No.

General Direction of Dam and Large Hydraulic Works
Ministry of Agriculture and Hydraulic Resources
The Republic of Tunisia

THE STUDY
ON
INTEGRATED BASIN MANAGEMENT
FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER
IN
THE REPUBLIC OF TUNISIA

FINAL REPORT

VOLUME-II MAIN REPORT

JANUARY 2009

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO.,LTD

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THE STUDY
ON
INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL
IN
MEJERDA RIVER
IN
THE REPUBLIC OF TUNISIA

Composition of Final Report

Volume I EXECUTIVE SUMMARY

Volume II MAIN REPORT

- **Part 1 General (Introduction & Current Conditions of Study Area)**
- **Part 2 Phase I Study : Understanding of Present Conditions and Formulation of Framework for the Master Plan**
- **Part 3 Phase II Study : Formulation of the Master Plan**

Volume III SUPPORTING REPORT

- **Supporting Report A : HYDROLOGY AND HYDRAULICS**
- **Supporting Report B : WATER SUPPLY OPERATIONS**
- **Supporting Report C : RESERVOIR OPERTION**
- **Supporting Report D : RIVER IMPROVEMENT AND FLOOD PLAIN MANAGEMENT**
- **Supporting Report E : FACILITIES DESIGN AND COST ESTIMATE**
- **Supporting Report F : BASIN PRESERVATION**
- **Supporting Report G : FFWS AND EVACUATION/FLOOD FIGHTING**
- **Supporting Report H : INSTITUTION AND ORGANIZATION**
- **Supporting Report I : ECONOMICS AND FINANCE**
- **Supporting Report J : ENVIRONMENTAL AND SOCIAL CONSIDERATION**

Volume IV DATA BOOK

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PREFACE

In response to a request from the Government of The Republic of Tunisia, the Government of Japan decided to conduct a study on The Study on Integrated Basin Management Focused on flood Control in Mejerda River and entrusted to the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Koji KAWAMURA of Nippon Koei Co., Ltd. between November, 2006 and November, 2008.

The team held discussions with the officials concerned of the Government of The Republic of Tunisia and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of The Republic of Tunisia for their close cooperation extended to the study.

January 2009

Ariyuki Matsumoto,
Vice President
Japan International Cooperation Agency

January 2009

Mr. Ariyuki MATSUMOTO
Vice President
Japan International Cooperation Agency

Letter of Transmittal

Dear Sir,

We are pleased to submit herewith the Final Report of "The Study on Integrated Basin Management Focused on Flood Control in Mejerda River in the Republic of Tunisia".

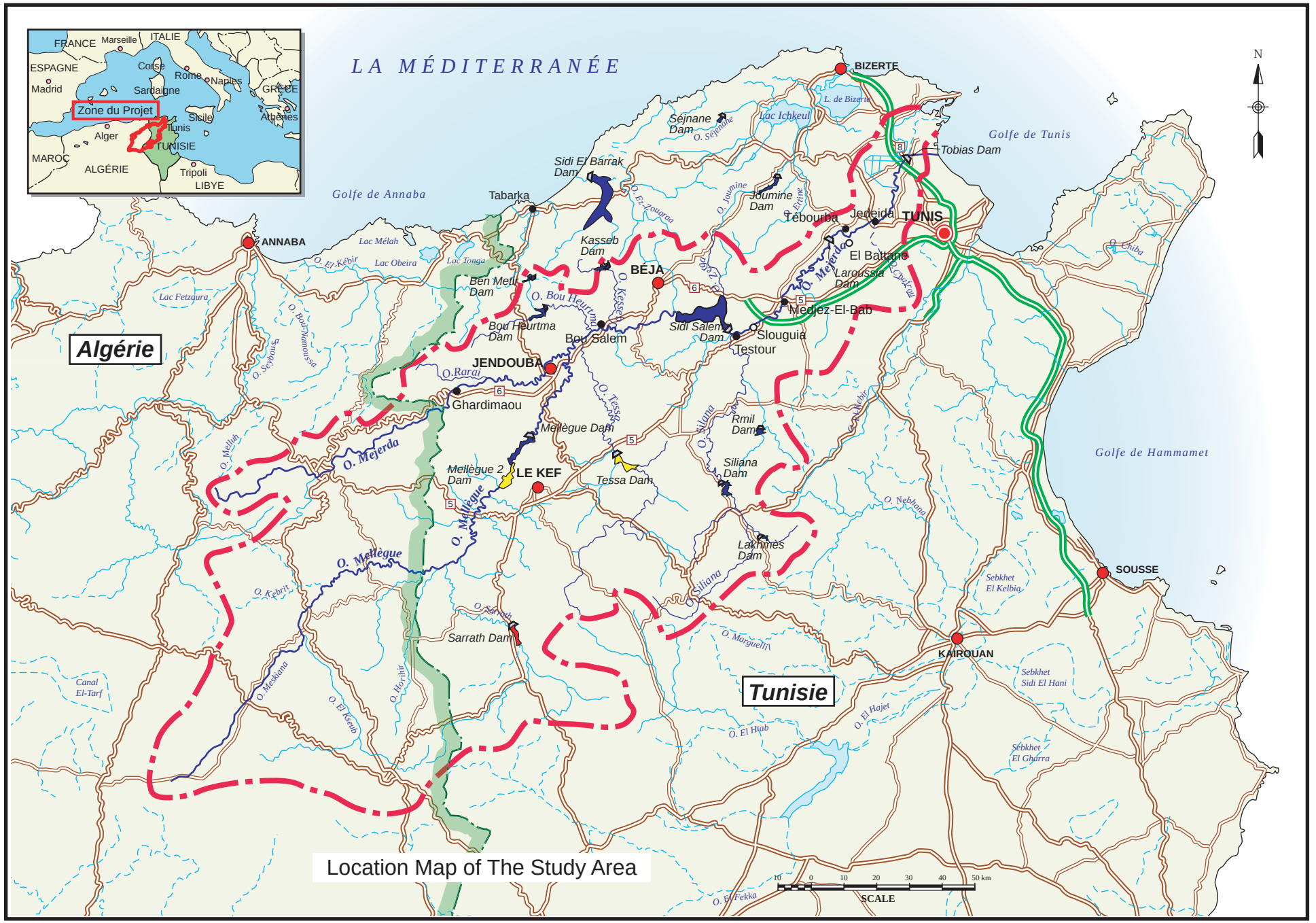
This Final Report has been prepared by Nippon Koei Co., Ltd. in accordance with the contracts with Japan International Cooperation Agency (JICA) in the period from November 2006 to January 2009.

The Study has formulated a master plan on integrated basin management focused on flood control in the Mejerda River. The Final Report presents the outcomes from the master plan study and consists of Executive Summary, Main Report, Supporting Report and Data Book.

We wish to express our sincere appreciation to the personnel concerned of your Agency and Advisory Committee for the guidance and support given throughout the Study period. Our deep gratitude is also expressed to the General Direction of Dam and Large Hydraulic Works of the Ministry of Agriculture and Hydraulic Resources and other concerned authorities of the Government of the Republic of Tunisia, JICA Tunisia Office, and the Embassy of Japan in Tunisia for their close cooperation and assistance extended during the course of the Study.

Very truly yours,

Koji KAWAMURA
Team Leader
The Study on Integrated Basin Management Focused on Flood Control in Mejerda River in the Republic of Tunisia



Location Map of The Study Area

Photographs

Signing for MM of Inception Report in MARH (December 2006)

The 1st Steering Committee Meeting on Inception Report (December 2006)

Site reconnaissance with counterpart personnel (December 2006)

Upper reaches of the Mejerda River near the boarder with Algeria

Middle reaches of the Mejerda River: vegetation growing in the river

Lower reaches of the Mejerda River: the historical bridge constructed in 17th Century

Flood marks recorded in Jendouba (May 2000 / January 2003)

Flooding in Bou Salem (January 2003): a lot of houses were inundated

Interview survey (September 2007): Residents' acceptance of flood risks

Interview survey (September 2007): Residents' acceptance of flood risks

Counterpart personnel training in Japan (October 2007): Super embankments of the Yodo River

2nd Seminar at Institute for Rural Equipment Engineers on 14 November 2008: Opening Remarks by the State Secretary of MARH

I. INTRODUCTION

1.1 This Final Report describes all findings and study results worked out in the Study on Integrated Basin Management Focused on Flood Control in Mejerda River (hereinafter referred to as "the Study") and consists of the following volumes:

Volume I	Executive Summary,
Volume II	Main Report,
Volume III	Supporting Report, and
Volume IV	Data Book.

1.2 The objectives of the Study are:

- To formulate a master plan on Integrated Basin Management focused on Flood Control in Mejerda River,
- To transfer technology and knowledge on integrated basin management focused on flood control to the Tunisian counterparts through their direct participation in the Study and training programme.

1.3 The study area basically covers the whole area of the Mejerda River basin. The extreme north and the Ishkeul basins are taken into account for the consideration of water management.

II. CURRENT CONDITIONS OF STUDY AREA

Physical Setting

2.1 Tunisia is situated in the centre of the North African seaboard and bordered by the Mediterranean to the North and the East, to the South by Libya, and to the West by Algeria. It covers 162,155 km^2, and is an ancient political entity of the Maghreb. Its capital is Tunis. Tunisia has a privileged geographic position at the cross-roads of the Eastern and the Western basins of the Mediterranean between Europe and Africa.

2.2 The Mejerda River runs over a distance of 312 km in Tunisia, and represents the country's single perennial river. The Mejerda River basin is located almost entirely in the climatic zone where the average annual rainfall ranges between 400 and 600 mm, and covers a total area of 23,700 km^2, of which 7,870 km^2 (33%) are located in Algeria.

2.3 The extreme north and the north areas of Tunisia where the Mejerda River basin is located can be distinguished by mild and wet winter, and hot and dry summer. Average annual rainfall and average temperature show decrease and increase trends respectively towards the south in the study area. The average annual rainfall exceeds 1,000 mm in the northwest part of the study area, whereas the southern part has a rainfall as low as 300 mm/year. Usually, temperature, evaporation, and sunshine duration reach their maximums in July and August in the study area, while humidity as well as precipitation becomes the smallest during these months. The annual average temperature in the study area ranges from 17 to 20ºC, and the annual mean relative humidity is from 60 to 68%.

The annual average evaporation varies from 1,300 to 1,800mm.

Socio-economy in Mejerda River Basin

3.1 Population within the Mejerda River basin was estimated to be 1,330 thousand in 2004. While the basin occupies 9.8% of the land area of Tunisia, the population of the basin accounted for 13.4% of the total population. The population density of the basin (84.0 per km^2) was higher than the national average of 61.1 per km^2. The densely populated areas are located mainly on the plains along the main stream of the Mejerda River. The population density in the basin is particularly higher in the alluvial plain near the river mouth, such as Tunis, Ariana and Manouba Governorates.

3.2 According to the 2004 CENSUS, the labor force in Tunisia by sector was as follows: services 48.9%, manufacturing industry 19.4%, non-manufacturing industry 14.5% and agriculture 16.2%.

3.3 The agriculture sector is still the core of the economy in the study area and it absorbs a substantial labor force (87.5 thousand). The agricultural sector in the basin is endowed with rich rainfall and fertile land. A vast agricultural area consists of dry farm land of 10,392 km^2 (65.6% of total land area of the basin), and irrigated areas of 1,489 km^2 (9.4%). The irrigated areas are located mostly on the plains along the main stream of the Mejerda River.

III. HYDROLOGY

Hydrological Characteristics of Past Major Floods

4.1 Flood runoff in the Mejerda River basin shows regional variations corresponding to rainfall features. Floods originating from the southern tributaries on the right bank tend to produce hydrographs with a sharp peak and could occur from spring (Apr. to May) to autumn (Sep. to Oct.). The upper reaches of the Mejerda River and the northern (left bank) tributaries are prone to cause flooding during the winter season from December to February/March due to high rainfall depths in this area, and are likely to have flatter hydrographs with longer duration than the right bank tributaries. With significant rainfall on the entire Mejerda River basin, though it can seldom be observed, the basin could be the origin of devastating floods.

4.2 The 1973 March flood, characterized by i) a high and single peak of inflow and rainfall, and ii) extensive rainfall in the entire basin, caused extensive inundation in the entire reaches of the Mejerda River. The probability of flood peak at Ghardimaou was estimated at 1/50, and the rainfall probability also reached 1/20 to 1/50 in the entire basin. The duration of high water level and inundation, on the other hand, was reported to be rather short (not more than one week).

4.3 The 2000 May flood caused severe inundation upstream of the Sidi Salem Reservoir, especially in the Jendouba and Bou Salem areas. The prominent hydrological features

of this flood are; i) high inflow to the Mellegue River with a single peak, and ii) localized rainfall. Rainfall concentrated on the Mellegue, Tessa and Rarai sub-basins (rainfall probabilities: 1/30 to 1/50 for these areas, 1/5 or higher for other sub-basins). The peak discharge at K13 on the Mellegue River was estimated at 1/80 of probability, while the peak at Ghardimaou falls into the range between 1/5 and 1/10.

4.4 Due to such a high and acute inflow in the Mellegue River, the Mellegue Dam needed to release water. The flood released from the Mellegue Dam exceeded flow capacity of the downstream river channels, and overflowed.

4.5 The 2003 January flood is distinguished by i) multiple peaks (long duration) of inflow at Ghardimaou and ii) multiple peaks (long duration) of rainfall. Similar characteristics was also observed in the 2004 January flood. The peak discharge at Ghardimaou is estimated at 1/15 probability, but the probability of the flood volume (197 million m^3, in total four peaks for 30 days) falls to 1/70.

4.6 The contrast between the 2000 May and 2003 January floods shows one of distinguishing features of the 2003 Flood. As presented in the table below, the peaks of inflow to the Sidi Salem Reservoir of the two floods were nearly identical. However, due to the long duration of high discharge during the 2003 January flood, the two floods resulted in two different peaks of outflow from the dam.

Inflows and Outflows at Sidi Salem Dam during the 2000 May and 2003 Jan. Floods

Flood	Inflow Max. (Sidi Salem)	Inflow Volume (at Bou Salem for 30 days)	Outflow Max. (Sidi Salem)	Note
2000 May Flood	1022 m^3/s	157 M m^3	52 m^3/s	Single peak
2003 Jan Flood	1065 m^3/s	827 M m^3	740 m^3/s	Four peaks

Source: MARH

The Sidi Salem Reservoir mitigated peaks of the first and second waves of the inflow, but needed to increase releasing discharge up to 740 m^3/s when the third peak arrived. A consequence of the multiple peaks of inflow and rainfall was the long duration of inundation on both upstream and downstream areas of the basin, especially in the downstream areas, which continued for a month or longer.

Implication of Hydrological Characteristics of Past Major Floods

5.1 The past floods prove that each flood bears different hydrological characteristics in the Mejerda River basin. The combination of the following hydrological features could determine the flood behavior in the basin:

- Inflow (peak and volume) to the upper Mejerda (at Ghardimaou) and the Mellegue (at K13) Rivers from Algeria
- Rainfall on the Mejerda River basin in the Tunisian territory of the basin (peak, volume, temporal variation, and regional variation)

5.2 The difference of runoff features from the left and right bank tributaries is another hydrological issue to be focused on.

5.3 The occurrence and behavior of floods are determined by influences of several hydraulic

conditions in the basin, including i) reservoir water levels, ii) outflow discharges from dams, and iii) flow capacity of the mainstream, tributaries, and structure sites, in addition to the above hydrological features.

IV. IDENTIFICATION AND STUDY OF PROBLEMS/ISSUES ON FLOOD CONTROL

Water Supply Operation

6.1 At present, the reservoir storage is kept as close as possible to the design normal water level in most reservoirs. Reservoir operations are focused on storing as much water as possible to satisfy demands in case of sequential drought years. The main constraints to flood control operations are all related to the fact that criteria for water supply operations are not well defined.

6.2 Attempts to develop operating rules of reservoirs and optimize the allocation of water resources were made in two previous studies: Eau 2000 and GEORE.

- Eau 2000 (1993) included a complex analysis of reservoirs using stochastic dynamic programming techniques to optimize the allocation of water resources. The documents made available to the Study do not clearly discuss or define the probabilities associated with water supply security. Furthermore, the analysis did not address the need to balance salinity in the Cap Bon Canal, which provides water to Greater Tunis and other major urban areas to the South.
- The GEORE project sponsored by GTZ in the late 80's created a computer-based optimization model intended to be used as a tool to optimize reservoir operations for water supply. Unfortunately, however, the model has become outdated because it does not include many of the newly constructed and proposed dams.

6.3 In the Study, reservoir storage volumes for water supply needed to be defined in order to proceed to flood control analysis. Since essential information on water supply was not available from the MARH, the Study carried out a water balance calculation to estimate how much storage volume should be reserved for water supply at each reservoir.

6.4 The calculation was made for the North Tunisian Water Supply System, a regional system of 27 reservoirs (existing and future) that are linked together to supply potable and agricultural water demands, based on a hydrological mass balance at each reservoir accounting for all inflows less all outflows and losses at each reservoir.

Initially, five drought scenarios of inflow were considered for the preliminary water balance:

Drought Scenarios Initially Considered

Drought scenarios		Total Inflow* mil. m^3	Total as % of average**	Type
1: 1 year	1960	1,044	55%	Dry
2: 2 year	synthetic	2,088	55%	Dry
3: 2 year	Historic 1987-88	1,582	41%	Very dry
4: 3 year	synthetic	3,132	55%	Dry
5: 3 year	Historic 1992-94	22,04.5	38%	Very dry

* inflow to 27 dams in Northern Tunisia **average inflow from 1946-1997=1912 mil. m^3/year
Source: the Study Team

The MARH defines hydrological drought as follows:

- a year is “dry” when inflows are less than 70% of the average, and
- a year is ”very dry” when inflows are less than 50% of the average.

The typical dry year is 1960/61 and it is selected because it has a frequency of 1 in 5 years (T=0.2). This frequency is consistent with the definition of a typical dry year used in the Eau 2000 study.

The 2 and 3 year historical droughts are quite severe. Preliminary analysis indicates that most reservoirs in both drought cases would need to be 100% at the start of the agricultural season in order to meet demands. In addition, demand restrictions need to be applied in the second and the third years to prevent complete depletion of stocks.

6.5 After discussion with the MARH it was decided to retain the following three scenarios of inflow for the water balance calculation.

Drought Scenarios of Inflow Selected for Water Balance

Drought scenarios		Total inflow (mil. m^3)	Recurrence interval (times)
1: 1 year	typical	1,044	1/5
2: 2 consecutive years	synthetic	2,088	1/9*
3: 3 consecutive years	synthetic	3,132	1/11**

Notes: * One cycle is 2 years. ** One cycle is 3 years. Source: the Study Team

The MARH also requested a separate analysis of the two year consecutive drought with a 20% demand restrictions applied to irrigation in the second year.

6.6 The water balance calculation has identified that the Northern Tunisia Water Supply Scheme will experience deficits during two and three year consecutive drought events, as summarized below.

Comparison of Storage Deficits for Selected Drought Scenarios of Inflow

Drought scenario	Demand Restriction	Year	Deficits Northern Tunisia (Mm^3/year)**		
			2010	2020	2030
1 year	none	1	0	0	0
2 year	none	1st	0	0	0
	20% agriculture	2nd	6.0	19.1	68.6
2 year	none	1st	0	0	0
	none	2nd	6.7	21.1	75.2
3 year	none	1st	0	0	0
	none	2nd	6.7	11.4	62.4
	none	3rd	84.5	267.1	377.8

** 27 dams in the Northern Tunisia Water Supply Scheme Source: the Study Team

6.7 For the two year consecutive drought, the deficits are localized and limited to the Mellegue II, Lakhmes, Siliana and R'Mil Reservoirs where the local agricultural demands exceed the capacity of the reservoirs. It is, therefore, possible to allocate "additional flood control storages" at other dams without affecting water supply in other parts of the system for a typical two year consecutive drought. In the Study, "the additional flood control storage" is defined as the reservoir storage volume which can be used for a flood control purpose below a design normal water level and above the top level of water supply storage to be secured to meet a water supply security.

This "two year consecutive drought" scenario is more realistic and provides an acceptable level of risk. Therefore, the MARH agreed to use this scenario to define storage allocation in reservoirs for water supply and also the additional flood control storage.

6.8 The three year consecutive drought cannot be managed unless significant system-wide demand restrictions are applied for potable water and agricultural irrigation. Under this scenario, the reservoirs at most dams in the system would need to be kept as full as possible at the beginning of September, which is the start of the hydrological year, in order to minimize water shortages. Therefore, an additional flood control storage is not advisable.

Flood Damage and Existing Measures

7.1 The flood prone areas suffering from habitual flooding are located mainly in the low undulated plains along the Mejerda mainstream. In the course of the Study, it was revealed that Jendouba, the Mellegue confluence, Bou Salem, Sidi Smail, Slouguia, Medjez El Bab, El Herri, Tebourba, El Battan, Jedeida, El Henna, the Chafrou confluence and El Mabtou have become flood prone towns/areas, which were seriously damaged by the past significant floods such as those that occurred in May 1973 and January to February 2003.

7.2 The flood damage due to past significant floods is categorized into agricultural products (crops, livestock, etc.), house and household effects, infrastructure and indirect damage such as work interruption, traffic blockade and aggravation of sanitary conditions.

7.3 Major agricultural crops that are damaged include mainly olive, cereal, vegetable and fruits. As to the households, the flood damage generally consists of houses (window, wall, roof, etc.), furniture and foods among others. The average damage value in the study area is estimated as follows:

- Farmers : TND 25,917 (per farmer)
- Shops : TND 5,044 (per shop)
- Industries : TND 10,963 (per factory)

7.4 The flood control measures existing in the Mejerda River basin are mainly dams and reservoirs, since the magnitude of flood is quite huge in terms of peak and volume. In fact, the Mellegue and Sidi Salem Dams have essential function for flood control. At present, a dike system along the river channels has been provided only at minimal level and limited in some short stretches in the basin.

7.5 In addition to the large scale dams, a movable weir at Hir Tobias has a vital role to control discharges in the lower Mejerda and the floodway to the sea. This floodway was completed in the 1950s.

Reservoir Operation

8.1 As the sizes and purposes of the reservoirs in the Mejerda River basin differ significantly, the efficiency of their flood control function was assessed and seven reservoirs were selected as important ones for further analysis and evaluation of reservoir operation during floods. These include the four existing reservoirs of Sidi Salem, Mellegue, Bou Heurtma and Siliana, and three reservoirs under planning or construction: Mellegue 2, Tessa and Sarrath.

8.2 Through reviewing historical operation records of dams, it can be mentioned that the past maximum water levels at most of the existing dams have never reached the designed highest water levels. This means that the designed flood control storages have not been fully used even during the past serious floods.

8.3 Only 13 % of the designed flood control storage of the Siliana Reservoir was used for a flood control purpose in December 2003 and roughly 18 % of the designed flood control storage of the Bou Heurtma Reservoir was used in January 2003. Both dams are provided with uncontrolled (non-gated) spillway facilities only for flood control. On the other hand, there is the only controlled (gated) spillway provided with the Mellegue Dam and that is why all outflows from the dam (spillway, bottom outlet, etc.) can be effectively controlled during floods. Almost all designed flood control storage (98.6 mil. m^3 = 96 % of the designed flood control storage) was used to successfully decrease the peak discharge in December 2003.

8.4 In view of the above, it might be said that roughly one half of the total designed flood storages in the Mejerda River basin is expected to be used under the current reservoir operation for flood control, although it depends on the magnitude of flood, the spatial and temporal distributions of flood, and other factors.

River Channel Management

9.1 Deposition of sediment material in river channels results in substantial decrease of cross-sectional flow area and consequently reduction of discharge capacity of river channels.

9.2 In fact, intensive use of water through reservoir operations for irrigation, drinking water, hydropower and protection against floods has resulted in long-term smaller discharges and velocities with riverbed aggradation in the downstream river reaches, which has sometimes been compensated by flushing effect of flood water release from reservoirs.

9.3 The cross-sectional flow area at the river crossing structure, such as a bridge, is usually smaller; in other words, such a bridge is usually a flow obstacle, causing the rise of the upstream water level up to the stretches several kilometers long. As an example, the

bridges in El Battan and the Andalous Bridge in Mejez El Bab (see the photo below) have affected the flow characteristics due mainly to a number of piers. A decrease in the cross sectional flow area generates more frequent catastrophic overflowing during floods.

Historical Andalous bridge in Mejez El Bab

Flood Forecasting and Warning

10.1 For the flood forecasting and warning system (FFWS) in the Mejerda River basin, installation of a new telemetry system has been developed through the technical and financial assistance of AFD (l'Agence Française de Développement)[1] in the program of PISEAU (Projet d'Investissement dans le Secteur de l'Eau)[2] since this basin seriously suffered from large floods in 2002/2003. The installation of a telemetry system was completed at 75 gauging stations in the whole Tunisia in August 2007 and is currently in experimental operation. Out of 75 stations, 56 stations exist in the Mejerda River basin.

10.2 The major agencies concerned with flood forecasting are DGRE, DGBGTH, IRESA and CRDA, which are organized under the authority of the MARH, and INM. Also, the major agencies concerned with the warning system are the governorate offices, Civil Protection, National Security, National Guard, the police and their regional offices at the governorate level, all under the authority of the Ministry of Interior.

10.3 The new telemetry system is composed of four sub-systems: a hydro-meteorological observation system, a data transmission system, an analysis system, and a warning dissemination system. The system has just been installed and hence it has been pointed out that several requirements need to be fulfilled so as to efficiently strengthen the function of and effectively achieve all the objectives of the FFWS.

Flood Fighting

11. The regional Civil Protection is responsible for evacuation and flood fighting activities in cooperation with the National Guard, the police and the military at the regional level. These agencies belong to the Ministry of Interior, except the military, which is under the Ministry of National Defense. In regard to evacuation and flood fighting activities, the following issues are identified:

[1] French Development Agency
[2] Water Sector Investment Project

i) It is not necessarily confirmed whether evacuation is successfully completed or not before the occurrence of inundation.
ii) Some residents have no means to move their properties and hence are compelled to stay in their houses without evacuation.
iii) No evacuation plan and map, which the residents can clearly and easily understand, has been prepared.

Organization and Institution

12.1 The Water Code (1975) is the basic law for water resources management. The paper, "MEDROPLAN (The Mediterranean Drought Preparedness and Mitigation Planning) Guidelines, Technical Annex" (Draft, May 2006), provides the basic information concerning the organizational and institutional framework of the present Integrated Water Resources Management (IWRM) in Tunisia. Planning and design standards and practices for the river works and water use facilities are reported to be not available in written form. Some technical rules and practices applied to the daily operation of management, planning, design, construction, operation, maintenance and monitoring activities have not also been documented yet.

12.2 The MARH is entrusted with water management according to Article 2 of the updated Decree No 2001-419 dated 13 February 2001 (JORT). Duties of the MARH are managed by its different directions and departments under the legal framework defined in the updated Decree No 2001-420 (13 February 2001, JORT).

12.3 Water Exploitation and Distribution National Company (SONEDE), established by Law No 68-33 (2 July 1968, JORT), is an autonomous institution under the umbrella of the MARH authorities, and it ensures the management of not only domestic water but also industrial and other (non-agricultural) uses over the country.

12.4 North Water Canal, Adductions and System Management Company (SECADENORD), established by the law No 84-26 (14 May 1984, JORT), has its financial autonomy under the authority of the MARH. It ensures the management and maintenance of the part of North West water network transfer: i.e., the north water canals, and the adduction for the canalization of water from the Sidi Salem Dam, the Ichkeul zone, and the extreme North West for the users in the North East, Centre and South of the country where there is fresh water shortage.

12.5 In Tunisia, flood control management has been executed occasionally and incidentally depending on the conditions of floods. Furthermore, the problems and issues concerning river basin planning and management focusing on flood control are identified from institutional and organization viewpoints as stated below.

a) There is no permanent division or service for flood control activities and management in the central and regional directions except services for risk and flood announcement.
b) There are no documented technical guidelines or standards for flood control and water supply planning and design, and no reservoir operation rule.

c) The competence for flood control is separated: the MARH for rural and agriculture areas, and the MEHAT for urban areas.
d) The competence for flood fighting activities is separated: forecasting and announcing by the MARH, and warning, fighting and evacuation activities by Civil Protection, the Ministry of Interior.
e) Sediment control in watersheds is insufficient: sedimentation inside river channels and reservoirs is one big factor of causing floods. And
f) Cooperation with Algeria for river basin management is insufficient: in particular rainfall and discharge data necessary for flood forecasting and warning.

Environmental and Social Considerations

13.1 In the framework of the Study centered on flood control, the Ichkeul National Park, a World Heritage site of UNESCO, which is not located in the immediate surrounding of the project area, seems not to be greatly affected; being guaranteed an equal annual water quota as other 2 users of the Extreme North waters, namely cities drinking water and irrigation.

13.2 The Feija National Park is the only park listed in the study area. The park seems to be secured from big floods of the Mejerda River considering its distance from that river and its high elevation. However, forest fires and land-slides need to be closely monitored to avoid reduction of the forest tree resources, which could cause land degradation and increased sedimentation in the Mejerda River due to runoff, considering the steep slopes observed in this area.

13.3 Although IUCN has presently identified about 80 species of mammals, 362 birds' species and more than 500 species of reptiles and fishes in the country, endangered species of flora and fauna are not confirmed in the flood plain and irrigable areas of the Mejerda River basin. However, the Study has confirmed that several fish species were introduced in the reservoirs of the many dams that were built over the years. It is, therefore, evident that several fish species are living in the Mejerda River and the Sidi Salem Reservoir.

13.4 Among these fish species, one can cite the berbel (Barbus callensis), which is endemic in North Africa, the common Tilapia (Cyprinus carpis), several species of mullets and the catfish. Conserving these fish species for the fishing activity of the riparians is important as many live off such activity. A minimum water flow is necessary in the Mejerda River, as well as a minimum water quality for the fish populations.

13.5 Although there are no historical remains or archeological sites listed as a World heritage in the study area, several bridges of cultural relevance exist along the Mejerda River, namely in Medjes el Bab, Jedeida and Bizerte Cities.

V. BASIC STRATEGY FOR MASTER PLAN FORMULATION

14.1 The primary purpose of the Study is to formulate a master plan for sustainable control and management of floods in the Mejerda River. The most important goal of the Study is to

implement the flood control measures in accordance with the master plan for security and safety against floods. Consequently, social welfare is promoted and it is expected to benefit the State in both regional and national economic development. Hence, flood control measures to be proposed under the Study shall be realistic and practical.

14.2 In view of the above, the master plan has been formulated based on the following strategies.

(1) Comprehensive approach for flood control on the basis of the concept of Integrated Flood Management

Flood management has focused on defensive practices until now, but it is widely recognized in recent years that a paradigm shift from defensive action to proactive management of risks due to floods is required. This paradigm shift favorably encourages implementation of Integrated Flood Management (IMF).

When implementing policies to maximize the efficient use of resources in a river basin, efforts are made to maintain or augment the productivity of the flood plains. However, economic and human life losses due to flooding in the basin cannot be ignored. Treating floods as isolated problems almost necessarily results in a piecemeal and localized approach. Therefore, IFM calls for a paradigm shift from the traditional fragmented approach of flood management, and requires planning of flood control using the following logical approaches for managing floods in an integrated manner:

- To manage the water cycle as a whole,
- To integrate land and water management,
- To adopt a best mix of strategies,
- To ensure a participatory approach, and,
- To adopt integrated hazard management approaches.

(2) Priority to water supply security

Water is one of the precious limited resources in Tunisia, being located in arid and semiarid zones, where there should never be a drop of water to waste. Hence, the State have developed a national water management plan placing primacy to water use. Therefore, to secure the amount of required water by exploiting the relatively abundant surface water in the northern areas where the Mejerda River basin lies is a crucial key issue of Tunisia.

Therefore, the flood control plan in the Majerda River basin is required to be harmonized with the water use plan in the basin giving priority to the realization of water supply with required security, because there would be a tradeoff between the water supply and flood control risks.

(3) Share of roles between structural and non-structural measures

Absolute protection from flooding is neither technically feasible nor economically or environmentally viable. Hence, flood control measures need to aim at minimizing flood damage, and a combination of appropriate structural and non-structural measures is essential to realize this purpose.

The structural measures will be focused on preventing inundation up to a design flood, which is not only technically feasible, but also economically viable and environmentally sound. The non-structural measures, on the other hand, would focus on mitigating flood damage due to excess floods which exceed the design flood. Furthermore, the non-structural measures shall also assume the tasks to sustain flood preventing effect of the structural measures.

(4) Attention to public acceptance of flood control measures

Flood control measures against flood risks and damage need to be formulated and provided in conformity with the expectations of the residents in the flood prone areas. Thus, in the Study, an interview survey to the residents on public acceptance of flood risk and two public consultation meetings with stakeholders, including central/local governmental agencies and local residents, were conducted in the upstream, middle and downstream reaches of the Mejerda River basin. These aimed to sound out the social needs, views, opinions and acceptance to proposed flood control measures. The master plan shall therefore pay careful attention to the voice of the residents.

VI. OUTLINES OF MASTER PLAN

15.1 In accordance with the basic strategies set up in the Study to formulate the master plan, the Study has proposed the flood control master plan be composed of the following six projects, with two and four projects for structural and non-structural measures, respectively, are proposed. The flood control projects are expected to definitely and timely yield their effects by 2030, the target year of the Study.

(1) Structural measures: to focus on protecting cities/towns/villages and also the agricultural land along the Majerda River from flooding up to design floods

1-1 Project on strengthening flood control function of reservoirs: to minimize flood peaks released from seven reservoirs (Sidi Salem, Mellegue, Bou Heurtma, Siliana, Mellegue 2, Sarrath and Tessa Reservoirs) and also in their downstream rivers

1-2 Project on river improvement: to prevent detrimental flood overtopping from rivers up to design floods

(2) Non- structural measures: to focus on mitigating flood damage caused by excess floods and also sustaining flood protection effect of the structural measures

2-1 Project on strengthening the existing flood forecasting and warning system: to effectuate earlier supply of flood information required for the projects on strengthening (i) flood control function of reservoirs (1-1) and (ii) evacuation and flood fighting system (2-2)

2-2 Project on strengthening evacuation and flood fighting system: to set up

human loss and minimize property damage during floods

2-3 Project on organizational capacity development: to set up well-organized and empowered institutional arrangements so as to facilitate effectuation of other flood control projects proposed in the master plan from planning to operation/maintenance stages

2-4 Project on flood plain regulation/management: to minimize flood risks/damage in low land areas subject to inundation during excess floods along the Mejerda River

The six projects above must be closely complementary to each other for their full and permanent effectuation. The interrelationship among the projects is illustrated in **Figure 15.1**, are as explained below.

15.2 Project 1-1 and Project 1-2: Both projects are planned to protect the floods together up to the design flood corresponding to the flood protection level so as to prevent flood inundation. Project 1.1 is to strengthen the flood control function of the seven selected reservoirs, four existing reservoirs (Sidi Salem, Mellegue, Bou Hertma and Siliana Reservoirs) and three future reservoirs (Mellegue 2, Sarrath and Tessa Reservoirs) through improvement of the current reservoir operation rules during floods, in order to reduce the flood peaks from the reservoirs as much as possible. The reservoirs, however, can not entirely prevent the flood inundation in their downstream, because their downstream rivers receive flood runoff from their own basins as well. For this reason, Project 1-2 is needed to successfully prevent flood overtopping from the downstream rivers.

15.3 Project 1-1 and Project 2-1: The enhancement of flood control function of reservoirs contemplated in Project 1-1 requires relevant and accurate flood information as earlier as possible. Therefore, Project 2-1 is necessary to provide Project 1-1 with the information, including flood forecast, through strengthening the existing FFWS.

15.4 Project 2-1 and Project 2-2: The evacuation and flood fighting activities, which are essential to prevent human loss due to flooding, also need information of flood as earlier as possible. Hence, Project 2-1 is also necessary to provide Project 2-2 also with earlier information of flood, including flood forecast, through strengthening the existing FFWS.

15.5 Project 2-3 and other projects: It is indispensable under the concept of IFM to provide well-organized and empowered institutional arrangements which shall support operation and maintenance as well as planning and design/construction of other projects in the master plan. This will secure sustainable effects expected in other projects.

15.6 Structural measures and Project 2-4: The structural measures, namely Project 1-1 and Project 1-2, could protect the area from floods up to the flood protection level, as mentioned above. This means that the flood control plan formulated in the master plan allows inundation during excess floods exceeding the design flood for river improvement works. Thus, low lying areas located along the Mejerda River are subject to inundation during excess floods. Currently, some of the low lying areas have been developed for

cultivation as well as dwelling, and hence flood plain regulation/management is essential so as to minimize flood risk/damage in the low land areas by the excess floods.

15.7 **Figure 15.2** presents the overviews of the master plan composed of the six proposed projects for flood control in the Mejerda River basin.

VII. PROJECT DESIGN

Project on River Improvement

16.1 In order to cope with the design flood discharges in each zone with 10-year and 20-year probabilities set as design flood discharges, the structures for river improvement works in the Mejerda River basin are composed of the following structures:

(a) River channel improvement,
(b) Bypass channel,
(c) Retarding basin,
(d) Ground sill,
(e) Sluiceway,
(f) Bridges,
(g) Other miscellaneous structures (revetment and detachable stop log structures), and
(h) Maintenance of river channel.

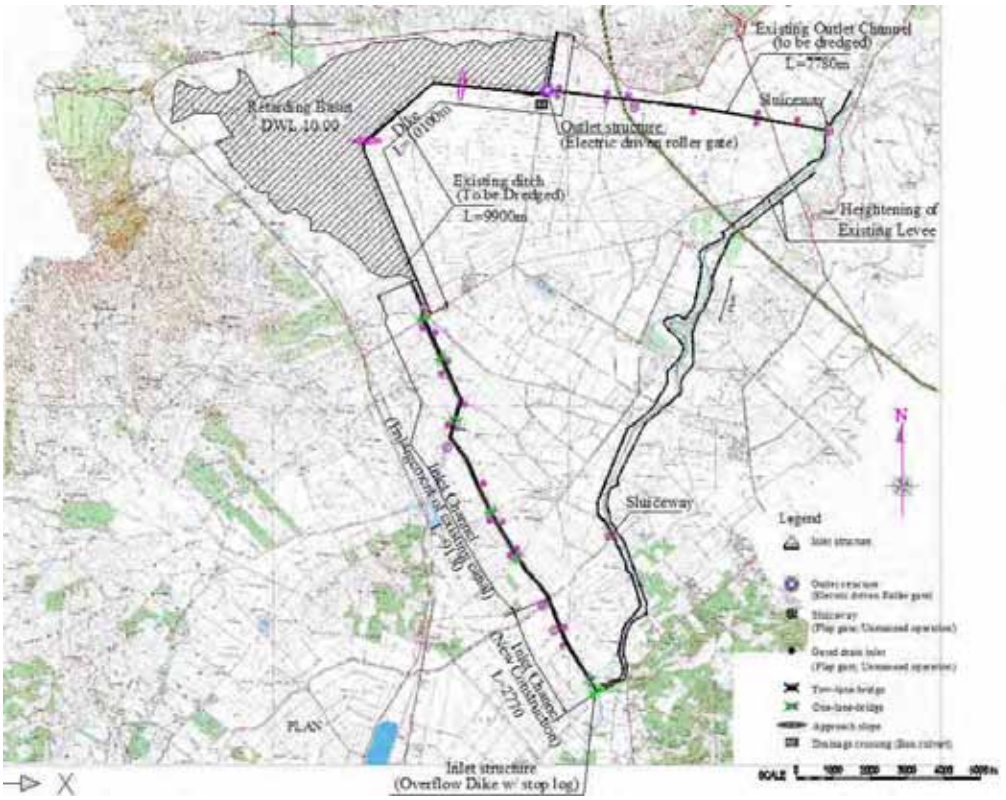
As for the river channel improvement, a combination of channel excavation/dredging and widening and levee construction is proposed through numerous trials to reach the optimum set of design channel geometry from technical and economic viewpoints. The major dimensions of the structures were determined in the preliminary design based on the topographic survey results obtained through the Study. The salient features of the structures proposed in the master plan are summarized at end of this section.

16.2 In order to cope with the present insufficient river flow capacity and difficulty of river channel widening in Mejez El Bab and Bou Salem Cities, construction of two bypass channels is recommended to accommodate the excess of the design flood discharge. In the case of Mejez El Bab City, the flow section at the historical old bridge (Andarrous Bridge) is a critical bottle neck. However, the bridge as a heritage structure will be conserved as it is in accordance with the request of DGBGTH, MARH as well as the public, conveyed in the stakeholders' meetings held in the course of the Study.

Bou Salem City is developed on both sides of the Mejerda River. The available space for river improvement works between both banks is quite limited. Almost the whole Bou Salem City is located in a flood prone area along the Mejerda River. The bypass channel is an effective measure to lower the risk of flood from the topographic point of view. The location of the bypass channels is shown in the general plans of river improvement works in **Figures 16.1** and **16.2**.

16.3 The El Mabtouh plain is significantly advantageous for creating a retarding basin to protect the downstream area of the Mejerda River (Manouba, Ariana and Bizerte

Governorates), which is widely developed as the breadbasket of the country. The designated area, 2,118 ha, with 50 million m^3 of total capacity will retard a maximum discharge 200 m^3/s out of 860 m^3/s of the peak discharge (10-year flood). As for the appurtenant structures for the retarding basin, an inlet channel with an overflow dike, a surrounding dike and sluiceways shall be constructed. The general layout is shown below:



Source: the Study Team

General Layout of El Mabtouh Retarding Basin

16.4 The proposed river improvement scheme excludes a short-cut channel so that the gradient of the present riverbed profile is not drastically changed before and after improvement works. The present riverbed is anticipated to rise up due to sedimentation. Consequently, it is judged that provision of a ground sill is not necessary on the Mejerda River except in the bypass channels at the inlet and outlet structures and at the inlet of El Mabtouh Retarding Basin.

16.5 Based on the hydraulic analysis with the latest river cross sections, it was clarified that four road bridges, one aqueduct with a foot path and two railway bridges would be affected. The elevations of these superstructures are lower than the design high water levels. The superstructure of the railway bridge at Jedeida (Zone D2) can be heightened by jacking up with placement of additional concrete on the top of substructure. The other six bridges should be replaced with new bridges.

16.6 The thick bush prevailing in the high water channel mainly consists of a kind of tree so-called “Tamarix” and can be seen almost at all stretches along the Mejerda River. Particularly, these trees make the flow area narrower and hinder the smooth water flow in the river channel. This is a serious problem to cope with flood prevention. On the

contrary, it is observed that they are somewhat contributing in prevention of river bank erosion. In order to efficiently utilize the Tamarix as site-oriented material, a Japanese traditional method for slope protection can be introduced in the Mejerda River basin.

16.7 The salient features of the major structures proposed as river improvement works are summarized by each zone in **Table 16.1**.

Project on Strengthening Flood Control Function of Reservoirs

17.1 All reservoirs in the Tunisian territory of the Mejerda River basin must be operated as one coordinated system in order to enhance their flood control functions, paying special attention to the seven important reservoirs selected for flood control. For this reason, it is necessary to provide fundamental rules for the well-coordinated operation of the system and ensure that the rules are followed at all times so as to optimize coordination of dam operation for the most effective flood control as well as successful water supply.

17.2 Under the above specific state of reservoir operation in the Mejerda River basin, the key to strengthening the flood control function of reservoirs is (i) to use the available flood control storage provided above a normal water level (NWL), including the additional flood control storage, as effectively as possible and (ii) to minimize flood peaks downstream of the dams.

17.3 In order to effectively realize the above strategies, this project is incorporated into the master plan, and the major programs and activities of the project are as presented below.

	Main Programs and Activities
1.	Improvement of simulation model for coordinated operation of dams
2.	Drafting improved operation rules of seven selected reservoirs for flood control
3.	Trial application (2 rainy seasons), review and improvement of the draft improved reservoir operation rules for flood control
4.	Coordination of institutional arrangements related to improved reservoir operation rules for flood control
5.	Strengthening function of collection, storing, analysis and dissemination of data/information
6.	Preparing monitoring plan to sustain project effects

Project on Strengthening Existing Flood Forecasting and Warning System

18.1 In the Study, the development and improvement plan for strengthening the existing FFWS is recommended in due consideration of the following aspects:

- As immediate measures to minimize flood risks and mitigate flood damage before completion of the planned structural measures,
- As measures to minimize the risk of and mitigate damage due to extraordinary floods exceeding the planning/design level of the structural measures, and
- As measures to contribute to coordinated operation of dams by providing timely and accurate hydrological information.

Therefore, the objectives of FFWS for the Mejerda River basin are:

- To provide hydrological information in order to conduct integrated management of

river structures including coordinated operation of dams, which would contribute to damage mitigation in inundation areas, and

- To provide hydrological information in order to make decisions of required actions for evacuation / flood fighting system.

18.2 To realize strengthening the existing FFWS, the following are the major programs and activities for the project.

	Main Programs and Activities
1.	Scrutiny on additional installation of telemetric rainfall and water-level gauges to existing telemetry system
2.	Installation of additional telemetric rainfall and water-level gauges
3.	Study on flood forecasting method and model
4.	Development of flood forecasting model
5.	Installation of measuring device of dam release discharge
6.	Improvement of FFWS based on trial application and review of the draft improved reservoir operation rules for flood control
7.	Preparation of a system operation manual
8.	Preparation of monitoring plan to sustain project effect

Project on Strengthening Evacuation and Flood Fighting System

19. The current evacuation / flood fighting system for the Mejerda River basin needs to be reconsidered to strengthen its function from the following two viewpoints:

(a) In order to decide well-timed commencement of evacuation / flood fighting activities, it is important to clarify precise commencement criteria.

(b) Raising of peoples' awareness of disaster mitigation is essential, since understanding and cooperation of the public and their communities are indispensable for evacuation activities.

Therefore, the following are proposed to be executed in the project.

	Main Programs and Activities
1.	Improvement of information sharing system among official agencies and communities regarding flood disaster management and evacuation plan
2.	Study and setting of alert levels at key water-level gauging stations for evacuation/flood fighting activities
3.	Formulation of precise criteria to commence evacuation/flood fighting activities
4.	Development of clear and understandable evacuation procedures and drilling at pilot areas
5.	Preparing monitoring plan to sustain project effect

Project on Organizational Capacity Development

20.1 An organizational capacity development plan for institutions and organizations in the Mejerda River basin is drafted to materialize the necessary actions for the problems/issues identified in the Study. This draft plan consists of the following eleven programs, classifying the programs into three attributes of institutional integration of river administration, namely (i) integrated administration, (ii) integrated planning and implementation and (iii) integrated operation and maintenance.

(i) Integrated administration
- Program 1: One management for one river basin (Mejerda River)
- Program 2: Permanent organization in central and regional directions to promote IFM
- Program 3: Supplement IFM to the Mission of National Water Council
- Program 4: Basin-wide environmental management and monitoring

(ii) Integrated planning and implementation
- Program 5: Integrated planning of structural and non-structural measures for flood control by Project Steering Committee under DGBGTH
- Program 6: Coordination by MARH in design to O/M stages of the project
- Program 7: Implementation and management by Project Management Unit under DGBGTH in design and construction stages
- Program 8: Documented technical guidelines, standards and rules
- Program 9: Arrangement of flood insurance

(iii) Integrated operation and maintenance,
- Program 10: Strengthening O&M of existing water supply system and large dams
- Program 11: Establishment of new agency for O&M of river course and river facilities of Mejerda River

20.2 It is realistic to materialize the drafted plan by step-wise, namely in three stages as shown below because there are limited experiences and practices of flood management and O&M of the river works in Tunisia.

Main Programs and Activities	
First Stage	
1.	Scrutiny and establishment of permanent division or direction in charge of Mejerda River basin inside DGBGTH
2.	Detailed study on 11 proposed programs for organizational capacity development
3.	Initiating the proposed programs
4.	Selection of a pilot project to be conducted in the second stage
5.	Provision of documented technical guidelines, standards and rules
Second Stage	
1.	Conducting a pilot project under proposed river improvement project of the Mejerda River
Third Stage	
1.	Scrutiny and establishment of an agency in charge of O/M of the Majerda River basin, if the pilot project justifies the viability of the agency
2.	Preparing monitoring plan to sustain project effect

Project on Flood Plain Regulation/Management

21.1 In order to reduce vulnerability to flood risk in the flood prone areas, a flood plain regulation/management is vital in the Mejerda River basin. The following four aspects should be focused on to prepare the action plan and associated activities:

- To delineate the flood prone area (flood risk map) based on the inundation analysis, latest land use and demographic information, which are supported by GIS system created through the Study with subsequent updating,

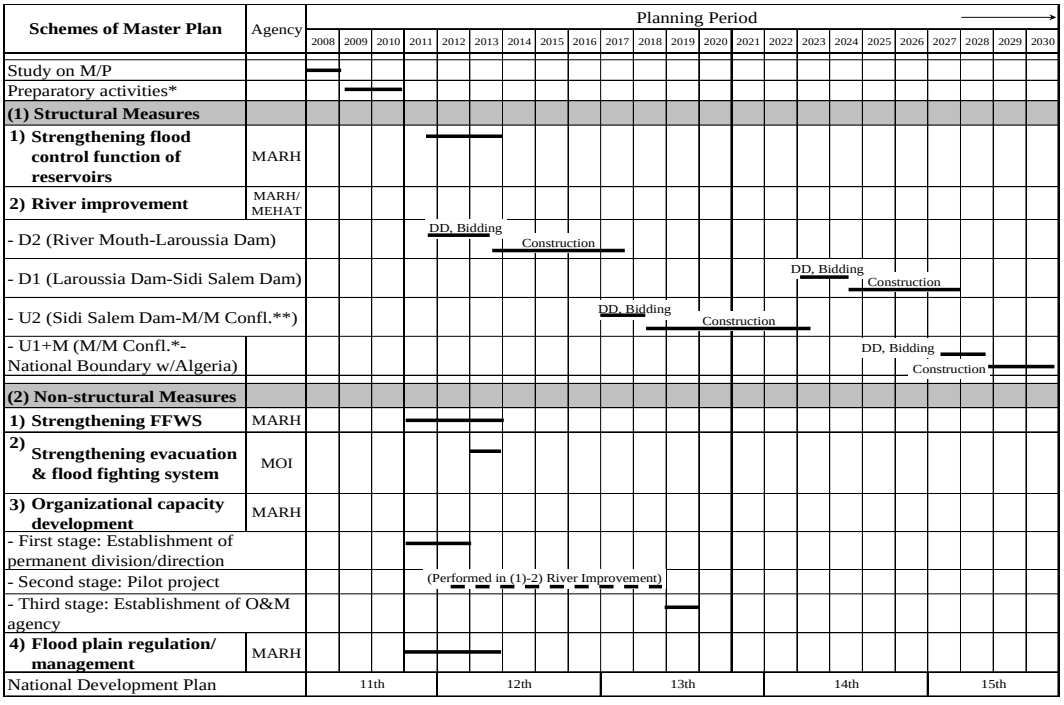
- To examine future land use plan on the flood risk map in order to mitigate the vulnerability to inundation and to enhance the productivity of agricultural development,
- To prepare the guidelines through the activities above to enable sustainable flood management including proper maintenance of structural measures as proposed in the Study, and
- To disseminate and promote the concept of the flood plain regulation/management over the Mejerda River basin (CRDAs and other local governments) by means of training and seminars in the course of programs.

In order to realize the concept of the project, following activities will be contemplated:

	Main Programs and Activities
1.	Delineation of flood prone area through review of runoff and inundation analysis of the Mejerda River basin
2.	Updating of GIS data base with current cropping information
3.	Preparation of flood risk map with zoning by risk level
4.	Analysis on improved cropping pattern based on current prevailing land use
5.	Preparation of guideline for flood risk mapping
6.	Preparation of guideline for enhanced land use control for urban and rural areas
7.	Dissemination, application, evaluation and validation of the guidelines in target CRDAs and local governments
8.	Training and seminar

VIII. IMPLEMENTATION SCHEDULE

22. The overall implementation schedule of the flood control measures recommended in the master plan is presented below.



Notes: * including Feasibility/Detailed Studies, fund arrangements, procurement of consulting services, etc. ** M/M Confl.=Mejerda-Mellegue Confluence

IX. PROJECT COST

23.1 The project cost of each scheme composed of the flood control measures in the master plan is estimated as summarized below.

(x10^3)

Schemes	TND Equiv.	USD Equiv.	Yen Equiv.
(1) Structural measures			
1.1 Project on river improvement			
- Zone D2	133,574	114,068	12,181,000
- Zone D1	173,657	148,298	15,837,000
- Zone U2	186,475	159,244	17,005,000
- Zone U1+M	60,079	51,306	5,479,000
Sub-total of 1-1	553,785	472,916	50,502,000
1.2 Project on strengthening flood control function of reservoirs	5,772	4,934	527,000
Total of (1)	**559,557**	**477,850**	**51,029,000**
(2)Non-structural measures			
2.1 Project on strengthening FFWS	5,592	4,775	510,000
2.2 Project on strengthening evacuation/flood fighting system	2,910	2,485	265,000
2.3 Project on organizational capacity development	7,135	6,093	651,000
2.4 Project on flood plain regulation/management	5,238	4,473	478,000
Total of (2)	**20,875**	**17,826**	**1,904,000**
Grand Total: (1)+(2)	**580,432**	**495,676**	**52,933,000**

Source: the Study Team

The project cost is estimated based on the price level as of June 2008 and the following exchange rates: TND 1 = JPY 91.20 = USD 0.854.

23.2 The project cost of "1.1 Project on river improvement" consists of (i) costs of construction, land acquisition, government administration and engineering services, (ii) physical and price contingencies, and (iii) taxes.

23.3 The government administration and engineering services costs are calculated as 3% of the sum of construction and land acquisition costs and 10 % of the construction cost, respectively. The physical contingency is computed as 10% of (i) above. In the calculation of the price contingency, the annual price escalation rates of 2.1% and 3.2% are applied to the foreign and local currency portions, respectively, for the cost components of (i) above and the physical contingency.

23.4 The project costs of "1.2" and "2.1 to 2.4" consist of (i) costs of engineering services and government administration, (ii) physical and price contingencies, and (iii) taxes.

X. PROJECT FUND ARRANGEMENT

Capital Cost for Project on River Improvement

24.1 The total capital cost of the project on river improvement proposed in the master plan is estimated at about 554 million TND. Of which, Zone D2 and Zone U2, having higher priority for implementation, need capital costs of 134 million TND and 186 million TND, respectively. Annual funds requirements are expected to vary from 22 to 44 million TND during the construction periods.

24.2 Since the project on river improvement need sizable capital investment, it is hoped that

part of the capital cost be covered by loan assistance from the donor agencies. On the other hand, as a result of general review on the assistance strategies as well as the amounts of past loan assistance from the major donors, it is deemed that a sizable assistance for a flood control project cannot be expected, except perhaps from either the French or the Japanese Governments.

24.3 Even though the Tunisian Government may successfully receive loan assistance from international development agencies, the government generally needs to allocate about 20 ~ 30% of the capital cost, which amounts to 4 million ~ 13 million TND per year.

Soft Component of Flood Control Project

25.1 The costs of the soft components proposed in this master plan study, namely the strengthening of the flood control function of reservoirs, strengthening the existing flood forecasting and warning system, organizational capacity development, strengthening evacuation and flood fighting system, and flood plain regulation/management, amounts to about 27 million TND in total.

25.2 The soft components consist mainly of technical assistance activities, and thus need relatively smaller capital expenditure. Accordingly, the soft components are considered eligible for grant-based technical cooperation projects in the light of the contents of project activities as well as the smaller capital costs.

XI. OVERALL EVALUATION OF MASTER PLAN

Economic Evaluation

26.1 The EIRRs of the whole project as well as individual projects in each zone were calculated in accordance with the implementation schedule, as shown below, ranging between 12.1% and 33.7%, and are above the economic discount rate of 12.0%. In addition, the economic net present value (ENPV) and benefit-cost ratio (B/C) adopting 12.0% of discount rate exceeds “0” and “1”, respectively. These calculation results have proven that all the proposed flood control projects are feasible from the economic point of view.

Summary of Economic Analysis (river improvement project)

	Zone D1	Zone D2	Zone U1+M	Zone U2	Whole Projects
EIRR	20.5%	33.7%	12.1%	14.6%	25.0%
ENPV(million TND)	19.96	230.31	0.29	13.60	264.16
B/C Ratio	2.73	5.83	1.01	1.28	3.04

Source: the Study Team

26.2 The sensitivity of the EIRR and ENPV was computed to access the robustness of the economic viability of the project to several adverse changes in project cost and benefits. A switching value analysis was also made to ascertain that the cost required to reduce the ENPV to 0 and the minus benefit to make the EIRR equal to the economic opportunity

cost of 12.0%.

Summary of Sensitivity Analysis

	Adverse Scenarios	EIRR	ENPV (million TND)	Switching Value
Zone D1	Base Case	20.5%	20.0	-
	a. Capital Cost Increase 20%	18.9%	17.7	+ 175%
	b. Flood Control Effect by -20%	18.5%	13.7	- 63%
	c. GDP Growth - 1% point	18.1%	11.8	-
	d. a + b + c	14.5%	4.8	-
Zone D2	Base Case	33.7%	230.3	-
	a. Capital Cost Increase 20%	30.7%	220.9	+ 487%
	b. Flood Control Effect by -20%	30.1%	174.7	- 83%
	c. GDP Growth - 1% point	31.9%	185.3	-
	d. a + b + c	25.5%	129.3	-
Zone U1+M	Base Case	12.1%	0.3	-
	a. Capital Cost Increase 20%	10.7%	-4.3	1.4%
	b. Flood Control Effect by -20%	10.4%	-4.0	1.4%
	c. GDP Growth - 1% point	10.5%	-3.5	-
	d. a + b + c	7.6%	-11.3	-
Zone U2	Base Case	14.6%	13.6	-
	a. Capital Cost Increase 20%	12.6%	3.9	+ 28%
	b. Flood Control Effect by -20%	12.2%	1.1	- 22%
	c. GDP Growth - 1% point	12.5%	2.2	-
	d. a + b + c	8.7%	-17.8	-
Whole Project	Base Case	25.0%	264.2	-
	a. Capital Cost Increase 20%	22.4%	238.3	+ 204%
	b. Flood Control Effect by -20%	21.8%	185.4	- 67%
	c. GDP Growth - 1% point	23.1%	195.8	-
	d. a + b + c	17.6%	105.0	-

Source: the Study Team

26.3 The sensitivity analysis shows that the economic viability of the proposed flood control projects in Zone D1, D2 as well as the whole project are robust under the various adverse assumptions. Also, economic viability of the zone U2 has sufficient robustness. When overrun of capital cost is within the range of 28% to the base case or there is a decrease in the economic benefits within minus 22% to the base case, the project sustains its economic viability.

26.4 In the case of the project in Zone U1+M of which the economic viability is rather low, since project implementation is scheduled to start in 2027, it is recommended to execute economic analysis again before implementation, taking into consideration the change in the economic development in the zone as well as the asset values in the probable flood area.

Environmental Evaluation

27. The conceivable impacts to be caused by implementation of structural measures of the project on river improvement are evaluated through the IEE. According to the IEE results, the following conclusion and recommendations were obtained:

(a) As for the river improvement works planned in the upper area, the Mellegue improvement works are recommended because of the least negative environmental

and social impacts due to its smaller scale. All other works in the upper area are recommendable because their negative medium impacts can be controlled through adequate mitigation measures and proper monitoring.

(b) As for the river improvement works planned for the middle area, all works are also recommendable considering that proper mitigation and monitoring measures can alleviate their negative medium impacts.

(c) The same thing as above can be said for the river improvement works planned for the lower area.

Technical Evaluation

28.1 Water is limited precious resources in Tunisia and there is never a drop of water to waste. Hence, the flood control master plan formulated in the Study has been satisfactorily harmonized with the water use plan in the Mejerda River basin assigning higher priority to realization of water supply, because the water supply risk and flood control risk is in a tradeoff position.

28.2 The flood control measures in the master plan have been formulated in principle by employing rather technically conventional knowledge and approaches that have been usually applied to flood control projects, and hence it is expected that there would be no technically challenging problems to be encountered in the project implementation and also its operation and maintenance stages.

28.3 The said flood control measures, in particular the projects on river improvement and on strengthening the existing FFWS, have reflected technical opinions and desires obtained from the local people, who have actually suffered from past serious floods. These opinions were gathered through the interview survey on public acceptance of the flood risks and at two stakeholders' meetings, which were conducted in the Study.

28.4 In the project on river improvement, the Study has proposed a kind of construction method for riverbank protection made with wood materials, which is widely adopted as a traditional way of riverbank protection in Japan. This construction method seems to be applicable to the Mejerda River by using trees, so-called "Tamarix", which have grown thick in the high water channels of the Mejerda River. If this method is effectively applicable with Tamarix, the cost of riverbank protection during the maintenance period can be significantly reduced. Furthermore, inhabitants who want to protect their own land from riverbank erosion will be able to do this with Tamarix by themselves, if they acquire the technical know-how on how to make it. No heavy machinery is needed. Therefore, maintenance works of river channel could be expected to be carried out by the local people, through participatory approach to some extent.

Conclusions and Recommendations

29.1 The projects proposed in the master plan have been formulated to effectively resolve the flood problems in the Mejerda River basin with the target year of 2030. This Study has confirmed that the projects will help alleviate the serious flood damage experienced

particularly in the recent years and are feasible technically, economically and environmentally.

29.2 In due consideration of the disastrous conditions in the study area having been frequently devastated by the recent serious floods and decreasing flow capacity of the river channels, it is strongly recommended for the Government of Tunisia to immediately take necessary actions for further steps such as securing finance, technical assistance and so forth, so as to actually realize the following positive effects among others:

- Prevention of long duration of flooding and health hazards,
- Alleviation of losses in the project area due to extended stagnant flooding,
- Resolution of paralysis in civic function due to traffic congestion caused by flood inundation in urbanized areas,
- Improvement of living environment conditions and boosting of local economy due to lesser risk of flood damage.

Among the proposed projects, the following four projects are recommendable as the priority projects that need feasibility/detailed studies to be conducted without any delay.

Priority projects	Project costs (10^3 TND)	Implementation schedule
1) River improvement for Zone D2 (between the estuary of the Mejerda River and Laroussia Dam)	133,574	2011 to 2017
2) Strengthening flood control function of reservoirs	5,772	2011 to 2013
3) Strengthening existing flood forecasting and warning system	5,592	2011 to 2013
4) Strengthening evacuation and flood fighting system	2,910	2013
Total	147,848	

Source: the Study Team

Table 16.1 Salient Feature of Major Structures (River Improvement Works) (1/2)

Zone D2

I. Mejerda River				
1) Embankment				
a) Length				
Whole river stretches under planning			60,310	m
(Heightening of existing levee)			20,280	m
Actual construction plan of embankment			55,843	m
		(Left bank)	29,365	m
		(Right bank)	26,478	m
b) Height			0.5-2.5	m
2) Channel excavation/widening		Length	63,838	m
		Volume	10.0	mil. m^3
3) Sluice gate			47	Nos.
4) Revetment	Concrete frame type		2,200	m
	Stone pitching type		500	m
	Fascine mattress type		2,400	m
5) Renewal of existing bridge			3	Location
6) Raising of existing railway bridge			1	Location
7) Raising of existing road			4,600	m
II. El Mabtouh Retarding Basin				
1) Inlet channel	Improvement of existing channel		9,130	m
	New channel construction		2,770	m
2) Outlet channel			7,780	m
3) Surrounding dike		Length	10,100	m
		Height	2.0-4.0	m
4) Design storage capacity			50 million	m^3
5) Design discharge		Inlet channel	Q=200	m^3/s
		Outlet channel	Q=50	m^3/s
6) Overflow dike of inlet channel (with stop log		Length	80	m

Zone D1

I. Mejerda River				
1) Embankment				
a) Length				
Whole river stretches under planning			79,552	m
Actual construction plan of embankment			70,580	m
		(Left bank)	36,671	m
		(Right bank)	33,909	m
b) Height			0.5-2.5	m
2) Channel excavation/widening		Length	81,224	m
		Volume	9.4	mil. m^3
3) Sluice gate			72	Nos.
4) Revetment	Concrete frame type		1,000	m
	Stone pitching type		500	m
	Fascine mattress type		2,700	m
5) Renewal of existing bridge			1	Location
II. Majez El Bab Bypass Channel				
1) Bypass channel		Length	4,512	m
		Excavation volume	2.7	mil. m^3
2) Channel bottom width			15	m
3) Design Discharge	Mejerda River		Q = 450	m^3/s
	Bypass channel		Q = 250	m^3/s

Table 16.1 Salient Feature of Major Structures (River Improvement Works) (2/2)

Zone U2

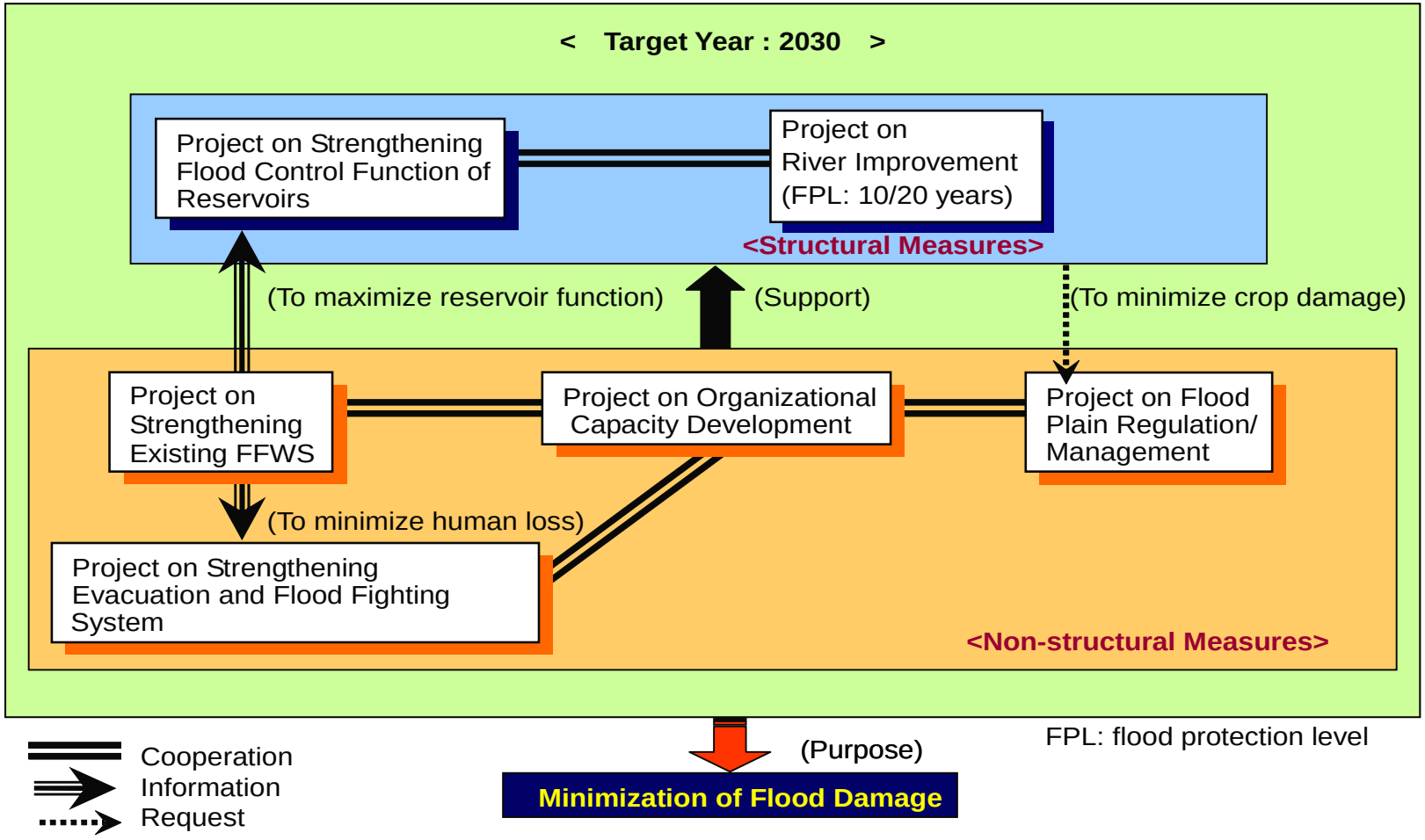
I. Mejerda River				
1) Embankment				
a) Length				
Whole river stretches under planning			54,971	m
Actual construction plan of embankment			67,499	m
		(Left bank)	34,833	m
		(Right bank)	32,666	m
b) Height			2.5-4.5	m
2) Channel excavation/widening		Length	42,726	m
		Volume	9.6	mil. m^3
3) Sluice gate			42	Nos.
4) Revetment	Concrete frame type		1,000	m
	Stone pitching type		500	m
	Fascine mattress type		3,300	m
5) Renewal of existing aqueduct with foot bridge			1	Location
II. Bou Salem Bypass Channel				
1) Bypass channel		Length	7,736	m
		Excavation volume	3.5	mil. m^3
2) Channel bottom width			25	m
3) Design Discharge	Mejerda River		Q = 1,140	m^3/s
	Bypass channel		Q = 700	m^3/s

Zone U1

I. Mejerda River				
1) Embankment				m
a) Length				
Whole river stretches under planning			5,124	m
Actual construction plan of embankment			5,124	m
		(Left bank)	2,264	m
		(Right bank)	2,860	m
b) Height			1.0-3.0	m
2) Channel excavation/widening		Length	48,217	m
		Volume	4.2	mil. m^3
3) Sluice gate			3	Nos.
4) Revetment	Stone pitching type		250	m
	Fascine mattress type		1,500	m

Zone M

I. Mellegue River				
1) Embankment				
a) Length				
Whole river stretches under planning			8,895	m
Actual construction plan of embankment			7,405	m
		(Left bank)	4,195	m
		(Right bank)	3,210	m
b) Height			1.0-3.0	m
2) Channel excavation/widening		Length	12,871	m
		Volume	0.6	mil. m^3
3) Sluice gate			3	Nos.



Source: the Study Team

Figure 15.1 Composition of M/P for Flood Control in Mejerda River Basin

Figure 15.2 OVERVIEW OF THE MASTER PLAN FOR FLOOD CONTROL IN MEJERDA RIVER BASIN

STRUCTURAL MEASURES

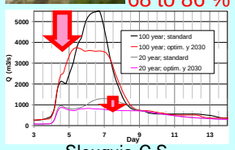
Strengthening Flood Control Function of Reservoirs

Legend:
- Sidi Salem Reservoir
- reservoirs to be coordinated
- discharge reference points

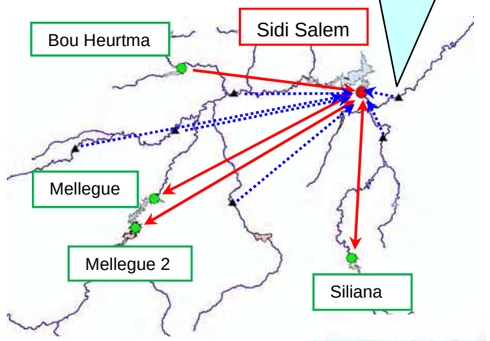
Sidi Salem Dam

effect of coordinated operation

68 to 86 %



Slouguia G.S.

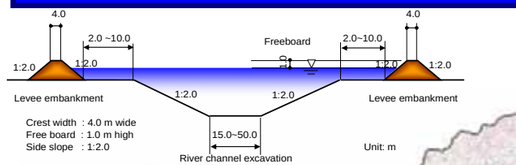


Mellegue Dam

Bou Heurtma Dam

Siliana Dam

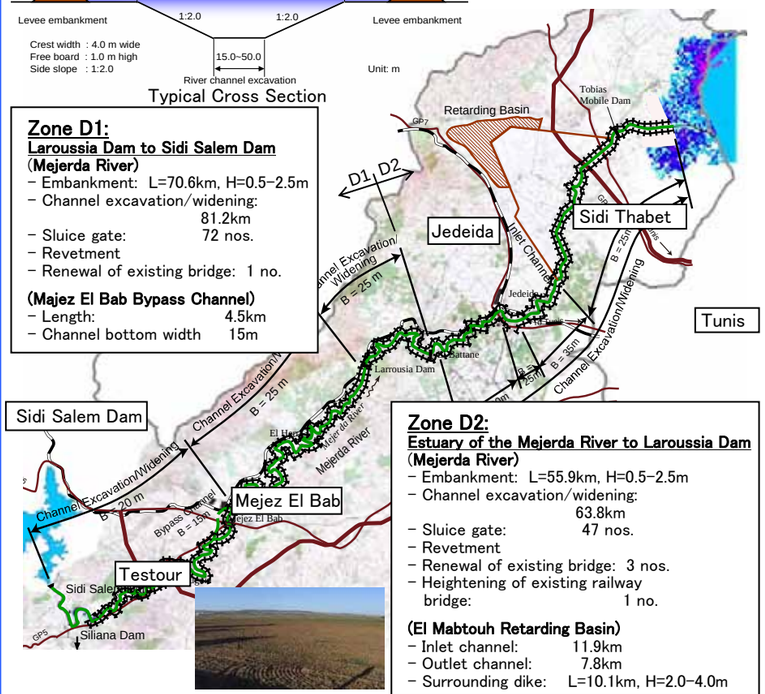
River Improvement



Typical Cross Section

Zone D1:
Laroussia Dam to Sidi Salem Dam
(Mejerda River)
- Embankment: L=70.6km, H=0.5~2.5m
- Channel excavation/widening: 81.2km
- Sluice gate: 72 nos.
- Revetment
- Renewal of existing bridge: 1 no.

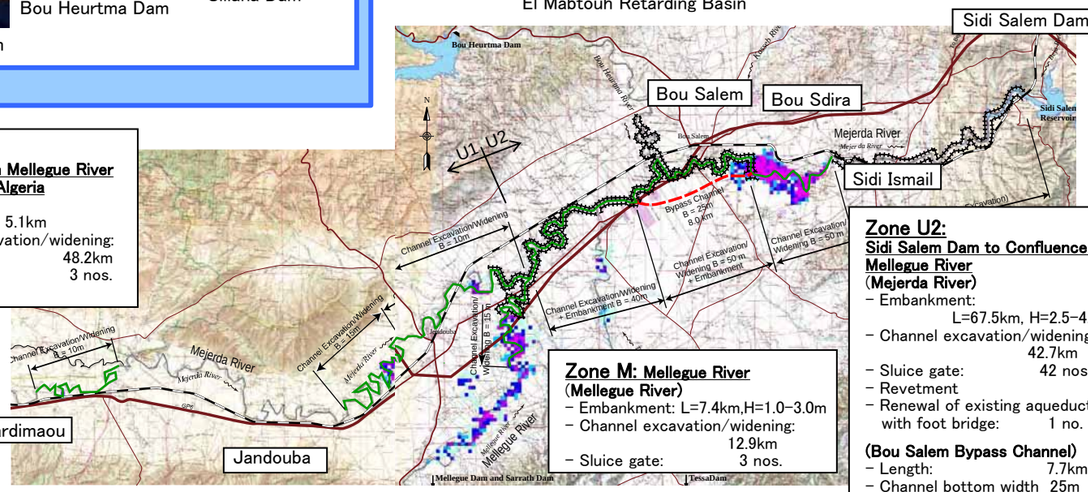
(Majez El Bab Bypass Channel)
- Length: 4.5km
- Channel bottom width 15m



Zone D2:
Estuary of the Mejerda River to Laroussia Dam
(Mejerda River)
- Embankment: L=55.9km, H=0.5~2.5m
- Channel excavation/widening: 63.8km
- Sluice gate: 47 nos.
- Revetment
- Renewal of existing bridge: 3 nos.
- Heightening of existing railway bridge: 1 no.

(El Mabtouh Retarding Basin)
- Inlet channel: 11.9km
- Outlet channel: 7.8km
- Surrounding dike: L=10.1km, H=2.0~4.0m

El Mabtouh Retarding Basin



Zone U1:
Confluence with Mellegue River to Border with Algeria
(Mejerda River)
- Embankment: 5.1km
- Channel excavation/widening: 48.2km
- Sluice gate: 3 nos.
- Revetment

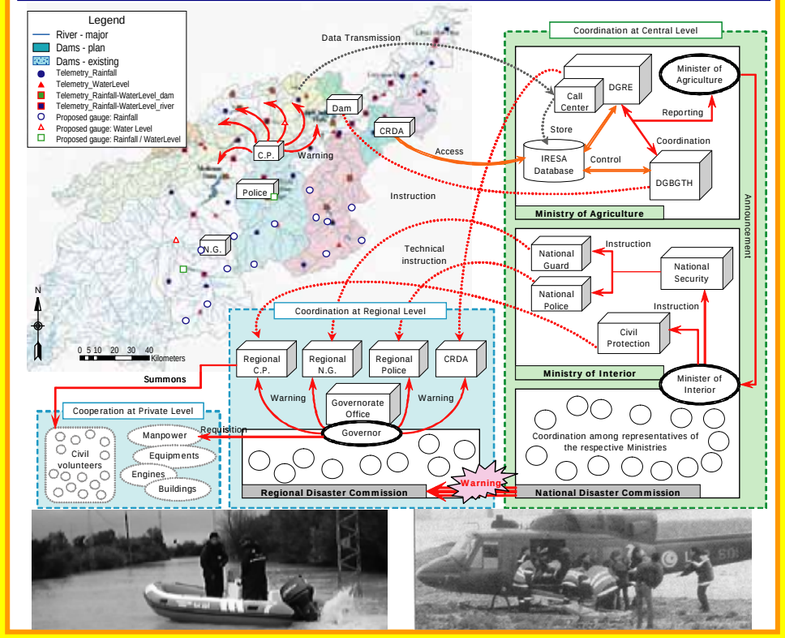
Zone M: Mellegue River
(Mellegue River)
- Embankment: L=7.4km,H=1.0~3.0m
- Channel excavation/widening: 12.9km
- Sluice gate: 3 nos.

Zone U2:
Sidi Salem Dam to Confluence with Mellegue River
(Mejerda River)
- Embankment: L=67.5km, H=2.5~4.5m
- Channel excavation/widening: 42.7km
- Sluice gate: 42 nos.
- Revetment
- Renewal of existing aqueduct with foot bridge: 1 no.

(Bou Salem Bypass Channel)
- Length: 7.7km
- Channel bottom width 25m

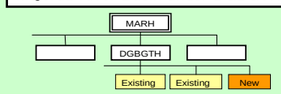
NON-STRUCTURAL MEASURES

Strengthening of Existing FFWS and Evacuation & Flood Fighting System



Organizational Capacity Development

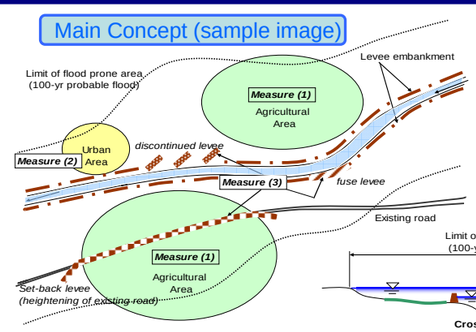
To establish new division in charge of Mejerda River Basin under DGBGTH



- To establish an organizational framework for integrated flood management (IFM)
- To materialize 11 proposed programs for organizational empowerment to promote IFM under the framework

Flood Plain Regulation/Management

Main Concept (sample image)



Measure (1)	Promotion of change of cropping pattern in flood prone area (100-yr Probable Flood)
Measure (2)	Restriction of construction of new house/building in urban area
Measure (3)	Construction of fuse levee, discontinued levee and secondary levee (set-back levee)

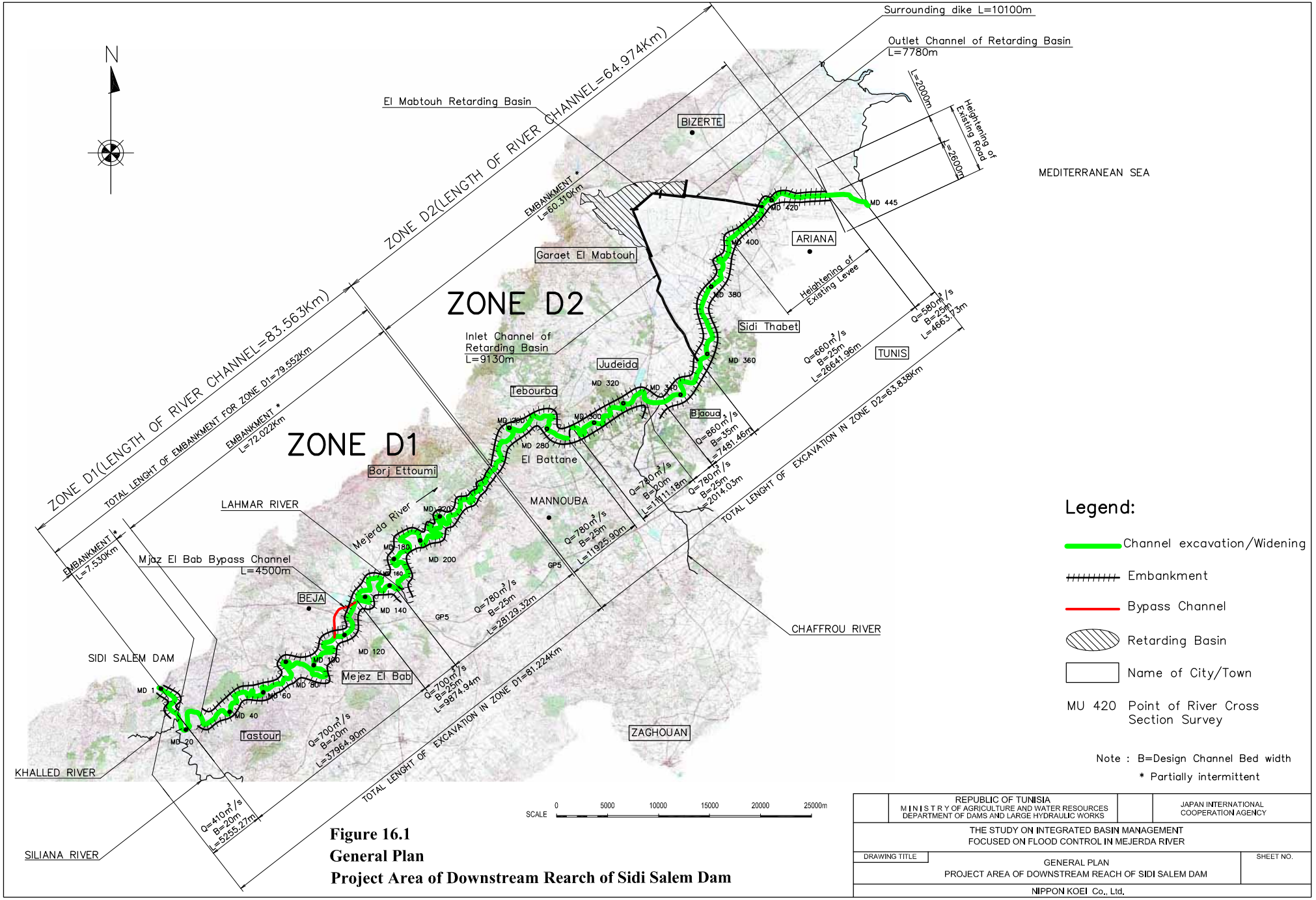


Figure 16.1
General Plan
Project Area of Downstream Rearch of Sidi Salem Dam

REPUBLIC OF TUNISIA MINISTRY OF AGRICULTURE AND WATER RESOURCES DEPARTMENT OF DAMS AND LARGE HYDRAULIC WORKS		JAPAN INTERNATIONAL COOPERATION AGENCY
THE STUDY ON INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER		
DRAWING TITLE: GENERAL PLAN PROJECT AREA OF DOWNSTREAM REACH OF SIDI SALEM DAM		SHEET NO.
NIPPON KOEI Co., Ltd.		

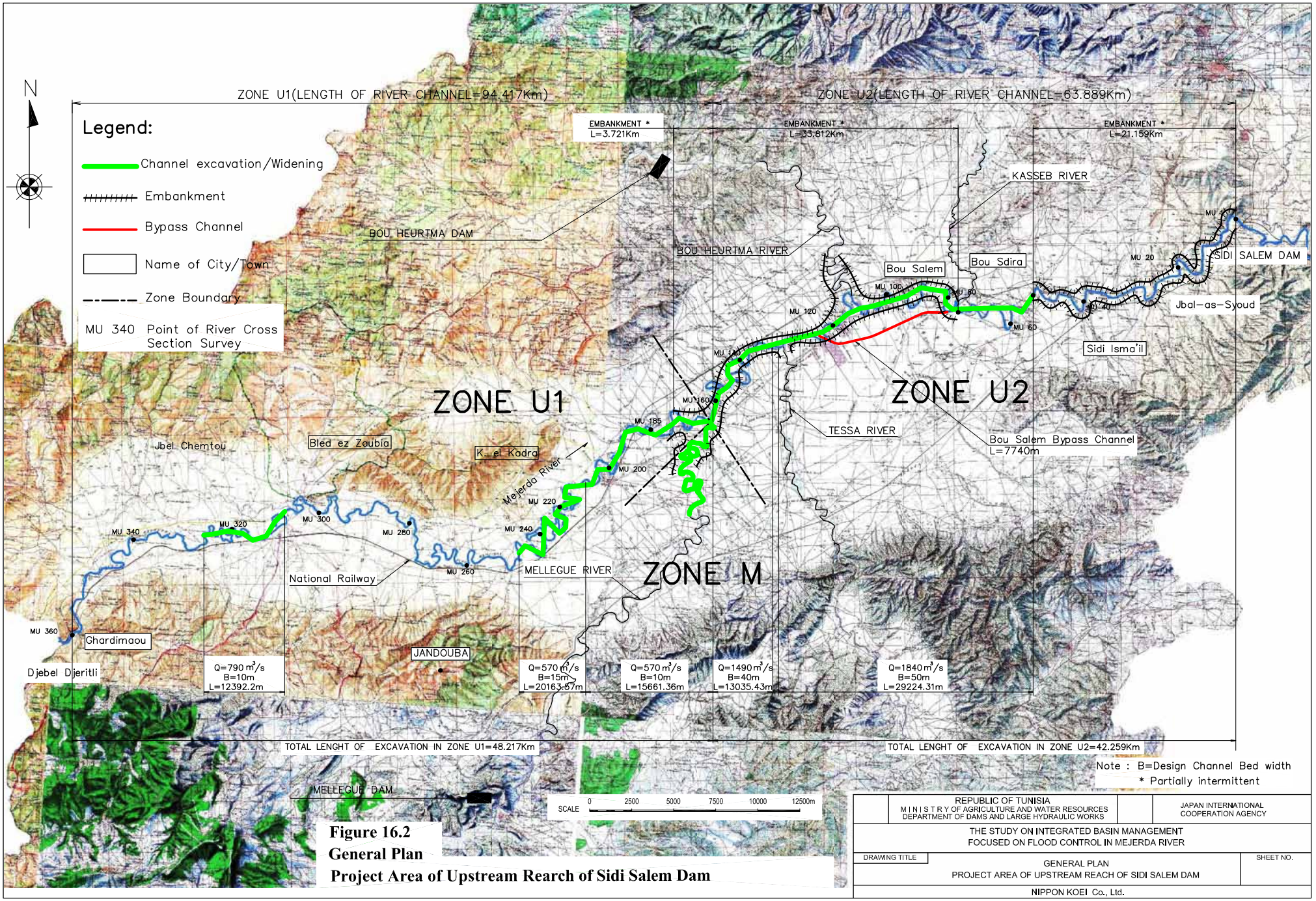


Figure 16.2
General Plan
Project Area of Upstream Rearch of Sidi Salem Dam

REPUBLIC OF TUNISIA MINISTRY OF AGRICULTURE AND WATER RESOURCES DEPARTMENT OF DAMS AND LARGE HYDRAULIC WORKS		JAPAN INTERNATIONAL COOPERATION AGENCY
THE STUDY ON INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL IN MEJERDA RIVER		
DRAWING TITLE	GENERAL PLAN PROJECT AREA OF UPSTREAM REACH OF SIDI SALEM DAM	SHEET NO.
NIPPON KOEI Co., Ltd.		

ABBREVIATIONS AND GLOSSARIES

French Origin Abbreviations for Names of Tunisian Institutions

	English	French
A/CES	Soil and Water Conservation Service	Arrondissement de la Conservation des Eaux et du Sol
A/EPPI	Public Irrigated Areas Exploitation Service	Arrondissement de l'Exploitation des Périmètres Publics Irrigués
AFD	French Development Agency	l'Agence Française de Développement
A/GR	Rural Engineering Service	Arrondissement du Génie Rural
A/ME	Maintenance of Equipments Service	Arrondissement de la Maintenance des Equipements
A/RE	Water Resources Service	Arrondissement des Ressources en Eau
AVFA	Agricultural Vulgarization and Training Agency	Agence de Vulgarisation et de la Formation Agricoles
ANPE	National Agency for the Protection of the Environment (Tunisia)	Agence Nationale de Protection de l'Environnement
BIRH	Hydraulic Inventory and Research Bureau	Bureau de l'Inventaire et des Recherches Hydrauliques
BCT	Central Bank of Tunisia	Banque Centrale de la Tunisie
BPEH	Bureau of Water Planning and Hydraulic Equilibriums(MARH)	Bureau de la Planification et des Équilibres Hydrauliques (MARH)
CITET	International Centre of Environment Technologies	Centre International des Technologies de l'Environnement
CNS	The Drought National Commission	La Commission Nationale de la Sécheresse
CNE	National Water Committee	Comité National de l'Eau
CRS	The Drought Régional Commission	La Commission Régionale de la Sécheresse
CRDA	Regional Commissary for Agricultural Development	Commissariat Régional au Développement Agricole
CSS	The Drought Specialized Commission	La Commission Sectorielle de la Sècheresse
DGACTA	General Direction of Development and Preservation of Agricultural Lands (under MARH)	Direction Générale de l'Aménagement et de la Conservation des Terres Agricoles (MARH)
DGAJF	General Direction of Juridical and Land Property	Direction Générale des Affaires Juridiques et Foncières (MARH)
DGBGTH	General Direction of Dams and Large Hydraulic Works (under MARH)	Direction Générale des Barrages et des Grands Travaux Hydrauliques (MARH)
DGEDA	General Direction of studies and Agricultural Development (under MARH)	Direction générale des ÉTUDES et du Développement Agricole (MARH)
DGEQV	General Direction of Environment and Life Quality (under MEDD)	Direction Générale de l'Environnement et de la Qualité de la Vie (MEDD)

	English	French
DGF	General Direction of Forests (under MARH)	Direction Générale des Forêts (MARH)
DGGREE	General Direction of Rural Engineering and Water Exploitation (under MARH)	Direction Générale du Génie Rural et de l'Exploitation des Eaux (MARH)
DGFIOP	General Direction of Financing, Investments and Professional Organisms (under MARH)	Direction Générale du Financement, des Investissements et des Organismes Professionnels (MARH)
DGPA	General Direction of Agriculture Production (under MARH)	Direction Générale de la Production Agricole (MARH)
DGPCQPA	General Direction of Agricultural Product Quality Control and Protection (under MARH)	Direction Générale de la Protection et du Contrôle de la Qualité des Produits Agricoles (MARH)
DGRE	General Direction of Water Resources (under MARH)	Direction Générale des Ressources en Eau (MARH)
DGSV	General Direction of Veterinary Services (under MARH)	Direction Générale des Services Vétérinaires (MAHR)
DHMPE	Direction of Surrounding Hygiene and Environment Protection	Direction de l'Hygiène du Milieu et de la Protection de l'Environnement
DTIS	Direction of the Scientific Information Processing	Direction du Traitement de l'Information Scientifique
GIC	Collective Interest Organizations	Groupements d'Intérêt Collectif
INAT	National Agronomical Institute of Tunisia (under MARH)	Institut National Agronomique de Tunisie
INM	National Institute of Meteorology (under Ministry of Transportation)	Institut National de la Météorologie (MT)
INS	National Statistics Institute	Institut National de la Statistique
INRGREF	National Research Institute for Rural Engineering, Water and Forestry (MARH)	Institut National de Recherche en Génie Rural, Eaux et Forêt
IRESA	Institution of Agricultural Research and Education	Institution de la Recherche et de l'Enseignement Supérieur Agricole
MARH	Ministry of Agriculture and Hydraulic Resources	Ministère de l'Agriculture et des Ressources Hydrauliques
MEDD	Ministry of Environment and Sustainable Development	Ministère de l'Environnement et du Développement Durable
MEHAT	Ministry of Equipment, Housing and Country Planning	Ministère de l'Equipement de l'Habitat et de l'Aménagement du territoire
MF	Ministry of Finance	Ministère des Finances
OEP	Animal Husbandry and Pasture Agency	Office de l'Elevage et de du Pâturage
ONAS	National Sanitation Agency	Office National de l'Assainisssement
OTED	Tunisian Observatory for the Environment and Sustainable Development	Observatoire Tunisien de l'Environnement et du Développement Durable
SECADENORD	The North Water Canal, Adductions and System Management Company	Société d'Exploitation, Canalisation et d'Adduction des Eaux du Nord

	English	French
SONEDE	Water Exploitation and Distribution National Company (WEDNC)	Société Nationale d'Exploitation et de Distribution des Eaux
UTAP	Tunisian Agriculture and Fishery Association	Union Tunisienne de l'Agriculture et de Pêche

French Origin Abbreviations for Other than Names of Tunisian Institutions

	English	French
GEORE	Optimum Management of Water Resources	Gestion Optimale des Ressources en Eau
JORT	Official Journal of the Republic of Tunisia	Journal Officiel de la Tunisie
MEDROPLAN	The Mediterranean Drought and Preparedness and Mitigation Planning	Etat de préparation de sécheresse et planification méditerranéenne de réduction
NGT	General Levelling of Tunisia (Topographic datum in Tunisia)	Nivellement Général de la Tunisie
PHE	Maximum Water Level	Niveau des Plus Hautes Eaux
PISEAU project	Water Sector Investment Project	Projet d'Investissement du Secteur de l'Eau
SINEAU	Water Resources National Information System	Système d'Information National des Ressources en Eau
SYCHTRAC	Real Time Hydrological Data Collection and Flood Warning System	Système de Collecte des Données Hydrologiques en Temps Réels st Annouce de Cures

English Origin Abbreviations (or Other Languages)

	English	French
AfDB	African Development Bank	Banque africaine de développement (BAfD)
BOD	Biological Oxygen Demand	Demande Biologiste en l'Oxygène
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora	Convention de Washington sur le Commerce International des Espèces de Faune et de Flore Sauvages Menacées d'Extinction
COD	Chemical Oxygen Demand	Demande Chimique de l'Oxygène
EIA	Environmental Impact Assessment	Evaluation de l'Impact sur l'Environnement
EIRR	Economic Internal Rate of Return	Taux Interne de Rentabilité Economique
FAO	Food and Agriculture Organization of the United Nations	Organisation pour l'Alimentation et l'Agriculture (FAO)
FFWS	Flood Forecasting and Warning System	Système de prévisions de crue et d'alerte
F/S	Feasibility Study	Etude de Faisabilité
GDP	Gross Domestic Product	Produit intérieur brut (PIB)

	English	French
GEOSS	Global Earth Observation System of Systems	Système Global d'Observation du globe des Systèmes
GIS	Geographical Information System	Système d'Information Géographique
G/S	Gauging station	Station de jaugeage
GSM	Global System for Mobile Communications	Système global pour communications mobiles
GTZ	German Office for Technical Cooperation (Deutsche Gesellschaft für Technische Zusammenarbeit)	Coopération Technique Allemande
IEE	Initial Environmental Examination	Examen Initial sur l'Environnement
IFAD	International Fund for Agricultural Development	Fonds International de Développement Agricole (FIDA)
IUCN	The World Nature Conservation Union	Union Internationale pour la Conservation de la Nature
JBIC	Japan Bank for International Cooperation	Banque Japonaise de Coopération Internationale
JICA	Japan International Cooperation Agency	Agence Japonaise de Coopération Internationale
MDGs	Millennium Development Goals	Objectifs du Millénaire pour le développement (OMD)
M/P	Master Plan	Plan directeur
NGO	Non-governmental Organization	Organisation Non Gouvernementale
O&M	Operation and Maintenance	fonctionement et Maintenance
PR1	Progress Report 1	Rapport d'Avancement n1
SMS	Short Message Service	Service de message court
TND	Tunisian Dinar	Dinar Tunisien
TOR	Terms of Reference	Termes de Référence1
UN	United Nations	Organisation des Nations unies (ONU)
UNDP	United Nations Development Programme	Programme des Nations Unies pour le Développement
UNESCO	United Nations Educational, Scientific and Cultural Organisation	Organisation des Nations Unies pour l'Education, la Science et la Culture
UNSO	United Nations Sudano-Sahelian Office	Office Soudano-Sahélien des Nations Unies
WB	The World Bank	La Banque Mondiale
WMO	World Meteorological OrganiZation	Organisation Mondiale de la Météorologie

Glossary (French Technical Terms, Tunisian Local Terms and Other Specific Terms)

Term	Explanation
governorate	A regional government unit under the state in Tunisia

MEASUREMENT UNITS

Length

mm	=	millimetres
cm	=	centimetres (= 10 mm)
m	=	meters (= 100 cm)
km	=	kilometres (= 1,000 m)
in.	=	inch (= 2.54 cm)
ft.	=	foot = 12 inches (= 30.48 cm)
yard	=	3 feet = 36 inches (= 0.9144 m)
mile	=	1760 yards (= 1,609.31 m)

Volume

cm^3	=	Cubic-centimetres (1.0 cm x 1.0 cm x 1.0 cm or 1.0 m-lit.)
m^3	=	Cubic-metres (1.0 m x 1.0 m x 1.0 m or 1,000 lit.)
lit.	=	Litre (1,000 cm^3)
cusec	=	ft^3 / sec
lpcd	=	Litre per capita per day

Area

cm^2	=	Square-centimetres (1.0 cm x 1.0 cm)
m^2	=	Square-meters (1.0 m x 1.0 m)
km^2	=	Square-kilometres (1.0 km x 1.0 km)
ha	=	Hectares (10,000 m^2)

Weight

g	=	Grams
kg	=	Kilograms (1,000 g)
ton	=	Metric tonne (1,000 kg)

Currency

US$	=	United State Dollars (USD)
¥	=	Japanese Yen (JPY)
TND	=	Tunisian Dinar

Time

sec.	=	Seconds
min.	=	Minutes (60 sec.)
hr.	=	Hours (60 min.)

THE STUDY
ON
INTEGRATED BASIN MANAGEMENT FOCUSED ON FLOOD CONTROL
IN
MEJERDA RIVER
IN
THE REPUBLIC OF TUNISIA

FINAL REPORT

VOLUME II MAIN REPORT

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Part 1

GENERAL

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Dams and water channels in Tunisia have been constructed since the 1970s based on the water resources master plan. About 95% of the potential water resources are scheduled to be developed until 2010 according to EAU2000. Promotion of efficient management on water resource facilities and economically effective water use is expected to be the central subject of the nation after 2010. Tunisian water resources management policy has traditionally focused on securing quantity of water resources, and thus flood control measures have been limited to urban areas.

During the January 2003 flood event, however, the agricultural land along the Mejerda River, which holds the largest catchment area in Tunisia, was inundated for a long period. The major cities, such as Medjez El Bab and Tunis, heavily suffered social and economic losses. In particular, the significant flood damage affected not only the agricultural production economy but has also impacted the social infrastructures in the areas including schools and hospitals.

On the other hand, before the 2003 flood event, a 3-year consecutive drought hit certain regions in the country. The need for a comprehensive study to determine a thorough solution against both risks in water use and flood damage in the Mejerda River basin has become a focus point. The Government of the Republic of Tunisia (hereinafter referred to as "the Government of Tunisia") requested the Government of Japan to grant a technical aid concerning comprehensive water resources management master plan for the Mejerda River basin covering flood control, soil erosion control and environmental preservation.

In response to the request of the Government of Tunisia, the Government of Japan decided to conduct the Study on Integrated Basin Management Focused on Flood Control in Mejerda River (hereinafter referred to as "the Study") in accordance with the relevant laws and regulations in force in Japan.

Accordingly, Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programmes of the Government of Japan, undertook the Study in close cooperation with the concerned authorities of the Government of Tunisia.

On the part of the Government of Tunisia, the Ministry of Agriculture and Hydraulic Resources (hereinafter referred to as "MARH") represented by the Director General of Dam and Large Hydraulic Works (hereinafter referred to as "DGBGTH") acted as the executing agency for the Study. DGBGTH also acted as a coordinating body in relation with other relevant government and non-governmental organizations concerned, for the smooth implementation of the Study.

1.2 Objectives of the Study

The objectives of the Study are:

(1) To formulate a master plan on Integrated Basin Management focused on Flood Control in Mejerda River, and
(2) To transfer technology and knowledge on integrated basin management focused on flood control to the Tunisian counterparts, through their direct participation in the Study and training programme.

In the Study, the master plan is formulated in consideration of the long-term balance of water resources development/use, sediment discharge and basin environment.

1.3 Study Area

The study area basically covers the whole area of the Mejerda River basin. The extreme north and Ishkeul basins should be taken into account for the consideration of water management.

1.4 Scope and Schedule of the Study

The Study was carried out in two phases: Phase I and Phase II. The scope of the Study in respective phases is summarized as follows:

Phase I: Understanding of Present Conditions and Formulation of Framework for the Master Plan.

(1) Collection and review of existing data and information
(2) Field Reconnaissance
(3) Specific Survey
(4) Analysis (runoff analysis, analysis of river channel discharge capacity, flood runoff/inundation analyses and sediment analysis, etc.)
(5) Identification and study of problems/issues for flood damage mitigation and water resources management
(6) Conducting public consultation meetings with stakeholders
(7) Formulation of framework for the integrated basin management focused on flood control
(8) Technology transfer

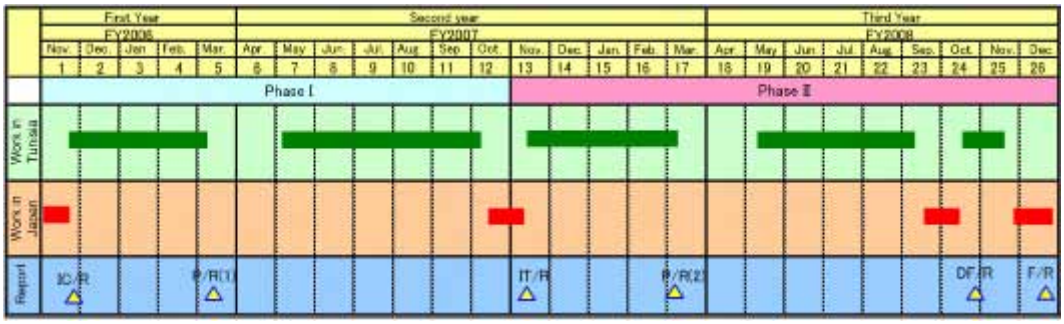
Phase II: Formulation of the Master Plan on Integrated Basin Management focused on Flood Control

(1) Preparation and study of alternative plans for integrated basin management focused on flood control
(2) Initial environmental examination of sub-projects for structural measures
(3) Formulation of the master plan (by focusing flood control from both structural and non-structural aspects, aiming at a well balanced management plan between effective use of water resources and safe and reliable flood control)
(4) Conducting public consultation meeting with stakeholders

(5) Overall evaluation of the master plan from technical, economic, financial, social and environmental aspects
(6) Selection of high priority projects/area and recommendation of implementation plan
(7) Technology transfer

The Study period is 26 months from November 2006 to December 2008.

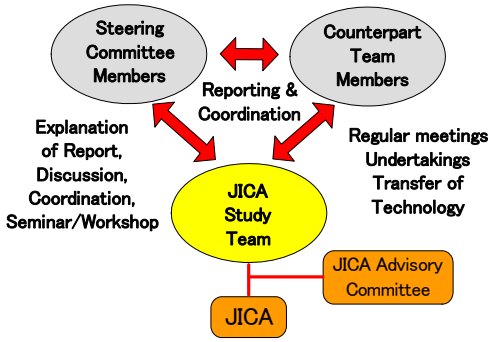
Schedule of the Study



1.5 Study Organization

(1) Organizational setup

The organizational setup for the Study is schematically shown below.



(2) Steering committee

In order to proceed with the Study effectively and smoothly, a Steering Committee was formed. According to 'Minutes of Meetings on Scope of Work for the Study' signed on 28 June 2006, the committee was composed of the representatives of the following organizations, under the chairmanship of MARH.

- MARH
  Department of Dams and Large Hydraulic Works
  Department of International Cooperation
  Department of Water Resources
  Department of Agricultural Studies and Development
- Ministry of Environment and Sustainable Development
- Ministry of Equipment, Housing and Country Planning
- Ministry of Foreign Affairs

(3) Counterpart team

In the First Work in Tunisia, a total of 13 counterpart personnel from the agencies concerned were assigned for the Study. The list of counterpart personnel is presented in **Table 1.5.1**.

(4) JICA Study Team

The JICA Study Team (hereinafter referred to as "the Study Team") comprises ten experts and one coordinator. The composition of the Study Team is also presented in **Table 1.5.1**.

1.6 Final Report

This Final Report is hereby submitted as the final product of the Study which was conducted from November 2006 to December 2008. This Final Report comprises three parts:

Part 1	General
Part 2	Phase-I Study: Understanding of Present Conditions and Formulation of Framework for the Master Plan
Part 3	Phase-II Study: Formulation of the Master Plan

The framework for the master plan was formulated in the Interim Report prepared in November 2007, as a result of the Phase-I Study. The proposed framework was explained and discussed during the 5th Steering Committee meeting, held in Tunis on 21 November 2007. The meeting was chaired by DGBGTH, Ministry of Agriculture and Hydraulic Resources. Said proposed framework was consequently approved by the Steering Committee.

After the approval of the proposed framework, the Phase-II Study commenced in the Third Field Works in Tunisia, for the formulation of the master plan.

This Final Report consists of the following volumes:

Volume I	Executive Summary
Volume II	Main Report
Volume III	Supporting Report
Volume IV	Data Book

CHAPTER 2 CURRENT CONDITIONS OF THE STUDY AREA

2.1 Physical Setting

2.1.1 Physiography and Topography

Tunisia is situated in the centre of the North African seaboard and bordered by the Mediterranean to the North and the East, to the South by Libya, and to the West by Algeria. It covers an area of 162,155 km^2, with a population of about ten million. It is an ancient political entity of the Maghreb and its capital is Tunis. Tunisia has a privileged geographic position at the cross-roads of the Eastern and Western basins of the Mediterranean between Europe and Africa.

Tunisia shares a 965 km border with Algeria and a 459 km border with Libya, while the coastline to the north and east is 1,290 km long. It is the smallest country in North Africa, measuring 1,200 km from north to south and an average of 280 km from east to west. Despite this, it has historically been of substantial strategic and commercial importance, given its location at the heart of the Mediterranean basin.

The Mejerda River runs over a distance of 312 km in the northern part of Tunisia, and represents the country's single perennial river. The Mejerda River basin is located almost entirely in the climatic zone where the average annual rainfall ranges between 400 and 600 mm, and has a total area of 23,700 km^2, of which 7,870 km^2 (33%) are located in Algeria.

2.1.2 Climate

(1) General

Tunisia, which lies on the frontier between the hot desert in the south and the Mediterranean in the north, is dominated by the air system of the subtropical Saharan desert in summer and of the moderate zone in other seasons.

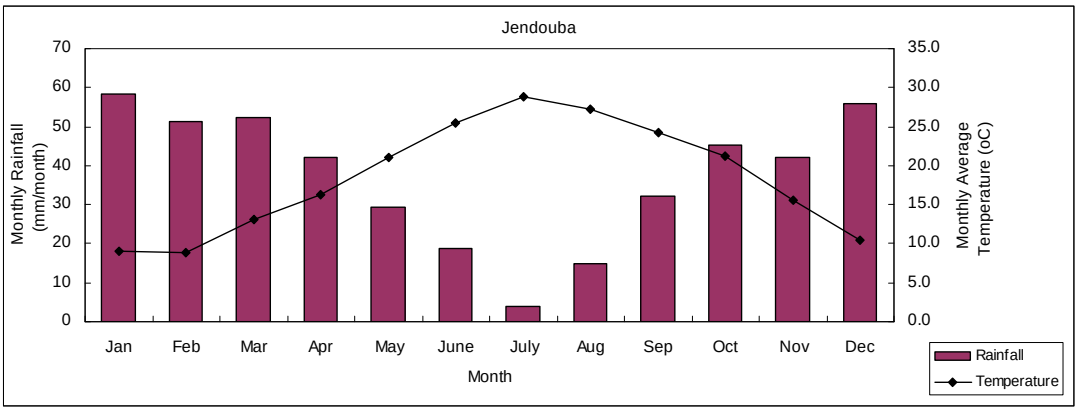
In summer, the weather in Tunisia is steady, with hot and dry climate due to the progression of subtropical high pressures towards the north. In winter and transition seasons when the subtropical pressures withdraws towards the south, Tunisia takes part in the west of the moderate air system, and is covered by frontal disturbances and masses of air from different origins. Hence, during these seasons, especially in the northern part of Tunisia where the study area is situated, the weather becomes rather unstable with observed frequent precipitation.

The average annual rainfall and average temperature shows decrease and increase trends, respectively, towards its south.

(2) Temperature, evaporation, sunshine, humidity and wind

The extreme north and other northern areas of Tunisia where the Mejerda River basin is located can be distinguished by a mild and wet winter, and a hot and dry summer. In the study area, temperature, evaporation, and sunshine duration usually reach their peaks in

July and August. Meanwhile humidity and precipitation are at their lowest during these months. The following graph illustrates typical seasonal variations of temperature and rainfall in the study area.



Source : Annual Report 2005 (Almanach 2005), INM

Average Monthly Rainfall (1961-1990) and Monthly Average Temperature in 2005

The annual average temperature in the study area ranges from about 17 to 20 ^{o}C. The monthly average temperature in July and August ranges from about 27 to 28.5 ^{o}C in the study area, but the average of monthly maximum temperature in these months reaches 32 to 37^{o}C. The recorded absolute maximum is even higher. At Jendouba, for instance, the average monthly temperature in July was 28.8 ^{o}C in 2005, but the absolute maximum temperature in the same month was recorded at 46.8 ^{o}C.

The annual average relative humidity in the study area ranges from 60 to 68%. Its highest ranges from 75 to 85% between December and January, while its lowest ranges from 49 to 60% in July.

In the study area, the annual average evaporation varies from 1,300 to 1,800 mm, and the monthly average wind velocity ranges between 2.0 to 4.5 m/s.

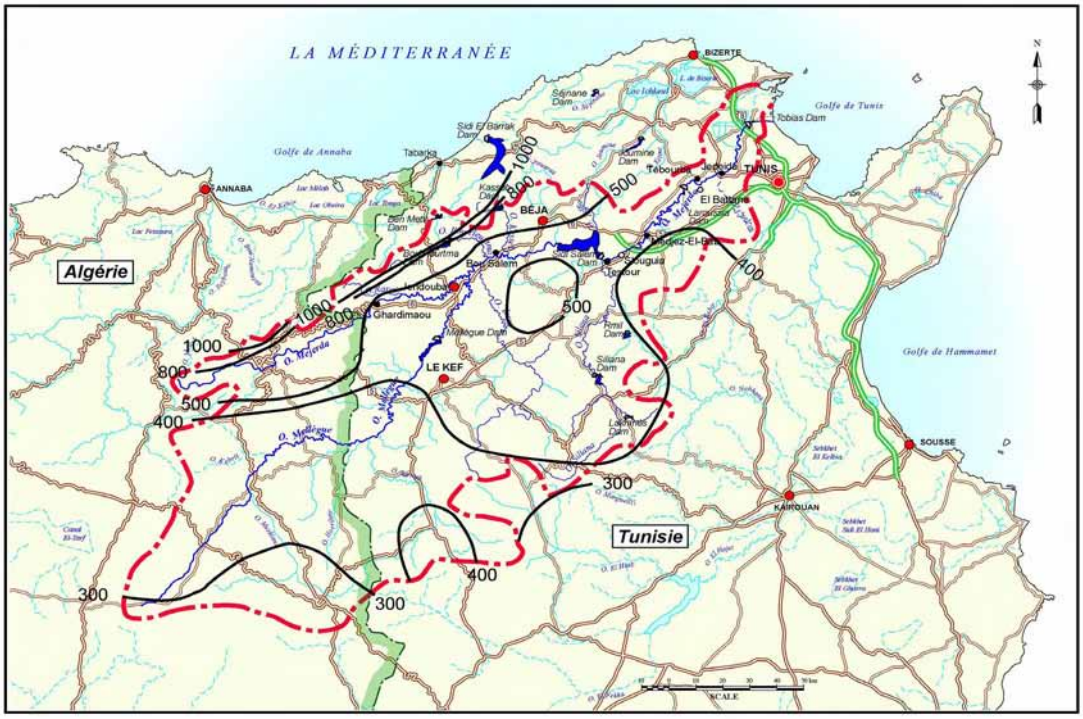
(3) Rainfall

Three major origins of rainfall in Tunisia are:

- Disturbances coming from the western Mediterranean (penetration of disturbances at the north Atlantic to Mediterranean or the ones born near the west end of the Mediterranean). This type covers about two thirds of the rainfall cases in Tunisia.
- Disturbances coming from the eastern Mediterranean (such as the region of Cyprus). This type occupies about 11% cases of rainfall. This disturbance tends to beobserved during autumn, and cause intensive rainfall.
- Disturbances of the north of Sahara moving towards east or northeast from southwest. After passing through Tunisia and resting on the Mediterranean, these relatively dry air masses could trigger heavy rainfall on the eastern parts of the country.

Precipitations in Tunisia show notable regional and seasonal variations. The average annual rainfall reaches 1,500 mm in the Kmir Mountains at the northwest edge of Tunisia, and reduces to about 200 mm towards the south end of the country. Rainfall characteristics display regional variation even within the study area as indicated in the

following isohyetal map.



Isohyetal Map of the Mejerda River Basin

The average annual rainfall exceeds 1,000 mm in the northwest part of the study area, whereas the southern part has an annual rainfall as low as 300 mm.

2.1.3 Geology and Soil

Geology

The geological history of the extreme northern Tunisia where the Mejerda River basin is located dates back to the Cretaceous period.

Lines of deep east to west oriented ridges began from the Trias period. It intensified during the Aptien period to scab a groove. Sandy loams and limestone have alternatively accumulated since then. This deep structure was maintained until the Lutetian stage. It appears that during this stage, a continental zone approximately corresponding to the catchment basins of the tributaries of right bank (Mellègue, Tessa, Siliana) emerged. Throughout the area where the Mejerda River is located, there is only one continental platform dominated by clastic sedimentation: sands, sandstone or clay in a marine or lagoon milieu. The Alpine thrust caused the emergence of this platform through the end of the Oligocene period. During the Miocene epoch, the course of the Mejerda took shape. The Orogeny modified the folds which became NE-SW. Then, series of parallel tectonic accidents limited the compartments where the Mejerda River has defined its course. This course underwent an important change beyond Oued Zarga where the Mejerda River goes from one compartment to another due to possible break at the end of the Villafranchien epoch. From this period, the North Tunisian hydrological network could be considered as having been definitively traced out and would undergo only minor changes.

Soil

Since Tunisia extends over both Mediterranean and Saharan regions, the soils show all the signs of climatic, morphological and geological diversity. According to the French system of soil classification, the soils of Tunisia are classified as podzols, vertisols, red Mediterranean soils, calcic-magnesic soils (dominant soils), brown and isohumic soils, saline and hydromorphic soils and also poorly evolved soils.

From the viewpoint of agronomic suitability of soil, the North West (sub-humid zone) is devoted mainly to silviculture and animal husbandry. Forest rangelands are covered with fodder crops. Supplemental water is needed at the foot slopes of the mountains and terraces to allow the cultivation of tree crops.

The Upper Tell plateaux and internal plains that extend towards the northeast, are the domains of vertisols and red soils. They form the cereal-growing zone where the best yields of the country are achieved (Jendouba - Béja - Le Kef - Siliana). In fact, field crops (durum wheat, soft wheat, barley, and oat, associated with fodder rotations) are mostly suited to these soils.

The North East which includes the sub-humid to semi-arid regions of Bizerte, Ariana, Zaghouan and Nabeul have various types of lands, suitable for field crops, olive trees, fruit trees and vineyards.

2.2 Socio-economy

2.2.1 Demographic Features of Tunisia

According to the 2004 Population Census, Tunisia had a population of 9,910,872. The population was estimated at 10,029,000 in 2005. The population growth rate has fallen sharply since 1980's, reaching 1.1% in 2005, after standing at an annual average of 1.21% during 1994-2004 and 2.35% in the previous decade.

Both National Statistics Institute (INS) of Tunisia[*1] and the United Nations (UN)[*2] forecast reveals a decreasing trend of population growth rate. The growth rate of the UN forecast is higher than the INS forecast by about 0.2% point. UN and INS forecasted that the population will reach 12,457,000 and 11,763,000 in 2029, respectively.

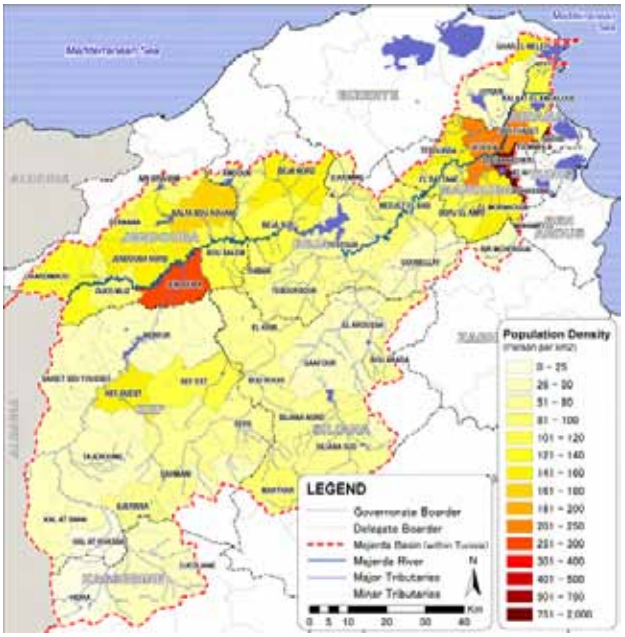
About three-quarters of the population live in the northern part of the country. The arid central and southern parts make 70% of the total land area, but have less than 30% of the population. The majority of the population lives in urban areas. The urbanization rate of the country rose from 37.5% in 1960 and 51.5% in 1980, to 64.8% in 2004, because of massive rural - urban migration. Population Division of the United Nations forecasted further advancement of urbanization of 69.1% in 2015 and 75.1% in 2030.

[1] Population forecast of Tunisia 2004-2029, National Statistics Institute
[2] Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision and World Urbanization Prospects: The 2005 Revision.

2.2.2 Demographic Features of the Mejerda River Basin

The population within the Mejerda River basin was estimated to be 1,330,000[*3] in 2004. While the Mejerda River basin occupies 9.8% of the land area of Tunisia, the population of the basin accounted for 13.4% of the total population in Tunisia.

The population density of the basin (84.0 per km^2) was higher than the national average of 61.1 per km^2. The figure at the right illustrates delegation-wise population density of the study area. As shown, densely populated areas are located mainly on the plains along the mainstream of the Mejerda River. The population density is particularly higher on the alluvial plain near the river mouth, such as Tunis, Ariana and Manouba Governorates. The plain area situated around the Jendouba delegate is also densely populated.



Source: the Study Team, Population CENSUS 2004

Population Densities in 2004

The population density is higher at the following delegates; Douar Hicher (1,058 per km^2), Jendouba (279 per km^2), Jedeida (214 per km^2), and Sidi Thabet (203 per km^2). On the other hand, population densities in the southwestern part of the study area, such as El Kef, Kasserine, and Siliana Governorates are quite low.

2.2.3 Macro Economic Conditions of Tunisia

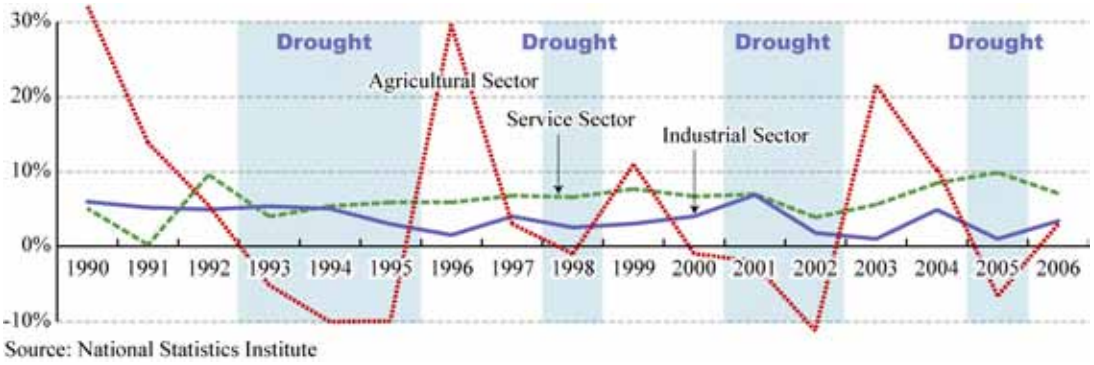
(1) General trend of the Tunisian economy

Tunisian economy has performed exceedingly well since the mid-1990s. In the past decade (1997- 2006), the nominal Gross Domestic Product (GDP) increased from 14,771 million Dinar in 1997 to 22,474 million Dinar in 2006 (at 1990constant prices) with an annual average growth rate of 4.77% in real terms. With such growth rate, the per capita GDP rose from US$ 1,976 in 1997 to US$ 3,081 in 2004. Such economic and social progress in Tunisia is the fruit of cautious macroeconomic policies and structural reforms initiated in 1987, which was further emphasized in the mid-1990's.

Agriculture sector's occupancy in GDP is relatively small in Tunisia. However, the Tunisian economy is considered to be dependent on agricultural sector and climatic conditions. The following graph shows the country's sector-wise GDP growth rate in real terms during 1990 – 2006. The figure shows that the agricultural sector's growth

[3] Population with the Mejerda River basin was estimated based on the delegation-wise data quoted from 2004 CENSUS. The population of delegation straddled the boarder of the basin and was allocated in proportion to the land area inside and outside the basin.

rate turned negative when severe drought occurred. It should be noted that growth rates of industrial and service sectors slowed down during the drought years and subsequent years. It is deemed that the agricultural sector's negative growth had significant ramification to other sectors (such as agro-processing industry, transport and retail sector). As a result, country's GDP growth rates fell during the drought years.



Sector-wise GDP Real Growth Rate of Tunisia 1990 - 2006

(2) Economic trend in Tunisia by sector

The agricultural sector is heavily dependent on climatic conditions. During the past decade (1997-2006), agriculture contribution to GDP decreased from 14.2% to 11.3%. The average annual growth rate during the period was 2.2%, which is a slight decline compared to that of 1990-1997, when the value was 3.1%. This average trend reflects the structural deformation of the economy in favor of the secondary and tertiary sectors. However, it masks the erratic long-term trend within the sector, with negative growth rates during years of drought and positive growth rates during years of abundant rainfall.

The industrial sector contributed 29.0% to GDP during the past decade, and grew at an average annual rate of 3.8%. This sector enjoys special attention, given its special role in promoting exports, investment and employment. However, with the opening of markets in the context of globalization, there is an absolute need to improve the business environment, with greater involvement of the private sector and diversification of external markets (other than Europe).

The services sector experienced strong growth during the past decade (5.8%), compared to agricultural sector (2.2%) and industrial sector (3.8%). It contributed about 61.4% to GDP in 2006 (56.2% in 1997). This trend partly stems from the fact that Tunisia, having few natural resources, has always considered human capital as its primary resource. While tourism has always driven this sector, it remains dependent on external shocks and presents some shortcomings. The tourism sector is becoming increasingly capitalistic whereas sector operators have limited own capital.

2.2.4 Economic Conditions in the Mejerda River Basin

(1) Agricultural sector

According to the 2004 Census, labor force in Tunisia by sector was as follows: services 48.9%, manufacturing industry 19.4%, non-manufacturing industry 14.5% and agriculture 16.2%. The agriculture sector occupied only 11% of GDP in 2006.

However, the sector is still the mainstay of the economy in the study area. Agriculture maintain a substantial labor force of 87,500.

Agricultural sector in the Mejerda River basin is endowed with rich rainfall and fertile land. A vast agricultural area consists of dry farm land of 10,392 km^2 (65.6% of total land area of the basin), and irrigated areas of 1,489 km^2 (9.4%). The irrigated land is located mostly on the plains along the mainstream of the Mejerda River.

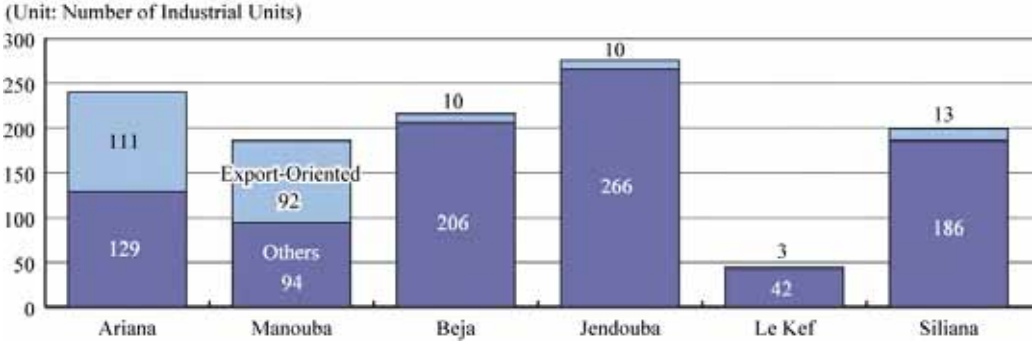
The Mejerda River basin occupies only 9.7% of land area of Tunisia. However, the basin provides significant contribution to the national production of food stuffs. In 2005, the study area produced 1,627,000 ton of wheat, and 465,000 ton of barley, which accounted for 51% and 34% of the national production, respectively

The Mejerda River basin is also a main hub of livestock agriculture. Production volumes of beef, goat meat and chicken in the study area accounted for 45.4%, 45.2% and 51.9% of the national production, respectively.

About 10.4% (1,646 km^2) of the land area of the Mejerda River basin is covered with forests, a large proportion of which is state-owned. The oak and pine forests of the basin are sources of exported cork. In 2005, the production volume of cork in the basin was estimated at 5,130 tons, which accounted for 75.7% of the national production. Forests also contribute as a source of firewood for local use.

(2) Industrial and service sectors in the study area

The following chart shows the numbers of industrial units in each governorate classified according to export-oriented industries and others. Export-oriented industries occupied about 50% in Ariana and Manouba Governorates, situated next to Tunis where the biggest port in the country is located. There are very limited numbers of export-oriented industries at the remaining four governorates.



Source: Foreign Investment Promotion Agency, Tunisia

Number of Industrial Units in Six Governorates

Jendouba Governorate is home to 276 industrial businesses, ten of which export their entire production. Industrial activity in the region is based on food processing, which accounts for 51% of the number of projects, 83% of investments and 65% of direct industrial employment, with two large firms of national repute, namely Complexe Sucrier Tunisien (Tunisian Sugar Company) and Laiterie du Nord-Ouest (Northwestern Dairy).

Manouba Governorate houses 186 industrial enterprises, of which 92 are wholly export-oriented. The main industries in the governorate are textiles, clothing and leather, food processing (especially milk, apples and pears) and electric and mechanical industries (especially automotive components).

Ariana Governorate has a varied and thick economic structure consisting of 240 industrial enterprises, of which 111 units are wholly export-oriented, operating in textiles, clothing, agro-industries, electronics industries, pharmaceuticals industries, leather, footwear industry, and services related to computer science and new information and communication technologies.

Beja Governorate has 216 industrial units. There are ten units in the region that export their entire production while foreign holdings in 16 companies work in the industrial, services, agricultural and tourism sectors. Major industry in the governorate is food processing. It includes 28 olive oil presses, two tomato canneries, the Beja Sugar Plant, a yeast plant, a semolina/flour mill, a carbonated drinks plant, and a dairy factory.

El Kef Governorate has 45 industrial enterprises including three wholly export-oriented ones. This region also has nine firms tied with foreign equity holdings, operating in industry, farming, tourism and services. Major industries located in the governorate are food processing industry (canning, semi-preserving, fruit and vegetable storage, essential oil extraction, mineral water bottling, milk processing), building materials (forestry by-products, marble and earthenware), ceramics and glass processing industries.

Siliana Governorate has three major industries classified according to production: 1) building materials (five marble quarries), 2) agro-industry (bottling of mineral water, animal feed concentrate plants, canned goods, partial preserving and stocking of fruits and vegetables, extraction of essential oils, etc.), and 3) textiles (several foreign exporters are established in the region). The region has 199 industrial enterprises including 13 working wholly for export. This governorate also has 12 firms tied with foreign equity holdings, operating in industry, farming, tourism and services.

2.3 National Development Plan

2.3.1 Principles and Targets of the Tunisian 11th National Development Plan

The priority of the 11th National Development Plan (2007-2011) is to speed up economic growth to about 6.5% per year and create jobs, especially for young graduates, with the objective of slashing the unemployment rate from 14.3% in 2005 to 10-11% in 2011. These objectives can be attained only through diversification of the economy, notably the productive and export sectors, and greater private sector involvement.

The major targets and activities of each sector are as follows;

(1) Agricultural sector

The agriculture sector, whose share of the GDP has stabilized at 11%, should be boosted, especially for crops whose European quotas have not yet been attained, notably olive oil or new crops such as bio-fuel crops. Also, in order to cope with the climatic risks, the Tunisian Government intends to increase irrigation areas up to 50%.

(2) Industrial sector

The manufacturing sector remains a pillar of growth and its objective is to raise product value-added so as to improve response to external shocks by increasing exports. Hence, the transformation taking place in the textile sector from subcontracting to co-contracting shall be encouraged and extended to the mechanical and electrical industries sector, which is developing rapidly and taking over from the textiles sector. Agro-industries, chemical and biochemical industries and other non-traditional industrial sectors with high value-added productions shall be developed, notably through new partnerships, techno poles or any other private initiatives.

(3) Service sector

Since the elasticity of employment remains low, the service sector, in particular the information and communication technologies (ICTs) which have major job creation potential, has been identified as a strategic sector. First of all, services do not require heavy investments and, secondly the productivity of ICTs can generate multiplier effects. In order to boost the development of these sectors, measures have been envisaged to ensure greater liberalization.

2.3.2 Measures to Achieve the Targets of the National Development Plan

To support the development of these sectors and, more specifically, the development of private enterprise, the Government has provided for a set of mechanisms and measures, namely:

(i) Greater liberalization, in particular elimination of prior authorizations for investments, streamlining of the incentives system, reform of labor regulations with a view to ensuring greater flexibility in lay-off while preserving the social safety net;

(ii) Promotion of export;

(iii) Upgrading and modernization programs in industry and tourism;

(iv) Setting-up of business creation structures and support funds, such as the Industrial Development Promotion Fund (FOPRODI), the seed capital fund, the Tunisian guaranty company (SOTUGAR), the Small and Medium Enterprises financing bank (BFPME);

(v) Tax and financial incentives aimed at promoting balanced regional development;

(vi) Reform of the educational and training system; and

(vii) Development of technological centers

As part of its efforts to open up its economy to the world, join the free trade area to be established with the European Union and modernize its industry, Tunisia has decided to develop innovative enterprises by setting up a mechanism for developing techno-parks and supporting business incubators and by encouraging research and innovation.

2.3.3 Tunisian Development Plan Related to Water Supply

Under the 11th National Development Plan, the Tunisian government intends to implement various flood control measures (including development of drainage network in urban area) to protect its cities and towns. These projects are expected to contribute in creating a synergy effect between the flood control projects, urban development projects and multimodal urban transport projects.

With regard to water resources, to cope with the increase in the needs for water from the various sectors (especially agricultural sector), the government has placed higher priority on water resource management (water and soil conservation, forest protection, and protection and management of flood plains).