weeks		27.50
International Travel - SGB		20.00
SWMA		10.00
Local Travel - SWMA	61.00	
Office and Research Supplies	36.60	3.00
Indirect Costs 25%		79.00
Sub-total	457.60	359.50
**** Vehicles and Equipment		33.00
Contingencies (5% DR Costs)	109.80	3.0
Total	567.40	395.50

* Assumes no Local staff costs

** Local expenses to be paid directly in local currency against presentation of documents.

*** It is obligatory that 10% of the SWMA's basic salary to be paid in local currency at the prevailing Bank of Sudan's official rate of exchange. Salary and benefits etc., will be paid to IIMI in equal installments.

**** Incl. : 01 (4 x 4)

Schedule II

SENIOR WATER MANAGEMENT ADVISER - SUDAN GEZIRA BOARD

Method of Payment

1. An initial payment 20% of the total estimate for one year i.e. 40,000 US $ payable upon the agreement coming into force and against a bank guarantee in the form given in appendix.

2. Payment to IIMI shall be on the basis of quarterly payment against invoices submitted for staff inputs together with any reimbursable costs incurred in the relevant months.

Schedule III

TERMS OF REFERENCE

The Senior Water Management Adviser will:

a. Be the principal adviser on water management to the Agricultural Manager of the SGB, who is a member of the Steering Committee of the Pilot Farm.

b. Advise the SGB on the identification of technical and managerial issues relevant to irrigation by means of problem identification and analysis at field and sub-system levels.

c. Translate the results of problem identification and analysis into research or remedial action programs.

d. Closely attend to the planning and progress being made on the Pilot Farm and, working through the Agricultural Manager, SGB, provide advise to the Steering Committee, the Project Manager

e. Advise SGB on the development of the Water management Advisory Unit foreseen in the IDA appraisal report on the Gezira Rehabilitation Project bearing in mind the progress made by the Pilot Farm and the Rehabilitation Project.

f. Make recommendations on type and content of training needed for SGB field staff of the Water Management Advisory Unit.

g. Organize short workshops or seminars geared toward issues in irrigation management and to be jointly attended by the staff of SGB, MOI, Universities and other relevant institutions.

h. Advise on drafting revised operating rules or procedures, to the extent that this may be necessary in relation to specific components o the system: in this he will pay special attention to the process of introducing revised rules and making them functional, including the related requirement of information flows within the system.

i. Liaise with national and international organizations active in the field of irrigation management research for the benefit of the system.

j. Promote and arrange the linkages between activates carried out in Sudan and similar activities under taken in countries participating in IIMI's international irrigation management research and development network.

APPENDIX II

IRRIGATION WATER MANAGEMENT - A SHORT AWARENESS COURSE FOR SGB SENIOR MANAGEMENT PERSONNEL

DURATION: 2 DAYS
SUGGESTED TOPICS

INTRODUCTION
IMPORTANCE OF ON-FARM WATER MANAGEMENT
WATER MANAGEMENT

- Block farming
- Land Preparation
- Rainfall and Water Management

PROJECT IRRIGATION SCHEDULING

- The Water Supply
- On-Farm Distribution
- Delivery of Water
  - On-demand
  - Semi-demand
  - Canal Rotation and Free Demand
  - Rotational System
  - Continuous Flow
- Monitoring the Operation
- Canal Regulation

OTHER ASPECTS OF IRRIGATION MANAGEMENT

- General Strategies
- Managing Systems with Perceived Shortages or Excesses
- Crop Production Functions
- Fertility and Yield
- Justification of Deficit Irrigation

IRRIGATION SCHEDULING - SUCCESSES AND FAILURES

- Farm Level Scheduling

DEVELOPING WATER MANAGEMENT PROGRAMS

IRRIGATION SYSTEM EVALUATION

APPENDIX III

TWO WEEK TRAINING COURSE ON ON-FARM WATER MANAGEMENT FOR BLOCK INSPECTORS AND ASST. INSPECTORS OF SGB

BACKGROUND

Inadequate water management at the HAWASHA level is widely regarded as the prime contributor to the low water use efficiency (unit weight of produce per unit volume of water) prevailing in the Gezira scheme. To improve on-farm water management the SGB has established a WATER MANAGEMENT UNIT within the Agricultural Administration. A good water management program requires that the technical personnel responsible for operating the program at the farm level and the farmers who ultimately use the water be adequately trained.

The course will address on-farm water management issues, which is particularly important for the irrigated agriculture of the Gezira scheme. Matching water application to actual requirements (when to irrigate ad how much to apply) optimises both water demand and productivity.

Benefits of good water management include maximizing yields and crop quality, reduced water and energy consumption thus making these supplies available for irrigating more land as well as deceasing cost of irrigation, reduced loss of fertilizer due to leaching or volatilization and reduced water logging.

The course will cover estimating irrigation requirement leading to preparation of indents, soil and crop parameters as they affect irrigation scheduling, irrigation efficiencies and other system performance parameters, irrigation management and integration of water management concepts.

PARTICIPANTS

Block Inspectors and Assistant Inspectors of the Sudan Gezira Board.

COURSE ORGANIZER

Water Management Unit, Agricultural Administration, Sudan Gezira Board.

COURSE COORDINATORS

Mr. Ahmed Badwi Mohammed Salih
Director, Agricultural Administration, SGB

Dr. Gamar El Din El Khatib
Manager, Water Management Unit, SGB

Mr. Mohammed Sid Ahmed
Manager, Agricultural Extension, SGB

Dr. K. Azharul Haq
Senior Water Management Advisor, SGB/IIMI

INSTRUCTORS

Professor Hassan Mohammed Ishag
Agricultural Research Corporation
Wad Medani

Dr. Gamar El Din El Khatib
Manager, Water Management Unit, SGB

Dr. Ahmed Salih
Deputy Director, Hydraulic Research Station, Ministry of Irrigation
Wad Medani

Prof. Saed Mohammed Farrah
Dept. of Agronomy, Agricultural Research Corporation
Wad Medani

Dr. Ahmed Ali Salih
Associate Professor Dept. of Soil Science
Agricultural Research Corporation
Wad Medani

Mr. Abbas Abdalla
Hydraulic Research Station
Wad Medani

Mr. Kamal Abdu
Hydraulic Research Station
Wad Medani

Dr. K. Azharul Haq
Sr. Water Management Advisor, SGB

COURSE CURRICULUM

1. Estimating Net Irrigation Requirement:

   Evapotranspiration, Crop coefficients, Yield Response to Water, Dependable and Effective Rainfall, Ground Water Contribution to Crop Water Requirements, Soil and Water Salinity and Leaching Requirements.

2. Soil and Crop Parameters:

   Estimating Soil Water Characteristics, Development of Soil Water Reservoir, Infiltration Rates and Methods for Determining Infiltration Characteristics.

3. Irrigation Efficiencies and Other System Performance Parameters:

   Conveyance Efficiency, Field Canal Efficiency, Field Application Efficiency, Distribution Efficiency and Project Efficiency.

4. Irrigation Management:

   Management Strategies, Irrigation Scheduling, Deficit Irrigation, Delivery System Schedules, On-Farm Water Control, Irrigation methods and Irrigation System Evaluation.

5. Integration of Water Management Concepts

APPENDIX IV

LIST OF PARTICIPANTS IN ON-FARM WATER MANAGEMENT TRAINING COURSE

1. Mr. El Tayeb Mohammed Ali
   Group Inspector, El Tahamid

2. Mr. Ahmed Yousif Mohammed
   Block Inspector, El Tahamid

3. Mr. Mahdi Khougali Habani
   Block Inspector, El Tahamid

4. Mr. Mohammed Baraka Mustafa
   Assistant Group Inspector, El Huda

5. Mr. Abdel Latif Nugod
   Block Inspector, El Huda

6. Mr. Gadella Salim Gadella
   Block Inspector, El Matouri

7. Mr. Abdel Gadir Mohammed Nur
   Block Inspector, El Ganobi

8. Mr. Abdin Ali Abdella
   Group Inspector, El Wasat

9. Mr. Dafaala Mohammed Dafaala
   Block Inspector, El Wasaat

10. Mr. Abdel Moneim Seid Ahmed
    Block Inspector, El Masallamia

11. Mr. Yousif Eltahir Hassan
    Block Inspector, Wad Habouba

12. Mr. Elrayah Elshiekh
    Block Inspector, Wadi Shaeir

13. Mr. Anass Sirel Khatim
    Seed Propagation Specialist, El Gorashi

14. Mr. Abdella Mohammed Ahmed
Block Inspector, El Shimali

15. Mr. Esmail Seid Ahmed
Horticulturist, Masaad

16. Mr. Abdalla Ahmed Elebeid
Assistant Group Inspector, El Mikashfi

17. Mr. Bahaeldin Mustafa
Block Inspector, El Mikashfi

18. Mr. Ahmed El Imam
Block Inspector, El Mansi

19. Mr. Yousif Musa Fadlelmoula
Assistant Group Inspector, El Mansi

20. Mr. Abdel Wahid Mohammed Ahmed
Assistant Group Inspector, Matouge

21. Mr. Hussein Mohammed Idris
Block Inspector, El Gamosi

22. Mr. Ali Mohammed Ahmed
Block Inspector, El Ganobi

23. Mr. El Tayeb Jahelrasoul
Block Inspector, El Wasat

24. Mr. Bashir Mustafa Yousif
Group Inpsector, El Masalmia

25. Mr. Elzein Yousif
Block Inspector, El Masalamia

26. Mr. Babiker Hassan Seid Ahmed
Extentionist, Wadi Shaeir

27. Mr. Mubarak Musa
Entomologist, Wad Habouba

28. Mr. Haj Hassan El Fawal
Assistant Group Inspector, El Shimali

29. Mr. Ahmed Abdel Mahmoud
Block Inspector, El Shimali

30. Mr. Mahjoub Ahmed Mohammed
Assistant Group Inspector, El Shimali West

31. Mr. Hasim Mohammed Abdalla
Irrigation Engineer, Ministry of Irrigation

APPENDIX V

EVALUATION OF THE COURSE ON ON-FARM WATER MANAGEMENT

1. **DURATION:**

Too long ______ Too short ______ About right _______

Suggestions for further improvement:

2. **CURRICULUM:**

Covered most topics needed for improving concept on on-farm water management issues

Yes ______ No ______

Suggestions for further improvement:

3. **TRAINING MATERIALS**

Adequate training materials including handouts were distributed

Yes ______ No ______

Suggestions for improvement:

4. Give the five most important subjects that should be covered in this course.

5. What are the strong points of this course?

6. What are the weak points?

7. How would you modify the course for the future?
List any subjects you would add or delete.

APPENDIX VI

TRAINING COURSE ON ON-FARM WATER MANAGEMENT

Name: Designation:

Date:

PRE-EVALUATION

1. In the Gezira scheme the Block Inspectors indent 5000 m^3 per NUMBER per day (12 Hrs.) What is the basis of this indent?

2. Underline one or more correct choices:

   A. In the soil-plant-atmosphere system, major resistance to water flow may occur (1) in the xylem vessels, (2) through stomates, (3) in the soil.

   B. Irrigation as infrequently as possible while maintaining adequate plant growth rate is good management (1) if a flooding method of irrigation is used, (2) if natural drainage is fast.

   C. Large pores in soils are essential for (1) high water retention, (2) rapid saturated water conduction, (3) adequate aeration.

   D. Water holding capacity is highest in (1) sandy soil, (2) loamy soil, (3) clay soil.

3. Define the following:

   Field capacity:

   Available water:

   Permanent wilting percentage:
   Evapotranspiration:

4. Name three flow measuring devices for open channel

5. Name three soil moisture measuring methods

6. If cotton undergoes brief, moderate water deficits prior to irrigation, yields are often higher than if irrigated more frequently. What is the physiological basis for this response.

APPENDIX VII

TRAINING COURSE ON ON-FARM WATER MANAGEMENT

FINAL EXAMINATION

1. Underline the correct choice:

   a. Permanent wilting point is the characteristics of (1) Plant (2) Water (3) Soil.

   b. Considering the slope the most suitable water measuring device for the Abu XX is (1) Weir (2) Vane flow meter (3) Parshall flume.

   c. The single most important climatic factor influencing evapotranspiration is (1) Humidity (2) Temperature (3) Solar radiation.

   d. Air entrapment in the soil affects infiltration in the following way (1) increases infiltration rate (2) Decreases infiltration rate (3) Has no effect.

   e. One of the main obstacles in achieving high application in surface irrigation is (1) Unevenness of soil surface (2) Large volume of water is used (3) Excessive runoff.

2. Define the following terms:

   (1) Crop coefficient (2) Advective energy (3) Leaching fraction (4) Management allowed depletion (5) Lysimeter

3. In the Gezira scheme delivery system follows a Fixed interval - Fixed volume schedule. List the disadvantages of such scheduling. Theoretically, which system of scheduling offers higher efficiencies and why.

4. In a low-flow year (water shortage) what steps you will recommend for optimizing water use.

5. Describe the procedure for determining soil moisture by gravimetric method.

6. Determine:

   A. Daily ET_0 by the Hargreaves and Class A pan methods

   B. ET_0 values for a certain crop with data as indicated

Month	T max		T min		RS	Evap.	Wind (U2)
	°F	°C	°F	°C	(ly)	(mm/day)	(Km/day)
July	81	27	43	6	638	8.9	72

Coefficient of the pan = 0.60
Crop coefficient for July = 1.09

7. A stream delivers 0.12 m^3/sec to a 38 ha field for 12 hrs. Determine gross volume of application and gross depth of application.

8. Soil -- Clay with 180 mm/m between FC and PWP
   Crop – Cotton
   Allowable depletion = 75%

Compute allowable depletion between irrigations

Daily Crop water use of the cotton crop is 8.35 mm/day. **What is the desired frequency?**