Supporting Report B

WATER SUPPLY OPERATIONS

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

FINAL REPORT

Supporting Report B: Water Supply Operations

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CHAPTER B1 INTRODUCTION

This report deals with the operation of reservoirs for water supply as part of the study on integrated basin management focused on flood control in the Mejerda River (hereinafter referred to as "the Study").

Present reservoir operations are focused on storing as much water as possible to prevent water shortages in case of severe and prolonged droughts.

The main purpose of this component of the Study is to determine the amount of storage that could be reallocated to flood control at each reservoir without changing the level of water supply security or reliability that the system was designed to deliver.

Reservoirs have been sized independently to provide yields that correspond to an 80% level of water supply security or reliability. Data collection carried out in the initial stages of the Study revealed that there are no storage allocation curves and no operating rules to guide decision makers and reservoir operators in the storage and release of water from reservoirs. Furthermore, the storage volume required to guarantee a given reliability of water supply is not known. Therefore, the Study has had to simulate the allocation of demands to reservoirs in the system in order to identify the requirement for water supply before proceeding with the analysis of flood control operations.

Water demand centers for the system have been identified and demand forecasts have been prepared for 2010, 2020 and 2030 (the target planning year of the Study).

The joint use of reservoirs for water supply and flood control purposes creates a problem for storage allocation. Water supply operations require as much water as possible to minimize the risk of shortages during dry years. On the other hand, flood control operations require that water levels be reduced to store some or all of the inflow from a flood event. Such competitive uses can share the same storage space. However, seasonal water supply needs must be clearly defined in order to know how much storage can be allocated to flood control without decreasing reliability of water supply.

A water balance model is used to simulate monthly storage at all reservoirs in the multi-reservoir water resources system of Northern Tunisia. The simulation uses a trial and error approach to identify how much water must be stored on a monthly basis to minimize deficits. Additional storage for flood control is identified when the active storage required for water supply operations with a given level of water supply security is less than the storage volume provided at normal water level.

CHAPTER B2 APPROACH AND METHODOLOGY

B2.1 General Approach and Data Requirements

To assess the potential for reallocating storage to flood control, it is first necessary to know what criteria for reliability has been used to calculate the yield of each reservoir in the system. Information that must be confirmed at the outset of the study includes:

- Yield and corresponding reliability of reservoirs,
- Existing water supply plan i.e. how water demand is allocated to each reservoir,
- Existing seasonal storage allocation curves for each reservoir, showing water levels that must be maintained to provide a yield with a selected reliability,
- Operating rules and policies governing storage and release decisions for water supply, and
- Storage-Yield-Probability curves for each reservoir.

After confirming conditions used for planning and design, the performance of reservoirs is reassessed based on revised water demand projections and the need to modify operations for flood control.

B2.2 Data Sources

(1) Eau XXI

Eau XXI is the most recent planning document discussing the development of water resources. Future water demands are estimated and compared to potential surface water and groundwater resources. The limits for conventional water resources are identified and the need for the development of new non-conventional resources is identified e.g. desalination of brackish water or re-use of treated wastewater for agriculture. The study does not provide information on storage boundaries at reservoirs. Reservoir yields are identified but there is no discussion of how they were calculated and no information on the probability or water levels associated with these yields.

(2) Eau 2000

The Eau 2000 study was published in 1993.The fundamental objective of Eau2000 was to suggest a water management strategy, defined as a plan of successive measures in time, aimed at meeting the nations water needs until 2010. It provides detailed hydrological data as well as an analysis of resources and demands.

The study included a complex analysis of reservoir operations using stochastic dynamic programming (SDP) techniques to optimize the allocation of resources to demands in order to determine the need for the development of new resources. The objective function for the analysis was to minimize the difference between demand and supply. The analysis produced monthly reservoir yields for two initial storage scenarios (50% full and empty) and three annual inflow conditions (typical dry year, average year, typical wet year) giving a total of six different possible operating scenarios. Unfortunately project documents made available to the Study Team do not clearly define the reliability or water supply security associated with each one of these operating scenarios. Furthermore, the analysis was only concerned with quantity and did not consider the need to balance salinity in the Cap Bon Canal. The results of the SDP study were never implemented by MAHR for reservoir operations.

(3) GEORE

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 study the optimization of reservoir operations for water supply. Unfortunately, the model was too complex and data intensive and MAHR was unable to sustain its use after the project was completed. The model is now outdated; it does not include new dams and water demands need to be revised.

B2.3 Missing Information

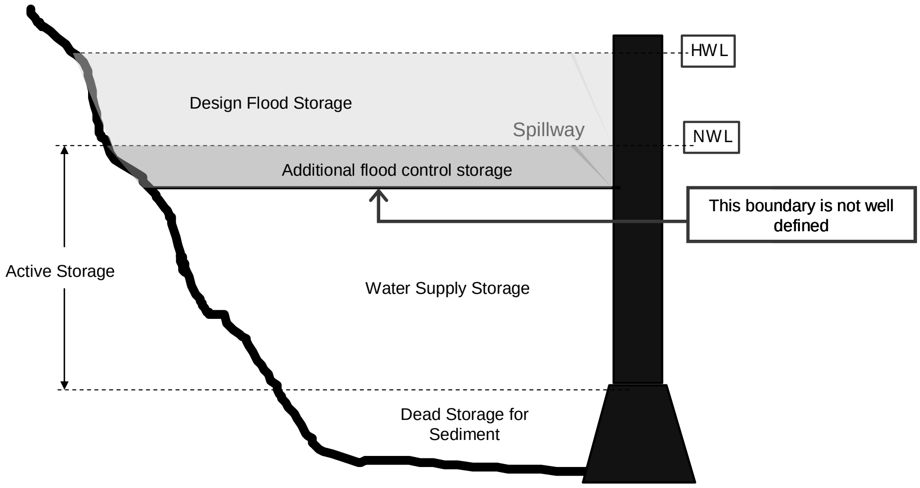
The lack of essential information on how reservoirs are currently operated is a main constraint to assessing the potential for reallocating storage:

- There is no information on the probability of yields for individual reservoirs or for the system of multiple reservoirs. Therefore, it is difficult to assess how changes in the allocation of demands might affect the guarantee of water supply.
- There is no operating policy to control the way in which the system's demand is allocated to the constituent reservoirs. Therefore, the storage boundaries for water supply are unknown. And
- There are no firm rules governing the release for water supply operations.

B2.4 Analysis Method

The reservoirs in the Mejerda River basin are part of a large and complex multiple reservoir water resources system covering the Northern Tunisia region. Most of these reservoirs serve multiple purposes (flood control, irrigation and potable water supply). In such systems, it is usually not practicable to allocate a fixed portion of storage for each purpose. In general, most purposes are served from the same active storage volume and their requirements are accommodated by complex release rules for reservoir operations. Release rules are often formulated as rule curves that indicate the rate of release as a function of the instantaneous storage and time of year.

Unfortunately, such rule curves have not yet been developed for the integrated system and the upper boundary for water supply storage is not defined.



Schematic Representation of Reservoir Storage Allocation Boundaries

Determining release rules and storage boundaries for operations in a large multi-reservoir system usually involves the determination of storage volumes at individual reservoirs and the best combination of releases from the different reservoirs in the system to meet the target, global demand placed on the system. Traditionally, this problem has been solved by optimization using advanced techniques such as linear or stochastic dynamic programming or genetic algorithms. Such a detailed analysis is very specialized and well beyond the scope of the present master planning study whose focus is flood control and not water supply planning.

In order to meet the study's objectives, a simplified storage simulation approach has been adopted by the Study to find a suitable planning level solution.

The Study has prepared a water balance model using an Excel spreadsheet to simulate the changes in storage in response to water demands for the year 2010, 2020 and 2030 (the target planning year of the Study). The simulation is carried out for different drought scenarios to identify how much water must be stored to meet water demands without deficits. Additional flood control storage is identified if volume of water required to meet water demands is less than the active storage volume.

CHAPTER B3 WATER RESOURCES

B3.1 General

Conventional water resources in Tunisia provide an estimated 4,840 million m^3 per year on average.

Classification of Conventional Water Resources for Tunisia

Conventional Water Resource	Million m^3 / year	Percent of total
Surface water	2,700	56%
Shallow aquifers	740	15%
Deep aquifers	1,400	29%
Total	4,840	100%

Source: DGRE, February 2008 Steering Committee

Surface water resources are an important component of the total amount available. Surface resources from northern Tunisia play an even more important role in water supply not only because of their quantity but also because of their quality.

Quantity and Quality of Surface Water Resources

Million m^3/year	North	Center	South	Total
Surface water resources	2,190	320	190	2,700
% of total	81%	12%	7%	100%
Resources with salinity < 1.5 g/l	1,796	153	6	1,955
% of total	92%	7.8%	0.2%	72%

Source: EAU XXI Long Term (2030) Sector Strategy

Large dams in the Mejerda River basin play a significant role in the water supply scheme providing about 25% of the total surface water resources available.

Water Resources Mobilized by Large Dams in the Mejerda River Basin

Million m^3/year	2010	2020	2030
Upper Mejerda	354.0	359.0	359.0
Sidi Salem and lower Mejerda	385.6	398.6	449.6
Total	739.6	757.6	808.6

Note: Based on yields estimated by MARH with 80% reliability.

B3.2 Multiple Reservoir Water Resources System of Northern Tunisia

The total annual rainfall is not sufficient to provide a stable year-round water source for agricultural crops and to satisfy other water demands. Therefore, a network of reservoirs and transfer schemes has been constructed in northern Tunisia over the years to store rainwater and fill the gap between wet years and drought years. Many of the structures have already been completed and others are being constructed or planned in order to store as much of the surface water runoff as possible.

This complex network consists of two main branches:

i) the Mejerda River branch depicted schematically in **Figure B3.2.1** (with main supply reservoirs of Sidi Salem, Ben Metir, Kasseb) and

ii) the Sejnane-Joumine branch coming from the extreme north as depicted in **Figure B3.2.2** (with main supply reservoirs of Sejnane, Joumine and Sidi Barrak).

Each branch feeds water into the Mejerda-Cap Bon Canal which issued to supply demands in Greater Tunis and areas to the south (Cap Bon, Sfax, Sahel, and Kairouan). Since these downstream demands are shared between both branches, all reservoirs in the network must be considered as an integrated system when evaluating storage requirements for reservoirs in the Mejerda River basin.

Water is transferred into the Mejerda River basin at the upper end of the catchment from the Barbara River (Zouitina and Melilla dams). At the lower end of the catchment, the Mejerda River is partially diverted by a control structure at Laroussia into the Mejerda-Cap Bon Canal to meet agricultural needs in Cap Bon and water supply needs of large cities to the south.

The canal has been being operated since May 1984, and it has a length of 120 km, capacities of 16 m^3/s at the upstream end and 5.5 m^3/s at the Beli treatment plant where it ends. Treated water from Beli is conveyed by pipeline to Cap Bon, Sousse and Sfax. Water in the canal is lifted twice along its course by pumping stations at Bejaoua and Fondouk.

B3.3 Reservoirs

(1) Reservoir yields

A total of 26 reservoirs are considered in the water balance simulation.

Region	Existing Dams	Future Dams
Mejerda River Basin	Zouitina (Barbara complex) Mellegue Old Ben Metir Bou Hertma Kasseb Sidi Salem Lakhmess Siliana R'Mil	Sarrath Mellegue II (replaces old) Tessa Beja Khalled
Extreme North	Zerga Sidi Barrak Sejenane Joumine Ghezala	Kebir Moula Ziatine Gamgoum El Harka Douimis Melah Tine

Reservoir yields and timeframes for implementation provided by DGBGTH are presented **Table B3.3.1.** Annual yields have 80% reliability but the relationship between yield and required active storage volume are not identified. A total of 8 reservoirs (Mellegue, Ben Metir, Lakhmes, Kasseb, Bou Heurtma, Sidi Salem, Siliana, R'Mil) are in operation in the Mejerda River basin providing an average 660 million m^3/year or about 60% of the total resources mobilized by dams in Northern Tunisia. An additional 80 million m^3 per year is transferred into the basin from the Barbara complex (Zouitina dam).

There is no information on how the yields were originally calculated. The typical Storage-Yield-Probability curves usually developed during reservoir engineering studies are not available. Therefore, it is not possible to evaluate yields for different levels of water supply security as required in the original scope of the Study. Furthermore, the yields are of little value for evaluating storage requirements since there is no information regarding the seasonal water levels that must be maintained to provide the stated level of security.

(2) Active storage

Active storage at each reservoir is decreasing with time as sedimentation fills the reservoir. Sedimentation rates and resulting active storage volumes used in the reservoir storage simulation are compiled in **Data B1.** Sedimentation rates are obtained from the results of recent bathymetric surveys where available or from the sedimentation rates reported and used in the Eau2000 study to calculate future available water resources.

Other data pertaining to the physical characteristics of reservoirs can be found in the data section of the inventory survey.

(3) Reservoir Inflows

The inflow time series used for reservoir storage simulation is based on historical monthly inflows for a typical dry year. Historical inflows to reservoirs are discussed in Supporting Report A: Hydrology and Hydraulics, and summarized here for completeness of presentation.

Average monthly and yearly inflows from 1946 to 1997 are presented in **Table B3.3.2.**

The aggregated average yearly inflow to 26 dams in the network for the period of record 1946-1997 was 1,912 million m^3.

The Ministry defines hydrological drought as follows:

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

A review of historical inflows has identified the following significant droughts.

Historical Drought Events

Drought Period			Total Inflow* mil. m^3	Total as % of average**	Type
1:	1 year	1960	1,044	55%	Dry
2:	2 consecutive years	1987-88	1,582	41%	Very dry
3:	3 consecutive years	1992-94	2,204.5	38%	Very dry

* inflow to 26 dams in Northern Tunisia **average inflow from 1946-1997=1,912mil.m^3/year

The year 1960 is selected as a typical dry year. It has a probability of non-exceedence of 0.2, which is the same criteria used in Eau2000 to select a typical dry year corresponding approximately to a water supply security level of 80%. Inflows for the typical dry year are presented in **Table B3.3.3**

(4) Evaporation losses

Evaporation losses are significant at each dam site and are included in the water balance calculation.

There are two sources of evaporation data that are used to estimate average monthly evaporation:

- Monthly evaporation in mil.m^3 calculated by DGBGTH at existing reservoirs based on average monthly surface areas. Monthly averages are calculated for the period of record September 1992 to December 2005, and
- Average monthly evaporation in meters presented in EAU2000 for all dams except Sarrath assuming the reservoir surface is constant at the normal water level. Evaporation in mil.m^3 = 0.7 (pan coefficient) x evaporation (m) x surface area (NWL)

Data from Eau2000 is used for all proposed dams. DGBGTH data is compared to Eau2000 and the larger of the two monthly values is used for existing dams

Monthly evaporation data is presented in **Table B3.3.4**. Net annual evaporation in the system is on average about 182 mil.m^3 or about 9% of the average annual inflow and can be as high as 17% of the annual inflow during the typical dry year. Just over 80% of the evaporation occurs in the period from April to September.

B3.4 Salinity of Surface Water Resources

There is a wide variation in water quality from one reservoir to another and from one region to another.

Salinity measurements are taken at reservoirs by DGBGTH and at Laroussia and in the Cap Bon Canal by SECADENORD. Monthly averages, calculated from available records for the years 2000 to 2007, are presented in the following table.

Average Monthly Salinity at Important Water Supply Points (Unit: g/liter)

Reservoir	S	O	N	D	J	F	M	A	M	J	J	A
Sejnane	0.56	0.56	0.54	0.53	0.52	0.53	0.51	0.53	0.53	0.58	0.56	0.56
Joumine	0.70	0.70	0.70	0.71	0.67	0.68	0.65	0.64	0.64	0.68	0.70	0.70
Ben Metir	0.31	0.31	0.31	0.31	0.30	0.26	0.30	0.31	0.31	0.31	0.31	0.31
Kasseb	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Sidi Salem	0.41	0.42	0.44	0.44	0.45	0.46	0.43	0.43	0.44	0.43	0.43	0.43
Laroussia	1.96	1.64	1.7	1.8	1.87	1.74	1.67	1.69	1.72	1.99	2.14	1.99
Cap Bon Canal at VR6	0.74	0.73	0.93	1.05	1.17	1.26	1.23	1.26	1.23	1.14	1.11	1.1

In general, water resources in the Mejerda River basin have a higher salt concentration than those of the Extreme North because of the different geology. Notable exceptions are Kasseb and Ben Metir, which have low salinity. This explains why Kasseb and Ben Metir are used exclusively for supplying potable water to Tunis by pipeline.

The salinity at Laroussia is two to three times higher than the salinity at Sidi Salem. The increase in salinity is caused mostly by drainage from large irrigation areas in the lower section of the Mejerda River and by contributions from Siliana.

CHAPTER B4 WATER DEMANDS

B4.1 General

The multiple reservoir water resources system in Northern Tunisia supplies water to a total of 47 demand centers:

- 6 potable urban water demand centers
- 40 agricultural irrigation schemes
- 1 environmental conservation flow to Lake Ichkeul

The demand centers are coded to simplify reference in tables and calculation sheets. A list of demand center codes is presented in **Data B2.**

B4.2 Agricultural Water Demand

The location of irrigation schemes in the Mejerda Basin is shown schematically in **Figure B4.2.1**. A list of irrigation schemes with monthly water demands for 2010, 2020 and 2030 is provided in **Data B3**. The totals are summarized below by region.

Water Resources Required for Agricultural

10^6 m^3/year	2010	2020	2030	Average Annual Growth Rate
Mejerda	461	513	501	0.4%
Extreme North	72	65	59	-1.0%
Cap Bon	94	85	77	-1.0%
Total	627	663	637	0.1%

Source: MARH 2006

Target water demand projections assume that improved irrigation techniques will contribute to a reduction in demand equal to 1 % per year. The construction of new irrigated perimeters in conjunction with the new Mellegue2 Dam adds a significant increase to the irrigation demand: 96 million m^3 in 2020 and 129 million m^3 by 2030.

Irrigation in the Mejerda river basin is extensive and accounts for nearly 80% of the total agricultural demand.

Distribution of the Agricultural Demand by Basin

10^6 m^3/year	2010	2020	2030
Mejerda	73%	77%	79%
Extreme North	12%	10%	9%
Cap Bon	15%	13%	12%
Total	627	663	637

Agricultural water demand varies seasonally with a peak demand during the summer months.

Monthly Irrigation Water Demand Coefficients **(unit: %)**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.1	1.2	6.0	11.2	20.4	14.2	16.3	15.5	8.2	4.3	2.6	0.1

B4.3 Potable Water Demand

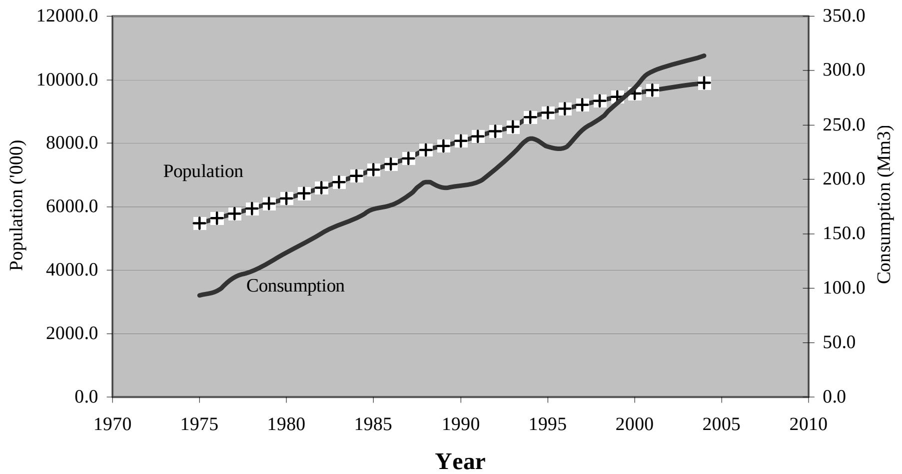
SONEDE, created in July 1968, is an autonomous institution operating under the umbrella of MARH. It is responsible for developing and managing the potable water supply systems (domestic, industrial and other non agricultural uses) in the country.

General Statistics on SONEDE Operations:

Number of customers	1,9 million
Water quantities produced	420 million m³
Water quantities distributed	390 million m³
Water quantities consumed	326 million m³
Global network efficiency	77,9 %
National service rate	96 %
Service rate in urban areas:	100 %
Service rate in rural areas (SONEDE)	52 %
Specific water consumption all users	110 liter / day / per capita supplied
Specific water consumption domestic connections	78 litter / day / inhabitant connected

Source: SONEDE Statistical Report 2005

Water consumption and population data for all Tunisia from 1975 to 2004 are presented in **Table B4.3.1**. Water consumption has grown rapidly except for two periods where droughts produced a decline in consumption. From 1996 to 2001, consumption grew at an average rate of 4.5% per annum. This has slowed down to 1.6% per annum between 2001 and 2005. Population growth rates have remained relatively steady at about 2% per annum until 2001 slowing to 1% per year between 2001 and 2004.



Population and Water Consumption Trends 1975-2004

Domestic use accounts for about 72% of all potable water consumed while industry and tourism account for 9% and 5%, respectively. SONEDE expects this ratio to stay the same until 2030.

Long-term water demand forecasts for Tunisia are prepared periodically by the Planning and Studies Directorate at SONEDE. The latest forecast, presented in **Table B4.3.2** was prepared in December of 2004 and provides growth factors that are applied to the demand estimates in the present study.

Consumption forecasts are derived by using actual water consumption in 2005 and applying the same growth rates in water consumption projected by SONEDE. Projections for total water consumption are presented below and details are presented in **Data B4.**

Estimated Water Consumption Estimate for Demand Centers Supplied by Reservoirs in North Tunisia

SONEDE 2004 estimate			Based on 2005 actual		
mil.m^3	Average Growth Rate	Year	Year	Average Growth Rate	mil.m^3
266.8		2006	2005		241.3
307.6	2.9%	2011	2010	2.9%	278.1
338.9	2.5%	2015	2015	2.5%	314.0
379.6	2.3%	2020	2020	2.3%	351.7
418.2	2.0%	2025	2025	1.9%	387.3
458.7	1.9%	2030	2030	1.9%	424.8
	2.3%			2.3%	

Source: Growth rates from SONEDE Strategy paper on development 2006-2030 applied to actual consumption reported in SONEDE Statistical Report 2005

Water consumed is converted into raw water required at the point of treatment by applying efficiency ratios reflecting losses in distribution and treatment systems. The average efficiency ratio is 0.85 as reported by SONEDE.

Estimated Potable Water Requirement from Reservoirs in North Tunisia (million m^3/year)

Urban Water Demand Center	2005	2010	2020	2030
UCTU: Tunis: SONEDE requirement	120.4	133.6	166.8	199.1
Less amount transferred to Cap Bon	-6	-6	-6	-6
Demand in Tunis	114.4	127.6	160.8	193.1
UBER : Towns along Ben Metir Pipeline	16.2	17.4	21.1	24.5
UBIZ : Bizerte	20.3	21.3	26.2	31.1
UNAB : Cap Bon : SONEDE requirement	23.2	26.1	31.9	38.5
Plus amount transferred from Tunis	+6	+6	+6	+6
Demand for Cap Bon	29.2	32.1	37.9	44.5
USFA: Sfax, Sidi Bouzid	40.7	49.0	64.2	79.0
USAK: Sousse, Monastir, Mahdia and Kairouan	65.5	78.6	101.2	124.5
Total required at point of production	286.3	326	411.4	496.7
Less local resources	55.5	55.5	55.5	55.5
SONEDE requirements	230.8	270.5	355.9	441.2
Plus abstraction losses 15%	34.6	40.6	53.4	66.2
Total required from reservoirs in North Tunisia	265.4	311.1	409.3	507.4

The potable water demand in each demand center is met in part by local groundwater resources totaling 55.5 million m^3. MARH adds 15% to the forecast provided by SONEDE as an allowance for abstraction losses to obtain the total amount of resources taken from reservoirs in North Tunisia.

Potable water demand varies from month to month with a peak occurring in July and August. Seasonal demand factors provided by SONEDE are used to obtain a monthly distribution of the annual water demand.

Monthly Distribution of Potable Water Demand **(unit: % of total)**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7.1%	6.3%	7.3%	7.5%	8.8%	9.3%	10.7%	10.4%	9.1%	8.6%	7.5%	7.3%

Source : SONEDE Direction des Etudes

Total monthly requirements for potable water abstracted from reservoirs in North Tunisia are presented in **Table B4.3.3.**

B4.4 Other Water Demands

(1) Environmental conservation flow

Conservation flow is defined as the minimum flow that should be maintained in rivers or streams for environmental purposes.

A conservation flow of 30 million m^3 per year is allocated to Sejnane reservoir by the Ministry to preserve the Lake Ichkeul. It will also be possible in future to supply the lake from new dams: El Harka, Gamgoum, Ziatine, Douimis, Melah and Tine.

Although several wetland areas have been identified in the Mejerda River basin the Ministry has not allocated any minimum flow for environmental conservation in channels downstream of the reservoirs.

(2) Hydro power

Small scale hydro power generation schemes exist at Mellegue, Bou Heurtma, Ben Metir, Kasseb and Sidi Salem.

These schemes at Ben Metir and Kasseb operate continuously because they are in line with the pipeline that supplies potable water to Tunis.

The other schemes are not allocated any priority and operate only when water is released to reduce volumes in the reservoirs.

B4.5 Total Demand

Total water demand will increase at an average growth rate of about 1% per year. Total monthly demand applied to reservoirs in Northern Tunisia is presented in **Table B4.5.1** and summarized as follows.

Total Demand Allocated to Large Dams in Northern Tunisia (million m^3/year)

Demand	**2010**	**2020**	**2030**
Potable Water	311.1	409.3	507.4
Irrigation	626.7	663.3	636.8
Lake Ichkeul	30	30	30
Total	967.8	1102.6	1174.6

At present, the demand for irrigation outweighs the demand for potable water by a factor of two. By 2030 potable water demand will require an almost equal share of the resources (43%). The increase in potable water demand will put more pressure on reservoir operations making it increasingly difficult to manage resources during long periods of drought.

B4.6 Salinity Thresholds

Each demand center has a different salinity threshold depending on the type of use. Upper limits for salinity determined by the Ministry are presented in **Table B4.6.1**.

Salinity in the Cap Bon Canal is controlled by SECADENORD by diluting the saline water arriving from the Mejerda River with freshwater transmitted by pipeline from the reservoirs located in the extreme north .

Target salinity in the canal is normally maintained between 1.0g/l to 1.5g/l with preference given to a lower limit when resources are plentiful. The amount required from the extreme north of the system fluctuates seasonally depending on the quality of the resources in the Mejerda River.

The possibility of drawing down reservoirs such as Sidi Salem and Siliana Dams to create flood storage space is limited by the need to balance salinity in the Canal.

CHAPTER B5 RESERVOIR STORAGE SIMULATION

B5.1 Demand Allocation

Water demands are classified as either local or shared depending on how many reservoirs are used to supply the demand. Local demands receive water from a single reservoir. Shared demands can receive water from more than one reservoir.

A list of the demands allocated to each reservoir is presented in **Table B5.1.1.** Shared demands are highlighted in bold face characters.

The Kasseb and the Ben M'Tir Reservoirs are dedicated to supplying potable water to Greater Tunis via gravity pipelines. The resources, dams and pipelines to Tunis are managed by SONEDE. Part of the demand for Greater Tunis is also supplied from the Cap Bon Canal.

Raw water from the Kasseb Dam is conveyed by gravity pipeline to the Mornagia Reservoir in Tunis. The pipeline has a conveyance capacity of 0.9 m^3/s. A treatment plant with a capacity of 0.4 m^3/s has been constructed at Medjez El Bab to supply the town. The treatment plant at Medjez El Bab can also supply treated water to the Ben M'Tir pipeline when needed to meet peak demands in Greater Tunis. A small 40 l/s treatment plant at the Kasseb Dam supplies the local communities in the vicinity of the dam.

Water from the Ben M'tir Dam is transferred a short distance to a 1.3 m^3/s treatment plant at Fernana. Treated water is conveyed by gravity pipeline to a reservoir at Ghdir El Goulla. The pipeline has a transmission capacity of 1.0 m^3/s. The Ben M'Tir pipeline provides treated potable water to towns located along the pipeline at Beja, Bou Salem, Mejez El Bab and Jendouba. A small 40 l/s treatment plant near Ben Metir feeds the local community of Ain Drahem.

Potable water supply to Bizerte is a local demand supplied directly from the Joumine Reservoir and is given priority over shared demands downstream.

Lake Ichkeul requirements have been allocated directly to Sejnane to simplify the computation even though some of the proposed dams can also be used to satisfy this requirement in the future (the Douimis and Tine Dams).

B5.2 Mass Balance between Water Demands and Reservoirs

A simple mass balance is prepared to confirm that the reservoir system has sufficient capacity to meet the projected demands. The mass balance is based on the quantity of resources available including local groundwater abstraction schemes to supply large urban centers with potable water. The water balance does not consider the need to mix water from the Mejerda River with the Extreme North to obtain desired salinity in the Cap Bon canal.

The mass balance is presented in **Table B5.2.1** and summarized in the following table. It indicates that based on yields with an 80% reliability there is a surplus of resources. The surplus indicates that there may be some potential for reducing the storage allocated to water supply operations in favor of improving flood control.

Balance of Water Resources and Water Demand

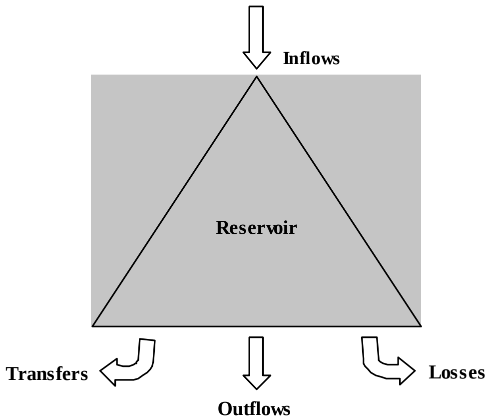
Million m^3 per year	2010	2020	2030
Demand	1023.3	1158.1	1224.7
Resource: Groundwater Abstraction	55.5	55.5	55.5
Resource: Large Dams	1142.2	1203.2	1254.2
Demand – Resources = Surplus	174.4	100.6	85.0

Having confirmed that the reservoir yields are sufficient to meet the demand the next step is to simulate reservoir operations considering the need to balance salinity in the Cap Bon Canal.

B5.3 Simulation of Reservoir Operations

(1) Reservoir Water Balance

Storage requirements at reservoirs are simulated by using a simple trial and error procedure. The simulation is based on satisfying continuity equations at each reservoir accounting for all inflows less all outflows and losses at each reservoir. Reservoirs are linked together and the outflow from upstream reservoirs is collected at the next downstream reservoir.



Water Balance Model

Storage at the end of each time period is computed from:

$$S_i = S_{i-1} + I_i + Tr_{in} - Tr_{out} - R_i - W_i - L_i - E_i - DS_i$$

Where:

S_{i-1} : storage at the end of the previous time period (initial storage for the first time period),

I_i : natural inflow for time period i,

Trin : amount arriving from upstream reservoirs for time period i,

Trout : amount withdrawn by pipeline from the reservoir for time period i,

Ri : release for downstream demands for time period i,

Wi : withdrawal for local water demands for time period i,

Li : infiltration loss for time period i,

Ei : evaporation loss (less rainfall) in time period i, and

DSi : amount released for desilting in time period i.

Infiltration losses include leakage through the dam and infiltration into the soil in the reservoir. Infiltration losses are usually not large but they exist and have been included in the calculation for completeness. Infiltration losses are not well documented and difficult to assess, therefore the reservoir balance calculation has assumed losses at each dam equal to 10% of the inflow.

De-silting operations occur every time there is inflow to the reservoir unless water is being released to downstream of reservoirs for other reasons such as balancing storage or supplying a downstream demand. The reservoir balance calculation assumes an amount equal to 15% of the inflow.

(2) Calculation procedure

The reservoir simulation is used to estimate the required active storage volume for within-year and over-year scenarios. The simulation includes all reservoirs and all demand centers in the multiple reservoir system.

The simulation begins in September to coincide with the start of the hydrological year. September is also a convenient starting point since it is the period when water levels should be reduced in preparation for the critical wet months that typically begin in December.

The time step for the simulation is 1 month.

The amount of storage available for water supply fluctuates between the top of dead storage and the normal water level. Therefore, in the calculation, S_{max} is equal to the active storage volume and S_{min} is equal to zero.

The initial storage volume S_i at each dam is set to 100% of the active volume for the first iteration, in other words the first water balance calculation, to find the smallest acceptable initial storage volume.

Water is allocated according to the following simplified operating rules:

- Water is first allocated to local demands
- Shared demands are then allocated to specific reservoirs as shown in **Table B5.3.1.**
- For reservoirs in series demands are met as much as possible from downstream reservoirs. If this is infeasible, then additional water is progressively taken from the

upstream reservoirs.

- For reservoirs in parallel the demand is apportioned to each reservoir in terms keeping the same ratio of fullness at the end of the period.
- Cap Bon Canal demands are divided into two portions on the basis of desired salinity. These demands are allocated to:
  - Sidi Salem Dam for the Mejerda branch and
  - Sejnane and Joumine Dams for the Extreme North

If all demands are met then the calculation is repeated with a smaller value of initial storage. This procedure is repeated to find the initial storage volume in September that will satisfy demands without depleting the reservoir below a 20% buffer that has been selected as an emergency reserve.

The storage at the end of the time period (S_i) is then compared with the maximum reservoir storage (S_{max}). If S_i is greater than S_{max} then the storage is set to the maximum storage,

$S_i = S_{max}$

and the Spill is computed as

$S_{pi} = S_{max} - S_i$

The release is also updated to include the spill unless the spill cannot be captured by a downstream reservoir,

$R_i = R_i + S_{pi}$

If the storage is less than the dead storage then the storage is set to the dead storage,

$S_i = S_{min}$

and the deficit is computed as

$D_i = (S_{min} - S_i)$

A sample calculation sheet for the reservoir simulation is presented in **Data B5**.

(3) Balancing salinity in the Cap Bon Canal

The Cap Bon Canal receives water from the Mejerda River and from a pipeline bringing a mixture of water from dams in the extreme north. Salinity in the Cap Bon Canal can be controlled by modulating the proportions contributed by the Mejerda River (high salinity) and the Extreme North (low salinity). Mix proportions vary monthly depending on the selected salinity targets and on the quality of resources which also has seasonal variations.

The total demand from the Cap Bon canal is divided into two parts using the following formula for concentration of salinity:

$V_N = \alpha \times V$ $V_S = V - V_N$

V_N :Volume abstracted from the Extreme North ($10^6 m^3$)

V_S :Volume abstracted from Mejerda River at Laroussia ($10^6 m^3$)

V :Total demand of Cap Bon Canal ($10^6 m^3$)

α : $\dfrac{1 - S_S}{S_N - S_S}$

S_c :Target salinity in Cap Bon Canal (= 1g/l),

S_S :Average salinity at Laroussia (g/l),

S_N :Average salinity of reservoirs in the Extreme North (g/l)

(4) Checking Pipeline and canal capacities

Pipeline and canal capacities are presented in **Table B5.3.2**.

If V_N exceeds pipeline capacity, the proportions are calculated as follows.

$V_N = V_P$

$V_S = V - V_P$ where, V_P = Pipeline capacity between Sejnane and Cap Bon Canal ($10^6 m^3$)

Similarly, the amount transferred by pipeline from all other reservoirs is limited to a maximum value that is equal to the capacity of the pipeline. The capacity of the Mejerda Cap Bon Canal is also verified.

B5.4 Inflow Series

Five drought inflow scenarios were initially considered for the reservoir balance:

Drought Scenarios Initially Considered

Scenario	Duration		Total Inflow* mil. m^3	Total as % of average**
1	1 year	Historic 1960/61	1044	55%
2	2 year	Synthetic	2088	55%
3	2 year	Historic 1987/88-88/89	1582	41%
4	3 year	Synthetic	3132	55%
5	3 year	Historic 1992/93-94/95	2204.5	38%

* inflow to 27 dams in Northern Tunisia,
** average inflow from 1946 – 1997 = 1912 mil. m^3/year

The 1 year drought that occurred in 1960/61 is selected as the typical drought with a recurrence of 1/5 years.

The 2 and 3 year historical droughts are quite severe. Reservoir simulations with historical 2 and 3-year drought inflows indicate that almost all reservoirs would need to be 100% full in September and demand restrictions would need to be applied in the second and third year of the drought to prevent complete depletion of stocks. This is not surprising since reservoirs have not been sized for such a high level of service.

After discussions with the steering committee and workshop participants it was decided to use more moderate drought scenarios to compare the storage options for flood control operations. The scenarios are based on the typical one year drought.

Drought Scenarios Selected for Reservoir Water Balance

Drought scenarios			Drought recurrence interval
1:	1 year	typical	1/5
2:	2 year	2 x typical	1/9*
3:	2 year	2 x typical with restrictions	1/9*
4:	3 year	3 x typical	1/11**

Notes * One cycle is 2 years. ** one cycle is 3 years

A demand restriction of 20% is applied to irrigation in the second year of drought scenario 3.

Details on the calculation of drought inflows and drought recurrence intervals are discussed in **Supporting Report A**.

CHAPTER B6 RESULTS AND DISCUSSION

B6.1 Water Supply Deficits

Reservoir simulations for the 4 drought scenarios were carried out in the basin-wide wter balance analysis to examine the smallest acceptable initial active storage required and how the active storage fluctuates over time given variations in monthly inflows and demands. Figure B6.1.1 exemplifies the reservoir simulation results at the Sidi Salem Dam in the years 2010, 2020 and 2030.

It is found through the reservoir simulation that the reservoir system experiences deficits during the selected two and three year drought events. The size of deficits is summarized in the following table.

Comparison of Supply Deficits for Selected Drought Scenarios (million m^3)

Drought Scenario	2010	2020	2030
1	-	-	-
2	5.4	15.0	54.5
3	6.2	15.2	75.2
4	81.4	205.8	336.3

** 26 dams in Northern Tunisia

For the two year droughts the deficits occur at the following reservoirs.

Reservoirs with Deficits Following 2 Sequential Dry Years

2010	2020	2030
▪ Lakhmes ▪ R'Mil	▪ Bouheurtma ▪ Lakhmes, ▪ Siliana ▪ R'Mil ▪ Zerga	▪ Bouheurtma ▪ Lakhmes, ▪ Siliana ▪ R'Mil ▪ Zerga ▪ Mellegue II

The deficits occur because the local agricultural demands exceed the capacity of the reservoir even when the reservoir is at normal water level (i.e. full) at the beginning of September. Therefore, these reservoirs cannot be expected to contribute any of their active storage capacity for flood control.

The same thing occurs with the three year drought except the local deficits are larger. In addition, reservoirs in the extreme North are severely depleted. Deficits occur at Sidi Barrack and Sejnane reservoirs affecting potable water supply to all large cities in the system.

The three year drought cannot be managed unless significant system wide demand restrictions are applied to 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 in order to minimize water shortages.

B6.2 Storage Allocation

Storage allocation determined by the reservoir simulation is shown in **Table B6.2.1** for dams in the Mejerda River basin.

The initial storage volume required in the reservoir at the beginning of September corresponds to the active storage volume required for water supply operations. The total storage available for flood control is divided into two components:

- Design flood storage: Volume between normal water level and high water level
- Additional flood storage: Volume between normal water level and the maximum volume that occurs from September to May.

Seven dams have been selected for improved flood control operations based on their capacity, catchment area and potential for reducing flood peaks. These dams are: Sarrath (under construction), Mellegue (existing), Mellegue II (planned), Bou Heurtma, Tessa (planned), Sidi Salem, and Siliana Dams.

The total additional flood control storage that can potentially be provided at the seven dams is estimated through the reservoir simulation, as presented in the following table.

Comparison of Flood Control Storage for Drought Scenarios

Drought scenario	Demand restrictions	Additional flood control storage (Mm3)**		
		2010	2020	2030
1 year	None	321	299	215
2 year	Yes	169	104	69
2 year	None	168	99	33
3 year	None	78	<10	<10

** for 7 dams in Mejerda Basin with flood control potential

As expected, the amount of active storage that could potentially be reallocated to flood control decreases over time and decreases with the duration of the drought.

CHAPTER B7 CONCLUSION AND RECOMMENDATIONS

The selection of an appropriate scenario for the allocation of storage space was discussed with the Steering Committee and workshop participants in October 2007. The outcome is as follows:

- Water levels identified for the 1 year drought scenario are unrealistically low and would require the significant release of resources to prepare for a flood. Decision makers consider this is too risky since future inflows might not be sufficient to fill the reservoir back to required levels. This scenario does not provide an efficient operating strategy and is rejected.
- The three-year drought scenario shows that severe demand restrictions would be required in the second and third year to prevent complete failure of the system. Reservoirs in Tunisia do not have sufficient over-year storage capacity for a 3 year drought and cannot be expected to perform well under such difficult conditions. According to the drought management guidelines for Tunisia published in 1999 a 3-year drought has a recurrence of approximately 1/100. This scenario is rejected because it is an extreme that exceeds the reliability criteria used for sizing the reservoirs.
- The typical two-year drought scenario is a more realistic measure of how the system can be managed to provide additional flood control storage without creating deficits that will have a negative impact on agriculture or potable water supply. Storage volumes identified under this scenario provide a level of water supply security of approximately 95%. The option of implementing a 20% demand restriction on agriculture in the second year provides a marginal advantage in terms of flood control but could result in economic hardship that would probably outweigh the benefits. This scenario is selected as the benchmark for determining storage allocation in reservoirs.

The analysis of flood control operations using the MIKE Basin model has proceeded with two scenarios:

- A standard reservoir operating scenario corresponding to the existing situation where the storage volume reserved for water supply operations is equal to the volume at normal water level (i.e. full useful capacity).
- An improved reservoir operating scenario where the storage volume reserved for water supply is reduced to levels that would be sufficient to manage a typical 2-year drought without significant negative impacts.

The following storage allocation is recommended for the analysis of flood control strategies for current stage of system development and proposed development in the years 2010, 2020 and 2030.

Storage Allocation based on 2 Sequential Dry Years

Dam	Year	Total storage (at HWL)	Total storage (at NWL)	Designed flood storage (HWL-NWL)	Total active storage (at NWL)	Reallocated to flood control	Active storage for water supply
Sarrath	2010	48.53	20.95	27.58	20.48	4.07	16.41
	2020	48.53	20.95	27.58	16.38	1.41	14.97
	2030	48.53	20.95	27.58	12.28	0.60	11.68
Mellegue	2010	147.54	44.40	103.14	27.53	3.42	24.11
Mellegue II	2020	334.00	195.00	139.00	161.00	4.33	156.67
	2030	334.00	195.00	139.00	127.00	2.42	124.58
Bou Heurtma	2010	164.0	117.50	46.50	109.80	-	109.80
	2020	164.0	117.50	46.50	108.60	15.98	92.62
	2030	164.0	117.50	46.50	107.40	23.99	83.41
Tessa	2030	73.43	44.43	29.00	29.13	1.67	27.46
Sidi Salem	2010	959.48	674.00	285.48	643.10	160.58	482.52
	2020	959.48	674.00	285.48	598.10	77.48	520.62
	2030	959.48	674.00	285.48	553.10	4.61	548.49
Siliana	2010	125.05	70.00	55.05	49.86	-	49.86
	2020	125.05	70.00	55.05	39.26	-	39.26
	2030	125.05	70.00	55.05	28.66	-	28.66

The review of existing water supply operations has highlighted the need for further study as follows:

- to carry out a storage-yield-probability analysis for individual reservoirs and to quantify the total system yield when reservoirs are operated in an integrated manner;
- to develop seasonal storage allocation curves and operating rules for each reservoir that could guide operators in making storage and release decisions;
- to carry out an system wide optimization study that determines an operating policy and identifies the target storage and the best combination of releases from the different reservoirs in the system;
- to develop the MIKE BASIN model prepared under the current study to include all reservoirs in the system and all water demands placed on the system (i.e. outside the Mejerda Basin). The model would be used as a tool by decision makers and operators to simulate the operation of the multi-reservoir water resources system of Northern Tunisia.

Tables

Table B3.3.1 Reservoir Yields and Timeframes for Implementation

	Reservoir Yield	Presence (+) or absence (-) of the dam			
Dam	10^6 m^3	2005	2010	2015-20	2025-30
1. Extreme North					
Zerga	19	+	+	+	+
Sidi El Barrak	167	+	+	+	+
Sejnane	80	+	+	+	+
Joumine	74	+	+	+	+
Ghezala	5.6	+	+	+	+
Kebir	24	-	+	+	+
El Moula	17	-	+	+	+
Ziatine	16	-	+	+	+
Gamgoum	6	-	-	+	+
Harka	7	-	-	+	+
Douimis	5	-	-	+	+
Melah	12	-	-	+	+
Tine	13	-	-	+	+
Total Yield 10^6 m^3		345.6	402.6	445.6	445.6
2. Ben M'Tir and Kasseb					
Ben Metir	38	+	+	+	+
Kasseb	34	+	+	+	+
Total Yield 10^6 m^3		72	72	72	72
3. Upper Medjerda					
Zouitina	80	+	+	+	+
Bou Heurtma	75	+	+	+	+
Mellegue	127	+	+	-	-
Mellila	25	-	-	+	+
Mellegue II	107	-	-	+	+
Sub-total 10^6 m^3		282	282	287	287
4. Lower Medjerda					
Sidi Salem	348	+	+	+	+
Lakhmes	4.6	+	+	+	+
Siliana	26	+	+	+	+
R'Mil	7	+	+	+	+
Sarrath	13	-	-	+	+
Tessa	24	-	-	-	+
Beja	14	-	-	-	+
Khaled	13	-	-	-	+
Sub-total 10^6 m^3		385.6	385.6	398.6	449.6
Total Mejerda 10^6 m^3		739.6	739.6	757.6	808.6
Grand Total 10^6 m^3		1085.2	1142.2	1203.2	1254.2

Source: Yields reported by MARH. The yield represents the amount of water that can be withdrawn from the reservoir annually with a 20% risk of deficit (i.e. water supply guarantee of 80%)

Table B3.3.2 Average Monthly and Annual Inflows

(Unit: million m^3)

	Name	S	O	N	D	J	F	M	A	M	J	J	A	Year
Mejerda	Zouitina	1.7	3.1	6.4	13.7	17.6	13.4	10.8	6.9	2.1	0.6	0.1	0.1	76.4
	Sarrath	2.3	2.8	1.3	1.0	1.0	0.9	1.5	1.5	1.5	1.4	0.7	1.2	17.0
	Mellegue	29.5	31.4	13.4	9.9	8.6	8.8	11.0	14.2	18.4	15.5	5.3	13.5	179.4
	Tessa	10.4	7.8	4.9	4.0	4.0	3.6	6.7	4.0	4.2	3.2	2.9	3.4	59.1
	Ben Metir	0.3	0.8	2.8	6.9	8.9	9.3	6.7	4.3	0.9	0.3	0.2	0.2	41.6
	Bou Hertma	1.0	2.5	7.9	19.3	25.3	26.5	20.0	12.9	3.6	1.3	0.7	0.9	121.9
	Kasseb	0.6	1.4	3.6	7.8	10.8	8.2	6.5	4.7	1.6	0.6	0.5	0.5	46.8
	Beja	0.2	0.6	1.3	2.8	4.0	2.9	2.5	1.7	0.6	0.2	0.2	0.2	17.2
	Sidi Salem	33.1	51.0	44.2	77.9	112.9	106.8	95.9	68.0	35.2	21.7	11.3	16.7	674.6
	Khalled	2.2	1.5	1.6	1.3	1.1	1.2	1.9	1.5	1.2	0.8	0.7	1.0	16.0
	Lakhmess	0.8	1.3	0.8	0.7	1.5	1.3	1.5	1.3	0.7	0.3	0.2	0.3	10.8
	Siliana	4.4	6.5	4.0	4.1	6.1	6.1	6.9	5.3	3.0	1.5	1.2	1.9	51.1
	R'Mil	0.9	1.8	0.9	1.1	1.4	1.3	1.4	1.0	0.6	0.3	0.2	0.4	11.2
Extreme North	Kebir	0.1	0.4	2.5	6.5	8.2	8.0	4.7	2.5	0.8	0.1	0.0	0.0	33.9
	Zerga	0.1	0.3	2.1	6.3	7.7	7.2	4.0	2.3	0.7	0.1	0.0	0.0	30.8
	Moula	0.1	0.4	1.7	4.3	5.4	4.2	3.2	2.0	0.6	0.1	0.0	0.0	22.0
	Sidi Barrak	0.9	4.1	13.9	33.0	42.3	32.7	28.1	16.5	4.9	1.1	0.5	0.5	178.4
	Ziatine	0.1	0.5	2.1	4.6	5.3	4.2	3.2	1.6	0.4	0.1	0.0	0.0	22.1
	Gamgoum	0.0	0.2	0.7	1.6	1.9	1.5	1.1	0.6	0.2	0.0	0.0	0.0	7.8
	El Harka	0.1	0.3	1.0	2.2	2.5	1.9	1.5	0.7	0.2	0.1	0.0	0.1	10.7
	Sejenane	0.4	2.3	9.9	21.6	24.1	18.5	11.2	4.8	0.9	0.2	0.1	0.1	94.1
	Douimis	0.1	0.3	0.9	1.7	2.0	2.0	1.2	0.5	0.2	0.0	0.0	0.0	8.9
	Melah	0.2	0.7	3.1	5.9	5.1	3.9	3.5	1.2	0.5	0.1	0.0	0.0	24.3
	Joumine	0.8	4.0	10.4	21.5	27.2	25.4	17.4	7.2	2.6	0.5	0.1	0.1	117.0
	Ghezala	0.1	0.2	0.8	1.8	2.2	2.0	1.4	0.6	0.2	0.0	0.0	0.0	9.4
	Tine	0.3	1.2	2.3	5.1	5.3	5.5	4.4	2.5	1.5	0.5	0.1	0.1	28.9
													Total	1911.7

Table B3.3.3 Monthly Inflows for the Typical Dry Year 1960/61

(Unit: million m^3)

Reservoir	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Year
Zouitina	4.81	2.14	2.20	9.12	28.18	8.27	4.76	0.98	0.45	0.19	0.08	0.05	61.23
Sarrath	0.72	1.40	0.56	0.78	0.88	0.61	0.58	0.56	0.50	1.00	1.41	0.88	9.87
Mellegue	3.33	10.50	1.74	4.05	5.02	2.26	2.01	1.70	1.01	6.30	10.70	5.02	53.64
Tessa	1.06	1.95	0.87	1.15	1.27	0.93	0.90	0.86	0.78	1.43	1.97	1.27	14.44
Ben Metir	1.87	0.20	0.24	3.49	10.30	4.98	2.43	0.76	0.34	0.25	0.19	0.19	25.24
Bou Hertma	1.87	0.42	0.50	11.77	36.51	8.74	4.88	1.18	1.85	1.09	0.82	0.32	69.95
Kasseb	2.38	0.95	1.14	4.86	14.90	4.40	2.21	1.68	1.33	1.13	1.11	1.03	37.12
Beja	0.85	0.34	0.41	1.73	5.31	1.57	0.79	0.60	0.47	0.40	0.40	0.37	13.24
Sidi Salem	31.40	42.50	34.00	51.60	130.00	66.90	28.20	14.70	10.10	14.10	15.10	9.90	448.50
Khalled	0.28	0.51	0.23	0.30	0.34	0.25	0.24	0.23	0.21	0.38	0.52	0.34	3.81
Lakhmess	0.32	0.04	0.03	0.11	0.51	0.18	0.14	0.07	0.04	0.03	0.00	0.00	1.47
Siliana	0.84	0.25	0.71	0.81	1.73	0.39	0.33	0.87	0.75	0.95	1.13	0.45	9.21
R'Mil	0.28	0.05	0.09	0.14	0.45	0.14	0.11	0.13	0.10	0.12	0.13	0.05	1.79
Kebir	0.01	0.01	0.04	2.65	13.05	1.26	0.62	0.14	0.05	0.03	0.03	0.01	17.90
Zerga	0.00	0.00	0.03	1.84	9.04	0.87	0.43	0.09	0.04	0.02	0.02	0.00	12.38
Moula	0.11	0.03	0.05	2.31	8.07	0.81	0.43	0.11	0.14	0.07	0.02	0.01	12.16
Sidi Barrak	2.03	0.54	0.73	23.51	52.84	5.60	3.35	1.10	2.32	1.12	0.19	0.12	93.45
Ziatine	0.12	0.03	0.04	2.86	6.91	0.84	0.34	0.07	0.14	0.07	0.01	0.01	11.44
Gamgoum	0.04	0.01	0.02	1.01	2.43	0.30	0.12	0.02	0.05	0.02	0.00	0.00	4.02
El Harka	0.05	0.01	0.02	1.13	2.72	0.33	0.13	0.03	0.06	0.03	0.00	0.00	4.51
Sejenane	0.00	0.00	0.00	11.70	30.20	4.10	1.08	0.00	0.00	0.00	0.00	0.00	47.08
Douimis	0.00	0.01	0.22	0.79	2.03	1.07	0.30	0.16	0.07	0.02	0.00	0.00	4.67
Melah	0.01	0.01	0.48	1.72	4.40	2.32	0.64	0.36	0.16	0.03	0.00	0.00	10.13
Joumine	0.00	0.00	0.00	7.47	18.70	4.98	0.94	0.00	0.00	0.00	0.00	0.00	32.09
Ghezala	0.00	0.01	0.22	0.78	1.99	1.05	0.29	0.16	0.07	0.02	0.00	0.00	4.59
Tine	0.08	0.13	5.44	1.29	3.22	18.35	5.41	4.03	1.77	0.38	0.01	0.00	40.11
Total	52.46	62.04	50.00	148.97	391.00	141.50	61.66	30.58	22.79	29.17	33.84	20.02	1044.04

Table B3.3.4 Average Monthly Evaporation Losses

Region	Reservoir	Data source	Area (ha)	Average Evaporation (10^6 m^3)												
				S	O	N	D	J	F	M	A	M	J	J	A	Yearly
Extreme North	Zerga	2	176	0.193	0.103	0.055	0.043	0.039	0.037	0.060	0.078	0.159	0.237	0.326	0.296	1.627
	Kebir	2	301	0.217	0.124	0.070	0.053	0.046	0.046	0.076	0.097	0.181	0.265	0.358	0.324	1.858
	El Moula	2	143	0.102	0.055	0.029	0.023	0.021	0.020	0.032	0.041	0.084	0.125	0.172	0.156	0.861
	Sid Barrak	1	3028	2.972	1.934	1.429	1.197	0.944	1.141	1.823	2.434	3.590	4.393	4.842	4.340	31.038
	Ziatine	2	285	0.313	0.168	0.090	0.070	0.064	0.060	0.098	0.126	0.257	0.383	0.529	0.479	2.635
	Gamgoum	2	149	0.164	0.088	0.047	0.037	0.033	0.031	0.051	0.066	0.135	0.200	0.276	0.250	1.378
	El Harka	2	448	0.492	0.263	0.141	0.110	0.100	0.094	0.154	0.198	0.405	0.602	0.831	0.753	4.143
	Douimis	2	300	0.374	0.187	0.097	0.076	0.069	0.063	0.101	0.134	0.300	0.452	0.643	0.580	3.074
	Sejnane	1	790	0.814	0.562	0.347	0.292	0.282	0.300	0.379	0.475	0.767	1.060	1.356	1.292	7.927
	Melah	2	303	0.335	0.165	0.085	0.068	0.062	0.055	0.089	0.121	0.267	0.403	0.573	0.518	2.740
	Joumine	1	660	0.610	0.396	0.214	0.149	0.143	0.171	0.328	0.445	0.712	0.986	1.201	1.028	6.381
	Ghezala	1	122	0.145	0.078	0.042	0.032	0.030	0.030	0.049	0.067	0.122	0.181	0.247	0.223	1.245
	Tine	2	589	0.837	0.416	0.214	0.169	0.157	0.140	0.227	0.301	0.668	1.010	1.439	1.295	6.873
Mejerda	Zouitina	1	422	0.295	0.232	0.129	0.108	0.093	0.118	0.227	0.257	0.397	0.530	0.563	0.490	3.437
	Bou Heurtma	1	800	0.749	0.491	0.239	0.167	0.180	0.175	0.389	0.445	0.728	1.016	1.268	1.141	6.989
	Ben Metir	1	350	0.390	0.250	0.147	0.108	0.103	0.110	0.211	0.230	0.358	0.485	0.615	0.566	3.572
	Kasseb	1	430	0.469	0.311	0.188	0.162	0.149	0.140	0.255	0.294	0.502	0.802	0.955	0.817	5.043
	Sarrath	3	300	0.319	0.157	0.081	0.065	0.059	0.052	0.085	0.115	0.254	0.383	0.545	0.492	2.607
	Mellegue	1	1010	1.110	0.802	0.459	0.297	0.295	0.374	0.620	0.872	1.334	1.927	2.441	1.984	12.514
	MellegueII	3	1280	1.246	0.735	0.413	0.281	0.281	0.338	0.586	0.834	1.288	1.700	2.088	1.931	11.721
	Tessa	2	75	0.081	0.051	0.030	0.017	0.016	0.022	0.044	0.051	0.083	0.127	0.140	0.127	0.789
	Beja	2	230	0.182	0.071	0.055	0.026	0.016	0.026	0.035	0.061	0.095	0.219	0.304	0.277	1.367
	Sidi Salem	1	5521	4.676	3.143	1.741	1.281	1.409	1.689	3.061	4.083	5.913	8.293	9.475	7.832	52.595
	Khalled	2	115	0.110	0.065	0.036	0.025	0.022	0.027	0.043	0.065	0.090	0.137	0.184	0.168	0.974
	Lakhmes	1	102	0.113	0.075	0.045	0.033	0.027	0.031	0.046	0.061	0.101	0.149	0.192	0.171	1.045
	Siliana	1	600	0.627	0.482	0.302	0.204	0.167	0.194	0.350	0.443	0.722	0.964	1.229	1.072	6.755
	R'Mil	2	62	0.068	0.042	0.024	0.018	0.016	0.017	0.027	0.034	0.059	0.084	0.109	0.100	0.598
Total				18.003	11.448	6.749	5.107	4.821	5.502	9.446	12.425	19.570	27.114	32.900	28.702	181.787

1. Data source: Monthly operating records for existing dams
2. Data source: Eau2000 estimated evaporation in meters x pan coefficient of 0.7 x reservoir surface area (assumed constant at highest normal water level)
3. Data source: Sarrath and MellegueII calculated from linear equation derived using data for other dams.

Table B4.3.1 Potable Water Historical Consumption and Production

All Tunisia (million m^3/year)

Year	Domestic	Industry	Tourism	Total	Growth rate	Loss ratio	Production (Y)	Population (x)
1975	74.9	11.6	6.9	93.4		0.66	141.8	5482.0
1976	77.2	13.5	7.0	97.7	4.6%	0.67	145.6	5628.2
1977	86.8	15.6	7.3	109.7	12.3%	0.69	158.1	5778.5
1978	91.5	16.4	7.7	115.6	5.4%	0.69	167.5	5933.5
1979	97.0	17.8	8.4	123.2	6.6%	0.69	178.9	6092.8
1980	102.4	21.5	8.7	132.6	7.6%	0.69	192.7	6256.9
1981	111.7	20.4	9.0	141.1	6.4%	0.69	205.0	6425.8
1982	121.0	20.9	8.5	150.4	6.6%	0.69	216.7	6599.6
1983	125.8	24.1	8.2	158.1	5.1%	0.71	222.3	6778.7
1984	132.6	24.0	7.9	164.5	4.0%	0.71	232.6	6966.1
1985	142.6	21.3	8.7	172.6	4.9%	0.73	237.0	7162.5
1986	146.0	21.0	9.4	176.4	2.2%	0.71	248.5	7339.0
1987	152.7	21.3	10.9	184.9	4.8%	0.71	261.4	7523.4
1988	161.4	24.3	11.6	197.3	6.7%	0.71	276.9	7785.7
1989	157.5	23.0	11.8	192.3	-2.5%	0.72	267.2	7909.5
1990	160.9	22.1	11.5	194.5	1.1%	0.70	276.9	8063.0
1991	165.6	22.3	9.7	197.6	1.6%	0.70	280.8	8219.7
1992	172.3	24.1	12.5	208.9	5.7%	0.73	286.0	8370.3
1993	186.4	23.3	13.8	223.5	7.0%	0.73	306.1	8523.6
1994	197.7	25.1	14.7	237.5	6.3%	0.74	322.1	8815.3
1995	191.2	24.9	14.3	230.4	-3.0%	0.74	312.1	8952.3
1996	189.9	25.3	14.1	229.3	-0.5%	0.74	309.0	9089.3
1997	203.1	26.5	15.7	245.3	7.0%	0.77	317.0	9214.9
1998	212.0	27.9	15.8	255.7	4.2%	0.78	326.2	9333.3
1999	225.0	28.7	16.7	270.4	5.7%	0.80	337.0	9455.9
2000	236.0	30.3	17.6	283.9	5.0%	0.82	345.5	9563.5
2001	248.6	32.4	18.1	299.1	5.4%	0.80	373.3	9673.6
2004	n.a.	n.a.	n.a.	313.9	1.6%	n.a.	n.a.	9911.0

n.a. = not available
data for 2002 and 2003 not reported

Table B4.3.2 SONEDE Provisional Water Demand Forecast 2004

Water Consumption

Large Demand Centers	2003 (actual)	2006	2011	2015	2020	2025	2030	Growth (ppa)
Greater Tunis	93.3	108	123	135	150	164	179	2.4%
Cap Bon	23.6	26	30	32.5	36	40	43.5	2.3%
Gt. Jendouba	5.9	6.4	7.1	7.7	8.5	9.2	9.9	1.9%
Gt. Beja	6.3	7.1	7.8	8.4	9.2	9.9	10.6	1.9%
Gt. Siliana	2.9	3.3	3.6	3.9	4.3	4.7	5.1	2.1%
Grand Sahel	51.7	59.2	70	78	89	99	110	2.8%
Gt. Kairouan	7	7.5	8.5	9.3	10.3	11.3	12.3	2.1%
Grand Sfax	30.7	35.5	42	47	53.5	59.5	66	2.9%
Gt Bizerte	16.2	17.1	19.2	21	23.1	25.3	27.4	2.0%
Zaghouan	3.2	3.6	4.3	4.9	5.6	6.2	6.9	2.9%
Gt. Le Kef	4.2	4.6	5.1	5.5	6	6.5	7	1.9%
Kerkennah	0.8	0.8	1	1.1	1.3	1.5	1.7	2.8%
Gt. Gabes	10.2	11.6	13.4	14.9	16.7	18.4	20.2	2.6%
ICM	6.3	7.1	7.4	7.7	8.1	8.5	9.3	1.5%
Jerba	9.4	11.4	13.8	15.8	18.1	20.5	22.9	3.4%
South East	10.3	12.5	15.1	17.1	19.7	22.3	24.8	3.3%
Gt. Kasserine	4.5	5	5.7	6.3	6.9	7.6	8.3	2.3%
Gt. Gafsa	7.5	8.2	9.1	9.8	10.7	11.5	12.4	1.9%
Gt. Tozeur	3.2	3.6	4	4.4	4.8	5.2	5.7	2.2%
Gt. Kebili	3.8	4.1	4.7	5.2	5.8	6.4	7	2.3%
	301	342.6	394.8	435.5	487.6	537.5	590	2.5%

(SONEDE Strategy Paper for Development 2006-2030, Part 1 Dec 2004)

Table B4.3.3 Resources required Northern Reservoir System for Potable Water

million m^3 | Abstraction loss 15%

Code	Demand Center 2005	Total demand	Local resources	Net required	Abstraction losses	Bulk water required	S	O	N	D	J	F	M	A	M	J	J	A
							9.1%	8.6%	7.5%	7.3%	7.1%	6.3%	7.3%	7.5%	8.8%	9.3%	10.7%	10.4%
UCTU	Greater Tunis	114.4	0.0	114.4	17.2	131.6	12.0	11.3	9.9	9.6	9.3	8.3	9.7	9.9	11.6	12.2	14.1	13.7
UBER	Towns along Pipeline	16.2	0.0	16.2	2.4	18.6	1.7	1.6	1.4	1.4	1.3	1.2	1.4	1.4	1.6	1.7	2.0	1.9
UBIZ	Bizerte	20.3	10.0	10.3	1.5	11.8	1.1	1.0	0.9	0.9	0.8	0.8	0.9	0.9	1.0	1.1	1.3	1.2
UNAB	Cap Bon	29.2	5.5	23.7	3.6	27.3	2.5	2.3	2.0	2.0	1.9	1.7	2.0	2.0	2.4	2.5	2.9	2.8
USFA	Sfax	40.7	20.0	20.7	3.1	23.8	2.2	2.0	1.8	1.7	1.7	1.5	1.7	1.8	2.1	2.2	2.5	2.5
USAK	Sahel & Kairouan	65.5	20.0	45.5	6.8	52.3	4.8	4.5	3.9	3.8	3.7	3.3	3.8	3.9	4.6	4.8	5.6	5.5
		286.3	55.5	230.8	34.6	265.4	24.1.	22.8.	19.9.	19.3.	18.8.	16.8.	19.5.	19.9.	23.5.	24.6.	28.4.	27.7.

Code	Demand Center 2010	Total demand	Local resources	Net required	Abstraction losses	Bulk water required	S	O	N	D	J	F	M	A	M	J	J	A
							9.1%	8.6%	7.5%	7.3%	7.1%	6.3%	7.3%	7.5%	8.8%	9.3%	10.7%	10.4%
UCTU	Greater Tunis	127.6	0.0	127.6	19.1	146.7	13.4	12.6	11.0	10.7	10.4	9.3	10.8	11.0	13.0	13.6	15.7	15.3
UBER	Towns along Pipeline	17.4	0.0	17.4	2.6	20.0	1.8	1.7	1.5	1.5	1.4	1.3	1.5	1.5	1.8	1.9	2.1	2.1
UBIZ	Bizerte	21.3	10.0	11.3	1.7	13.0	1.2	1.1	1.0	0.9	0.9	0.8	1.0	1.0	1.1	1.2	1.4	1.4
UNAB	Cap Bon	32.1	5.5	26.6	4.0	30.6	2.8	2.6	2.3	2.2	2.2	1.9	2.2	2.3	2.7	2.8	3.3	3.2
USFA	Sfax	49.0	20.0	29.0	4.4	33.4	3.0	2.9	2.5	2.4	2.4	2.1	2.4	2.5	3.0	3.1	3.6	3.5
USAK	Sahel & Kairouan	78.6	20.0	58.6	8.8	67.4	6.1	5.8	5.1	4.9	4.8	4.3	5.0	5.1	6.0	6.2	7.2	7.0
		326.0	55.5	270.5	40.6	311.1	28.3.	26.7.	23.4.	22.6.	22.1.	19.7.	22.9.	23.4.	27.5.	28.8.	33.2.	32.5.

Code	Demand Center 2020	Total demand	Local resources	Net required	Abstraction losses	Bulk water required	S	O	N	D	J	F	M	A	M	J	J	A
							9.1%	8.6%	7.5%	7.3%	7.1%	6.3%	7.3%	7.5%	8.8%	9.3%	10.7%	10.4%
UCTU	Greater Tunis	160.8	0.0	160.8	24.1	184.9	16.8	15.9	13.9	13.4	13.1	11.7	13.6	13.9	16.4	17.1	19.8	19.3
UBER	Towns along Pipeline	21.1	0.0	21.1	3.2	24.3	2.2	2.1	1.8	1.8	1.7	1.5	1.8	1.8	2.1	2.2	2.6	2.5
UBIZ	Bizerte	26.2	10.0	16.2	2.4	18.6	1.7	1.6	1.4	1.4	1.3	1.2	1.4	1.4	1.6	1.7	2.0	1.9
UNAB	Cap Bon	37.9	5.5	32.4	4.9	37.3	3.4	3.2	2.8	2.7	2.6	2.4	2.7	2.8	3.3	3.5	4.0	3.9
USFA	Sfax	64.2	20.0	44.2	6.6	50.8	4.6	4.4	3.8	3.7	3.6	3.2	3.7	3.8	4.5	4.7	5.4	5.3
USAK	Sahel & Kairouan	101.2	20.0	81.2	12.2	93.4	8.5	8.0	7.0	6.8	6.6	5.9	6.9	7.0	8.3	8.7	10.0	9.7
		411.4	55.5	355.9	53.4	409.3	37.2.	35.2.	30.7.	29.7.	29.0.	26.0.	30.1.	30.7.	36.2.	37.9.	43.7.	42.7.

Code	Demand Center 2030	Total demand	Local resources	Net required	Abstraction losses	Bulk water required	S	O	N	D	J	F	M	A	M	J	J	A
							9.1%	8.6%	7.5%	7.3%	7.1%	6.3%	7.3%	7.5%	8.8%	9.3%	10.7%	10.4%
UCTU	Greater Tunis	193.1	0.0	193.1	29.0	222.1	20.2	19.1	16.7	16.1	15.8	14.1	16.3	16.7	19.6	20.6	23.7	23.2
UBER	Towns along Pipeline	24.5	0.0	24.5	3.7	28.2	2.6	2.4	2.1	2.0	2.0	1.8	2.1	2.1	2.5	2.6	3.0	2.9
UBIZ	Bizerte	31.1	10.0	21.1	3.2	24.3	2.2	2.1	1.8	1.8	1.7	1.5	1.8	1.8	2.1	2.2	2.6	2.5
UNAB	Cap Bon	44.5	5.5	39.0	5.9	44.9	4.1	3.9	3.4	3.3	3.2	2.8	3.3	3.4	4.0	4.2	4.8	4.7
USFA	Sfax	79.0	20.0	59.0	8.9	67.9	6.2	5.8	5.1	4.9	4.8	4.3	5.0	5.1	6.0	6.3	7.2	7.1
USAK	Sahel & Kairouan	124.5	20.0	104.5	15.7	120.2	10.9	10.3	9.0	8.7	8.5	7.6	8.8	9.0	10.6	11.1	12.8	12.5
		496.7	55.5	441.2	66.2	507.4	46.2.	43.6.	38.1.	36.8.	36.0.	32.2.	37.3.	38.1.	44.9.	47.0.	54.2.	52.9.

Table B4.5.1 Total Monthly Demand Applied to the Reservoir System of North Tunisia

(Unit: million m3)

2010	S	O	N	D	J	F	M	A	M	J	J	A	Total
Potable	28.3	26.7	23.4	22.6	22.1	19.7	22.9	23.4	27.5	28.8	33.2	32.5	311.1
Agricultural	52.1	27.8	16.2	0.9	0.4	7.9	37.0	68.8	126.2	89.7	103.2	96.4	626.7
Environmental	0.0	0.0	6.0	6.0	6.0	6.0	6.0	0.0	0.0	0.0	0.0	0.0	30.0
Total	80.4	54.5	45.6	29.5	28.5	33.6	65.9	92.2	153.8	118.5	136.5	128.9	967.8

2020	S	O	N	D	J	F	M	A	M	J	J	A	Total
Potable	37.2	35.2	30.7	29.7	29.0	26.0	30.1	30.7	36.2	37.9	43.7	42.7	409.3
Agricultural	54.6	29.5	17.1	0.8	0.4	8.4	39.9	74.4	135.4	94.1	107.6	101.2	663.3
Environmental	0.0	0.0	6.0	6.0	6.0	6.0	6.0	0.0	0.0	0.0	0.0	0.0	30.0
Total	91.8	64.6	53.9	36.5	35.4	40.3	75.9	105.2	171.6	132.0	151.3	143.9	1102.6

2030	S	O	N	D	J	F	M	A	M	J	J	A	Total
Potable	46.2	43.6	38.1	36.8	36.0	32.2	37.3	38.1	44.9	47.0	54.2	52.9	507.4
Agricultural	50.8	27.4	15.9	0.8	0.6	9.2	39.3	71.4	127.8	91.5	105.7	96.3	636.8
Environmental	0.0	0.0	6.0	6.0	6.0	6.0	6.0	0.0	0.0	0.0	0.0	0.0	30.0
Total	96.9	71.0	60.0	43.6	42.6	47.4	82.6	109.5	172.7	138.5	160.0	149.3	1174.2

Table B4.6.1 Target Salinity for Demand Centers

Code	Description	Name	Max Salinity g/liter
BA01	Agricultural demand	Mornag CMCB	1.50
BE01	Agricultural demand	Testour	2.00
BE02	Agricultural demand	Tebourba Mjez	2.00
BE05	Agricultural demand	Goubellat	2.00
BE07	Agricultural demand	Sidi Ismail	2.00
BE08	Agricultural demand	Nefza Ouechtata	2.00
BE10	Agricultural demand	Skhira	2.00
BE11	Agricultural demand	El-Herri	2.00
BI02	Agricultural demand	Utique	2.00
BI03	Agricultural demand	Tobias Bizerte	2.00
BI04	Agricultural demand	El Aalia Menzel Jmil	2.00
BI05	Agricultural demand	Cap Serrat	2.00
BI06	Agricultural demand	Ghezela	2.00
BI07	Agricultural demand	Teskraya	2.00
BI09	Agricultural demand	Sejenane (Sidi Barak)	2.00
BI10	Agricultural demand	Mateur	1.00
BI11	Agricultural demand	Ras Jebel - Ousja	1.00
BI12	Agricultural demand	Zouaouine	1.00
JE01	Agricultural demand	Bouhertma sect I et II	1.50
JE03	Agricultural demand	Bouhertma sect IV	1.50
JE04	Agricultural demand	Badrouna	2.00
JE07	Agricultural demand	Bouhertma sect VI	2.00
JE08	Agricultural demand	Sidi Shili	2.00
JE09	Agricultural demand	Tabarka Mekna	2.00
JE11	Agricultural demand	Bouhertma phase III	2.00
JE12	Agricultural demand	Hammam Bourguiba Fernana	2.00
KF02	Agricultural demand	Sidi Khiar	2.00
KF10	Agricultural demand	Nebeur	2.00
LA03	Agricultural demand	Kalaat Landlous	3.00
LA09	Agricultural demand	Borj Toumi Nouveau	3.00
LA34	Agricultural demand	Basse Vallée (ancien)	3.00
LA35	Agricultural demand	Tobias Ariana	3.00
NA03	Agricultural demand	Grombalia	1.50
NA04	Agricultural demand	Nouvelle Sauvegarde	1.50
NA06	Agricultural demand	Soliman-Ml Bouzelfa	1.50
NA07	Agricultural demand	Korba Menzel Temim	1.50
NA08	Agricultural demand	Ancienne Sauvegarde	1.50
SL01	Agricultural demand	Lakhmes	1.00
SL02	Agricultural demand	Gaafour-Laroussia	1.00
SL09	Agricultural demand	Rmil	1.00
UBER	Urban water demand	Towns along the pipeline (Ben M'Tir)	1.50
UBIZ	Urban water demand	Bizerte	1.50
UCTU	Urban water demand	Tunis	1.50
UNAB	Urban water demand	Cap Bon (Nabeul)	2.50
USFA	Urban water demand	Sfax & Sidi Bouzid	1.50
USAK	Urban water demand	Sahel & Kairouan	1.50
EN02	Environmental demand	Lake Ichkeul	2.00

Table B5.1.1 List of Demands Allocated to Reservoirs

Region	Code	Reservoir	Agricultural	Potable	Environmental
Mejerda	BE	Beja	BE12		
	BH	Bou Heurtma	JE03, AG04	-	
	BM	**Ben Mtir**	-	UBER, **UCTU, UNAB**	
	KA	**Kasseb**	-	**UCTU**	
	KH	Khalled	BE13		
	LA	Lakhmes	SL01	-	
	ME	Mellegue	AG02, BE07,JE04,JE08	-	
	RM	Rmil	SL09	-	
	SA	Sarrath	KF11		
	SI	Siliana	SL02	-	
	SS	**Sidi Salem**	**AG01**, AG06, AG07	**UAG2, UCTU, UNAB**	
	TE	Tessa	AG03		
	ZO	Barbara	JE 12	-	
Extreme North	**DO**	**Douimis**	**AG01**		**EN02**
	EH	**El Harka**	**AG01**		**EN02**
	EM	El Moula			
	GA	**Gamgoum**	**AG01**		**EN02**
	GH	**Ghezala**	**AG01**, BI06		**EN02**
	JO	**Joumine**	**AG01**, BI10	UBIZ, **UAG2**	
	KE	Kebir	-	-	
	ML	**Melah**	**AG01**		**EN02**
	SB	Sidi Barak	BE08, BI09	-	
	SE	**Sejnane**	**AG01**, BI07	**UAG2, UCTU, UNAB**	**EN02**
	TI	**Tine**	**AG01**		**EN02**
	ZE	Zerga	IE09	-	
	ZI	**Ziatine**	**AG01**, BI05	-	**EN02**

Note: shared demands are highlighted in bold type face

Table B5.2.1 Water Resource Mass Balance (1/2)

(Unit : million m^3)

		Year			
		2005	2010	2020	2030
Zone 1 Extreme North to Bejaoua					
Water Demand					
	Bizerte Potable	20.3	21.3	26.2	31.1
	Abstraction losses	1.5	1.7	2.4	3.2
	Agriculture	71.7	71.7	64.9	58.8
	Ichkeul	30.0	30.0	30.0	30.0
	Transfer to Bejaoua at Cap Bon Canal	150.5	205.5	231.5	247.5
Water Resources					
	Groundwater Sources	10.0	10.0	10.0	10.0
	Reservoirs in the extreme north	345.6	402.6	445.6	445.6
Balance		81.5	82.4	100.6	85.0
Zone 2 Mejerda river-Cap Bon Canal to Bejaoua					
Water Demand					
	Agriculture	450.6	461.0	513.3	496.0
	Transfer to Cap Bon Canal	217.0	206.6	172.3	240.6
Water Resources					
	Reservoirs in Mejerda basin	667.6	667.6	685.6	736.6
Balance		0.0	0.0	0.0	0.0
Zone 3 Ben M'Tir and Kasseb					
Water Demand					
	Towns along Pipeline - potable	16.2	17.4	21.1	24.5
	Abstraction losses	2.4	2.6	3.2	3.7
	Transfer to Gdir El Goulla	53.4	52.0	47.7	43.8
Water Resources					
	Reservoirs	72.0	72.0	72.0	72.0
Balance		0.0	0.0	0.0	0.0
Zone 4 Greater Tunis					
Water Demand					
	Tunis potable	114.4	127.6	160.8	193.1
	Abstraction losses	17.2	19.1	24.1	29.0
	Transfer to other zones	197.4	225.3	266.6	309.9
Water Resources					
	Gdir El Goulla	53.4	52.0	47.7	43.8
	Cap Bon Canal at Bejaoua	217.0	206.6	172.3	240.6
	Pipeline from the Extreme North	150.5	205.5	231.5	247.5
Balance		92.0	92.0	0.0	0.0
Zone 5 Cap Bon					
Water Demand					
	Cap Bon potable	29.2	32.1	37.9	44.5
	Abstraction losses	3.6	4.0	4.9	5.9
	Agricultural	94.0	94.0	85.1	77.0
	Transfer to other zones	76.1	100.7	144.2	188.0
Water Resources					
	Groundwater Sources	5.5	5.5	5.5	5.5
	Cap Bon Canal	197.4	225.3	266.6	309.9
Balance		0.0	0.0	0.0	0.0

Table B5.2.1 Water Resource Mass Balance (2/2)

(Unit : million m^3)

		Year			
		2005	2010	2020	2030
Zone 6 Sfax & Sidi Bouzid					
Water Demand					
	Sfax & Sidi Bouzid potable	40.7	49.0	64.2	79.0
	Abstraction losses	3.1	4.4	6.6	8.9
	transfer to other zones	52.3	67.4	93.4	120.2
Water Resources					
	Groundwater Sources	20.0	20.0	20.0	20.0
	Canal Cap Bon	76.1	100.7	144.2	188.0
Balance		0.0	0.0	0.0	0.0
Zone 7 Sahel & Kairouan Area					
Water Demand					
	Sahel & Kairouan	65.5	78.6	101.2	124.5
	Abstraction losses	6.8	8.8	12.2	15.7
Water Resources					
	Groundwater Sources	20.0	20.0	20.0	20.0
	Canal Cap Bon	52.3	67.4	93.4	120.2
Balance		0.0	0.0	0.0	0.0
Total Water Balance					
Water Demand					
	Potable Water Demand	286.3	326.0	411.4	496.7
	Abstraction losses	34.6	40.6	53.4	66.2
	Agricultural demand	616.3	626.7	663.3	631.8
	Ichkeul	30.0	30.0	30.0	30.0
	Total Demand	967.2	1023.3	1158.1	1224.7
Water Resources					
	Groundwater Abstraction	55.5	55.5	55.5	55.5
	Large dams	1085.2	1142.2	1203.2	1254.2
	Mejerda	667.6	667.6	685.6	736.6
	Kasseb Ben M'Tir	72.0	72.0	72.0	72.0
	Pipeline from the Extreme North	345.6	402.6	445.6	445.6
	Total resources	1140.7	1197.7	1258.7	1309.7
Demand allocation					
	Demand supplied by groundwater	55.5	55.5	55.5	55.5
	Demand supplied from large dams	911.7	967.8	1102.6	1169.2
Balance of resources remaining in reservoirs		173.5	174.4	100.6	85.0

Note: does not consider transfer capacities or salinity balance

Abstraction losses applied to potable water demand only 15%

Table B5.3.1 Allocation of Shared Demands

Reservoir Code		SE	JO	ME	BH	BM	KA	SS
Shared Demands	AG01	X	X					X
	AG05			X	X			
	UCTU	X	X			X	X	X
	UNAB	X	X					X
	USFA	X	X					X
	USAK	X	X					X

Table B5.3.2 Pipeline Transfer Capacities

Reservoir	Pipeline capacity	Maximum monthly volume million m^3												
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
	m3/s	30	31	30	31	31	28	31	30	31	30	31	31	
Barbara	7.0	18.14	18.75	18.14	18.75	18.75	16.93	18.75	18.14	18.75	18.14	18.75	18.75	220.75
Ben M'Tir	1.0	2.59	2.68	2.59	2.68	2.68	2.42	2.68	2.59	2.68	2.59	2.68	2.68	31.54
Kasseb	1.1	2.85	2.95	2.85	2.95	2.95	2.66	2.95	2.85	2.95	2.85	2.95	2.95	34.69
Kebir	1.4	3.63	3.75	3.63	3.75	3.75	3.39	3.75	3.63	3.75	3.63	3.75	3.75	44.15
El Moula	2.0	5.18	5.36	5.18	5.36	5.36	4.84	5.36	5.18	5.36	5.18	5.36	5.36	63.07
Sidi Barrak	8.4	21.77	22.50	21.77	22.50	22.50	20.32	22.50	21.77	22.50	21.77	22.50	22.50	264.90
Ziatine	0.7	1.76	1.82	1.76	1.82	1.82	1.65	1.82	1.76	1.82	1.76	1.82	1.82	21.44
Gamgoum	0.4	1.04	1.07	1.04	1.07	1.07	0.97	1.07	1.04	1.07	1.04	1.07	1.07	12.61
El Harka	2.4	6.09	6.29	6.09	6.29	6.29	5.69	6.29	6.09	6.29	6.09	6.29	6.29	74.11
Sejnane - pump stn	11.6	30.17	31.18	30.17	31.18	31.18	28.16	31.18	30.17	31.18	30.17	31.18	31.18	367.08
Sejnane-Joumine Pipeline	12.0	31.10	32.14	31.10	32.14	32.14	29.03	32.14	31.10	32.14	31.10	32.14	32.14	378.43
Douimis	4.00	10.37	10.71	10.37	10.71	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	126.14
Melah	1.25	3.24	3.35	3.24	3.35	3.35	3.02	3.35	3.24	3.35	3.24	3.35	3.35	39.42
Joumine - Sidi M'Barek	4.00	10.37	10.71	10.37	10.71	10.71	9.68	10.71	10.37	10.71	10.37	10.71	10.71	126.14
Joumine - Bizerte	1.00	2.59	2.68	2.59	2.68	2.68	2.42	2.68	2.59	2.68	2.59	2.68	2.68	31.54
Ghezala	0.30	0.78	0.80	0.78	0.80	0.80	0.73	0.80	0.78	0.80	0.78	0.80	0.80	9.46
Tine	0.87	2.26	2.33	2.26	2.33	2.33	2.10	2.33	2.26	2.33	2.26	2.33	2.33	27.44
MCB canal: Laroussia - Bejaoua	16.00	41.47	42.85	41.47	42.85	42.85	38.71	42.85	41.47	42.85	41.47	42.85	42.85	504.58
MCB canal: Bejaoua-Cap Bon	8.80	22.81	23.57	22.81	23.57	23.57	21.29	23.57	22.81	23.57	22.81	23.57	23.57	277.52
Pipeline Bejaoua - Tunis	5.50	14.26	14.73	14.26	14.73	14.73	13.31	14.73	14.26	14.73	14.26	14.73	14.73	173.45

Table B6.2.1 Storage Allocation for Reservoirs in the Mejerda Basin (1/3)

Dam	Year	Reservoir Characterisitics (Mm3)		Storage volumes at the beginning of the month (Mm3)											Flood storage volumes (Mm3)		
		Total Storage HWL	Total storage NWL	Scenario	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Max	Designed (NWL to HWL)	Additional (below NWL)	Total
Sarrath	2010	48.53	20.95	3a	18.90	18.20	18.55	18.58	19.10	19.70	19.95	19.51	18.30	19.95	27.58	1.00	28.58
				2b	15.83	15.13	15.48	15.51	16.03	16.63	16.88	16.44	15.23	16.88	27.58	4.07	31.65
				2a	14.81	14.10	14.46	14.49	15.01	15.61	15.86	15.42	14.21	15.86	27.58	5.09	32.67
				1a	10.71	10.01	10.36	10.39	10.91	11.51	11.76	11.32	10.11	11.76	27.58	9.19	36.77
	2020	48.53	20.95	3a	19.31	18.61	18.96	18.99	19.51	20.11	20.36	19.92	18.71	20.36	27.58	0.59	28.17
				2b	18.49	17.79	18.14	18.18	18.69	19.29	19.54	19.10	17.89	19.54	27.58	1.41	28.99
				2a	18.49	17.79	18.14	18.18	18.69	19.29	19.54	19.10	17.89	19.54	27.58	1.41	28.99
				1a	13.58	12.88	13.23	13.26	13.78	14.38	14.63	14.19	12.98	14.63	27.58	6.32	33.90
	2030	48.53	20.95	3a	19.72	19.11	19.52	19.58	20.10	20.70	20.95	20.59	19.53	20.95	27.58	-	27.58
				3a	19.11	18.50	18.90	18.97	19.49	20.08	20.35	19.99	18.93	20.35	27.58	0.60	28.18
				2a	19.11	18.50	18.90	18.97	19.49	20.08	20.35	19.99	18.93	20.35	27.58	0.60	28.18
				1a	15.42	14.81	15.22	15.28	15.80	16.40	16.67	16.30	15.24	16.67	27.58	4.28	31.86
Mellegue	2010	147.54	44.40	3a	25.13	24.03	31.25	32.08	35.54	39.90	40.98	38.81	33.77	40.98	103.14	3.42	106.56
				2b	25.13	24.03	31.25	32.08	35.54	39.90	40.98	38.81	33.77	40.98	103.14	3.42	106.56
				2a	25.13	24.03	31.25	32.08	35.54	39.90	40.98	38.81	33.77	40.98	103.14	3.42	106.56
				1a	25.13	24.03	31.25	32.08	35.54	39.90	40.98	38.81	33.77	40.98	103.14	3.42	106.56
Mellegue II	2020	334.00	195.00	3a	186.95	179.94	183.98	182.43	185.91	190.28	190.67	184.78	171.59	190.67	139.00	4.33	143.33
				2b	186.95	179.94	183.98	182.43	185.91	190.28	190.67	184.78	171.59	190.67	139.00	4.33	143.33
				2a	186.95	179.94	183.98	182.43	185.91	190.28	190.67	184.78	171.59	190.67	139.00	4.33	143.33
				1a	130.60	123.59	127.63	126.08	129.56	133.93	134.32	128.43	115.24	134.32	139.00	60.68	199.68
	2030	334.00	195.00	3a	188.65	181.74	185.84	184.32	187.80	192.17	192.59	186.78	173.75	192.59	139.00	2.41	141.41
				2b	188.65	181.74	185.84	184.32	187.80	192.17	192.58	186.77	173.73	192.58	139.00	2.42	141.42
				2a	188.65	181.74	185.84	184.32	187.80	192.17	192.58	186.77	173.73	192.58	139.00	2.42	141.42
				1a	150.55	143.64	147.74	146.22	149.70	154.07	154.48	148.67	135.63	154.48	139.00	40.52	179.52
Ben Metir	2010	73.43	57.20	3a	57.20	55.62	52.84	50.28	50.11	55.06	56.26	55.20	52.95	57.20	16.23	-	16.23
				2b	46.94	45.36	42.59	40.03	39.86	44.80	46.01	44.94	42.69	46.94	16.23	10.26	26.49
				2a	46.94	45.36	42.59	40.03	39.86	44.80	46.01	44.94	42.69	46.94	16.23	10.26	26.49
				1a	31.56	29.98	27.20	24.64	24.47	29.42	30.62	29.56	27.31	31.56	16.23	25.64	41.87
	2020	73.43	57.20	3a	57.20	55.62	52.84	50.28	50.11	55.06	56.26	55.20	52.95	57.20	16.23	-	16.23
				2b	47.22	45.64	42.87	40.31	40.14	45.08	46.29	45.22	42.97	47.22	16.23	9.98	26.21
				2a	47.22	45.64	42.87	40.31	40.14	45.08	46.29	45.22	42.97	47.22	16.23	9.98	26.21
				1a	32.26	30.68	27.90	25.34	25.17	30.12	31.32	30.26	28.01	32.26	16.23	24.94	41.17
	2030	73.43	57.20	3a	57.20	55.62	52.84	50.28	50.11	55.06	56.26	55.20	52.95	57.20	16.23	-	16.23
				2b	47.50	45.92	43.15	40.59	40.42	45.36	46.57	45.50	43.25	47.50	16.23	9.70	25.93
				2a	47.50	45.92	43.15	40.59	40.42	45.36	46.57	45.50	43.25	47.50	16.23	9.70	25.93
				1a	32.96	31.38	28.60	26.04	25.87	30.82	32.02	30.96	28.71	32.96	16.23	24.24	40.47

1a=1 year drought 1960/61 2a=2 year synthetic drought +demand restrictions 2b=no demand restrictions 3a=3 year synthetic drought

Table B6.2.1 Storage Allocation for Reservoirs in the Mejerda Basin (2/3)

		Characteristic volumes (Mm3)		Storage volumes at the beginning of the month (Mm3)											Flood storage volumes (Mm3)		
Dam	Year	Total Storage HWL	Total storage NWL	Scenario	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Max	Designed (NWL to HWL)	Additional (below NWL)	Total
Bou Heurtma	2010	164.0	117.50	3a	84.56	76.00	70.04	66.37	77.31	111.54	117.50	114.23	99.65	117.50	46.50	-	46.50
				2b	84.56	76.00	70.04	66.37	77.31	111.54	117.50	114.23	99.65	117.50	46.50	-	46.50
				2a	84.56	76.00	70.04	66.37	77.31	111.54	117.50	114.23	99.65	117.50	46.50	-	46.50
				1a	46.13	37.57	31.61	27.94	38.88	73.11	80.07	76.80	62.23	80.07	46.50	37.43	83.93
	2020	164.0	117.50	3a	84.92	75.52	69.25	65.96	76.91	111.14	117.50	113.28	96.63	117.50	46.50	-	46.50
				2b	68.63	59.23	52.96	49.67	60.62	94.85	101.52	97.30	80.64	101.52	46.50	15.98	62.48
				2a	63.20	53.80	47.53	44.24	55.19	89.42	96.09	91.87	75.21	96.09	46.50	21.41	67.91
				1a	52.34	42.94	36.67	33.38	44.33	78.56	85.23	81.01	64.35	85.23	46.50	32.27	78.77
	2030	164.0	117.50	3a	79.91	71.57	65.91	62.97	73.92	108.14	114.99	112.81	97.88	114.99	46.50	2.51	49.01
				2b	58.43	50.09	44.43	41.49	52.44	86.66	93.51	91.33	76.40	93.51	46.50	23.99	70.49
				2a	47.69	39.35	33.69	30.75	41.70	75.92	82.77	80.59	65.66	82.77	46.50	34.73	81.23
				1a	42.32	33.98	28.32	25.38	36.33	70.55	77.40	75.22	60.29	77.40	46.50	40.10	86.60
Kasseb	2010	92.6	81.88	3a	63.27	61.74	59.19	57.01	57.55	65.63	66.13	64.58	62.70	66.13	10.72	15.75	26.47
				2b	53.97	52.44	49.89	47.71	48.24	56.32	56.82	55.28	53.39	56.82	10.72	25.06	35.78
				2a	53.97	52.44	49.89	47.71	48.24	56.32	56.82	55.28	53.39	56.82	10.72	25.06	35.78
				1a	41.57	40.03	37.49	35.30	35.84	43.92	44.42	42.87	40.99	44.42	10.72	37.46	48.18
	2020	92.6	81.88	3a	66.88	65.34	62.79	60.61	61.15	69.23	69.73	68.18	66.30	69.73	10.72	12.15	22.87
				2b	54.87	53.34	50.79	48.61	49.14	57.22	57.72	56.18	54.29	57.72	10.72	24.16	34.88
				2a	54.87	53.34	50.79	48.61	49.14	57.22	57.72	56.18	54.29	57.72	10.72	24.16	34.88
				1a	42.87	41.33	38.79	36.60	37.14	45.22	45.72	44.17	42.29	45.72	10.72	36.16	46.88
	2030	92.6	81.88	3a	67.38	65.84	63.29	61.11	61.65	69.73	70.23	68.68	66.80	70.23	10.72	11.65	22.37
				2b	55.77	54.24	51.69	49.51	50.04	58.12	58.62	57.08	55.19	58.62	10.72	23.26	33.98
				2a	55.77	54.24	51.69	49.51	50.04	58.12	58.62	57.08	55.19	58.62	10.72	23.26	33.98
				1a	44.17	42.63	40.09	37.90	38.44	46.52	47.02	45.47	43.59	47.02	10.72	34.86	45.58
Beja	2030	46.0	26.40	3a	11.20	11.27	11.23	11.36	12.63	16.59	17.68	17.91	17.67	17.91	19.60	8.49	28.09
				2b	11.20	11.27	11.23	11.36	12.63	16.59	17.68	17.91	17.67	17.91	19.60	8.49	28.09
				2a	11.20	11.27	11.23	11.36	12.63	16.59	17.68	17.91	17.67	17.91	19.60	8.49	28.09
				1a	11.20	11.27	11.23	11.36	12.63	16.59	17.68	17.91	17.67	17.91	19.60	8.49	28.09
Tessa	2030	73.43	44.43	3a	41.52	42.12	43.53	44.15	44.43	44.43	43.68	42.16	40.80	44.43	29.00	-	29.00
				2b	38.60	39.21	40.62	41.24	42.06	42.76	42.01	40.49	39.13	42.76	29.00	1.67	30.67
				2a	38.60	39.21	40.62	41.24	42.06	42.76	42.01	40.49	39.13	42.76	29.00	1.67	30.67
				1a	29.87	30.47	31.88	32.50	33.32	34.02	33.28	31.76	30.39	34.02	29.00	10.41	39.41
Khalled	2030	37.00	34.00	3a	29.74	29.34	29.37	29.34	29.54	29.77	29.84	29.55	28.83	29.84	3.00	4.16	7.16
				2b	25.48	25.08	25.11	25.08	25.28	25.51	25.58	25.29	24.57	25.58	3.00	8.42	11.42
				2a	25.48	25.08	25.11	25.08	25.28	25.51	25.58	25.29	24.57	25.58	3.00	8.42	11.42
				1a	21.22	20.82	20.85	20.82	21.02	21.25	21.32	21.03	20.31	21.32	3.00	12.68	15.68

1a=1 year drought 1960/61 2a=2 year synthetic drought +demand restrictions 2b=no demand restrictions 3a=3 year synthetic drought

Table B6.2.1 Storage Allocation for Reservoirs in the Mejerda Basin (3/3)

		Characteristic volumes (Mm3)		Storage volumes at the beginning of the month (Mm3)											Flood storage volumes (Mm3)		
Dam	Year	Total Storage HWL	Total storage NWL	Scenario	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Max	Designed (NWL to HWL)	Additional (below NWL)	Total
Sidi Salem	2010	959.48	674.00	3a	413.29	402.17	408.16	417.25	453.08	552.95	600.33	590.74	549.10	600.33	285.48	73.67	359.15
				2b	326.39	315.27	321.26	330.34	366.18	466.05	513.42	503.84	462.19	513.42	285.48	160.58	446.06
				2a	326.39	315.27	321.26	330.34	366.18	466.05	513.42	503.84	462.19	513.42	285.48	160.58	446.06
				1a	239.49	228.37	234.36	243.44	279.27	379.15	425.52	415.93	374.29	425.52	285.48	248.48	533.96
	2020	959.48	674.00	3a	513.70	499.34	499.60	503.22	534.08	635.88	674.00	664.38	623.97	674.00	285.48	-	285.48
				2b	433.54	419.19	419.45	423.07	453.77	554.63	596.52	586.26	545.26	596.52	285.48	77.48	362.96
				2a	433.54	419.19	419.45	423.07	453.77	554.63	596.52	586.26	545.26	596.52	285.48	77.48	362.96
				1a	326.67	312.32	312.58	316.20	346.90	447.76	489.65	479.39	438.39	489.65	285.48	184.35	469.83
	2030	959.48	674.00	3a	527.20	509.87	505.22	504.40	531.04	632.60	670.63	657.04	614.38	670.63	285.48	3.37	288.85
				2b	527.20	509.87	505.22	504.40	530.50	631.36	669.39	655.80	613.14	669.39	285.48	4.61	290.09
				2a	502.73	485.41	480.75	479.94	506.03	606.89	644.92	631.33	588.67	644.92	285.48	29.08	314.56
				1a	380.39	363.07	358.42	357.60	383.70	484.56	522.58	509.00	466.34	522.58	285.48	151.42	436.90
Lakhmes	2010	8.36	7.22	3a	7.22	7.08	6.64	6.24	6.22	6.58	6.59	6.45	6.44	7.22	1.14	-	1.14
				2b	7.22	7.08	6.64	6.24	6.22	6.58	6.59	6.45	6.44	7.22	1.14	-	1.14
				2a	7.22	7.08	6.64	6.24	6.22	6.58	6.59	6.45	6.44	7.22	1.14	-	1.14
				1a	5.11	4.97	4.53	4.13	4.11	4.46	4.48	4.34	4.33	5.11	1.14	2.11	3.25
	2020	8.36	7.22	3a	7.22	7.11	6.71	6.35	6.33	6.69	6.71	6.59	6.58	7.22	1.14	-	1.14
				2b	7.22	7.11	6.71	6.35	6.33	6.69	6.71	6.59	6.58	7.22	1.14	-	1.14
				2a	7.22	7.11	6.71	6.35	6.33	6.69	6.71	6.59	6.58	7.22	1.14	-	1.14
				1a	5.44	5.33	4.93	4.57	4.55	4.91	4.93	4.81	4.80	5.44	1.14	1.78	2.92
	2030	8.36	7.22	3a	7.22	7.13	6.77	6.44	6.43	6.78	6.81	6.71	6.70	7.22	1.14	-	1.14
				2b	7.22	7.13	6.77	6.44	6.43	6.78	6.81	6.71	6.70	7.22	1.14	-	1.14
				2a	7.22	7.13	6.77	6.44	6.43	6.78	6.81	6.71	6.70	7.22	1.14	-	1.14
				1a	5.53	5.44	5.08	4.75	4.74	5.10	5.13	5.03	5.02	5.53	1.14	1.69	2.83
Siliana	2010	125.05	70.00	3a	70.00	68.72	66.47	64.82	64.87	66.08	65.75	64.68	64.90	70.00	55.05	-	55.05
				2b	70.00	68.72	66.47	64.82	64.87	66.08	65.75	64.68	64.90	70.00	55.05	-	55.05
				2a	70.00	68.72	66.47	64.82	64.87	66.08	65.75	64.68	64.90	70.00	55.05	-	55.05
				1a	47.56	46.28	44.04	42.39	42.44	43.64	43.31	42.24	42.46	47.56	55.05	22.44	77.49
	2020	125.05	70.00	3a	70.00	68.85	66.80	65.34	65.42	66.63	66.34	65.37	65.59	70.00	55.05	-	55.05
				2b	70.00	68.85	66.80	65.34	65.42	66.63	66.34	65.37	65.59	70.00	55.05	-	55.05
				2a	70.00	68.85	66.80	65.34	65.42	66.63	66.34	65.37	65.59	70.00	55.05	-	55.05
				1a	54.30	53.15	51.10	49.63	49.72	50.93	50.64	49.67	49.89	54.30	55.05	15.70	70.75
	2030	125.05	70.00	3a	70.00	68.97	67.09	65.80	65.92	67.13	66.88	65.99	66.21	70.00	55.05	-	55.05
				2b	70.00	68.97	67.09	65.80	65.92	67.13	66.88	65.99	66.21	70.00	55.05	-	55.05
				2a	70.00	68.97	67.09	65.80	65.92	67.13	66.88	65.99	66.21	70.00	55.05	-	55.05
				1a	61.40	60.37	58.50	57.20	57.32	58.53	58.28	57.40	57.62	61.40	55.05	8.60	63.65
R'Mil	2010	6.00	4.00	3a	4.00	3.94	3.64	3.39	3.43	3.75	3.76	3.67	3.73	4.00	2.00	-	2.00
				2b	4.00	3.94	3.64	3.39	3.43	3.75	3.76	3.67	3.73	4.00	2.00	-	2.00
				2a	3.00	2.94	2.64	2.39	2.43	2.75	2.76	2.67	2.73	3.00	2.00	1.00	3.00
				1a	-	-	-	-	-	-	-	-	-	-	2.00	4.00	6.00
	2020	6.00	4.00	3a	4.00	3.96	3.69	3.47	3.51	3.83	3.86	3.77	3.84	4.00	2.00	-	2.00
				2b	4.00	3.96	3.69	3.47	3.51	3.83	3.86	3.77	3.84	4.00	2.00	-	2.00
				2a	4.00	3.96	3.69	3.47	3.51	3.83	3.86	3.77	3.84	4.00	2.00	-	2.00
				1a	2.95	2.91	2.64	2.42	2.46	2.78	2.81	2.72	2.79	2.95	2.00	1.05	3.05
	2030	6.00	4.00	3a	4.00	3.98	3.73	3.54	3.58	3.91	3.94	3.87	3.93	4.00	2.00	-	2.00
				2b	4.00	3.98	3.73	3.54	3.58	3.91	3.94	3.87	3.93	4.00	2.00	-	2.00
				2a	4.00	3.98	3.73	3.54	3.58	3.91	3.94	3.87	3.93	4.00	2.00	-	2.00
				1a	2.95	2.93	2.68	2.49	2.53	2.86	2.89	2.82	2.88	2.95	2.00	1.05	3.05

1a=1 year drought 1960/61   2a=2 year synthetic drought +demand restrictions   2b=no demand restrictions   3a=3 year synthetic drought

Figures

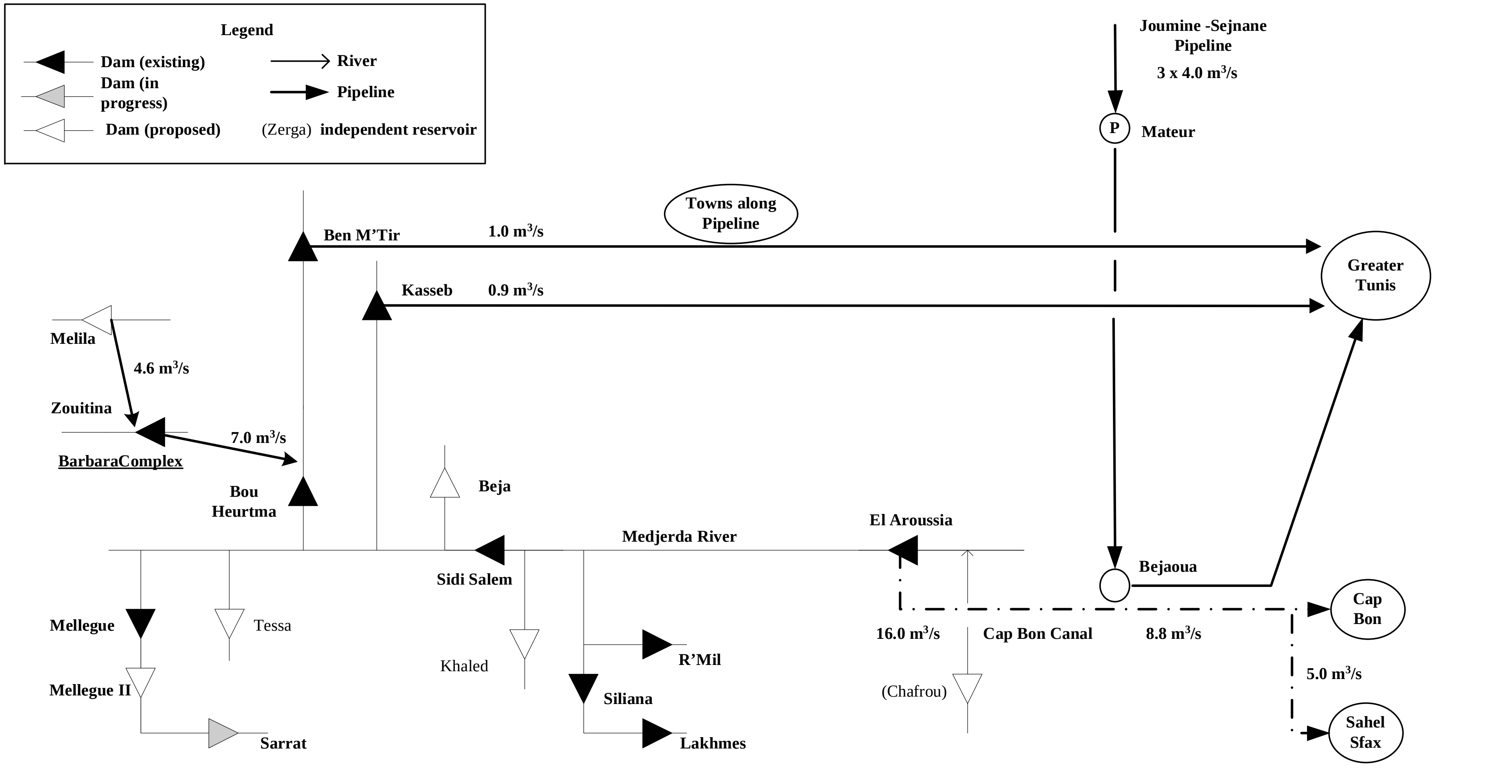


Figure B3.2.1 Schematic Diagram of Dams and Water Transfer Schemes of the Mejerda River Basin

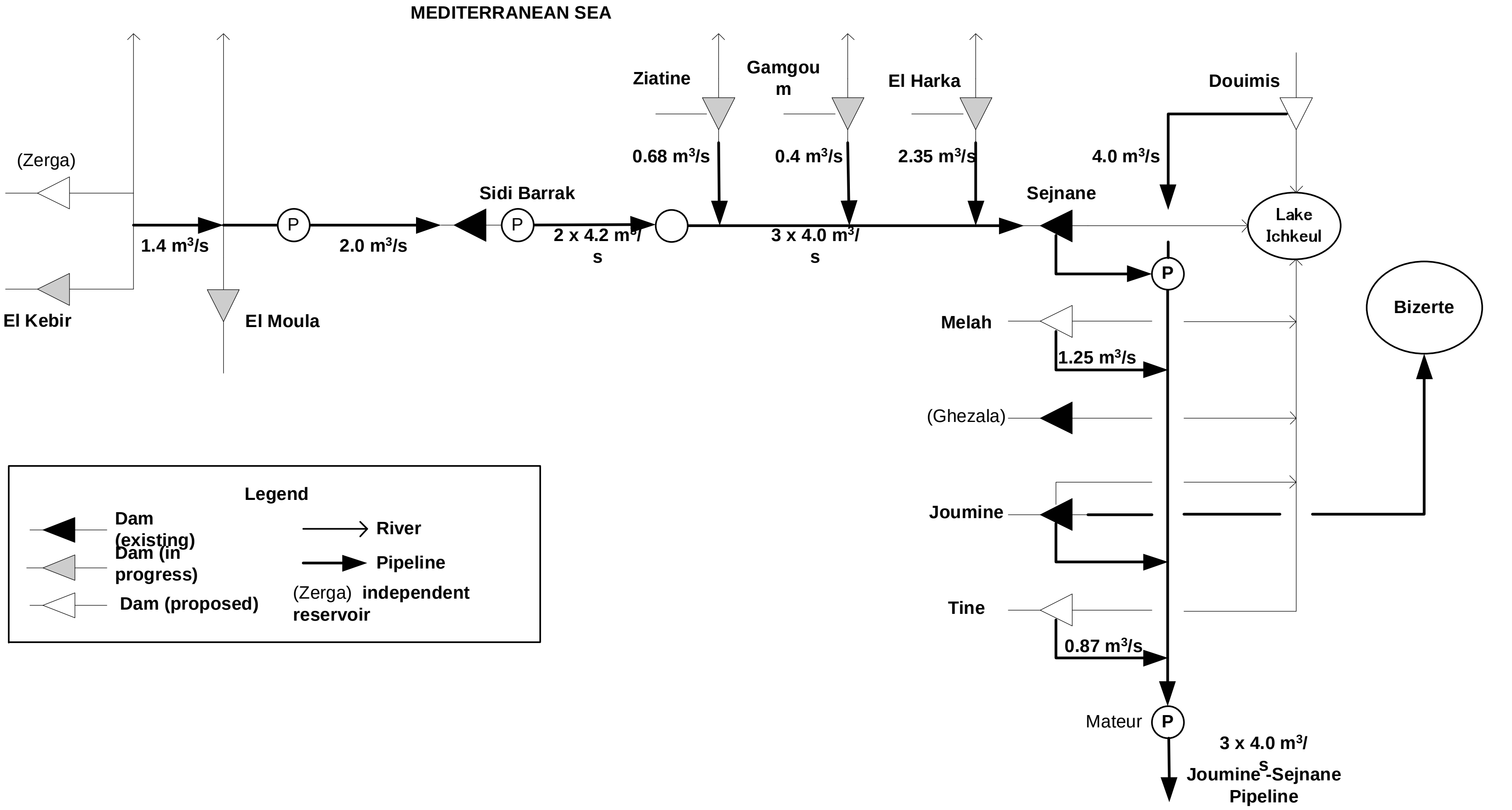


Figure B3.2.2 Schematic Diagram of the Dams and Water Transfer Schemes of the Extreme North

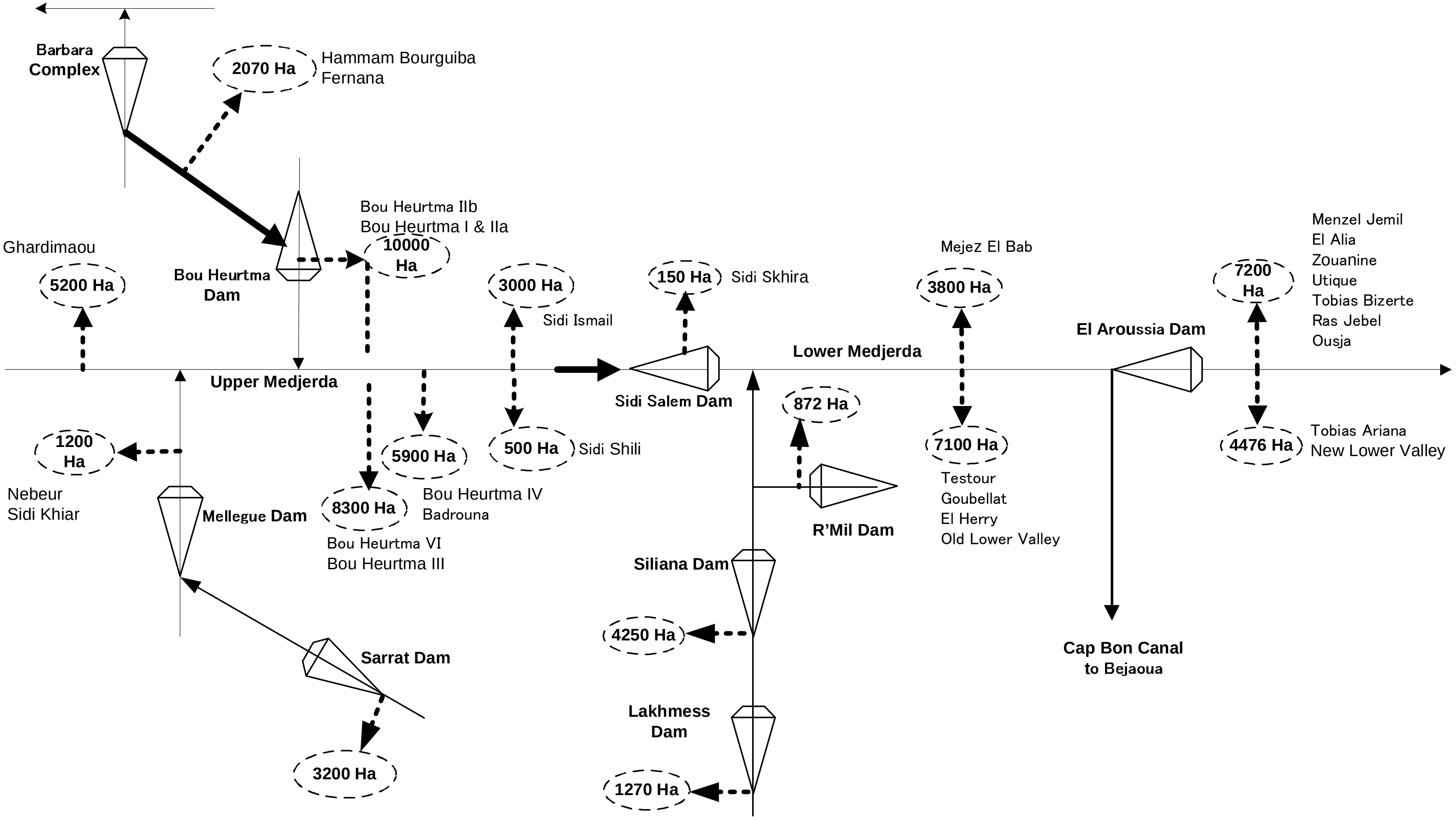
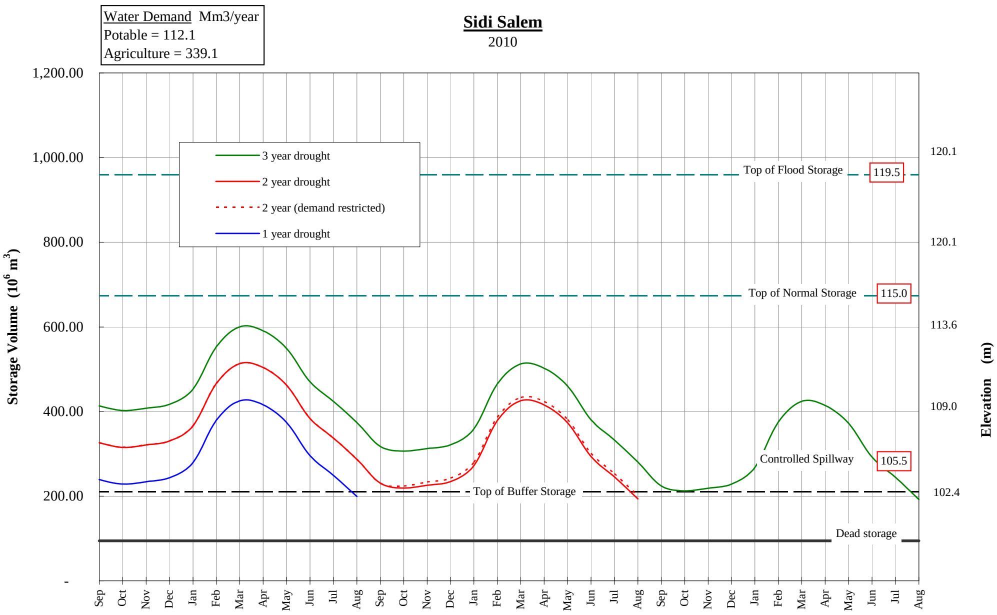
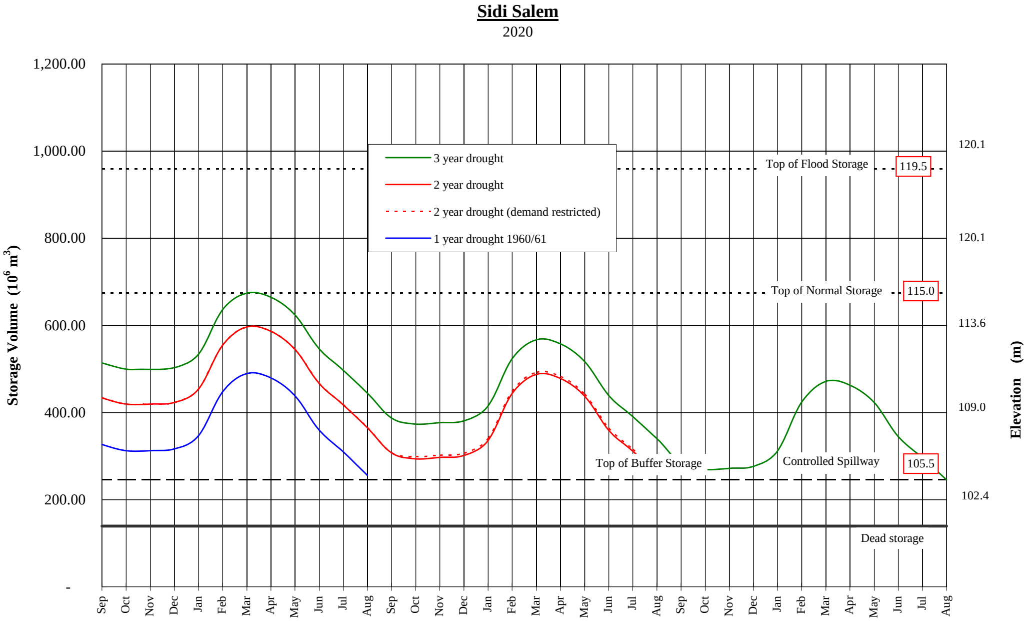


Figure B4.2.1 Irrigation Schemes in the Mejerda River Basin





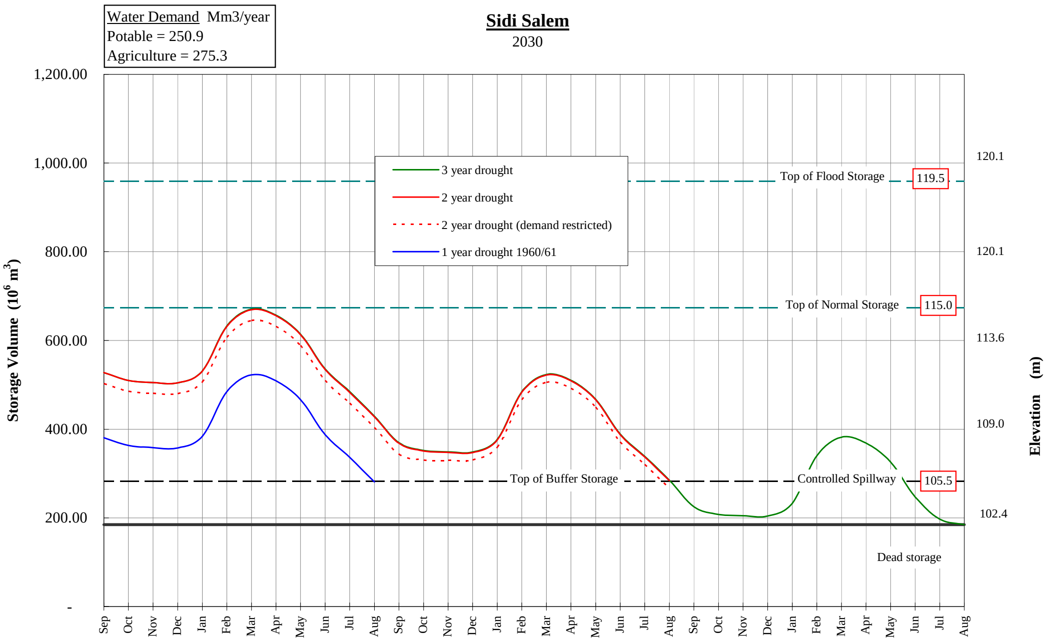


Figure B6.1.1 Reservoir Simulation in Bain-wide Water Balance Analysis

Supporting Report C

RESERVOIR OPERATION

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

FINAL REPORT

Supporting Report C : Reservoir Operation

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CHAPTER C1 INTRODUCTION

Nine (9) dams/reservoirs were constructed in the Mejerda River basin in the last 50 years and other six (6) are under construction or in a design/planning stage. However, the details of reservoir operation rules for flood events have not been formally documented as an operation standard or manual in Tunisia. The guidelines entitled “Flood Management of Main Rivers in Tunisia and Operation of Hydraulic Facilities” were prepared by DGBGTH [1] in year 1988, but at present are not much used.

Currently, the general framework of reservoir operation has been determined among stakeholder organizations in consideration of storage conditions of other related dams, rainfalls, flood discharges, overall conditions of the river system concerned, etc., and actual reservoir operation is owed to experiences and decision of the operation staff at site.

In principle, only two reservoirs, namely the Mellegue Reservoir constructed in 1954 and the Sidi Salem Reservoir in 1981, were built in the Mejerda River basin mainly for the purpose of flood control. It means that not every reservoir in the Mejerda River basin can significantly contribute to flood mitigation or flood protection. Therefore, using some criteria in relation to a size of flood control storage, a catchment area of reservoir and facilities for effective flood control, 7 important reservoirs have been chosen in this study for analysis and evaluation of optimum operation during floods.

For evaluation of reservoir operation and flood routing in river channels, was prepared a mathematical model by using software for water management analytical tool.

Analysis of reservoir operation has been done for the current stage of reservoirs and for the reservoir stages of three target years (2010, 2020 and 2030) in the cases of floods of 2, 5, 10, 20, 50, 100 and 200 year return periods.

The results of reservoir operation analysis have given information about behavior and response of the whole Mejerda River basin on the respective floods. Optimum operations of each reservoir under different flood conditions have been studied and limitations of flood mitigation by reservoir were scrutinized. The study has arrived at the conclusion that the 7 selected reservoirs should be operated as one coordinated system of reservoir operation, in other words a coordinated operation system.

Moreover, reservoir operation analysis was conducted to estimate probable discharges released from reservoirs for flood protection plan of river channel. The fundamental rules for reservoir operation were formulated and effect of reservoir pre-release based on discharge/rainfall monitoring and forecast was also evaluated. Furthermore, operation principles and basic operation rules for each reservoir were derived and effectiveness of cooperated operation of reservoirs was discussed.

CHAPTER C2 MAIN CHARACTERISTICS OF DAMS AND RESERVOIRS IN MEJERDA RIVER BASIN

C2.1 Overview of Reservoirs in Mejerda River Basin

Currently 9 dams are in operation in the Mejerda River basin; one of them, namely Laroussia Dam, is only a high weir, providing backwater for water offtake for the Cap Bon Canal and the Mejerda Canal. There are six dams under construction or in a design/planning stage in the basin now. Therefore, totally 14 reservoirs, as tabulated below, are taken into account in water supply and flood control analysis in this study.

Reservoirs in Mejerda River Basin

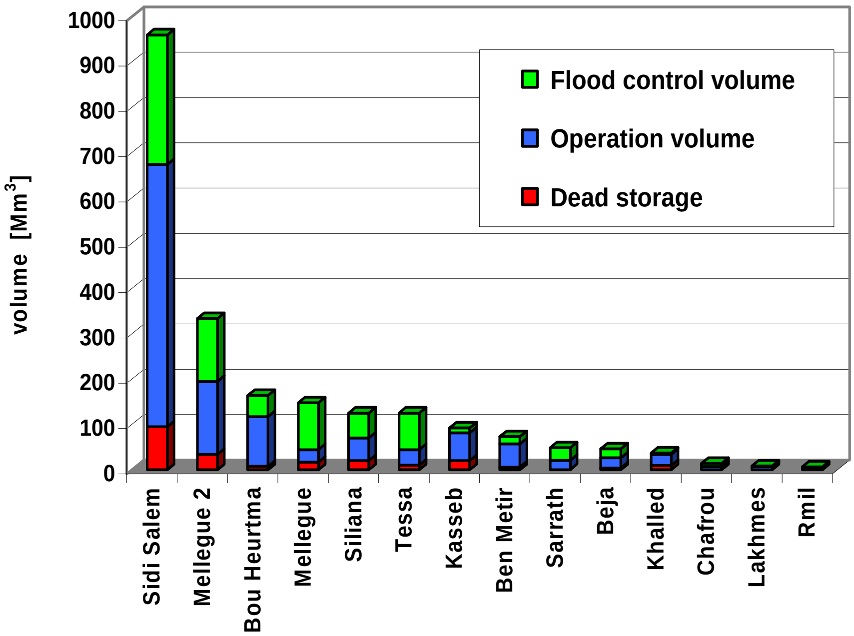
Name of dam	Catchment area (km^2)	Normal water level		Maximum water level		
		Elevation (m)	Actual TOTAL capacity (Mil. m^3)	Elevation (m)	TOTAL Volume (Mil. m^3)	Flood control volume (Mil. m^3)
Sidi Salem	18,191	115.00	674.0	119.50	959.5	285.5
*Mellegue 2**	*10,100*	*295.00*	*195.0*	*304.00*	*334.0*	*139.0*
Bou Heurtma	390	221.00	117.5	226.00	164.0	46.5
Mellegue	10,309	260.00	44.4	269.00	147.5	103.1
Siliana	1,040	388.50	70.0	395.50	125.1	55.1
*Tessa**	*1,420*	*361.00*	*44.4*	*369.00*	*125.0*	*80.6*
Kasseb	101	292.00	81.9	294.40	92.6	10.7
Ben Metir	103	435.10	57.2	440.00	73.4	16.2
*Sarrath**	*1,850*	*546.00*	*21.0*	*552.00*	*48.5*	*27.6*
*Beja**	*72*	*230.00*	*26.4*	*234.00*	*46.0*	*19.6*
*Khalled**	*303*	*207.00*	*34.0*	*213.60*	*37.0*	*3.0*
*Chafrou**	*217*	*49.00*	*7.0*	*51.00*	*14.0*	*7.0*
Lakhmes	127	517.00	7.2	521.20	8.4	1.2
Rmil	232	285.00	4.0	288.00	6.0	2.0

Note: * under construction or in design/planning stage
Source: MARH

The above table shows the designed reservoir normal water level, its corresponding storage volume, the designed maximum water level and its resultant flood control storage for each reservoir. The substantial part of designed flood control storages, namely 729 mil. m^3 (91.4 %), is provided in the reservoirs of the Sidi Salem Dam and its upstream dams. The flood control operation and cooperated operation of these reservoirs has crucial importance in the light of flood situation and flood propagation in the Mejerda River from Testour up to the estuary. More detailed data on these 14 reservoirs are compiled in **Table C2.1.1**.

In principle, only two reservoirs in the Mejerda River basin, the Mellegue Reservoir (1954) and the Sidi Salem Reservoir (1981), were built mainly for the purpose of flood control. The main purpose of other reservoirs (and also the Sidi Salem Reservoir) is to meet water demand in the northern Tunisia together with 9 reservoirs (Sidi El Barrak, Sejnane, Joumine and other six reservoirs) situated in the extreme north area of Tunisia close to the Mediterranean Sea.

The storage volume of each reservoir, as well as division of the volume into dead storage (which cannot be used for any purposes), operation volume (for water supply) and flood control storage are as presented below.



Storages of Reservoirs in Mejerda River Basin

The biggest reservoir in the Mejerda River basin is the Sidi Salem Reservoir with a total storage volume of 960 mil. m^3 at the maximum water level. It is also the most important reservoir from a viewpoint of flood control: the designed flood control storage is about 286 mil. m^3. Owing to the flood control storages (103 mil. m^3) at the Mellegue Dam and its ability to effectively control the outflow from the reservoir by gate operation, the Mellegue Dam also can significantly influence the discharge downstream of the dam.

Other dams are mainly equipped with uncontrolled spillways only and are operated with a normal water level at an uncontrolled spillway crest level, i.e. their flood control storage cannot be sufficiently controlled. In spite of this fact, some mid-scale dams built on tributaries contribute to attenuate flood peaks to some extent and reduce flood damage along the Mejerda River, although flood control effects are rather less significant than the two largest reservoirs, the Sidi Salem and the Mellegue Dams as mentioned above.

The Ben Metir, Bou Heurtma and Kasseb Reservoirs can significantly reduce the magnitude of flood flow in Bou Salem City, which is located in the area which has been most seriously affected by flood inundation in the Mejerda River basin. In addition to the Sidi Salem Reservoir, the Siliana Reservoir can retard the peaks of flood discharge flowing into the Mejerda mainstream downstream of the Sidi Salem Dam.

C2.2 Real Operation of Reservoirs with Controlled/Uncontrolled Spillway

Through analyzing historical operation records collected from dam sites, it is found that the past maximum water level almost never reached the designed maximum water level as shown below. It means that the designed flood control storages have not been used completely even during past severe floods (e.g. flood from year 2003).

Historical Maximum Values at Existing Reservoirs

Name of dam	Spillway	Maximum water level		Historically maximum events		
		Elevation (m)	Designed flood control volume (Mil. m^3)	Water level (m)	Flood control volume (Mil. m^3)	Used FCV / designed FCV
Sidi Salem	cont. / uncont.	119.50	285.5	117.50	156.0	55%
Mellegue	controlled	269.00	103.1	268.70	98.6	96%
Siliana	uncontrolled	395.50	55.1	389.70	7.1	13%
Bou Heurtma	uncontrolled	226.00	46.5	222.00	8.4	18%
TOTAL			490.2		270.1	55%

There are many reasons why only a part of flood control storage was used for retarding flood discharge in the reservoir. However, it is in fact impossible to store flood water at a higher water level (e.g. close to maximum water level) at any discharge in reservoir with an uncontrolled spillway. The actually maximum water level (and also actually maximum flood control storage) depends completely on inflow discharge into a reservoir in an uncontrolled spillway case.

It can be seen from the table above that e.g. only 13 % of designed flood control storage of the Siliana Reservoir was used for flood control in December 2003 and roughly 18 % in the cases of the Bou Heurtma Reservoir in January 2003. Both dams are equipped with uncontrolled spillways only. There are 2 kinds of spillways at the Sidi Salem Dam: the main spillway is controlled by 3 gates and the second one (morning glory type spillway) is uncontrolled. However, the discharge capacity of morning glory type spillway is not so big (700 m^3/s; comparable with typical flood peak discharge in Mejerda River at this site): the low capacity of morning glory type spillway enables water level to increase and consequently a large amount of flood control storage is used during flood events, e.g. 55 % of designed flood control storage in January 2003.

On the other hand, there is only a controlled spillway at the Mellegue Dam and that is why all outlets of the reservoir (spillway, bottom outlet, etc.) can be fully controlled during flood. As seen in the table above, almost all designed flood control storage (98.6 mil.m^3 = 96 % of designed flood control storage) was used for successful decrease of peak discharge in December 2003.

According to the above discussion, it is evident that only a part (roughly one half) of designed flood storages in the whole Mejerda River basin can be used for effective flood control, which depends on excess probability of the flood, spatial distribution of the flood and on many other factors. However, some additional flood control storages (bellow spillway crest level) at some reservoirs would be really appreciable, as discussed hereafter.

CHAPTER C3 METHODOLOGY FOR EVALUATION OF FLOOD CONTROL ABILITY OF RESERVOIRS

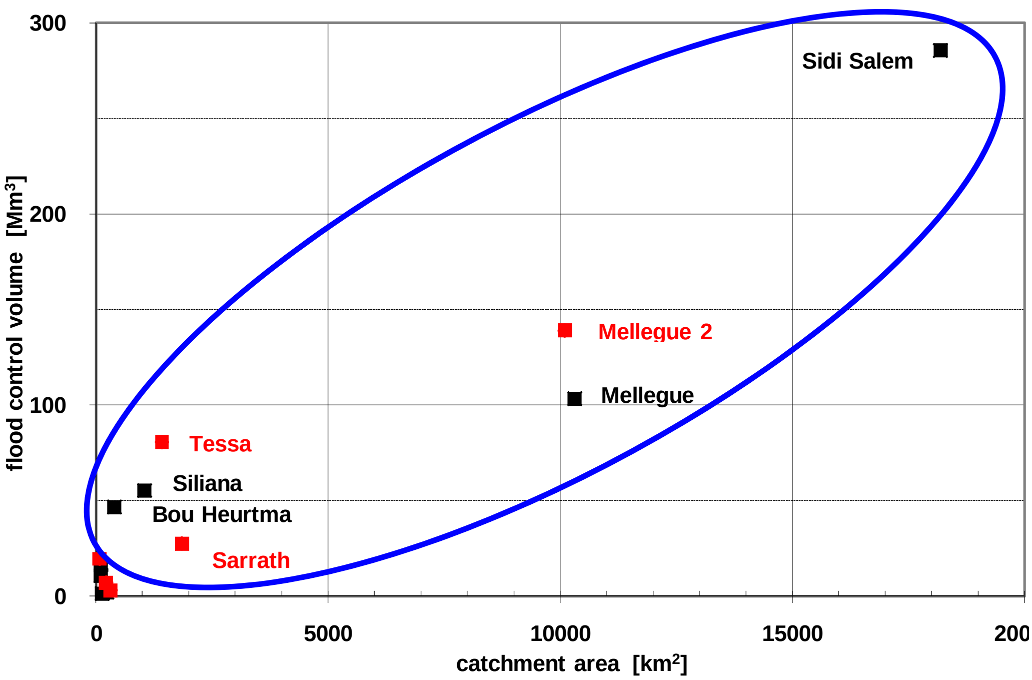
C3.1 Selection of Important Reservoirs for Effective Flood Control

C3.1.1 Criteria for Selection of Reservoirs for Effective Flood Control

Not every reservoir in the Mejerda River basin can effectively contribute to flood mitigation or flood protection. As the sizes and purposes of the reservoirs which are already constructed, under construction or in a planning stage only in the Mejerda River basin differs significantly from one another, their efficiency of flood control was evaluated according to the following criteria:

- Flood control storage volume,
- Catchment area of reservoir (because the flood peak discharge and flood volume depends on the catchment area wherein a flood is produced), and
- Dam facilities for effective flood control (e.g. possibility to control outflow from the reservoir through a spillway equipped with gates, capacity of a spillway, capacity of a bottom outlet, etc.).

Using these criteria, all reservoirs in the Mejerda River basin were plotted in one diagram. The most important reservoirs from a viewpoint of flood control are situated in the upper-right corner and the reservoirs which cannot substantially influence outflow from the catchment area are in the lower-left corner of this diagram.



Flood control Storages of Reservoirs in Mejerda River Basin

C3.1.2 Selected Important Reservoirs for Effective Flood Control

According to the aforementioned criteria, 7 reservoirs (4 existing: Sidi Salem, Mellegue, Bou Heurtma and Siliana Reservoirs and 3 planned or under construction: Mellegue 2, Tessa and Sarrath Reservoirs) have been chosen for further analysis and evaluation of operation rules during floods. The total designed flood control storage of the 7 reservoirs is 518 mil. m^3 (year 2010), 554 mil. m^3 (year 2020) and 634 mil. m^3 (year 2030), which represent roughly 91 to 95 % of the flood control storage of all reservoirs in Mejerda River basin when reservoir development up to the target year 2030 is considered. Other reservoirs are eliminated in the succeeding study on flood control due mainly to too small flood control storage and/or catchment area. This is in fact the reason why the Beja Reservoir, for example, has not been selected: it has a relatively big flood control storage (19.6 mil. m^3), but the catchment area of 72 km^2 can hardly create some bigger floods which would substantially effect flow in Mejerda River.

Reservoirs in Mejerda River Basin Chosen for Evaluation of Flood Control Function

Name of dam	Catchment area (km2)	Spillway	Maximum high water level				
			Elevation (m)	TOTAL Volume (Mil. m^3)	Designed flood control volume (Mil. m^3)		
					year 2010	year 2020	year 2030
Sidi Salem	18,191	cont. / uncont.	119.50	959.5	285.5	285.5	285.5
Mellegue	10,309	controlled	269.00	147.5	103.1		
Siliana	1,040	uncontrolled	395.50	125.1	55.1	55.1	55.1
Bou Heurtma	390	uncontrolled	226.00	164.0	46.5	46.5	46.5
Mellegue 2*	10,100	uncontrolled	304.00	334.0		139.0	139.0
Tessa*	1,420	uncontrolled	369.00	125.0			80.6
Sarrath*	1,850	uncontrolled	552.00	48.5	27.6	27.6	27.6
T O T A L					517.8	553.6	634.2
In all reservoirs in Mejerda catchment					547.9	583.7	693.9
In chosen reservoirs					95%	95%	91%

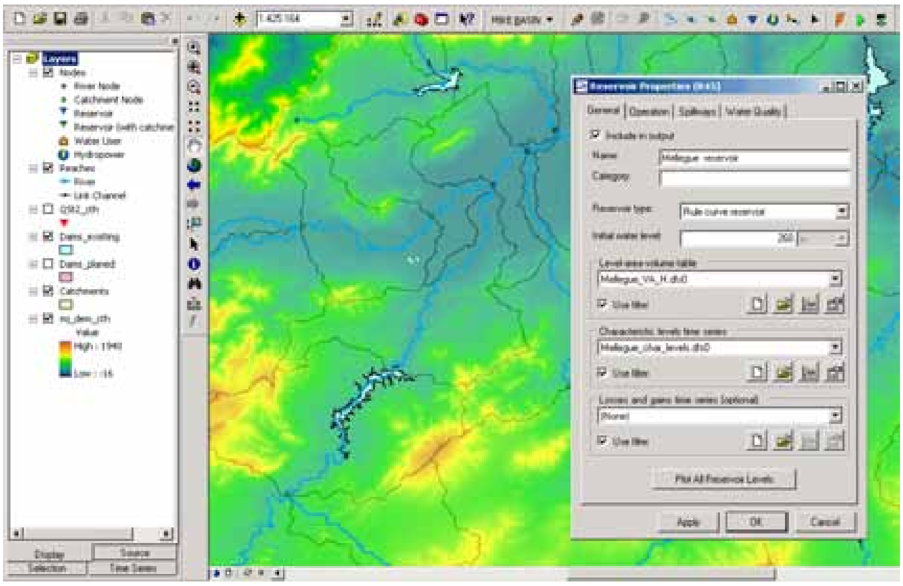
Note: * under construction or in design/planning stage

The 7 reservoirs above could control the outflow from important and relatively large catchment areas: the smallest catchment area is 390 km^2 for the Bou Heurtma Reservoir, and are expected to significantly influence flood routing and flood conditions in the whole Mejerda River basin.

C3.2 Mathematical Model for Reservoir Operation Analysis

C3.2.1 Description of Reservoir Operation Model

For the study on reservoir operation of the 7 chosen reservoirs, a mathematical model was prepared by using software MIKE Basin (developed by DHI Water & Environment & Health, Denmark). MIKE Basin is a water management analytical tool, combining ArcGIS with water resources modeling simulation tools. For hydrological simulations, including reservoir operation, MIKE Basin builds on a network model in which branches represent individual river reaches and the nodes represent confluences, diversions, reservoirs, or water users (see the figure below). Technically, MIKE Basin is a quasi-steady-state mass balance model, however allowing for routed river flows also.



MIKE Basin Model for Mejerda River Basin

C3.2.2 Model Calibration for Mejerda River Basin

The mathematical model of reservoirs and river reaches in the whole Mejerda River basin prepared by using MIKE Basin software was calibrated based on records of historical floods at dams and gauging stations. The most complete and useful data sets are coming from floods in May 2000, in January up to February 2003 and in December 2003 up to January 2004, and then these flood event data were used for calibration.

Calibration of river reaches in MIKE Basin models means finding of flood routing equations parameters which cause the same or very close flood waves propagation and reduction of flows computed by model as observed in the field. MIKE Basin model offers four options for describing the translation of flow in river reach (i.e. between two “nodes” of river model):

- no routing
- linear reservoir routing
- Muskingum routing
- wave translation

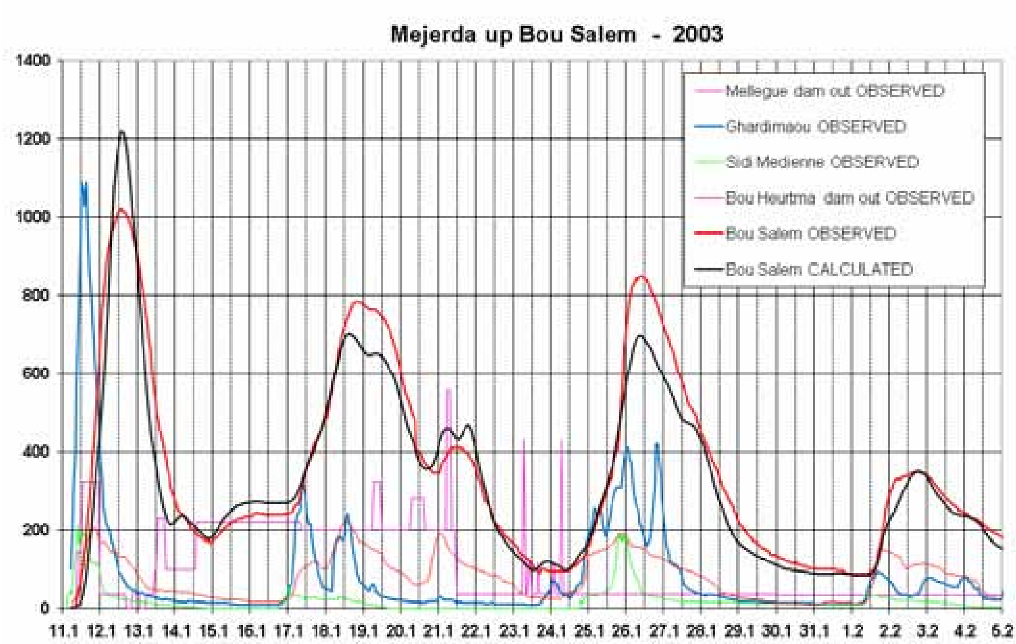
Depending on the method selected, two parameters describing the flow delay and the hydrograph shape should be specified. It is important to take into account flood routing when there is a significant delay and smoothing in the hydrograph between two nodes.

The muskingum flood routing method is commonly used for river reaches of the MIKE Basin model of the Mejerda River basin. Only several steep river reaches (the upper Sarrath or Tessa Rivers) have been calibrated by using the “wave translation” method.

The calculated discharge hydrographs in the most important cross sections (at gauging stations or dam sites) are compared with really observed discharge hydrographs, as seen below, for the Bou Salem gauging station as an example case. It could be seen in the following figure, that the calculated hydrograph coincides with the observed one relatively well. For quantitative evaluation, the following criteria are employed:

- Convergence of flood propagation times:
  Replication of observed time with difference < 10 % (at maximum)
- Convergence of discharge values:
  Replication of observed discharges with difference of peak discharge < 20 % (at maximum)

These criteria have been fulfilled in the simulation at the Bou Salem gauging station and also for all other study sites with small exceptions only which can be neglected. Therefore, the mathematical model developed for the study describes flood routing and flood wave propagation properly and has been used for analysis on reservoir operation and optimization of operation rules during floods.



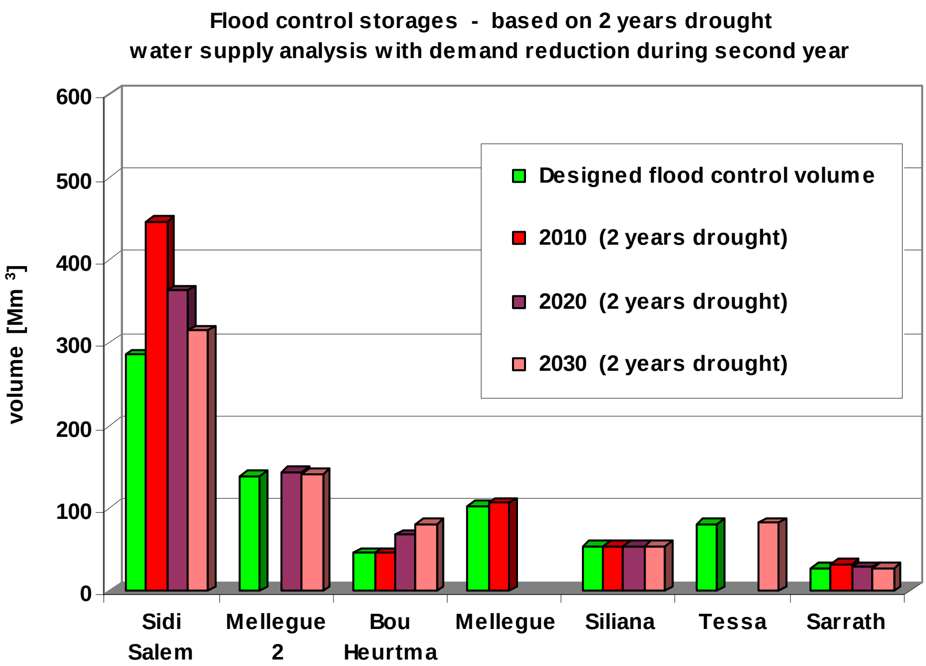
Calibration of MIKE Basin Model – Bou Salem Gauging Station

CHAPTER C4 OPTIMIZED RESERVOIR OPERATION

C4.1 Necessity of Optimized Reservoir Operation

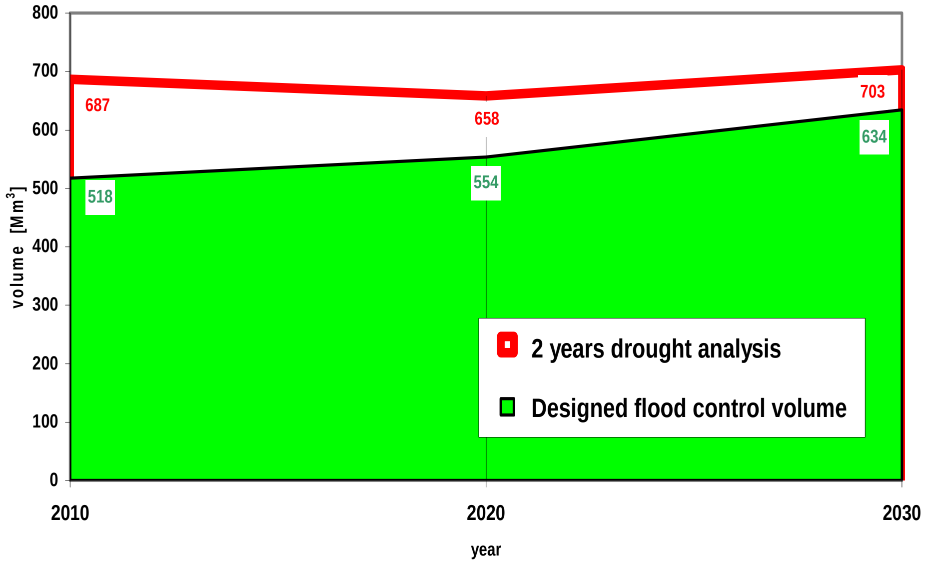
As mentioned in Chapter C2.2, the full capacity of designed flood control storage cannot be practically used at most existing reservoirs for mitigating flood flow. In addition, many reservoirs are equipped with uncontrolled spillways (non-gated spillways) only and hence are operated for flood control with the normal water levels (NWLs) correspondent to the uncontrolled spillway crest levels; in other words, the designed flood control storage provides only flood control function without any flexible regulation through gate operation.

Based on the above understanding, the key to improving flood control by dams is to find some additional flood control storage for each reservoir permanently or even temporarily. The additional flood control storage which could be secured bellow the spillway crest can be made usefully used by operating a bottom outlet(s).



Possible Increase of Flood Control Storages in Important Reservoirs

Comprehensive water supply analysis has been done (see Supporting Report B) and its results showed that some additional flood control storages can be found at some reservoirs. The possible increase of flood control storages for chosen reservoirs is seen in the figure above for the target years 2010, 2020 and 2030. In this figure, designed flood control storage and increased ones (based on 2 years drought water supply analysis) are compared for each reservoir. It is evident that only for the Sidi Salem and Bou Heurtma Reservoirs, some significantly additional flood control storage can be found if 2 years consecutive drought is taken as a base for water supply analysis. The total increase of flood control storages in all 7 chosen reservoirs is as drawn below. The total flood control storage could be increased up to 687 mil. m^3 in year 2010 (by 33 %) and up to 703 mil. m^3 in target year 2030 (by 11 %).



Possible Increase of Flood Control Storage in 7 Chosen Reservoirs

This is one secret for optimized operation of dams, which could be strongly supported by well-timed releasing from a reservoir (at the beginning of flood or even before flood) within a limitation up to the "flow capacity" of its downstream river course. The flow capacity of the Mejerda River and its tributaries (the Mellegue, Tessa, Bou Heurtma, Siliana Rivers, etc.) differs from site to site along the river courses. The Study estimated that the current flow capacity ranges between 200 and 400 m^3/s only in many river reaches, Any discharge higher than the capacity causes riverbank overflowing and spreading out into flood plains.

To make a decision about reservoir release, it is necessary to optimize the release based on information about the inflow from the upstream, several rainfall/water level gauging stations in the downstream and knowledge of flood propagation times to the downstream. Furthermore, it is necessary to determine the release so as to prevent flood peaks of two or more subbasins from joining at one site. This is another secret, which could be supported by well coordinated dam operation.

The effective use of available flood control storage including additional storage, and coordination of dam operation has a crucial importance for flood control in the Mejerda River basin in view of the hydrological characteristics in the basin regarding a flood runoff mechanism and flood propagation.

Currently, detailed rules of reservoir operation during floods have not been formally documented as operation standards or manuals in Tunisia. Guidelines entitled "Flood Management of Main Rivers in Tunisia and Operation of Hydraulic Facilities" were prepared by DG/BGTH in year 1988, but at present are not usefully employed to actual operation of flood related facilities even though some nomograms can be used for determining outflows from reservoirs according to actual inflows and water levels. Besides, though a general framework of reservoir operation is commonly determined among stakeholder organizations concerned in due consideration of storage conditions of other dams, regional rainfalls, overall conditions of the river system concerned, etc., actual reservoir operation depends on experiences and ad hoc decisions of the operation staff at site.

In view of the state above, it is essential to introduce an optimized operation system of dams based on firm and reasonable operation rules backed up by computerized mathematical models of flood forecast and reservoir simulation so as to effectively and efficiently minimize flood discharges in the Mejerda River basin.

C4.2 Fundamental Rules for Optimized Reservoir Operation

There are many factors which have to be considered during preparation of reservoir operation rules and making decisions of operation. The 14 reservoirs (8 existing and 6 under construction or in a design/planning stage) in the Mejerda River basin have established in fact a water management structure. And all these reservoirs must be operated as one structure, i.e. a coordinated one. Thus, it is necessary to provide fundamental rules and follow the rules at any time to realize an optimum dam operation including coordination, for the most effective flood control and for successful water supply as well.

All reservoirs in the Mejerda River basin are recommended to be operated during flood events based on decision by one control center, which is to be continuously supplied all necessary “on-line“ information (discharges in gauging stations, current status and operations at all dams, discharge forecast, rainfall forecast, etc.). Control and making decisions by one center can provide the most practical and effective coordination of dams; operations are not done separately based on the inflow at each reservoir, but are done consistently according to hydrological situation in the whole Mejerda River basin. The dam operators do not decide on operations. They only follow decisions of a control center as a rule. However, the operators must be also provided with all information and materials for emergency operation by themselves for the case of failing in connection with the control center.

The main goal of optimum reservoir operation is to use the available flood control storage above the normal water level (NWL) as effectively as possible and to minimize flood peaks downstream of dams. Therefore, the following should be carefully considered as the fundamental rules for reservoir operation:

(a) During non-flood period:

- To keep the water level in reservoirs properly at NWL (actually valid and approved) which is designed for suitable water supply regulation.

(b) During floods:

- The highest priority has to be given to safety of dam in all operations.
- Pre-release of reservoir water
  To lower water level in reservoirs as soon as the information about flood attack is given, by releasing reservoir water equal to the flood discharge anticipated to reach the reservoir during the flood attack up to the flow capacity of the downstream river channels (hereinafter referred to as “the channel capacity”). This pre-release can be determined from the information about observed discharges in upstream reaches of the reservoir or from the results of discharge forecast based on rainfall data.
- Release of reservoir water equal to the channel capacity
  To operate the reservoir in such a way that the downstream river does not overflow for as long a period as possible due to releasing reservoir water.
- Avoidance of flood peaks joining at one site
  To control outflow from the reservoir according to knowledge of flood propagation times downstream of the dams with the aim of avoiding joining of flood peaks from two or more subbasins at one site so as to minimize the flow in the downstream.
- Operating a cascade of reservoirs (e.g. Mellegue and Mellegue 2)
  To fill the upper reservoir with flood water at first and to empty the lower reservoir at first,
- Release of flood control storage for next flood
  After water level culmination in reservoir, the flood control storage must be released for preparation of the next flood. At first, the flood control storage is released by outflow exceeding a little bit inflow into the reservoir: the outflow is continuously decreased. As soon as outflow drops to the channel capacity downstream of the dam, the reservoir water is released with this “channel capacity” discharge (or close – according to situation on tributaries) until a flood control storage is empty.

CHAPTER C5 ANALYSIS OF FLOOD CONTROL ABILITY OF IMPORTANT RESERVOIRS

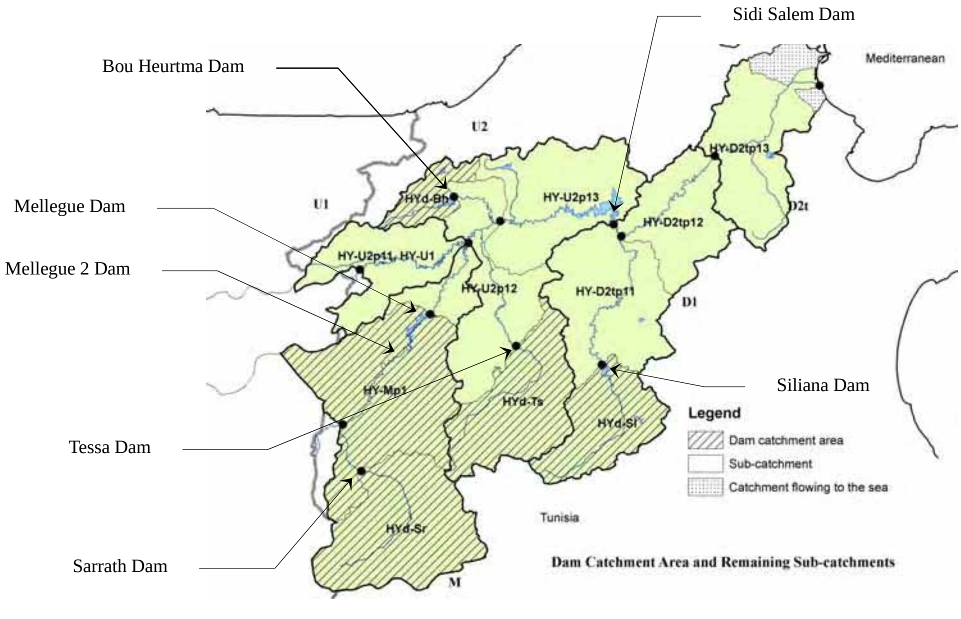
C5.1 General

As mentioned in Sub-section C3.1.1, finally 7 reservoirs (4 existing reservoirs: Sidi Salem, Mellegue, Bou Heurtma and Siliana Reservoirs and 3 reservoirs under construction or in a design/plan stage: Sarrath, Mellegue 2 and Tessa Reservoirs) were selected for analysis of flood control ability in the Mejerda River basin with improvement of reservoir operation during floods.

The analysis was carried out at the following 4 stages of flood control storages in the selected reservoirs:

Stages	Flood control storages
Current stage	originally designed flood control storage (OFCS)
Year 2010 stage	OFCS + additionally available storage straight below OFCS for flood control in water supply security of 2-year consecutive drought with a once in 9 time recurrence under 2010 water demand
Year 2020 stage	OFCS + additionally available storage straight below OFCS for flood control in water supply security of 2-year consecutive drought with a once in 9 time recurrence under 2020 water demand
Target year 2030 stage	OFCS +additionally available storage straight below OFCS for flood control in water supply security of 2-year consecutive drought with a once in 9 time recurrence under 2030 water demand

The analysis has dealt with the floods of 2, 5, 10, 20, 50, 100 and 200 year return periods and the hydrological conditions in the Mejerda River basin for the analysis were taken from the results of flood runoff analysis described in Supporting Report A: Hydrology and Hydraulics. The subdivision in the Tunisian territory of the Mejerda River basin is as shown in the figure below.



Subdivision in Tunisian Territory of Mejerda River Basin for Analysis

The Tunisian territory of the Mejerda River basin consists of:

- 5 sub catchments upstream of existing and/or designed/planned dams,
- 7 sub catchments of the Mejerda River and its tributary sub catchments downstream of the dams, and
- 2 inflows from the Algerian territory.

C5.2 Analysis of Mejerda River with No Dam

Simulation results of "no dams" condition in the Mejerda River basin give us information about response and behavior of the whole Mejerda River basin in a hypothetic situation, in other words before construction of dams and under current conditions of river channels and flood plains. This means that these results describe flood propagation and discharges of floods with different return periods under the situation that "no dam" is built in the whole Mejerda River basin. The results, which are as referred to in **Data C1**, are used for quantification of impact produced by reservoirs on flood flow characteristics.

C5.3 Analysis of Existing Reservoirs in "Current Stage"

The analysis of reservoir operation during floods gives basic information about flood control ability of reservoir to mitigate floods in its downstream river basin. The most important results related to the 4 existing reservoirs, namely the Bou Heurtma, the Siliana, the Mellegue and the Sidi Salem Reservoirs, are discussed hereinafter, which include:

- Peak inflow into each reservoir,
- Peak outflow from the reservoir expressed as a percentage of peak inflow (i) under "standard reservoir operation", which is defined as the reservoir operation carried out in a standard way by using existing spillway and outlet facilities for flood water release and (ii) under optimized reservoir operation, and
- Peak discharge from a tributary at its confluence with the Mejerda River, expressed also as a percentage of the peak discharge computed with "no dam" conditions in the tributary (discussed in Section C5.2).

C5.3.1 Flood Control Ability under Standard Reservoir Operation

(a) **Bou Heurtma** Reservoir (designed flood control storage up to 46.5 mil. m^3)

The Bou Heurtma Dam is equipped with an uncontrolled spillway (crest level: 221.00 m) and the normal water level is currently set at the spillway crest level. The Bou Heurtma Reservoir can rather successfully mitigate the flood peaks downstream of the dam within the whole range of evaluated probable floods, as shown below. Contribution to flood mitigation on the Mejerda River is relatively high: the peak discharge at the confluence of the Mejerda and the Bou Heurtma Rivers represents 55 to 69 % of the original flow coming from the Bou Heurtma River without the Bou Heurtma Dam. The Bou Heurtma Reservoir is also able to safely pass a 200 year flood (max. inflow into the reservoir: 3,390 m^3/s) and to mitigate it significantly.

Flood Control Ability of Bou Heurtma Reservoir

Return period of flood	Max. inflow (m^3/s)	Max. outflow / max. inflow	Peak discharge "with dam" / peak discharge "with no dam" at lower end of Bou Heurtma River
5 years	491	~ 42 %	~ 55 %
10 years	745	~ 46 %	~ 59 %
20 years	1,083	~ 48 %	~ 61 %
50 years	1,732	~ 52 %	~ 66 %
100 years	2,426	~ 54 %	~ 69 %

(b) **Siliana** Reservoir (designed flood control storage up to 55.1 mil. m^3)

The Siliana Dam is equipped with two uncontrolled spillways (main spillway and circle spillway; crest level: 388.50 m each) and the current normal water level is at the spillway crest level. The Siliana Reservoir can also rather successfully mitigate the flood peaks downstream of the dam, but not so effectively as the Bou Heurtma Reservoir even in the case of the floods with lower return periods, as seen below.

Flood Control Ability of Siliana Reservoir

Return period of flood	Max. inflow (m^3/s)	Max. outflow / max. inflow	Peak discharge "with dam" / peak discharge "with no dam" at lower end of Siliana River
5 years	334	~ 56 %	~ 78 %
10 years	508	~ 61 %	~ 80 %
20 years	738	~ 65 %	~ 83 %
50 years	1,180	~ 72 %	~ 87 %
100 years	1,654	~ 74 %	~ 89 %

The spillways of the Siliana Dam were designed for the discharge higher than that of the Bou Heurtma spillway, so that smaller part of flood control storage has been used compared to the Bou Heurtma Dam. Contribution to flood mitigation in the Mejerda River is rather small due to relatively long river reaches from the dam to its confluence with the Mejerda River. The peak discharges at the confluence represents 78 to 89 % of the original flows coming from the Siliana River without the Siliana Dam. The Siliana Reservoir is able to pass a 200 year flood (max. inflow into the reservoir: 2,312 m^3/s) without any problem.

(c) **Mellegue** Reservoir (designed flood control storage up to 103.1 mil. m^3)

The Mellegue Dam is equipped with a controlled spillway (gated spillway with 3 gates) and the current normal water level is at 260.00 m (maximum water level: 269.00). With a relatively big flood control storage and due to "fully controlled" release of flood flow downstream of the dam, the Mellegue Reservoir can excellently mitigate small floods up to the 10 year flood (see the following table). As the returned period of flood gets bigger, the flood control ability of reservoir is smaller; the deduction effect of peak discharge is 7% only in the case of the 100 year flood.

The Mellegue Reservoir is unable to safely pass the flood of 200 year return period (max. inflow into the reservoir: 8,558 m^3/s) under standard reservoir operation. The total release capacity of all spillway facilities and outlets, which is at maximum 5,920 m^3/s at a maximum high water level, is not sufficient and the flood control storage is very quickly filled during such a flood with a max. inflow of 30 mil. m^3/hour. The Mellegue Reservoir is feared to be finally overtopped during the 200 year flood event. In spite of this fact, the Mellegue Reservoir remains a position of the second important reservoir for flood control in Mejerda River basin.

Flood Control Ability of Mellegue Reservoir

Return period of flood	Max. inflow (m^3/s)	Max. outflow / max. inflow	Peak discharge "with dam" / peak discharge "with no dam" at lower end of Mellegue River
5 years	1,262	~ 25 %	~ 31 %
10 years	1,884	~ 32 %	~ 37 %
20 years	2,821	~ 64 %	~ 72 %
50 years	4,452	~ 74 %	~ 84 %
100 years	6,108	~ 93 %	~ 94 %

(d) **Sidi Salem** Reservoir (designed flood control storage up to 285.5 mil. m^3)

The Sidi Salem Dam is equipped with a main controlled spillway with 3 gates and an uncontrolled morning glory type spillway with a crest level of 115.00 m and the current normal water level is 115.0 m. With the biggest flood control storage out of all reservoirs in the Mejerda River basin, the Sidi Salem Reservoir can successfully mitigate flood flows within a whole range of probable floods, as shown below. As the return period of flood gets bigger, the efficiency of reservoir is smaller but not so drastically as in the case of the Mellegue Reservoir.

The Sidi Salem Reservoir is able to safely pass a 200 year flood (max. inflow into the reservoir: 8,725 m^3/s) without overtopping the dam due to relatively large flood control storage, but the maximum water level in the 200 year reservoir during the flood exceeds the "designed max. water level" (119.50 m) by 2 m, which is really dangerous to the dam.

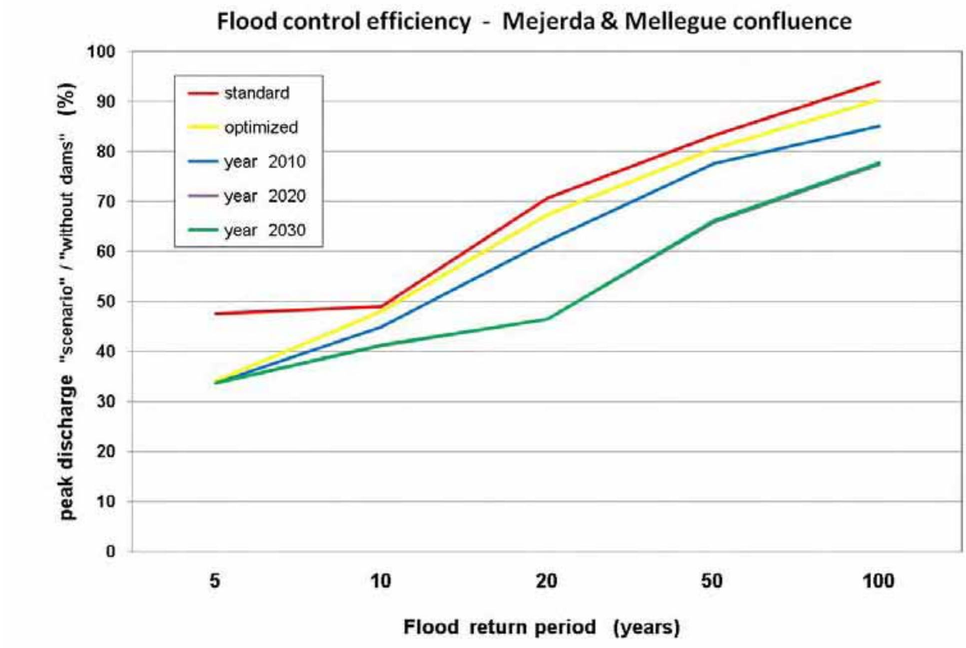
Flood Control Ability of Sidi Salem Reservoir

Return period of flood	Max. inflow (m^3/s)	Max. outflow / max. inflow
5 years	925	~ 46 %
10 years	1,331	~ 51 %
20 years	2,321	~ 53 %
50 years	4,249	~ 66 %
100 years	6,055	~ 89 %

(e) Response of Mejerda River to reservoir operation

As for the response of the Mejerda River to reservoir operation, it is found that the flood flow in the Mellegue River, which is the most important river with the biggest catchment area upstream of the Sidi Salem Reservoir, is successfully mitigated by the Mellegue Reservoir up to the 10 year flood. The peak discharge adjacently downstream of the Mejerda - Mellegue confluence is reduced by more than 50 % compared to that of the without dam case (see the figure below).

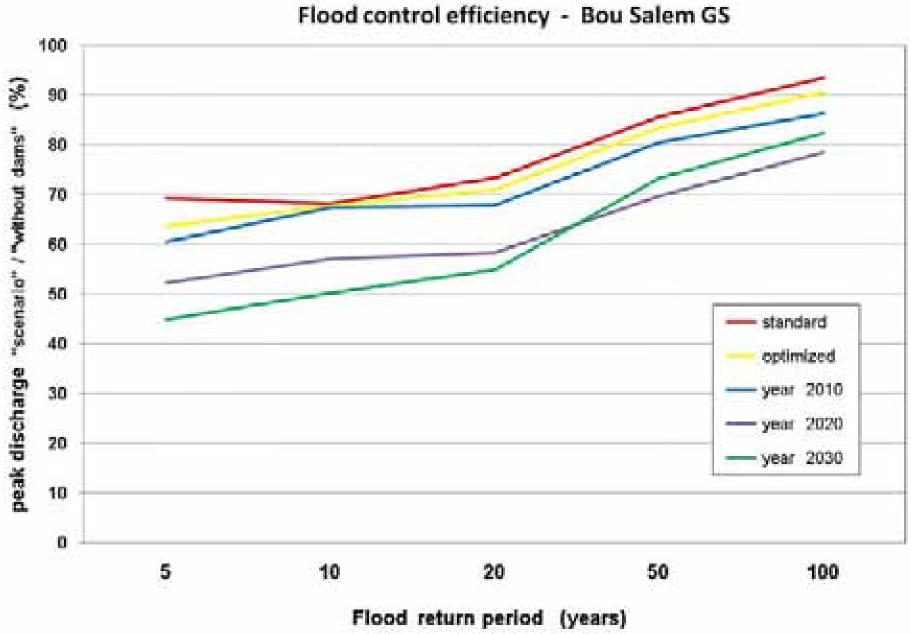
On the other hand, the peak discharge at the Bou Salem gauging station, located about 26km downstream of the Mejerda - Mellegue confluence, is caused by the inflow from the remaining sub-catchments of the Mejerda River and also the Tessa River. The peak discharge reduction of about 30 % only compared to that of the without dam case (see the next figure for Bou Salem GS) is less effected by the Mellegue Reservoir operation.



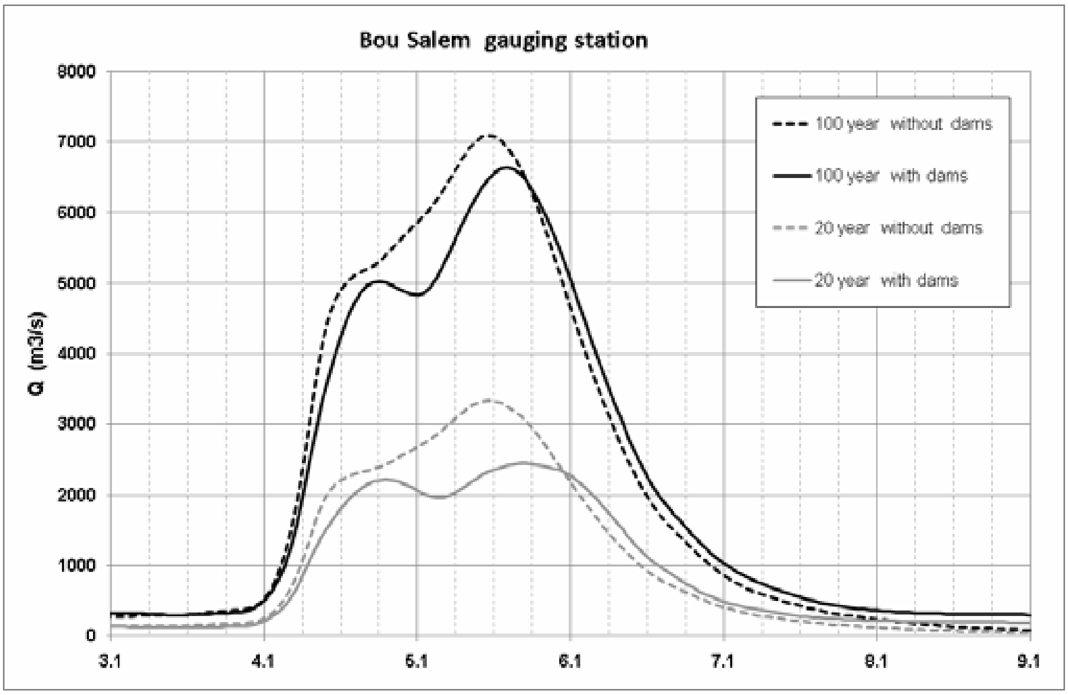
Flood Control Efficiency Downstream of Confluence of Mejerda and Mellegue Rivers

Flood reduction efficiency of the Mellegue Reservoir for bigger floods is significantly smaller: if evaluated adjacently downstream of the Mejerda - Mellegue confluence, the peak discharge reduction rates range from less than 30 % for the 20 year flood to 6 % only for the 100 year flood (as seen in the figure above). This is also the reason why the peak discharge at the Bou Salem gauging station for these floods (bigger than the 20 year flood) always correspond to the peak discharges at the Mejerda - Mellegue confluence (i.e. they are caused by release from the Mellegue Reservoir).

The peak discharge reduction for "standard reservoir operation" scenario, compared with the scenario "with no dam", for 20 to 100 year floods are very similar for both "check points": namely, the Mejerda - Mellegue confluence and the Bou Salem gauging station.



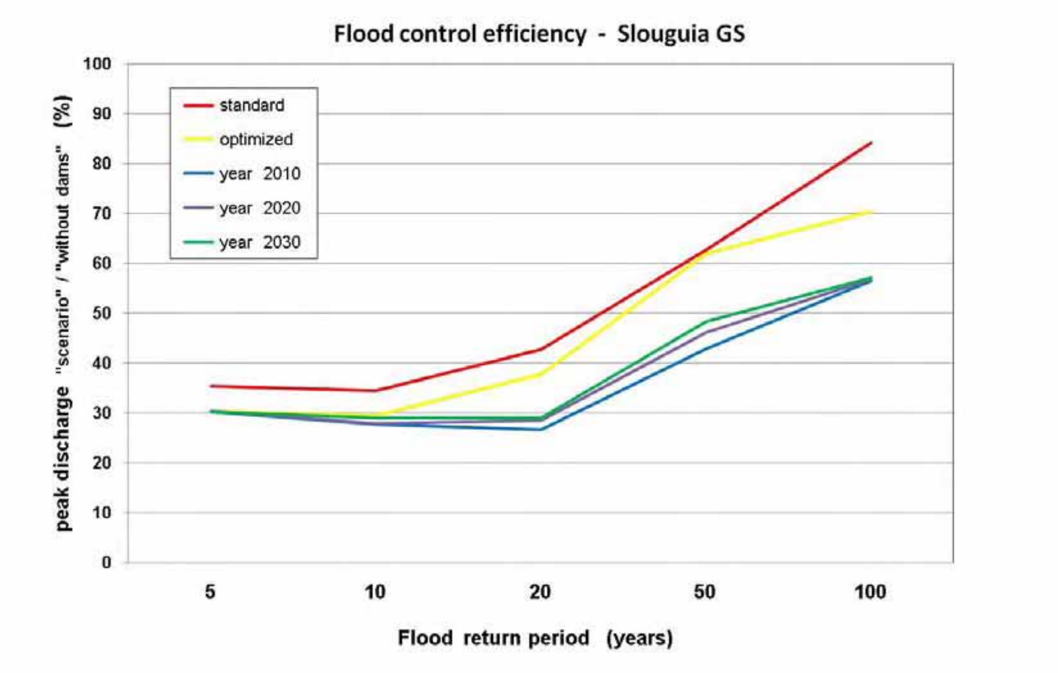
Flood Control Efficiency at Bou Salem GS



Flood Mitigation Effect in Bou Salem Gauging Station

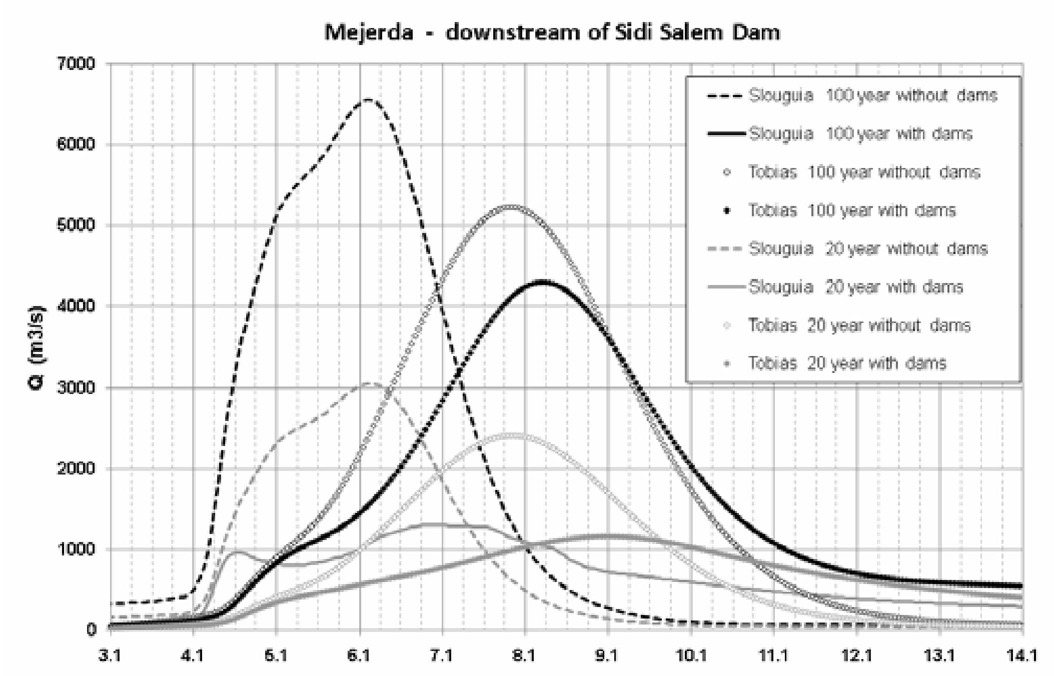
The flood mitigation effect caused by cooperation of the Mellegue and the Bou Heurtma Reservoirs in the flooding area、 represented by the Bou Salem gauging station (one of the most important flooding areas upstream of the Sidi Salem Dam)、could be seen in the figure above. During the 20 year flood, the peak discharge is decreased by 900 m^3/s (i.e. by 27%) and the peak comes late by 6 hours, while during the 100 year flood, the peak discharge is decreased by 450 m^3/s only (i.e. by 7%) and the delay of peak discharge occurrence is 3 hours, compared to those of with no dams case.

The flood response downstream of the Sidi Salem Dam is influenced mainly by the Sidi Salem Reservoir and partially by the Siliana Reservoir. The area in the vicinity of Mejez el Bab City and the large area from Jedeida City to the Tobias Weir are relatively flat and hence were many times seriously affected by floods in the past.



Flood Control Efficiency at Slouguia GS

The flood flow downstream of the Sidi Salem Dam is successfully mitigated up to the 20 year flood: namely by 50 to 60 % of peak discharge under the scenario of with no dam (see the figure above for the Slouguia gauging station). The peak discharges of the bigger floods (50 and 100 year floods) are also significantly reduced due to a relatively big flood control storage of the Sidi Salem Reservoir (285 mil.m^3). The first sinewy peak discharge downstream of the Sidi Salem Dam is caused by the flow released from the Siliana River and from the remaining sub-catchments along the Mejerda River downstream of the Sidi Salem Dam and cannot be effected by the Sidi Salem Reservoir. Flood control efficiency of the Siliana Reservoir is rather low and from a point of view of flood flow in the Mejerda River almost negligible: the reduction of peak discharge at the Mejerda - Siliana confluence ranges from 10 to 20 % only within the range up to the 100 year flood.



Flood mitigation effects in Mejerda River downstream of Sidi Salem Dam

An example of flood mitigation along the Mejerda River reaches downstream of the Sidi Salem Dam is given in the above figure, wherein floods at two important gauging stations are compared. The Sidi Salem Reservoir is able to significantly reduce discharges during the 20 year flood: the peak discharge is reduced by 1,700 m^3/s at Slouguia and by 1,250 m^3/s at Tobias, which represent reduction rates of 52 to 57 % of the original discharges (with no dam). The delay of peak discharges is roughly 24 hours. On the other hand, during the 100 year flood the peak discharge is reduced by 1,000 m^3/s at Slouguia and by 900 m^3/s at Tobias, which represent reductions of 16 to 18 % of the original discharges. The delay of peak discharges is 12 hours, i.e. roughly one half, compared to the peak delay during the 20 year flood case.

C5.3.2 Flood Control Ability under Optimized Reservoir Operation

In the case of the Mellegue River and the Mejerda River upstream of the Sidi Salem Dam, the flood flow mitigation effect in the “current stage” under optimized reservoir operation is found to be very close to the results under the standard reservoir operation mentioned in Subsection C5.3.1. The only one exception is a 5 year flood case: postponed reservoir release and partially opened bottom outlet (1 pipe) is able to reduce peak discharge at the Mejerda - Mellegue confluence by additional 15 % of the original peak discharge for the scenario “without dams” (see the figure for the Mejerda - Mellegue confluence).

The flood control efficiency of reservoirs examined at the Bou Salem gauging station is slightly higher than that under the standard reservoir operation. The originally designed normal water level at the Bou Heurtma Reservoir (equal to the uncontrolled spillway crest level = 221.00 m) limits any flexible reservoir operation: any higher inflow into the reservoirs automatically spills out. The pre-release effect of this reservoir is negligibly small owing to limitation of bottom outlet capacity and also limitation of river channel capacity downstream of the Bou Heurtma Dam: the reduction of peak discharge at the Mejerda - Bou Heurtma confluence is less than 10 %.

The flood flow mitigation effect in the Mejerda River downstream of the Sidi Salem Dam is also similar to the results under the standard reservoir operation, though the effect is a little bit higher due to a longer lead time of prior information about oncoming flood, i.e. a longer time for pre-release of the Sidi Salem Reservoir, compared with the Mellegue Reservoir. On the other hand, the pre-release of the Sidi Salem Reservoir cannot be used in the most efficient way because during the period for pre release some floods come from the Siliana catchment and the sub-catchments along the “lower” stretches of the Mejerda River, which is the constraint for pre-release from the Sidi Salem Reservoir.

C5.4 Analysis of Reservoirs in Years 2010, 2020 and 2030 under Optimized Reservoir Operation

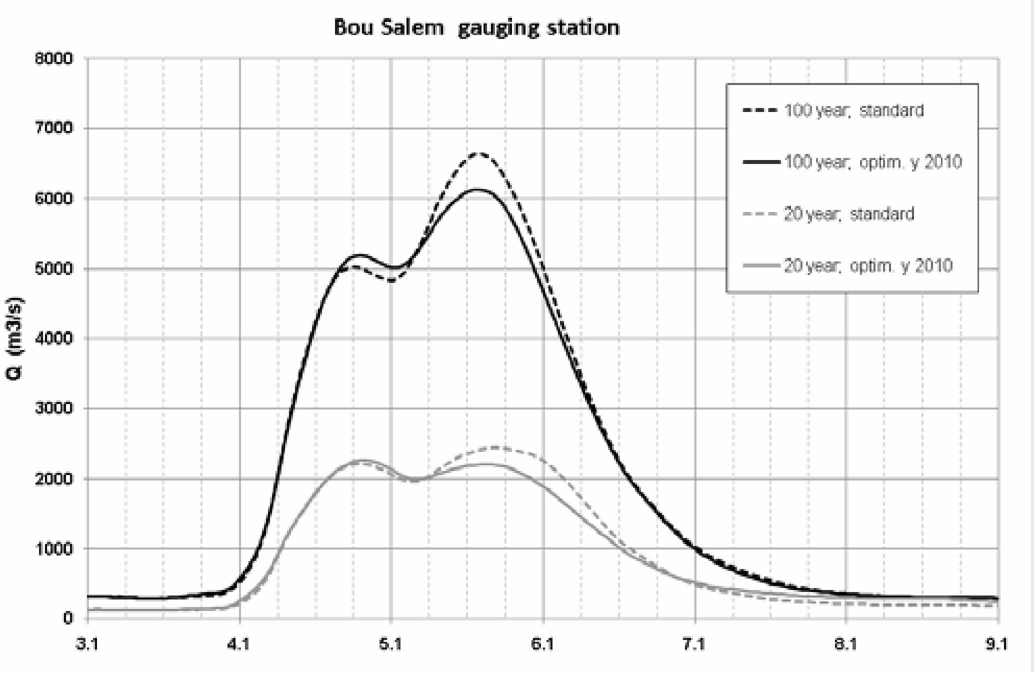
Analysis of reservoir operation in the future years up to the target year 2030 has been carried out with the aim to evaluate contribution of the 3 newly constructed/planned reservoirs (the Mellegue 2, the Sarrath and the Tessa Reservoirs) to flood control in the Mejerda River. In addition, the aim of the evaluation was to find optimum reservoir operation at the 7 selected reservoirs (the Mellegue, the Bou Heurtma, the Sidi Salem, the Siliana Reservoirs and the 3 newly constructed/planned reservoirs) in due consideration of the additionally available flood control storages which have been estimated straight below the originally design normal water level through the water supply operation study under 2010, 2020 and 2030 water demands (see Supporting Report B).

The fundamental rules of optimum reservoir operation mentioned in Chapter 4.2 were applied to this analysis, and the resultant flood discharges were compared to those derived from the analysis of existing reservoirs with the “standard reservoir operation” (see Sub-section C5.3.1) so as to clarify the effect of optimum reservoir operation.

C5.4.1 Flood Control Ability in Year 2010

The analysis of flood control ability in the year 2010 stage incorporated the flood control effect of the Sarrath Reservoir, which is expected to be constructed before 2010, in addition to those of the Mellegue, the Bou Heurtma, the Sidi Salem and the Siliana reservoirs.

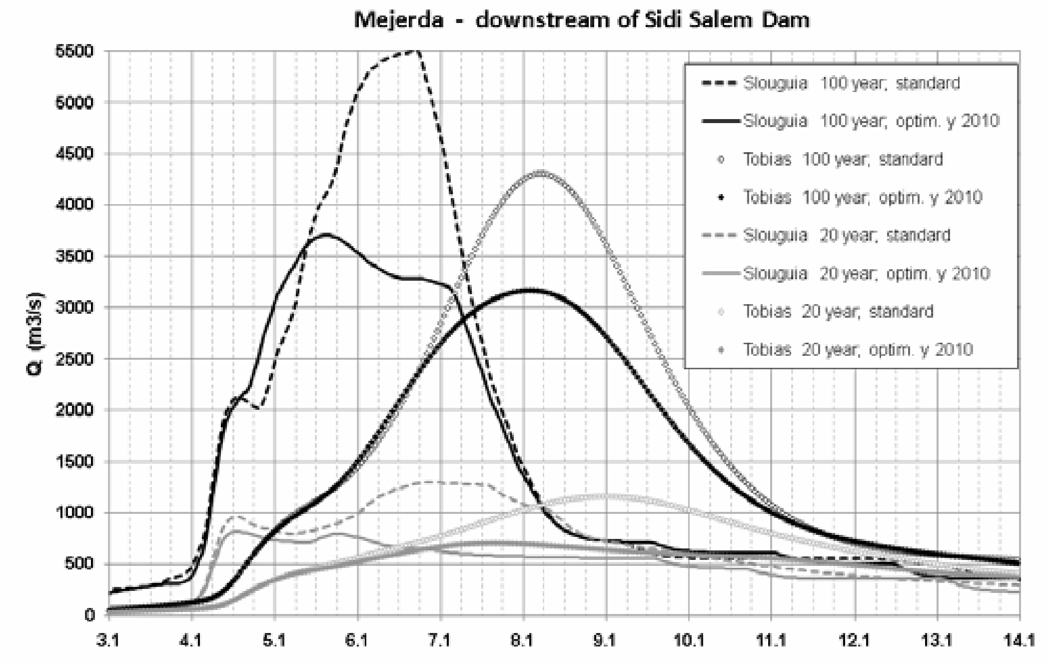
The flood flow in the Mellegue River is mitigated by the Mellegue Reservoir and also the newly constructed Sarrath Reservoir. The flood control storage of the Sarrath Reservoir (28 mil.m^3) is relatively small and hence the reduction of flood peak is also small. The most important effect of the Sarrath Reservoir on flood control consists in delay of release of floods into the reservoir, so that flood peaks from the Mellegue and the Sarrath Rivers may not meet at the Sarrath - Mellegue confluence. The reduction rate of flood peak is estimated to be 30 % at maximum at the K 13 gauging station located upstream of the Mellegue Dam. As a result, the cooperation of the Mellegue and the Sarrath Reservoirs additionally bring about flood peak reduction up to 5 % at the Mejerda - Mellegue confluence (see the aforementioned figure for the Mejerda - Mellegue confluence). The same reduction effect at the Bou Salem gauging station could be seen in the aforementioned figure for the Bou Salem GS, and also in the next figure. During the 20 year flood, the peak discharge is decreased by 180 m^3/s (i.e. by 7%), while during the 100 year flood, the peak discharge is decreased by 500 m^3/s (i.e. by 8%) without significant difference in time of peak occurrence, compared to those under the standard reservoir operation.



Flood Mitigation Effect in Bou Salem Gauging Station in 2010

Mitigation of flood flow downstream of the Sidi Salem Dam is the most effective in the year 2010, because according to the water supply operation study (see Supporting Report B) the Sidi Salem Reservoir could be operated with a lowed normal water level of 111.83 m (3.17m lower than the current design normal water level of 115.0 m), which can provide an additional flood control storage of 161 mil. m^3, resulting in a total flood control storage up to 446 mil. m^3. As a result, smaller floods (say, up to a 20 year flood) are successfully mitigated with flood peak reduction rates of more than 70 % (see the next figure for Slouguia gauging station). Moreover, bigger floods (50 year and 100 year floods) are also relatively well mitigated.

In the case of the 20 year flood, the Sidi Salem Reservoir is able to reduce flood peaks by 500 m^3/s at Slouguia and by 460 m^3/s at Tobias, which represent reduction rates of 37 to 40 % of flood peak under the standard reservoir operation. During the 100 year flood event, the peak discharge reduction is also relatively high: 1,800 m^3/s at Slouguia and more than 1,100 m^3/s at Tobias, which represent reduction rates of 26 to 33 % of flood peak under the standard reservoir operation (see the next figure).



Flood Mitigation Effects in Mejerda River Downstream of Sidi Salem Dam in 2010

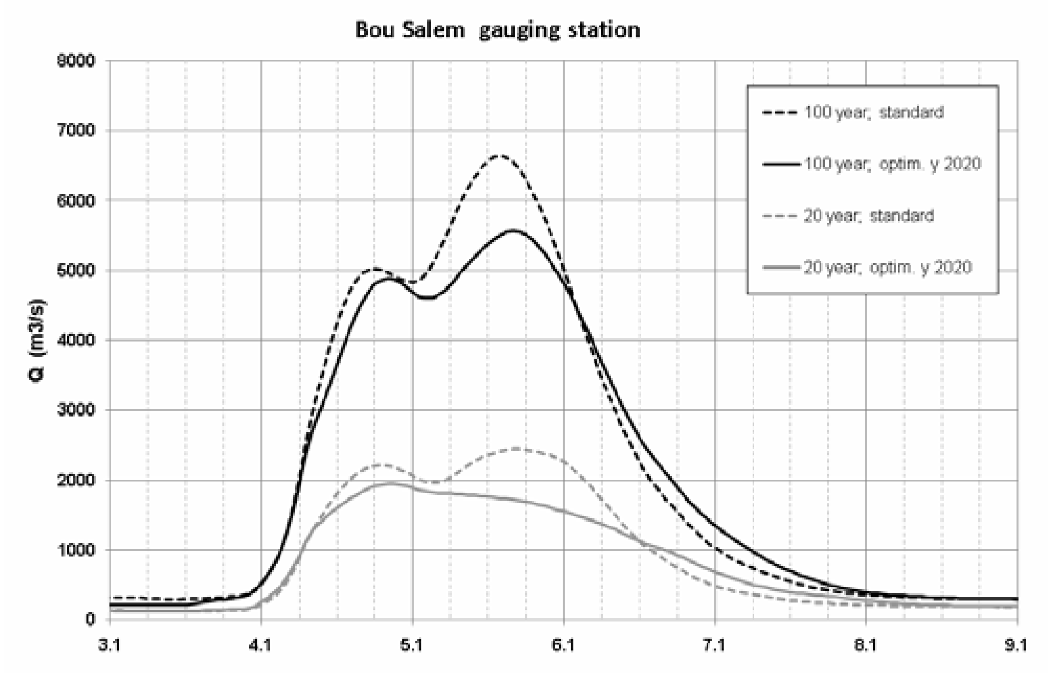
C5.4.2 Flood Control Ability in Year 2020

The analysis of flood control ability in the year 2020 stage incorporated the flood control effect of the Mellegue 2 Reservoir, which is expected to be constructed after 2010 and before 2020, in addition to those of the Sarrath, the Mellegue, the Bou Heurtma, the Sidi Salem and the Siliana reservoirs

The flood flow situation in the Mellegue River is changed by the addition of the new Mellegue 2 Reservoir. The existing Mellegue Reservoir will not be used for water supply after the operation of the Mellegue 2 Reservoir, but will remain for flood control with the originally designed flood control storage of 103 mil. m^3 at minimum. According to the latest MARH's design of the Mellegue 2 Dam, it will be equipped with an uncontrolled spillway. Hence, only a small part of the designed flood control storage will be used during a small flood event. On the other hand, a significant flood retarding effect of the Mellegue 2 Reservoir can been brought about in the case of a big flood, because the flood control storage of 143 mil. m^3 available in the year 2020 stage can be fully used during a big flood event.

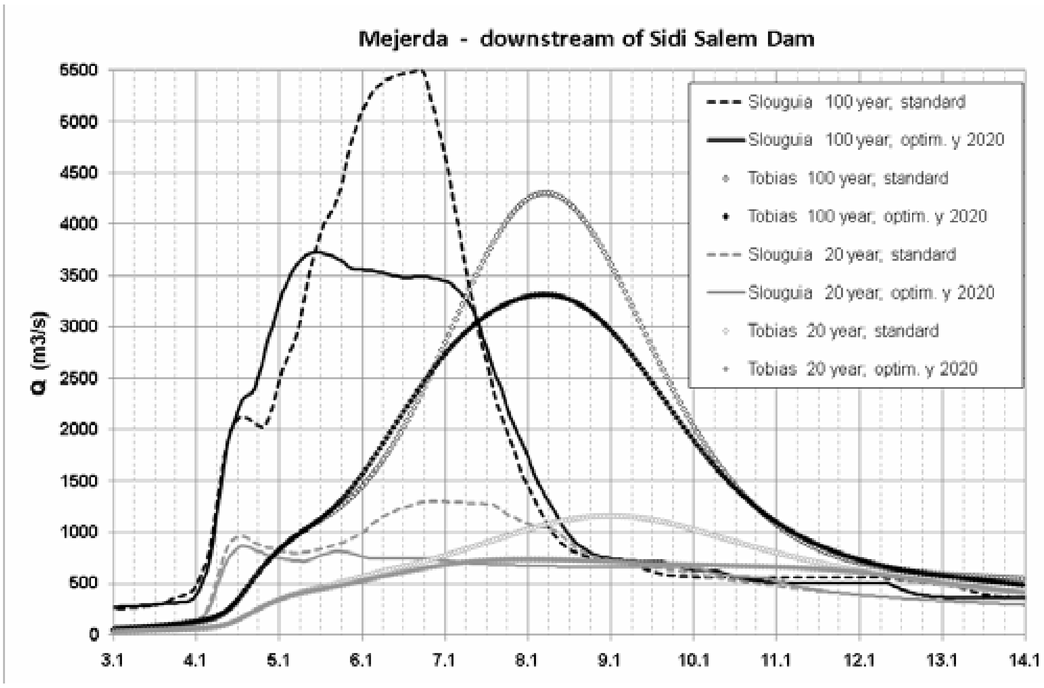
The Mellegue 2 Reservoir causes both effects of food peak reduction and flood water retardation, and hence the flood peak discharge at the Mejerda - Mellegue confluence is reduced with additional 4 to 8 % to the reduction in the year 2010 stage. Finally, small flood peaks up to 20 year floods are reduced by more than 50 % at the confluence under cooperation of the three reservoirs (Sarrath, Mellegue 2 and Mellegue), and even in the 100 year flood case, the flood peak reduction reaches 23 % of the "no dams" scenario case.

The similar effect is observed at the Bou Salem gauging station. The flood reduction due to the flood control by the three reservoirs in the Mellegue River basin is made more significant by the Bou Heurtma Reservoir which is operated with a lowered normal water level to 218.38 m in the year 2020 stage, providing an additional flood control storage of 21 mil. m^3 straight below the originally designed normal water level. During the 20 year flood event, the peak discharge at the Bou Salem gauging station is decreased by 500 m^3/s (i.e. by 21%), while during the 100 year flood, the peak discharge is decreased by more than 1,000 m^3/s (i.e. by 16%), compared to the situation of the standard reservoir operation case, as show below.



Flood Mitigation Effect in Bou Salem Gauging Station in 2020

The flood mitigation downstream of the Sidi Salem Dam is close to the situation in the year 2010 stage, particularly in small flood cases. The flood peak reduction of big floods is not so effective, because the Sidi Salem Reservoir in the year 2020 stage should be operated with a normal water level at 113.54 m (see Supporting Report C: Reservoir Operation), which provides an additional flood control storage of 77 mil. m^3, i.e. roughly 50% of the additional flood control storage in the 2010 stage.



Flood Mitigation Effects in Mejerda River Downstream of Sidi Salem Dam in 2020

The Sidi Salem Reservoir is able to significantly reduce peak discharge during the 20 year flood event. The peak is reduced by 430 m^3/s at Slouguia and by 420 m^3/s at Tobias, which represent reduction rates of 33 to 36 % of the discharges under the standard reservoir operation case. During the 100 year flood, the peak discharge reduction is relatively close to that of 2010: by 1,800 m^3/s at Slouguia and by 1,000 m^3/s at Tobias, which represent reduction rates of 23 to 32 % of discharge under the standard reservoir operation, as seen in the figure above.

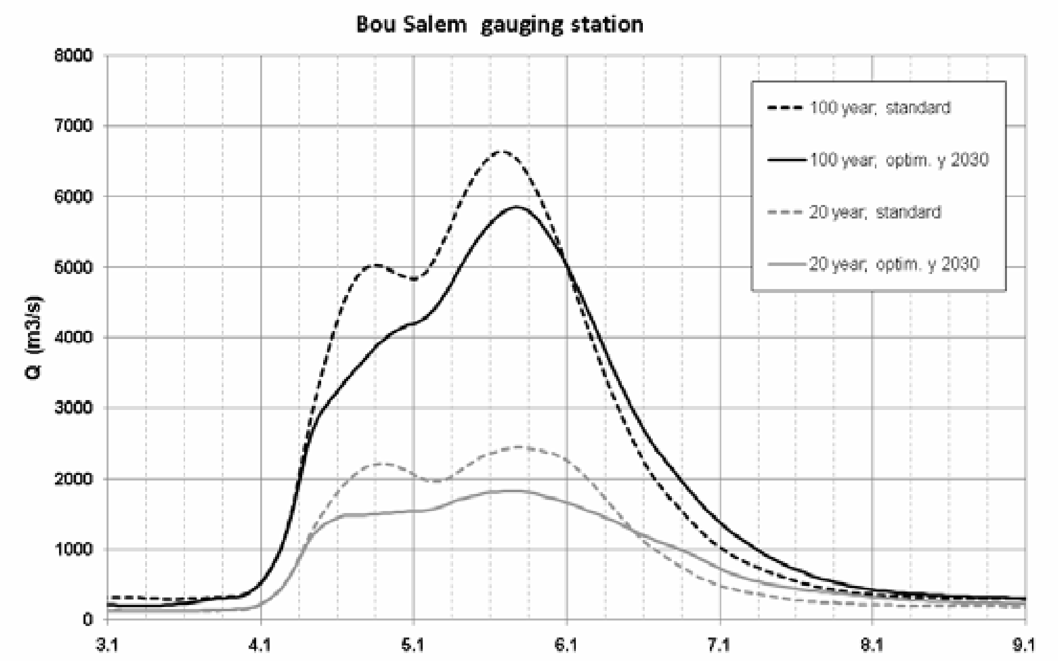
C5.4.3 Flood Control Ability in Target Year 2030

The analysis of flood control ability in the target year 2030 incorporated also the flood control effect of the Tessa Reservoir, which is expected to be constructed after 2020 and before 2030, in addition to those of the Mellegue 2, the Sarrath, the Mellegue, the Bou Heurtma, the Sidi Salem and the Siliana reservoirs.

There is almost no difference of flood peak mitigation effect in the Mellegue River basin between the years 2020 and 2030, because the normal water level of the Mellegue 2 Reservoir for the target year 2030 is by 0.18 m lowered from the originally designed normal water level of 295.0 m, and is only 15 cm higher than the normal water level of the Mellegue 2 Reservoir for the year 2020, in other words the flood control storage additionally available below the originally designed normal water level is 141 mil. m^3 in the year 2030, which is only 2 mil. m^3 less compared to the additionally available storage in 2020. That is why the flood peak reduction effects are almost the same between 2020 and 2030 in each evaluated flood event.

On the other hand, the 2030 situation of flood peak reduction at the Bou Salem gauging station, located downstream of the Mejerda - Tessa confluence, differs from the 2020 situation. The inflow from the Tessa River basin is controlled by the Tessa Reservoir with a flood control storage of 82 mil. m^3. The Tessa Dam is equipped with an uncontrolled spillway and affects flood flow in the downstream river channel due to flood flow retardation effect to flood flows. The maximum bottom outlet capacity of the Tessa Dam is 75 m^3/s only, which considerably limits pre-release operation of reservoir water. In combination with the uncontrolled spillway, the Tessa Reservoir can be controlled and transformation effect on flood hydrograph in the reservoir is expected. The Tessa Reservoir decreases discharges at an initial stage of flood.

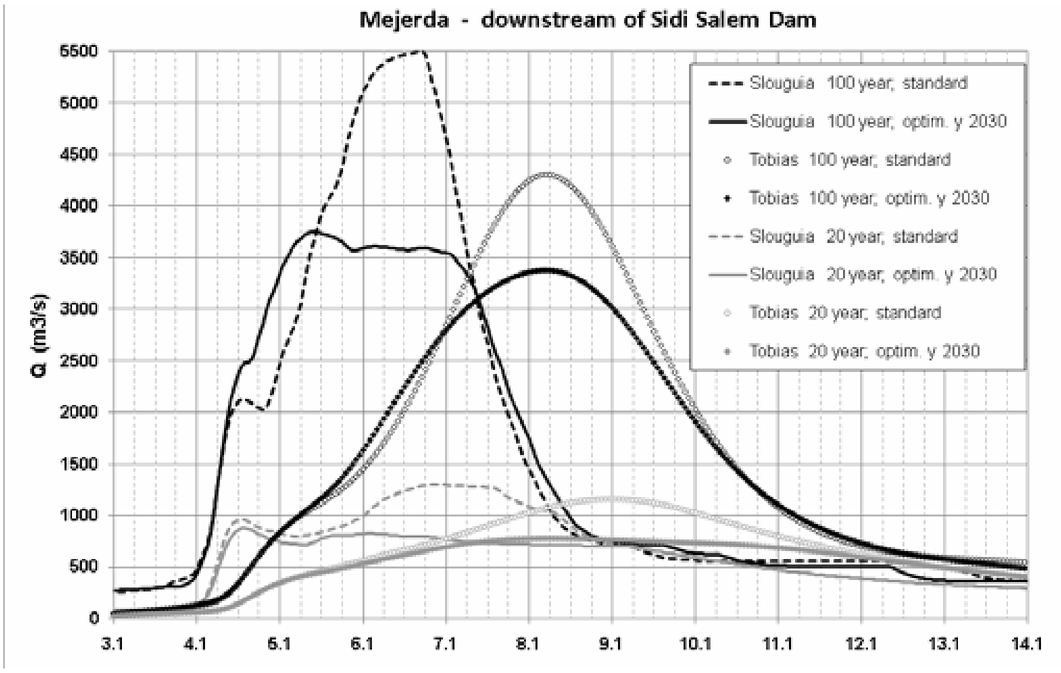
At the Bou Salem gauging station, the flood discharge in an initial stage is mitigated also by the Bou Heurtma Reservoir (see the figure below). This reservoir is operated with the lowed normal water level of 216.77 m for each future stage case, which represents an additional flood control storage of 35 mil. m^3 below the uncontrolled spillway crest.



Flood Mitigation Effect at Bou Salem Gauging Station in 2030

The Sidi Salem Reservoir in the target year 2030 is able to reduce discharges even during the 100 year flood event due to an increased flood control storage of 29 mil. m^3 straight below the current normal water level and also effective operation of all reservoirs upstream of the Sidi Salem Dam. The flood control efficiency of the Sidi Salem Reservoir is very close to the situation in the year 2020.

The following hydrographs show the effects of flood control function under improved reservoir operation downstream of the Sidi Salem Dam in 2030.



Flood Mitigation Effects in Mejerda River Downstream of Sidi Salem Dam in 2030

The Sidi Salem Reservoir is operated in the above analysis with an additional flood control storage of 29 mil. m^3 and an improved operation rule, and it is found that the dam is able to significantly reduce the downstream flood discharges even during a 100 year flood; the peak discharge is reduced by 1,770 m^3/s at Slouguia and by 930 m^3/s at Tobias, which are equivalent to 22 % and 32 % reduction rates of peak discharge at respective sites, compared to those under the standard reservoir operation.

As for the 20 year flood, the peak discharges are reduced by 420 m^3/s at Slouguia and by 385 m^3/s at Tobias, which mean 32 % and 33 % reduction rates of peak discharges at the sites, respectively.

With the above in view, it is not too much to say that adoption of improved reservoir operation at the Sidi Salem Dam could improve flood control to such an extent that flood inundation damage in the downstream areas is significantly alleviated.

Furthermore, it can be formulated that the reservoirs in the Mejerda River basin can successfully mitigate flood flow up to the 20 year floods: in the 2030 case, by 50 % of the peak discharge in the “with no dam” scenario case at the Mejerda - Mellegue confluence and also at the Bou Salem gauging station, and by 70 % at the Slouguia gauging station. As for bigger floods, the 50 year flood has an flood control efficiency of 20 % or lower ones at all check points.

C5.5 Operation Sheets for 7 Selected Reservoirs

The most important characteristics, including major reservoir water levels, subdivision of reservoir storages, dimensions of such structures as spillways, conduits and bottom outlets, from a viewpoint of reservoir operation for flood control were found out based on all data collected and through the flood analysis during the Study. They have been organized as “operation sheets” into **Data C2**.

CHAPTER C6 RECOMMENDATIONS FOR RESERVOIR OPERATION DURING FLOOD EVENTS

All reservoirs in the Tunisian territory of the Mejerda River basin must be operated as one coordinated system so as to enhance their flood control functions. Thus, it is necessary to provide the system with fundamental operation rules and follow the rules at any time to realize optimized coordination of dam operation for the most effective flood control and for successful water supply as well.

The main goal of optimum reservoir operation is to use an available flood control storage provided above a normal water level (NWL) as effectively as possible and to minimize flood peaks downstream of dams. Therefore, the following recommendations, which are generally valid and/or based on the analysis results obtained in Chapter 5, should be carefully and fully considered for future reservoir operation during flood events:

- To keep the water level in reservoirs properly at a normal water level which is to be actually valid and approved, and is to be designed for suitable water supply regulation as well.
- To give the highest priority to safety of dam in all operations.
- To pre-release reservoir water, as soon as the information about upcoming flood attack is given, by releasing the discharge which is equal to flow capacity of the downstream river channels (hereinafter referred to as “the channel capacity”).
- To cooperate reservoirs and control outflows from the reservoirs according to knowledge of flood propagation times downstream of the dams with the aim of avoiding join of flood peaks from two or more subbasins at one site so as to minimize the flow in the downstream. and
- After water level culmination in a reservoir, to release the discharge equal to the channel capacity downstream of the reservoir so as to provide against the next flood.

Furthermore, based on the analysis results of flood flow made in the several probable flood cases in this study, the following recommendations is formulated to enhance the effects from the newly planned dams:

1. Higher flood control efficiency could be brought about, in particular for floods up to a 20 year flood, if the newly planned Mellegue 2 and Tessa Dams are equipped with controlled spillways with gates.
2. During the floods in the upper Mejerda River basin, flood flows down from the Tessa River basin reach to the Bou Salem area earlier than those from the Mellegue River. However, the maximum bottom outlet capacity of the Tessa Dam is 75 m^3/s only, which considerably limits pre-release of reservoir water. As discussed in Sub-section C5 4.3, the Tessa Reservoir postpones peak discharges, which makes peak discharges in the Bou Salem area bigger due to join of inflows from the Mellegue and Tessa Rivers. Increasing the discharge capacity of the bottom outlet at the Tessa Dam up to the channel capacity of the Tessa River downstream of the Tessa Dam (about 250 m^3/s) can give to the dam operator a suitable tool for more effective reservoir operation.

Tables

Table C2.1.1 Principal Features and Other Information of Reservoirs in Mejerda River Basin

Name of dam	Gouvernerate	Year in service	Catchment area km^2	Hydraulic data: Inactive water level				Dead storage - 2010		Spillway		Normal water level				Maximum high water level (spill)				
				Bottom level at the dam (m)	Lowest threshold of outlet (m)	Inactive volume $Mil.m^3$	Level of lowest gate for water supply (m)	Level (m)	Volume $Mil.m^3$	Spillway crest level (m)	controlled / uncontrolled	Elevation (m)	Area (ha)	Initial capacity $Mil.m^3$	Actual total capacity $Mil.m^3$	Dam crest elevation (m)	Elevation (m)	Total Volume ($Mil.m^3$)	Spillway capacity (m^3/s)	Bottom outlet m^3/s
Ben Metir	Jendouba	1954	103	375.0	390.0	0.30	406.8	406.8	5.92	425.00	controlled	435.10	300.00	61.63	57.20	443.00	440.00	73.43	610	360
Kasseb	Beja	1968	101	241.0	251.0	4.58	257.5	272.2	19.86	292.04	uncontrolled	292.00	430.00	81.88	81.88	295.00	294.40	92.60	400	77
Bou Heurtma	Jendouba	1976	390	184.0	186.0	2.17	196.0	196.0	7.7	221.00	uncontrolled	221.00	894.00	117.50	117.50	228.00	226.00	164.00	2,500	163
Mellegue	Le Kef	1954	10309	205.0	212.0	0.00	216.0	254.2	16.87	255.20	controlled	260.00	1,010.00	182.20	44.40	270.00	269.00	147.54	5,261	625
*Mellegue2**	*Le Kef*	*P*	*10100*	*254.5*	*260.0*		*260.5*	*274.5*	*34.0*	*295.00*	*uncontrolled*	*295.00*	*1,280.00*	*195.00*	*195.00*	*305.00*	*304.00*	*334.00*	*7,938*	*1,113*
*Sarrath**	*Le Kef*	*C*	*1850*	*523.0*	*525.0*		*527.0*	*527.0*	*0.47*	*546.00*	*uncontrolled*	*546.00*	*300.00*	*21.00*	*20.95*	*556.00*	*552.00*	*48.53*	*5,800*	*93*
*Tessa**	*Siliana*	*P - 2008*	*1420*	*330.0*	*341.0*		*352.0*	*353.0*	*10.1*	*361.00*	*uncontrolled*	*361.00*	*694.00*	*46.00*	*44.43*	*371.50*	*369.00*	*125.00*	*5,079*	*75*
*Beja**	*Beja*	*P - 2008*	*72*					*212.0*	*3.7*			*230.00*	*220.00*		*26.40*	*237.00*	*234.00*	*46.00*	*1,000*	*60*
Sidi Salem	Beja	1981	18191	65.0	72.5	0.00	75.0	97.4	94.65	105.00	controlled	115.00	5,656.00	762.00	674.00	122.00	119.50	959.48	4,870	550
Khalled:	*Beja*	*P - 2011*	*303*					*189.0*	*9.5*			*207.00*	*185.00*		*34.00*	*216.00*	*213.60*	*37.00*	*2,210*	*80*
Rmil	Siliana	2002	232						0.0			285.00	62.00	4.00	4.00		288.00	6.00	810	112
Siliana	Siliana	1987	1040	356.0	357.0		370.0	376.6	20.1	388.50	uncontrolled	388.50	600.00	70.00	70.00	398.00	395.50	125.05	3,200	183
Lakhmes	Siliana	1966	127					509.0	0.18			517.00	109.20	8.22	7.22	523.50	521.20	8.40	1,000	9
*Chafrou**	*Manouba*	*P*	*217*									*49.00*	*471.00*		*7.00*	*53.00*	*51.00*	*14.00*	*1,600*	

Name of dam	Gouvernerate	Year in service	Catchment area km^2	Hydraulic data: Siltation				Hydrologic data: Inlfow								Hydro-electric production	
				Measured $Mil.m^3$	Annual $Mil.m^3/year$	siltation %	Denudation of catchment mm/year	Average yearly $Mil.m^3$	Minimum since in service $Mil.m^3$	Average rainfall (mm/year)	Evaporat. average (mm/year)	1,000 year flood m^3/s	100 year flood m^3/s	10 year flood m^3/s	Average annual salinity (g/l)	Power Mw	Intake m^3/s
Ben Metir	Jendouba	1954	103	4.00	0.14	6.49	1.39	40.57	3.74	1,200	1,559				0.2	9	6
Kasseb	Beja	1968	101	2.80	0.20	3.42	1.98	45.55	7.84	1,000	1,400				0.3	0.66	up 1.5
Bou Heurtma	Jendouba	1976	390	2.00	0.12	1.70	0.30	118.41	8.39	685							
Mellegue	Le Kef	1954	10309	137.80	2.81	75.63	0.32	179.40	36.20	400	1,093	11,300	4,500		2.2	13	2 x 12.5
*Mellegue2**	*Le Kef*	*P*	*10100*		*3.40*			*170.00*		*400*					*2.4*		
*Sarrath**	*Le Kef*	*C*	*1850*		*0.41*			*26.00*		*450*		*8,000*	*3,800*		*0.9*		
*Tessa**	*Siliana*	*P - 2008*	*1420*		*0.52*			*37.25*		*395*	*1,455*	*3,500*	*2,500*	*1,250*	*1.6*		
*Beja**	*Beja*	*P - 2008*	*72*		*0.37*			*18.34*		*585*	*1,975*	*750*	*500*	*240*	*1.5*		
Sidi Salem	Beja	1981	18191		4.50			666.61	94.29	450	1,265				1.4	36	100
Khalled:	*Beja*	*P - 2011*	*303*		*0.32*			*16.00*		*509*	*1,210*		*865*		*2.0*		
Rmil	Siliana	2002	232		0.35			11.52	1.61	405							
Siliana	Siliana	1987	1040	16.96	1.06	24.23	1.02	49.43	3.67	550							
Lakhmes	Siliana	1966	127	1.00	0.03	12.19	0.23	10.96	0.86	450							
*Chafrou**	*Manouba*	*P*	*217*					*7.00*		*450*	*1,300*	*1,667*	*1,045*	*471*	*3.5*		

Note: * under construction or in design/planning stage

Supporting Report D

RIVER IMPROVEMENT AND FLOOD PLAIN MANAGEMENT

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

FINAL REPORT

Supporting Report D :
River Improvement and Flood Plain Management

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CHAPTER D1 INTRODUCTION

In the Mejerda River basin, several large scales of dams and reservoirs have been constructed and some schemes are under planning or construction through the initiative of MARH. However, it is quite evident that only the existing dams and reservoirs as a structural measure cannot control huge flood discharge as experienced in the recent floods in 2003, 2004 and 2005. In this context, aside from improvement of the operation rules of existing reservoirs on flood time, river improvement works shall be undertaken to mitigate the flood risk.

Firstly, the issues and problems regarding flood protection in the basin were identified in the course of the review of past damage records and field reconnaissance in order to decide fundamental policy of flood control. The areas to be protected from flooding were carefully selected and prioritized based on the frequency of floods and extent of the damage potential. Since any standards/criteria for determination of appropriate flood protection level has not been established in Tunisia, it was decided from benefit-cost performance by dividing into five zones in the basin. The results of inundation analysis by means of MIKE FLOOD with GIS database system were fully utilized to estimate flood control benefit.

After selection of flood protection level, preliminary design of river facilities and cost estimate of river improvement works was carried out. The optimum flood protection level was selected. With the premises of the outflow from the major reservoirs by improved reservoir operation rules, inundation areas along the Mejerda and major tributaries were assessed. The configuration of river channel improvement was intensively tested and repeated in combination with the inundation analysis. The preliminary design of river improvement works such as channel excavation/widening levee embankment, bypass channel and retarding basin, etc. are described in Supporting Report E.

In particular, since such a large scale of river improvement works as proposed herein has not been conducted from the independence of the country in Tunisia, it is expected that the planning procedure and design concept in the Mejerda will able to present a showcase for application to other river systems in the future. However, the river improvement plan explained herein is preliminarily proposed master plan, which will become a Grand Design for further elaboration through detailed hydraulic analysis and facility design in succeeding feasibility study stage after the current Study.

This Supporting Report D consists of seven Chapters with the issues consisting of river improvement plan, flood protection level, cost allocation for future multipurpose dam projects, implementation schedule of river improvement works and flood plain management.

CHAPTER D2 EXISTING CONDITION ON FLOOD DAMAGE AND COUNTERMEASURES

D2.1 Available Data and Information

Flood damage records are required to be compiled in order to utilize as the basis of economic analyses of structural measure options. The major source of flood damage data/information collected through the current Study is as follows:

(1) Documents and reports of past major flood events mainly prepared by MAHR (available for 1969, 1973 and 2003 floods)

(2) Data/information collected at CRDA Offices by “Flood Inundation and Damage Survey”, which has been conducted between December 2006 and March 2007 (by ECO Ressources International)

(3) Information on damages collected through interview survey (300 samples same as (2)) to the farmers, residents, shops and factories

(4) Data/information on flood damage and maintenance works due to the floods in 2003, 2004 and 2005 collected from CRDAs.

Further, inundation area maps corresponded with the past significant floods were collected and compiled as much as possible for the Study to verify the inundation areas and extent of flood damage.

D2.2 Flood Damage in Past Significant Floods

D2.2.1 Flood Prone Areas

The flood prone area suffering from habitual flooding are located mainly in the lowly undulated plains along the mainstream of the Mejerda River. Through the field reconnaissance and interviews with the governmental agencies concerned, it was revealed that Jendouba, Mellegue Confluence, Bou Salem, Sidi Ismail, Slouguia, Medjez El Bab, El Herri, Tebourba, El Battan, Jedeida, El Henna, Chafrou Confluence, El Mabtouh and Kalaat Andelous have become flood prone towns/areas, which were seriously damages by the past significant floods such as those occurred in May 1973, January to February 2003 and January 2004. The following table shows quick reference for the area of inundation occurred due to significant floods with some remarks.

Occurrence of Inundation due to Major Floods and
Availability of Related Data/Information on Flood Damage

Flood Event	Governorate: Jendouba	Governorate: El Kef	Governorate: Siliana	Governorate: Beja	Governorate: Manouba	Governorate: Bizerte	Governorate: Ariana	Remarks
	Ghardimaou Jendouba Bou Salem	Mellegue Dam Mellegue Dam DS	Tessa Dam Siliana Dam Lakhmes Dam Rmil Dam	Sidi Salem Testour Slouguia Mejez El Bab El Herri	Laroussia Dam Tebourba El Battane Jedeida	El Mabtouh Hir Tobias (left bank side) Kalaat Landelous	Sidi Thabet Hir Tobias (right bank side)	
1973 Mar-Apr	○	○	○	○	○	○	○	Experienced maximum inundation along the entire reaches
	Yes	Yes	No	Yes	Yes	Yes	Yes	
2000 May	○	○	×	×	×	×	×	Experienced maximum in Jendouba
	Yes	Yes	–	–	–	–	–	
2003 Jan-Feb	○	○	○	○	○	○	○	Experienced maximum inundation, but smaller discharge than 1973 flood
	Yes	Yes	No	Yes	Yes	Yes	Yes	
2003 Sep	×	×	×	×	○	○	○	Jedeida area only
	–	–	–	–	Yes	Yes	Yes	
2004 Jan	○	○	○	○	○	○	○	Downstream area from Chafrou River
	No	No	No	Yes	Yes	No	No	
2005 Jan-Feb	×	×	×	○	○	○	○	Downstream area from Chafrou River
	–	–	–	Yes	Yes	No	Yes	
2005	×	×	×	○	○	○	○	Mejez El Bab, upstream of Pont Andalous Bridge
	–	–	–	Yes	Yes	Yes	Yes	

Legend: Upper Cell → ○, Inundated; ×, No inundation; ?, To be confirmed
Lower Cell → Availability of damage data: Yes, Some infomration available; No, No information available; -, Not applicable; ?, To be confirmed

Source: the Study Team
(Based on the Flood Reports prepared by MARH and results of "Flood Inundation and Damage Survey" under the current Study)

D2.2.2 Flood Damage Records

The flood damage due to past significant floods, which are classified by major damaged items namely agricultural crops, house and household effects, infrastructure and indirect damages, is enumerated by the Governorates concerned as shown in the following tables:

Flood damage in May 2000

Governorate: **Jendouba**
Category: Agriculture

No.	Type of Damage	Affected area (ha)	Loss (TND)	Affected farmers (head)	Lost wells (nos.)	Lost pumps (nos.)	Dmaged pipes (km)	Damaged stables (nos.)
1	Cereal	1450	560,000	814	73	59	347	20
2	Green animal food	125	46,000					
3	Dry animal food	-	118,000					
		180	50,000					
4	Vegetable	287	515,000					
5	Industrial plantation	34	70,000					
6	Fruit tree	31	15,000					
	Total	2107	**1,374,000**					

Flood damage in Jan – Feb 2003

Governorate: **Jendouba**
Category: Infrastructure

No.	Kind of Structures	Damage (TND 1,000)
1	Irrigation pumps	60
2	Irrigation network	80
3	Rural roads	300
4	Drainage network	600
5	Drinkwater infrastructure	586
6	Soil and water conservation	525
7	Mountain dams	145
8	Gound water recharge	55
9	Forest roads	480
	Total	**2,831**

Governorate: **Beja**
Category: Agriculture

No.	Type of Damage	Damaged Area (ha)	Value (TND)
1	Cereal	2,360	395,000
2	Green animal food	707	71,000
3	Vegetables	296	250,000
4	Fruit trees	752	148,000
	Total	4,115	**864,000**

Governorate: **Ariana**
Category: Agriculture, Infrastructure and river administration

	Type of Damage	Unit	Value
1	Agriculture	Number of victims	490
		Area damaged (ha)	4,900
		Loss (TND)	2,900,000
2	Rural roads	Affected length (km)	40
		Loss (TND)	320,000
3	Drainage canal	Affected length (km)	60
		Loss (TND)	215,000
4	Irrigation network	Affected length (km)	16.5
		Loss (TND)	157,500
5	Pumping stations	Repair cost (TND)	120,000
6	Samll dam	Repair cost (TND)	112,500
	Total	Cost (TND)	**3,825,000**

Flood Damage in Sep. – Dec. 2003

Governorate: **Ariana**
Category: Agriculture, Infrastructure and river administration

	Type of Damage	Unit	Value
	Agriculture	Number of victims	218
		Area damaged (ha)	1,035
		Loss (TND)	1,676,900
	Rural roads	Affected length (km)	41
		Loss (TND)	352,000
	Drainage canal	Affected length (km)	72
		Loss (TND)	148,000
	Tributaries management	Repair cost (TND)	420,000
	Samll dam	Repair cost (TND)	445,000
	River dredging	Cost (TND)	30,000
	Forest roads	Cost (TND)	35,000
	Reforestation	Cost (TND)	50,000
	Urban forestation and green z	Cost (TND)	315,000
	Total	Cost (TND)	**3,471,900**

Flood Damage in Jan. – Feb. 2005

Governorate: **Beja**
Category: Agriculture (land)

	Type of Damage	Unit	Testour	Mejez El Bab	Total
	Cultivated land	ha	35	770	805
	Vegetable	ha	10	13	23
	Fruit trees	ha	10	104	114
	Olive trees	ha	0	3	3
	Total	ha	55	890	**945**
	Number of victims	Head	37	144	181

D2.2.3 Characteristics on Flood Damage due to Significant Floods

(1) Sep. – Oct. 1969 Flood

The peak discharges at Bou Salem and K13 G/S in the Mellegue during the flood were reported 1,485 m^3/s and 4,480 m^3/s respectively. Especially at K13, second largest of peak inflow at Mellegue Dam was recorded after its construction until present (the biggest one is 4,770 m^3/s in 1988). However, rather than the Mejerda River basin, the areas seriously hit were central part of Tunisia.

(2) Mar. – Apr. 1973 Flood

In March 1973, almost the whole area in the Mejerda River basin was attacked by heavy downpour of high intensity and overflow of flood discharge from river channels occurred in several towns along the Mejerda mainstream. The monthly rainfall in March 1973 accumulated to about 3 to 7 times of the average monthly rainfall as shown in the following table. The rainfall concentrated on 26 and 27 March over the whole basin. The amounts of 24-hour maximum rainfall were equal to or exceeded the monthly average records of March.

Overview of Rainfall Records in March 1973 in Mejerda River Basin

Gauging Station	Average Rainfall in March (mm)	Monthly Rainfall in March 1973 (mm)	24 hrs Max. Rainfall in March 1973 (mm)	Date Recorded	Monthly Index
	a	b			b/a
Tunis	47.2	179.6	53.0	Mar.26	3.81
Bizerte	51.6	183.8	50.3	Mar.27	3.56
Mateur	43.9	291.3	90.0	Mar.27	6.64
Tabarka	84.2	288.4	73.5	Mar.27	3.43
Beja	61.1	261.5	60.5	Mar.27	4.28
Teboursouk	58.1	259.2	80.0	Mar.27	4.46
Medjez El Bab	46.7	190.0	52.0	Mar.27	4.07
Jendouba	49.9	185.8	46.3	Mar.26	3.72
Ain Draham	166.1	543.4	138.0	Mar.27	3.27
Le Kef	57.2	261.0	90.0	Mar.26	4.56
Siliana	34.2	255.9	89.3	Mar.27	7.48

Source: "Practical Guide of Flood Management for Engineers and Technicians of DGBGTH, MARH, 1988"

When the flood occurred, Sidi Salem Dam had not been constructed yet, though Mellegue dam existed. Thus it can be said that the downstream reaches were natural condition exposed to the flood without retarding by the dam. As seen in the map, the wide area in Jendouba, Mejez El Bab, Tebourba- El Battane-Jedeida and Kalaat Landelous. However, the map information of inundation area is not remained enough.

(3) May 2000 Flood

Intensive rainfalls were recorded, particularly in the Mellegue River basin in May 2000. At K13 (G/S) installed upstream of the Mellegue dam, in fact, the maximum discharge as recorded in 1969 (4,480 m^3/s) was measured on 26 May 2000. The maximum water level during the flood was at the elevation of 135.5 m NGT at K13, while the elevation of 134.8 m NGT was recorded at Jendouba which is located adjacently upstream of the confluence of the Mellegue River with Mejerda River.

As seen in Figure D2.2.1, flood water overtopped the left bank of the Mellegue River (22 km upstream from the confluence with the Mejerda mainstream). Then it ran beside east side of Jendouba town proper and eventually emptied into the Mejerda mainstream at 2 km upstream of the confluence with the Mellegue. It should be noted that similar pattern of inundation had occurred during the March 1973 flood. According to the field reconnaissance by the Study Team in August 2007and cross section survey, ground elevation at the overtopped section is relatively lower than up and down stream stretches.

(4) Jan. – Feb. 2003 Flood

A distinct feature of the flood in January 2003 has four peak discharges on 12, 18, 26 January and 2 February in the Mejerda mainstream. Low lying areas along the middle to the lower reaches were widely inundated for one week to more than one month in some lower reaches. Many flood marks still remain on the walls of buildings and houses in Jendouba, Bou Salem, Sidi Ismail and other surrounding towns.

According to the existing studies, the monthly rainfall in January 2003 exceeded those of 100-year return period in the Mellegue River basin and the upper areas along Mejerda River as in the following table. In the lower areas, on the other hand, the return periods of monthly rainfall were estimated to be less than 100-year according to the technical report prepared by MARH as follows:

Monthly Rainfall in January 2003

Gauging Station	Average Monthly Rainfall in January (mm)	Monthly Rainfall in January 2003 (mm)	Monthly Index	Return Period (year)
Mellegue Bridge	53	229	4.32	>>100
Jendouba	64	204	3.19	>100
Ain Draham	256	660	2.58	>100
Beja	74	246	3.32	>>100
Teboursouk	84	295	3.51	>>100
El Herri	62	186	3.00	82
El Aroussia Dam	61	168	2.75	40
El Battane	52	122	2.35	21
Ghar el Melh	81	130	1.60	8

Source: "Rapport De Synthèse, Crue et inondations Dans Le Bassin Versant De La Medjerda, MARH, May 2003"

On the other hand, the Study Team conducted frequency analysis by means of a series of the recorded annual peak discharges updated in the current Study. The peak discharge and corresponded probability at Ghardimaou and K13 G/S are compared among the significant floods as below:

Comparison of Scale of Flood Peak Discharges of Significant Floods

Flood	Ghardimaou G/S		K13 G/S	
	Paek Q (m^3/s)	Probability	Paek Q (m^3/s)	Probability
1973 March	2,370	1/70~1/100	1,280	1/5~1/10
2000 May	737	1/5~1/10	4,480	1/70~1/100
2003 Jan – Feb	1,090	1/15~1/20	2,600	1/30
2004 January	1,470	1/30	2,480	1/30

Source: the Study Team

As for the inundation maps of the remarkable historical floods, coverage of the affected areas is most substantial for Jan. – Feb. 2003 flood. Some of the maps focused on the heavily damaged areas are shown in **Figures D2.2.2** to **D2.2.9**.

(5) Dec. 2003 – Jan. 2004 Flood

The flooded area was extended in the downstream of Sidi Salem dam because of the large spill out from the dam. In December 2003, relatively big rainfall was observed twice (110 mm in 3 days from Dec.10 and 40 mm in 2 days from Dec.22, 2003). Because the preceding rainfall at upstream area of the Mejerda was rather big, the reservoir water level gradually rose up and spilled out excess water to downstream. Inundation has occurred from Medjez El Bab to Hir Tobias on Dec.14 to 15, 2003. Although no inundation map at upstream area is available, it was confirmed that inundation had occurred in Jendouba and Nebeur by means of interview though “Flood Damage and Inundation Survey” conducted in the current Study. A peak discharge of 1,040 m3/s was recorded at Jendouba at 9 am on Dec.13, 2003.

At downstream area, inundation has occurred at just downstream of the old bridge in Jendouba. The overbanking flow has rushed into the lowland of El Henna and Henchir Lizdine at north. Further downstream part of the Chafrou River near the confluence with the Mejerda and El Mabtouh plain was inundated as well. **Figures D2.2.10** and **D2.2.11** illustrate the inundation area.

(6) Jan – Feb 2005 Flood

During the latest flood in Jan – Feb 2005, the flood water has overtopped at El Henna, when the gauge reading at dry stone wall at Jedeida G/S was 8.03 m (Q=200 m^3/s). The overtopping began at 2 am on Feb.20, 2005 and lasted until 7 am on Feb.23. After the flooding second overflow occurred at 18:00 on Mar. 1 and continued until 17:00 on Mar. 3. The outlet gate of the Chaout channel was closed during the flood. On the other hand, the outlet gate of the Mabtouh channel was constantly opened. On Mar.23, in the zone of El Mabtouh, the drainage network was completely clogged and mal functional since the flood of Jan-Feb 2003 and thus did not allow water runoff which ends in the El Mabtouh channel in accordance with “Flood in the Mejerda, January – February 2005”.

These two consecutive floods in 2004 and 2005 hit the area between Jedeida to Hir Tobias show the vulnerable points in the lower Mejerda. The inundation map from Mejez El Bab to Jedeida is presented in **Figure D2.2.12**.

D2.3 Results of Flood Inundation and Damage Survey

(1) Objective and Target Respondents

In order to grasp the current condition of flood damage and inundation occurrence, the "Flood Inundation and Damage Survey" was carried out between December 2006 to March 2007. The interview survey was mandated to Eco Ressources International, which is one of Tunisian consulting firms. By means of interview sheets for farmers, residents, shops and industries, direct interview by visiting the total 300 respondents was undertaken. The questionnaire sheets consists of four sections, i.e. I: General Information, II: Flood Damage, III: Experience of Inundation and Lessons, IV: Evacuation and Early Warning. Through the survey, valuable information was collected which can be referred to for the master plan formulation. The number of respondents by the target municipalities is tabulated as below:

Number of Target Respondents for Flood Inundation and Damage Survey

	Name of City	Code	Governorate	Number of Respondents				
				Total	Farmers	Residents	Shops	Industries
1	Nebeur	NB	Le Kef	**15**	4	11	0	0
2	Jendouba	JN	Jendouba	**40**	19	16	4	1
3	Bou Salem	BS	Jendouba	**40**	10	20	8	2
4	Sidi Ismail	SI	Beja	**10**	10	0	0	0
5	Zone Amont SS	ZA	Beja	**5**	5	0	0	0
6	Testour	TS	Beja	**20**	20	0	0	0
7	Slouguia	SL	Beja	**30**	30	0	0	0
8	Mejez El Bab	MB	Beja	**40**	7	20	7	6
9	Mouatisse- El Herri	EH	Beja	**20**	20	0	0	0
10	Tebourba	TB	Manouba	**20**	9	8	2	1
11	Jedeida	JD	Manouba	**20**	10	9	1	0
12	El Battane	EB	Manouba	**20**	15	5	0	0
13	Chaouat - Sidi Thabet	CS	Manouba - Ariana	**20**	20	0	0	0
	Total			**300**	**179**	**89**	**22**	**10**

Source: the Study Team

(2) Serious Floods

The most serious flood events were asked to each respondent. In the upstream area such as in Jendouba, people who responded that the serious flood was 1973 and 2000 is almost even. On the other hand at downstream of Bou Salem except Slouguia, all municipalities answered that 2003 was the severest one. As discussed in previous **Section D2.2**, the flood event in 1973 and 2003 were extraordinary events in terms of rainfall amount and runoff volume in the basin.

Most Serious Flood Experienced

Farmers

No.	Code	Answers as most severe flood 1973	2000	2003	Total
1	NB	0	1	3	4
2	JN	9	9	1	19
3	BS	3	0	7	10
4	SI	0	0	10	10
5	ZA	0	0	5	5
6	TS	4	0	16	20
7	SL	21	0	9	30
8	MB	3	0	4	7
9	EH	3	0	17	20
10	TB	5	0	4	9
11	JD	6	0	4	10
12	EB	10	0	5	15
13	CS	6	0	14	20
Total		70 39%	10 6%	99 55%	179 100%

Residents

No.	Code	Answers as most severe flood 1973	2000	2003	Total
1	NB	0	0	11	11
2	JN	8	7	1	16
3	BS	2	0	18	20
4	SI	-	-	-	0
5	ZA	-	-	-	0
6	TS	-	-	-	0
7	SL	-	-	-	0
8	MB	7	0	13	20
9	EH	-	-	-	0
10	TB	3	0	5	8
11	JD	1	0	8	9
12	EB	1	0	4	5
13	CS	-	-	-	0
Total		22 25%	7 8%	60 67%	89 100%

Shops

No.	Code	Answers as most severe flood 1973	2000	2003	Total
2	JN	0	2	2	4
3	BS	0	0	8	8
8	MB	0	0	7	7
10	TB	0	0	2	2
11	JD	0	0	1	1
Total		0	2	20	22

Industries

No.	Code	Answers as most severe flood 1973	2000	2003	Total
2	JN	0	1	0	1
3	BS	0	0	2	2
8	MB	0	0	6	6
10	TB	0	0	1	1
Total		0	1	9	10

Source: the Study Team

(3) Inundation Depth and Duration (Ref. **Tables D2.3.1** and **D2.3.2**)

Among the farmers' respondents, the maximum inundation depth and duration (both average of respondents) were 295 cm and 76 days respectively, which are the records at Slouguia (farmers respondents). The second largest group is Zone Amont, Mejez El Bab and El Herri, which are 140 to 160 cm of inundation depth and 39 to 55 days for inundation duration. The length of the inundation is quite long and this should have seriously affected to the damage to agricultural crops, house, household properties, and infrastructure, etc. In fact, the seriousness of inundation reflects to the answer of interruption period of shops and industries, of which maximum is 80 days at Mejez El Bab.

(4) Flood Damage (Ref. **Tables D2.3.1**)

Major damage to agricultural crops is mainly olive, cereal, vegetable, fruits and other corps. Regarding the common household, the flood damage consists of house itself (window, wall and roof, etc.), furniture and foods, etc. in the basin. Average damaged value among the target municipalities is summarized as follows:

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

Regarding compensation received from the governmental agencies concerned, the municipalities, of which more than 50 % of respondents replied "received", are Bou Salem, Slouguia, El Herri, Tebourba, Jedeida and El Battane with great difference between municipalities. On the other hand, only two respondents among 32 (shops and industries) has received insurance for flood damage.

(5) Lessons Learnt and Flood Protection Measures (Ref. **Tables D2.3.2**)

More than 70 % of the respondents in overall have showed their negative feeling (toward efforts of self-help) after the last destructive flood. In connection with this issue, most of people revealed their threat of suffering from the loss and damage if same magnitude of flood would occur and hit their properties in the future. It can be confirmed through their comments in the lessons learnt.

The answers to question about cognizance on the existing flood management structures (dike and canal, etc.) nearby their location showed that 70 to 90 % dose not know it at all. Further, regarding to the question of the most important flood protection measures, “construction of structure measures” and “early warning system” shares 80 to 90 % in overall. The share of “proper instruction”, “supporting staff” and “evacuation assistance” was rather small. It is noteworthy that the answer has a quite conspicuous tendency in between municipalities as follows:

Relationship between Required Flood Protection Measures and Municipalities

Most important flood protection measure (among five categories)	Municipalities who replied as the most important flood protection measure
Construction of structural measures	Nebeur, Bou Salem, Mejez El Bab, El Herri
Installation of early warning system	Jendouba, Sidi Ismail, Testour, Slouguia, Tebourba, Jedeida, El Battane

This fact was taken into account for appropriate countermeasures in formulation of structural and non-structural measures in the subsequent studies.

(6) Evacuation and Early Warning (Ref. **Table D2.3.3**)

The 79 % of farmers and 76 % of resident have an experience of evacuation due to devastated flood in 1973, 2000 and/or 2003. The source of the information about the evacuation depends on each municipality. Among the farmers, 67 % reacted by their own judgment whether they evacuated or not. Although the answers might have a bias the location of samples somewhat, this information will be useful for formulation of the plan for information dissemination of early warning system and flood fighting in the future stage.

Only less than 20 % of the respondents have heard warning of evacuation from certain agency. Further, recognition about the evacuation plan is as low as about 20 % in overall. On the other hand, more than 80% of the respondents mentioned that they know where and how to evacuate. However, around 80 % of the respondents recognize necessity of appropriate evacuation plan for securing their properties. In the target area, the evacuation drill seems not to be commonly organized, because 92 % of the farmers and 82% of the residents replied that they “have not participated in the evacuation drill”.

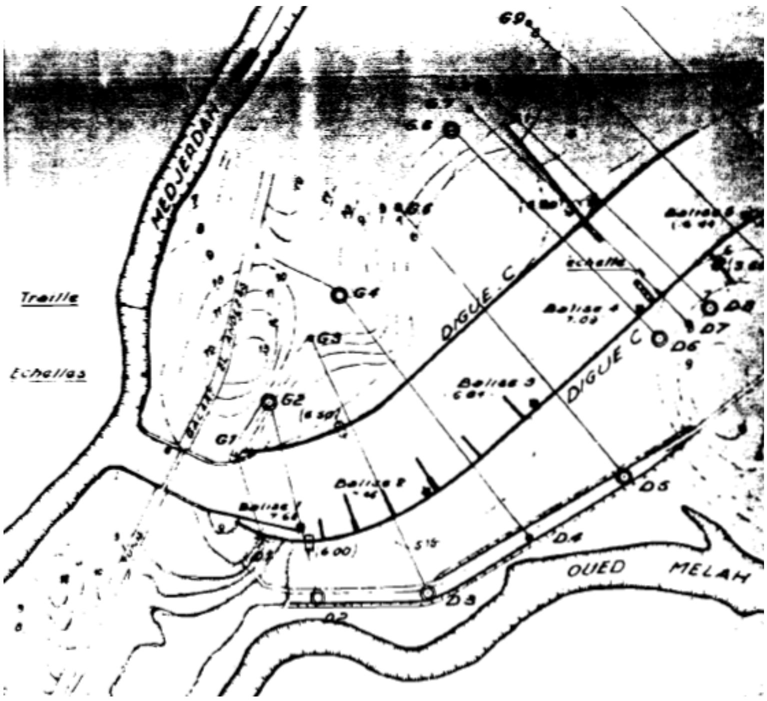
D2.4 Existing Flood Control Measures

The existing flood management measures in the Mejerda River basin mainly dam and reservoirs, since the magnitude of the flood in terms of peak discharge and runoff volume are quite huge. In fact, Mellegue and Sidi Salem Dams have essential function for mitigation of flood risk at downstream. Therefore, the diking system with river improvement has been done only at minimal level and limited in short stretches at downstream between Jedeida and Hir Tobias.

Aside of the large scale of dams, a movable weir at Hir Tobias has vital role to control discharge in the lower Mejerda and floodway to the sea. This floodway has been completed before 1950. After its construction, the original channel of the Mejerda was covered by concrete revetment and drastically reduced its width. The movable weir has been completed in 1990 and the pumping station nearby, which is operated by SECADENORD, was constructed in 1991.

The following sketch shows the layout of the old Mejerda and new floodway just after its completion.

Changes at Hir Tobias (Branch Point of the Original Mejerda and Floodway)



Layout of the Original Mejerda and Floodway

Source : Flood discharge survey report in 1959, MARH

Based on the review of the past major floods in the Mejerda River basin, problems and issues on flooding essentially concerned with plan formulation were identified and discussed in next Section D2.5.

D2.5 Identification of Current Problems on Flood Control

(1) General

Based on the intensive review of related documents of the past flood events as well as field reconnaissance, problems on flooding were identified before preparation of the Framework Plan. The river stretches of mainstream were divided into four major stretches, i.e. (i) Mejerda upstream, (ii) Mejerda confluence with Mellegue, (iii) Mejerda middle stream, and (iv) Mejerda downstream. **Table D2.5.1** summarizes the following items in each stretch:

(a) Principal feature of watershed and river channel
(b) Flooding conditions
(c) Flood damage
(d) Possible countermeasures
(e) Notable issues to be considered

Some essential findings are described with photographs as follows:

(2) Mejerda Upstream (from Ghardimaou to Jendouba)

The upstream area was hit three times in March 1973, May 2000 and Jan- Feb 2003. In particular the wide area was inundated along the meandering stretches of the Mejerda between Ghardimaou and Jendouba. The inundation area is extended along north side of Road No.6. This river section has deep channel (10 to 20 m in height) with steep bank slope. Especially in surrounding area of Jendouba, the situation is rather serious. Therefore, Jendouba City is one of major target to be protected in the Mejerda River basin. In Jendouba, the inundation depth and area due to May 2000 flood was more serious than Jan-Feb 2003. At the junction with Rarai River near Chamtou, a flood plain is extended, where the back water from the Mejerda affects. According to the hydraulic computation result by HEC RAS software based on the cross sections newly obtained in the present Study (December 2006 ~ March 2007), the present flow capacity (bankfull) is estimated as follows:

- National border ~ Ghardimaou : 500 m^3/s <
- Rarai confluence ~ Jendouba : 250 m^3/s
- Jendouba ~ Mellegue confluence : 200 ~ 250 m^3/s

Upstream view of Jendouba Bridge (heavy siltation and narrow section by bridge structure)

Flood marks of May 2000 and Jan 2003 floods in the town center of Jendouba

(3) Mejerda Confluence with Mellegue including Mellegue Downstream

Up to approximately 22 km from confluence along the Mellegue, the river channel has relatively wide section (Ref: photograph below). As close to the Bridge of Road No.6 over the Mellegue, the channel becomes narrow and tends to meander with 10 to 15 m high steep bank. Near the confluence lowly undulated area is lying, where natural retarding basin to retard peak discharge down to Bou Salem exists.

At 22 km upstream section, overtopped flow rampaged to east of Jendouba City and join again with the Mellegue near the confluence with Mejerda. The course of flood flow of March 1973 and May 2000 was almost same along the old channel of the Mellegue (depression area). It was verified through the field reconnaissance in August 2007.

- Mellegue confluence ~ Tessa confluence : 200 ~ 250 m^3/s
- Tessa confluence ~ Bou Heurtma confluence : 400 m^3/s
- Bou Heurtma confluence ~ Sidi Salem Dam : 250 ~ 350 m^3/s

Downstream view of Mellegue River (at 22 km from confluence with Mejerda = Overtopped at left bank in Mar 1973 and May 2000)

Confluence of Mejerda and Mellegue, Jendouba (candidate site for natural retarding basin)

(4) Mejerda Middle Stream (from Bou Salem to Mejez El Bab)

Bou Salem city is one of most vulnerable city against flood and inundation due mainly to the topography and river morphology. Several factors are interconnected for occurrence of frequent floods such as back water from Sidi Salem reservoir (deposition of suspended sediment because of reducing flow velocity is keen issue to be solved at present), bottleneck at Boe Salem Bridge, influence of Bou Heurtma River and very low ground elevation of the town proper, etc.

New bypass floodway route was identified and incorporated in the proposed river improvement plan. It should be noted that earth dike was constructed in the river section at Bou Salem Bridge from June to July 2007 by MEHAT. According to MARH, it was constructed to protect the river bank from bank erosion at around 200 m downstream (right). A new low water channel was constructed at left side within the original river course at downstream of the Bous Salem Bridge. More appropriate measure with bank protection to further mitigate erosion force toward right bank would be absolutely necessary.

Further, the Bou Heurtma River is heavily vegetated by “Tamarix” and it reduces the flow section drastically. River improvement will be required after evaluating the extent of back water effect from the confluence with the Mejerda.

- Bou Salem ~ Sidi Salem Dam : 250 ~350 m^3/s
- Sidi Salem Dam ~ Siliana confluence : 250 m^3/s
- Siliana confluence ~ Slouguia : 450 m^3/s
- Slougiua ~ Mejez El Bab : 600 m^3/s

A view from upstream of Bou Heurtma Railway Bridge (heavy vegetation and narrow section)


Downstream view from Bou Salem Bridge (A low water channel was constructed)

(5) Mejerda Downstream (from Mejez El Bab to river mouth)

The old heritage bridge and a weir are located at downstream reaches of the Mejerda. Since the cultural values are unlimited, removal of such structures will be rather difficult. Therefore, to reduce the peak discharge from Sidi Salem dam at maximum extent would be inevitable. The critical areas were already identified through the lessons in past flood events and succeeding technical studies by MARH. It should be noted Mejez El Bab, Jedeida, El Battane, El Henna and Chafrou confluence are high risk zone against inundation. Appropriate countermeasures will be examined taking account of structures and properties to be protected and assessed possibility of introducing effective non-structural measures.

- Mejez El Bab ~ Laroussia Dam : 200 ~ 250 m^3/s
- Laroussia Dam ~ Tobias Dam : 100 ~ 200 m^3/s


Downstream view from Jedeida Old Bridge (thick vegetation and heavy siltation can be seen at both banks)


New Highway to Tunis (south bound) at Zaouia (A part of El Mabtouh plain)

D2.6 Existing River Channel Maintenance

In the Mejerda Rive basin, a large scale of river improvement works have never been conducted in past. In terms of mandatory rules of river channel management of the Mejerda River, CRDAs have responsibility to carry out in his territory of the Governorate. It should be noted in recent years channel excavation and tree cuttings were conducted in Governortae Manouba after the serious flood in November 2003 to January 2004.

Form May to November in 2004, the CRDA Manouba conducted channel excavation as well for 5 km reaches from the new road bridge in Jedeida to Sidi Thabet (the boundary of Governorate Ariana) including cutting "Tamarix" in the channel (budget: TND 50,000). "Tamarix" is deciduous shrub and can appear as a small tree that can grow in many different substances. "Tamarix" has been nominated as among 100 of the "World Worst" invaders.[1] Within two years after cutting in 2004, most of "Tamarix" has again grown up to 2 to 4 m high from remained roots.

On the other hand, at 500 m reach at upstream side of the road bridge in Jedeida, the roots of "Tamarix" has been removed by means of bulldozer with ripper, which were belong to the Military. In this case, after grubbing the young "Tamarix", it could not grow so fast and became less dense of habitat according to the officer in charge in CRDA Manouba. In fact, CRDA has suffered from maintenace of channel due to the fast-growing "Tamarix". Some ideas of recycle of the "Tamarix" in utilizing as revetment (slope protection) is discussed in Supporting Report E.

Further, the Chafrou River was excavaetd by a dredger machine along 2.5 km from its confluence with the Mejerda River in 2004. Other than the improvement works above mentioned, only some irrigation perimeters and drainage cannal have been conducted.

In other streches in the Mejerda River, any improvement works of river channel has not been conducted up to the present.

Branches of "Tamarix"

Dense "Tamarix" near outlet of El Chouat drainage canal (from left bank)

[1] Ref: "Global Invasive Species Database" (http//www.issg.org/database/species/ecology.asp?si)

CHAPTER D3 RIVER IMPROVEMENT PLAN

D3.1 Basic Concept for Plan Formulation

In Tunisia, any standard, guideline or criteria for formulation of a flood control plan or planning of river improvement works has not been established yet. Therefore, it is decided that common river engineering techniques as well as knowledge accumulated through river administration works in Japan should be substantially referred in the current study.

In principle, applicable structural measures in the Study Area can be primarily divided into, (1) reservoir operation of dam/reservoir, and (2) river improvement works. It should be noted that, priority of such structural measures was mutually agreed by Tunisian side in the light of utilization of existing structures at maximum extent.

In order to screen the priority areas for river improvement in the Mejerda River basin, the following basic concept were adopted:

(1) The areas which have experienced serious inundation by major floods in 1973, 2000, 2003 ,2004 and 2005 (confirmed through flood damage and inundation survey, stakeholder meeting as well as a series of field reconnaissance together with technical staff of DGBGTH)
(2) Urban centers which are densely populated in the flood prone areas
(3) Agricultural land and plantation with or without irrigation system

D3.2 Methodology

As the first priority of structural measure in the Mejerda River basin, a study for optimization of reservoir operation rules under the condition of projected storage volume of major reservoirs in 2030 was conducted. With recognition of the result of computation (flood peak discharges and volumes) as the given conditions, preliminary planning of river improvement works were worked out in order to determine the flood control protection level.

In this purpose, following rules for river improvement were applied to decide the scale of each construction works (river reaches for improvement, channel bottom width, height of embankment, etc.) in conformity with the the peak discharge under optimized operation of the reservoirs:

(1) Empirical practices/theories for planning of river channel improvement are to be applied to assume longitudinal profile and design cross section to cope with probable flood peak discharges (e.g. to approximate existing channel riverbed gradient, minimizing excavation of river banks for setting excavation line, etc.)
(2) Considering the existing inundation condition versus channel flow capacity, overtopping of the river banks is allowed to decrease water levels as much as possible (allowing overtopping river banks taking account of current land use conditions).
(3) In connection with item (2) above, due care shall be taken not to increase flood risk at downstream areas due to widening/deepening of river channel at upstream reaches.

(4) Existing channel flow capacity should be utilized at maximum extent to reduce the volume of channel exavation and embankment of levee with assuming design channel geometry.
(5) As for planning of new bypass canal to augment flow capacity, widening of existing river channel shall be practically considerd to the maximum extent as fisrt priority (accommodating excess discharge over the flow capacity of original river course by new bypass canal).
(6) Minimum size of bypass canal shall be considered from the aspect of operation and maintenance and appropriate proportion of peak discharges between existing channel and new bypass canal.

Although short-cutting of meandering portion is one of common improvement manner for stabilizing river channel and/or lowering water level at downstream reaches, it was not applied in this study. In order to avoid unexpected slope protection works and strengthening of levee embankment against erosion in the future, it was judged not advantageous in general. Further, it is envisaged that incremental land acquisition cost for shortcut channel will make less viable of the proposed improvement works. However, based on the further detailed examination of hydraulic analysis, boundary of PHD and social impact by proposed channel improvement etc., short-cut of existing channel still remains due consideration in the next study stage.

D3.3 Priority Areas for River Improvement

In accordance with the basic concept as above, following eight priority areas were selected in accordance with review of past flood events and field reconnaissance:

Priority Areas for River Improvement

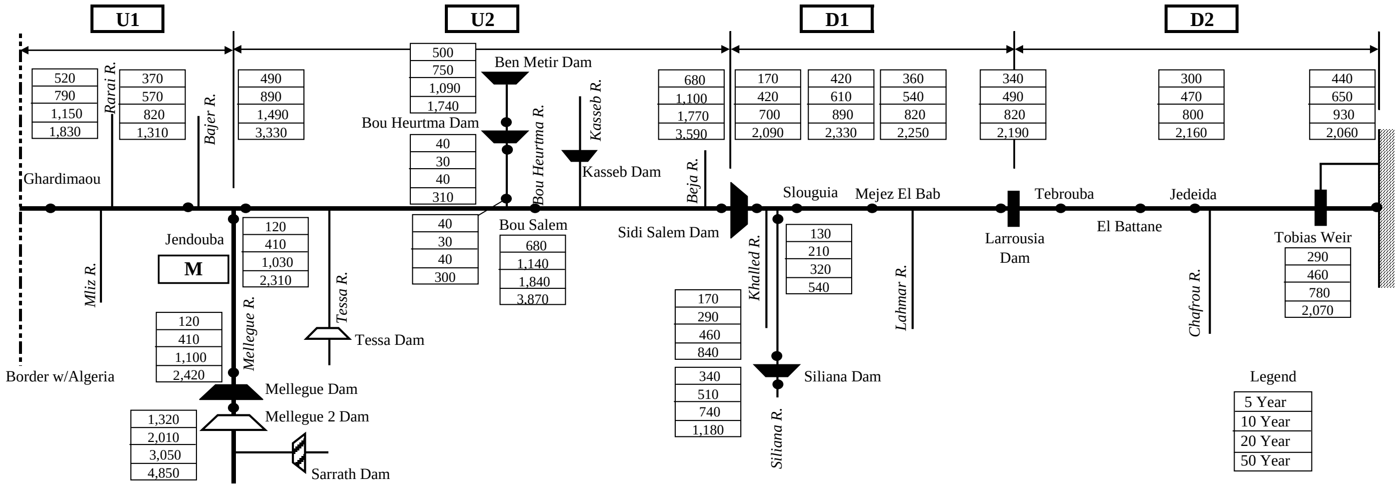
Zone	Selected Priority Areas
U1	Ghardimaou, Jendouba
U2	Bou Salem, Sidi Ismail, U/S of Sidi Salem Dam
M	Lower reaches of Mellegue River near the confluence
D1	Slouguia, Mejez El Bab
D2	Tebrouba- El Battane, Jedeida, El Mabtouh- Tobias Movable Weir, Tobias Movable Weir – Oued El Hmadha canal (floodway)

Note: The subject area of “Zone” is described in Section D4.1.
Source: the Study Team

D3.4 Configuration of River Improvement Works

D3.4.1 Distribution of Probable Flood Discharges

Based on the reservoir operation study by integrated manner (optimum operation rules) and hydraulic/inundation analyses by MIKE FLOOD, probable discharges at each element of river stretches in the Mejerda River basin were computed. The distribution of the probable discharges, which was utilized for the study on flood protection level is shown as below:



Source: the Study Team

Distribution of Probable Flood Discharge

D3.4.2 Configuration of River Improvement Works

In order to determine the major dimensions of river improvement works for preliminary cost estimate in the study of flood protection level, following basic concept was applied to meet the respective magnitude of probable discharges:

(1) Longitudinal Profile of River Bed

River channel bed excavation with widening was firstly considered to accommodate the discharge as described in Section D3.2. As for setting the channel bed elevation, longitudinal gradient of the lowest river bed was assumed taking account of the existing channel bed profile. In particular, existing river crossing structures, such as Sidi Salem Dam, El Herri Weir, Larrousia Weir and Tobias Movable Weir, were duly considered as fixed vertical control points.

(2) Width of River Bed (Channel Geometry)

The extent of widening of channel bed was decided in the light of existing channel width at bridge site and dominant width in urban areas aiming to minimize the impact to the existing properties. Excavation lines of channel (with slope gradient of 1:2.0 both sides) were fit on the cross sections based on the longitudinal gradient.

(3) Treatment of tributaries

In principle, the back levee with height of same elevation of the one along main stream of the Mejerda was assumed for protection of the riparian areas along tributaries.

(4) Alignment and Height of Levee Embankment

In case of the incremental capacity of the discharge by channel excavation is not sufficient, levee embankment was considered at such river stretches. The alignment of the embankment was decided based on the shoulder of the river bank with proposed excavation lines. Height of levee embankment was determined by estimated water levels and required free board. Detailed criteria is presented in Supporting Report E.

(5) Alignment of Bypass Channel

In order to avail the magnitude of probable discharges up to 50-year, four sites of bypass channel route were selected for cost estimate of river improvement works in examination of the optimum flood protection level. Some technical information at candidate sites are described below:

1) Jendouba Bypass Channel

In accordance with the CRDA Jendouba as well as verification of related documents concerned, the urban area of Jendouba is not inundated in January to February 2003, while huge downstream area was inundated along the Mejerda River. On the other hand, the result of inundation analysis in Zone U1 (between Ghardimaou and confluence with the Mellegue River), overtopping can be confirmed under 10-Year probable flood at approximately 10 km upstream from Jendouba city (meandering section).

To cope with the flood discharge, a bypass channel is considered at left bank by detouring at 4.9 km (No.MU211) from Jendouba road bridge and connect with the Bajar River at 1.7 km up from the confluence with the Mejerda. A total length of the bypass channel will be 4.7 km with crossing maily flat cereal cultivation field.

However, since it was verified that channel widening would be rather advantageous than construction of bypass channel from economic point of view. Therefore, the bypass channel was eventually not applied at Jendouba.

2) Bou Salem Bypass Channel

Bou Salem city is one of the most heavily damaged caused by the flood in January-February 2003. Most of the urban zone were submerged under water for about three weeks in accrdance with the “Flood Damage and Inundation Survey, March 2007”. The hydraulic model for inundation analysis was substantially calibrated through verification of flood mechanism in the current study. Due to its geographic location in the basin, where situated at downstream of the confluence with the Mellegue and Bou Heurtma Rivers, it should be noted that this area is highly susceptible to floods.

In order to mitigate the flood risk, a large scale of a bypass channel will be required. The candidate route starts at 5.5 km upstream from the confluence with the Bou Heurtma River (No.MU124) and empties to the Mejerda at 6.9 km downstream from the Bou Salem road bridge at right bank side. The bypass with a total length of 8.0 km will cross a flat irrigated land, which is owned by the National Government. At right downstream side of the outlet with the Mejerda, the Kasseb River joins at MU75 in meandering section. It is expected to utilize the river area of the meandering section for flood retarding before flowing to downstream area.

3) Mejez El Bab Bypass Channel

As same as Bou Salem city, Mejez El Bab city is also one the most significantly affetced area in the basin. In accordance with the agreement with the Tunisian side, the old Andarous Bridge (constructed in early 17th century) crossing the Mejerda should be remained as it is. This means that another waterway is absolutely necessary to prevent the city and heritage bridge from inundation. In particular, the ground elevation of the city center is quite low and it makes effective flood protection in this areas makes rather difficult.

Flood water in this subject river stretches near Mejez El Bab will overflow by 10-year probable flood. The proposed bypass route is located at left bank to detour from 3.4 km upstream of the old bridge and to connect at 1.9 km down stream of the same bridge with a total lengh of 4.7 km. The current land use along the route is mainly agriculture. Since the bypass will cross the existing road at four locations, same number of new bridges should be constructed.

4) El Battane Bypass Channel

One of outstanding outcome through the inundation analysis in the current study might be verification of overtopped location of excessive flood discharge along the Mejerda mainstream under the optimized reservoir operation (anticipated Year 2030 conditions with intermittent timing as well). In between Laroussia Dam and Tebrouba – El Battane area was proved to be safe up to the level of 10-year probable flood. However, the simulation results show that water level of 20-year probable flood will be beyond the left bank elevation and the flood water will reach to Jedeida. Same magnitude of flood discharge will overtop between Jedeida – El Henna - El Chaouat as well and inundation will cover the whole El Mabtouh plain to Utique – Kalaat Andalous zone.

El Battane Bypass Channel with 1.7 km length has been once conptemplated to divert 20-year probable flood at 2.6 km upstream of El Battane weir, which was contructed in almost same era as the Old Andarous Bridge in Mejez El Bab, and rejoin with the Mejerda at 2.3 km downstream from the same weir. The affected alnd long the channel route is mainly cereal and fruit plantation such as pear, applea and citrus, etc.

However, since the design discharge in Zone U2 was set at 10-year return period, the bypass channel at El Battane became not necessary. As the resutls, two bypass channels at Bou Salem and Mejez El Bab were applied.

(6) Alignment of Retarding Basin

1) El Mabtouh Retarding Basin

The area of El Mabtouh is located at left bank of the Mejerda between Jedeida and Tobias Movable Weir, where belongs to Governorate Bizerte at north and to Governorate Manouba at south. This plain having a total area of approximately 20,000 ha has been developed mainly in agricuture as bread basket for increasing demand in the metrpolitan Tunis. On the other hand, the area has been suffered from frequent floodings. In fact, three-year consecutive floodings from 2003 to 2005 seriously hit this area.

Taking account of the lowly undulating topography (NGT 7 m to 15 m), the area has been utilized as natutral retarding basin allowing stagnation of flood water during high stage of water levels in the Mejerda River. In order to improve the situation, a technical study has been conducted and the results are complied in a report of "Dymnamique De La Crue De 2002 – 2003 Dans La Plaine El Mabtouh, by Teib Moncef(2, August 2007". The study recommneds five important issues in conclusion, such as heightening of the section of road GP8 between the bridge of Bizerte and Zhana, improving the some flow passage along GP8 to avoid stagnation of water, and widening of the present bed of El Mabtouh drainage canal to have a double capacity, etc.

In this connection, the Study Team conducted site reconnaissance to confirm current oconditions of existing drainage network and related facitilies in the plain in January 2008. The results are presented in **Figures D3.4.1** to **D3.4.4**, which contains a plan showing existing drainage system with site pictures and location maps of sluiceway along the El Mabtouh Canal.

Through integration of those infromation as above, developlment plan of the El Mabtouh retarding basin was studied. Basic concept of retarding flood discharge was prepared as follows:

(a) To allow overtopping the left bank of the Mejerda River at Henchir El Henna located approximately 7.5 km from the confluence of Chafrou River (cross section No.MD356)

(b) To lead the flood water toward the most lowest areas to temporarily store (Presently abandoned with utilizing as grazing land partially. Cultivation is not suitable due to wet and salined soil characteristics)

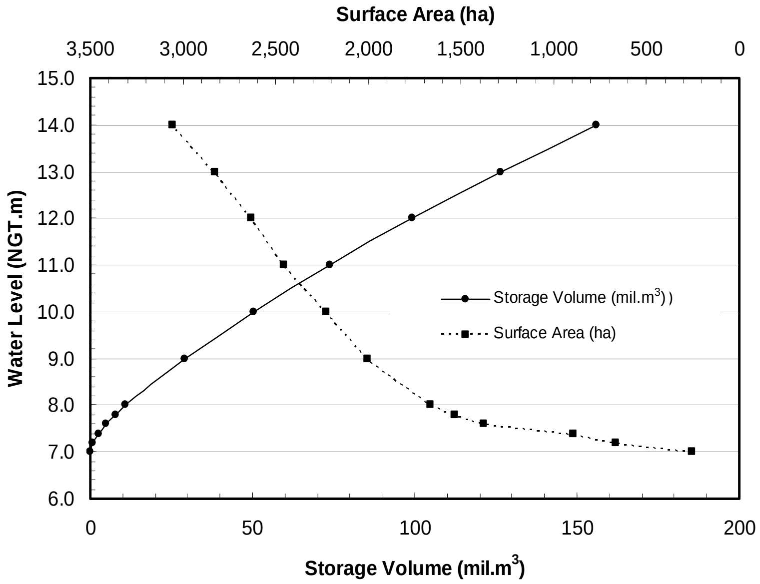
(c) To clearly delineate zones for the purpose of development by pelimeter diking and drainage canal system (existing drainage networks should be effectively connected and rearranged)

(d) To rehabilitate the deteriorated facilities (control gates and canals, etc.) which were heavily damaged due to past floods

(e) To safely retrun to drain into the Mejerda River through El Mabtouh drainage canal considering its flow capacity at downstream (ex. Tobias Movable Weir) as well as back water effect to upstream

(2 Chief Engineer of CRDA Bizerte. The JICA Study Team made joint site inspection and had discussions with him on practical countermeasures against flood problems in the El Mabtouh Plain in September and December 2007.

Based on the topographic survey conducted from January to March 2008, the water level-area-storage volume curve of the the retarding basin was elaborated as follows:



Water Level (NGT m)	Area (m^2)	Surface Area (ha)	Average Area (ha)	Storage Volume (mil.m^3)	Accumu. Volume (mil. m^3)
7.0	2,546,131	255	0	0.00	0.00
7.2	6,666,711	667	461	0.92	0.92
7.4	8,937,236	894	780	1.56	2.48
7.6	13,755,205	1,376	1,135	2.27	4.75
7.8	15,313,480	1,531	1,453	2.91	7.66
8.0	16,640,484	1,664	1,598	3.20	10.85
9.0	20,065,933	2,007	1,835	18.35	29.21
10.0	22,298,045	2,230	2,118	21.18	50.39
11.0	24,530,491	2,453	2,344	23.41	73.80
12.0	26,316,934	2,632	2,542	25.42	99.23
13.0	28,264,801	2,826	2,729	27.29	126.52
14.0	30,541,927	3,054	2,940	29.40	155.92

Source: the Study Team

Water Level – Area – Storage Curve of El Mabtouh Retarding Basin

Based on the development concept, the salient hydraulic feature of the proposed retarding basin is summarized as follows:

Salient Feature of El Mabtouh Retarding Basin

(1)	Inlet channel			
	Construction of earth canal,			
	Improvement of existing channel		9,130	m
	New construction		2,770	m
(2)	Outlet channel			
	Dredging of existing canal		7,780	m
(3)	Reservoir			
	Surrounding dike		10,100	m
	Design storage capacity		50,000,000	m^3
(4)	Outlet structure			
	Sluice, roller gate	Design discharge	Q=50	m^3/s max
		Size	3.00x3.00x3 nos.	
(5)	Inlet structure			
	Overflow dike with stop log	Design discharge	Q=200	m^3/s
		Crest length of overflow dike	80	m

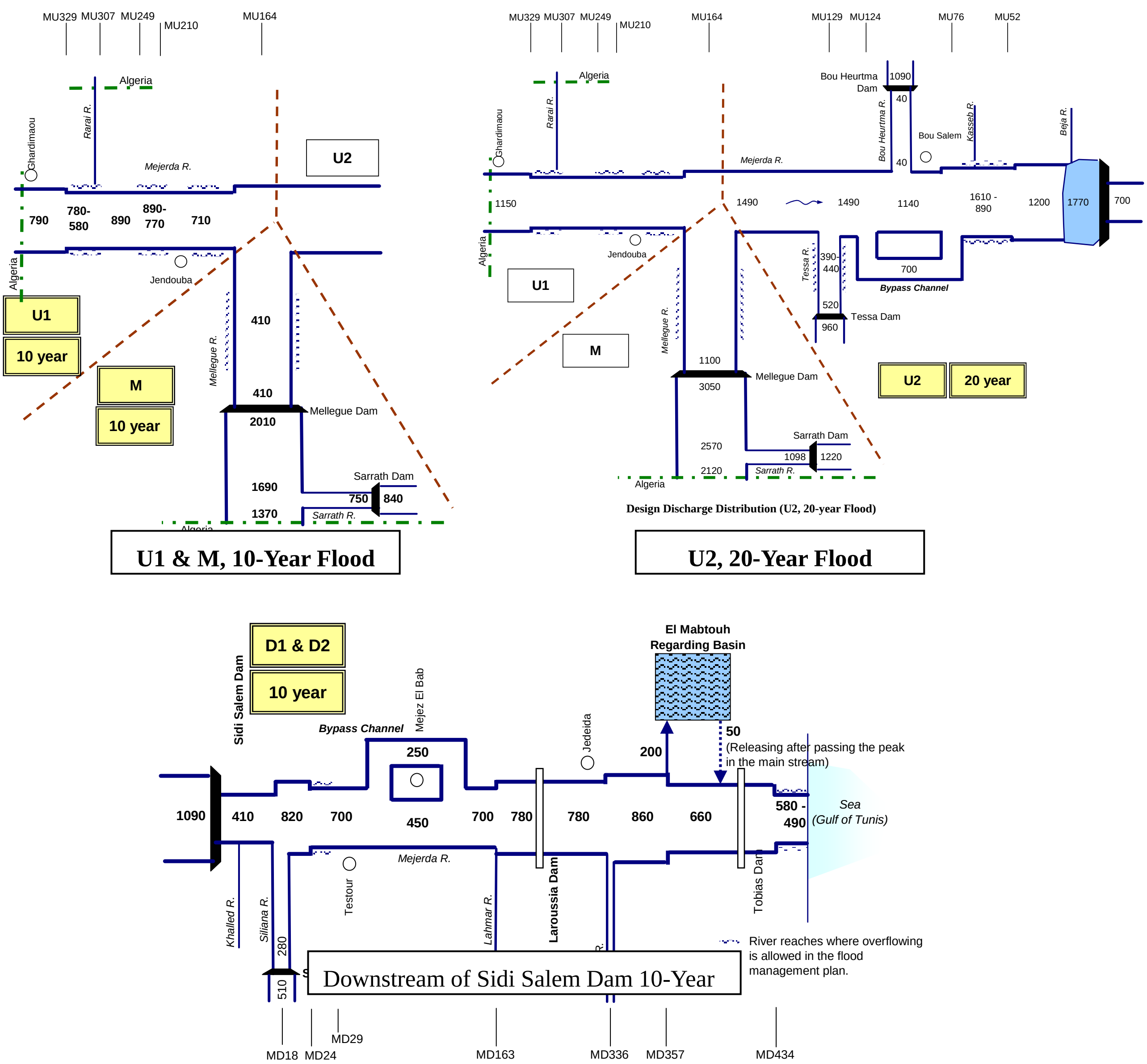
Source: the Study Team

D3.5 Distribution of Design Flood Discharges

As the result of the study on flood protection level as described in Chapter D4, probability of design flood was decided by zone as below:

- Zone U2 : 20-year return period
- Zone U1, M, D1 and D2 : 10-year return period

Based on the flood protection level, further detailed hydraulic analysis to examine the design flood water levels were carried out. In order to prepare preliminary design of river improvement works, the distribution of disgn flood dischagre in the entire study area was established as shown below:



Downstream of Sidi Salem Dam (D1 & D2), 10-year flood Source: the Study Team

Distribution of Design Flood Dischage

D3.6 Proposed River Improvement Plan

Based on the results of hydraulic/inundation analyses as well as comments from Tunisian side on the Iterim Report and Progress Report (2), some elabolations were conducted in the course of finalization of river improvement plan.

Figures D3.6.1 and **Figures D3.6.2** illustrates the logitudinal profiles of downtstream and upstream of Sidi Salem Dam respectively. **Figures D3.6.3** and **D3.6.4** show the genral plans of river improvement at upstream and downstream of Sidi Salem Dam. Further, major dimenstions of the proposed river improvmeent works are tabulated in **Table D3.6.1.**

CHAPTER D4 STUDY ON FLOOD PROTECTION LEVEL

D4.1 Methodology

D4.1.1 General

Based on the Framework of Master Plan, optimum protection level of flood control in the whole Mejerda River basin were examined. This is one of crucial premises for Master Plan formulation as an ultimate goal of the current study. In this respect, cost-benefit performance associated with combination of river improvement works such as riverbed excavation, river channel widening, embankment, and construction of bypass channel and retarding basin etc. were studied. In order to evaluate the protection level to further proceed the study of structural measure(s), the preliminary Cost – Benefit relationship was worked out. This Chapter presents the detailed methodology and study results of the analysis with background information concerned.

D4.1.2 Basic Principle for Formulation of Structural Flood Control Measures

Aiming at maximizing the flood control effect, following two-step measures were applied:

(1) Improvement of reservoir operation for flood control is prioritized.

(2) When the improvement of reservoir operation can not satisfactorily achieve flood control, river improvement is additionally incorporated into the measures.

D4.1.3 Fundamental Rule of River Improvement

Following fundamental rule for river improvement works were applied:

(1) The river improvement shall attach importance to the urbanized areas having suffered serious flood damage so far, and the flood damage in the areas is to be equitably alleviated by the river improvement. Further, flood damage in the agricultural land along the Mejerda River is also to be equitably alleviated by the river improvement.

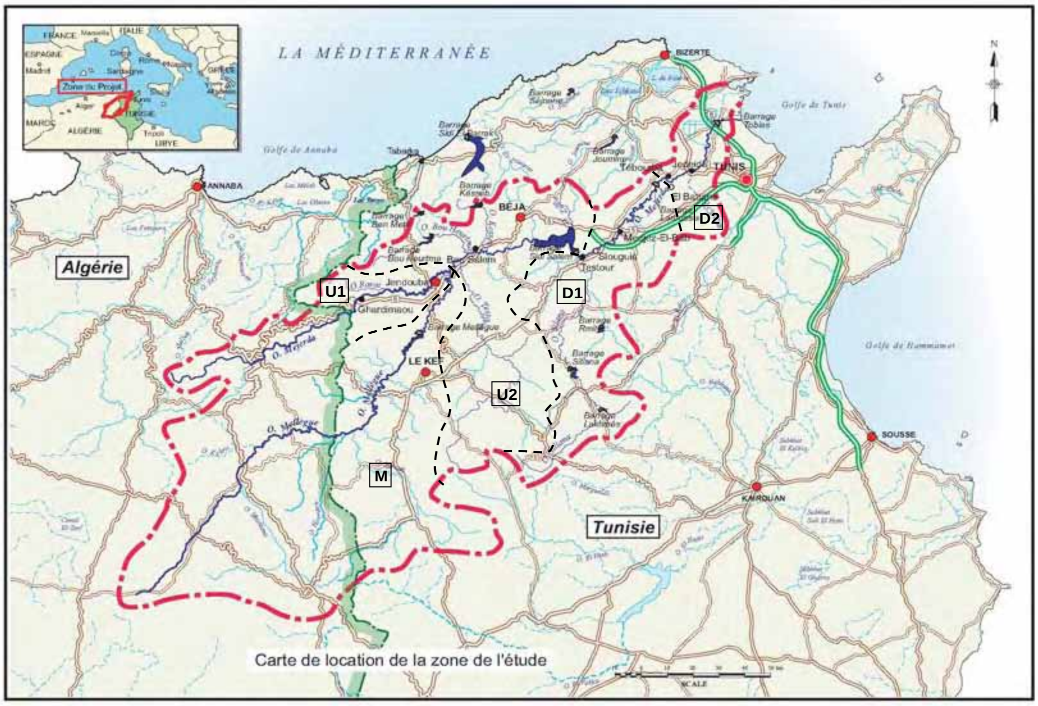
(2) River improvement which has no risk of detrimental artificial flood in downstream areas is to be employed.

D4.1.4 Zoning (Division) of Mejerda River Basin

The study area (the Mejerda River basin in the Tunisia territory) is as wide as 15,830 km2 and regional importance and development level as well as regional flood characteristics is uneven in the area. Therefore, the study area is divided into 5 sub-basins (zones) and a flood protection level is to be examined and prepared for each zone.

Since the Sidi Salem Dam has a huge flood control volume, the flood control at the dam divides the continuity of flooding phenomenon along the Mejerda River. Therefore, the study area is largely divided into two sub-basins, namely the upstream and downstream sub-basins of the dam site.

Further, the upstream sub-basin is divided into M, U1 and U2, and the downstream one into D1 and D2, resulting in 5 sub-basins (zones) in total. The location map and some key information of each zone are presented as follows:



Zoning of Study on Flood Protection Level

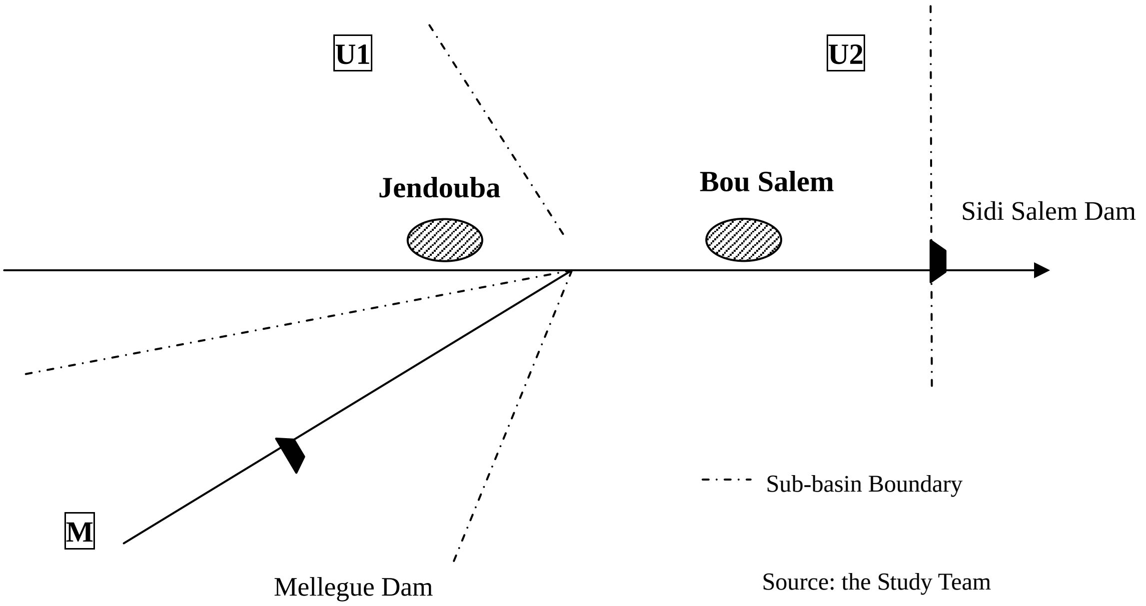
Key Information of Each Zone

Code No.	Nominal Stretch	River Stretches	Distance (km)	Cross Section No.
U1	Upper most reach	National boundary with Algeria at outskirts of Ghardimaou – Confluence with Mellegue River	94.4	MU193-MU360
U2	Upper middle reach	Confluence with Mellegue River – Sidi Salem reservoir upstream end	63.9	MU1-MU192
M	Mellegue River	Mellegue River basin (from national boundary to confluence with Mejerda)	45.0 (D/S of Mellegue Dam)	MG1-MG114
D1	Lower middle reach	Downstream of Sidi Salem dam – Laroussia Dam	83.5	MD1-MD252
D2	Lower most reach	Laroussia Dam – River mouth of Mejerda	65.0	MD253-MD447

Source : the Study Team

D4.2 Optimum Flood Protection Level

D4.2.1 Upstream Sub-basin of Sidi Salem Dam



Schematic Feature of Upstream Basin of Mejerda River

(1) Optimum flood protection level for U1 and M

(a) For each of U1 and M, the protection level with a highest B/C ratio is to be examined as an optimum flood protection level (B: Flood control benefit from river improvement in each zone, C: Direct construction cost of river improvement works for each region).

(b) Areal rainfall covering each zone is to be used for the zone.

(2) Optimum flood protection level for U2

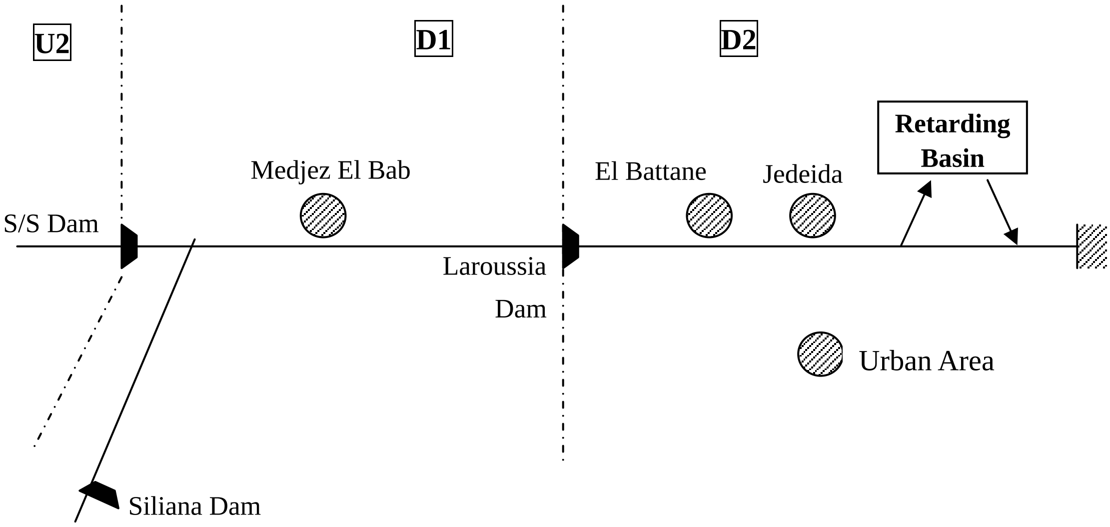
(a) Under the condition that river improvement works corresponding to the optimum flood protection levels obtained in (a) above are employed in U1 and M, the optimum flood protection level for U2 is to be examined as the protection level with a highest B/C ratio.

(b) Areal rainfall covering U2 and its upstream areas is to be used so as to ensure simultaneity in rainfall occurrence.

(3) If the above river improvement works in U1 and M have a risk of causing detrimental artificial flood in U2, the optimum flood protection levels in (a) and (b) are to be reviewed to avoid the artificial flood.

(4) In the review above, the protection level with a highest $\Sigma B/\Sigma C$ ratio of U1, M and U2 is to be examined as an optimum flood protection level for each of U1, M, U2 under the condition that the river improvement works in U1 and M have no risk of causing detrimental artificial flood in U2.

D4.2.2 Downstream Sub-basin of Sidi Salem Dam



Source: the Study Team

Schematic Feature of Downstream Basin of Mejerda River

(1) Optimum flood protection level in D1

(a) For D1, the protection level with a highest B/C ratio is to be examined as an optimum flood protection level.

(b) Areal rainfall covering D1 and its upstream areas is to be used so as to secure simultaneity in rainfall occurrence.

(c) Flood water after control by Sidi Salem Dam is to flow into the upper end of the Mejerda River in D1.

(2) Optimum flood protection level for D2

(a) Under the condition that river improvement works corresponding to the optimum flood protection level obtained in (a) above are employed for D1, the optimum flood protection level for D2 is to be examined as the protection level with a highest B/C ratio.

(b) Areal rainfall covering D2 and its upstream areas is to be used so as to secure simultaneity in rainfall occurrence.

(3) If the above river improvement works in D1 have a risk of causing detrimental artificial flood in D2, the optimum flood protection levels in (a) and (b) are to be reviewed to avoid the artificial flood.

(4) In the review above, the protection level with a highest ΣB/ΣC ratio of D1 and D2 is to be examined as an optimum flood protection level for each of D1 and D2 under the condition that the river improvement works in D1 have no risk of causing detrimental artificial flood in D2.

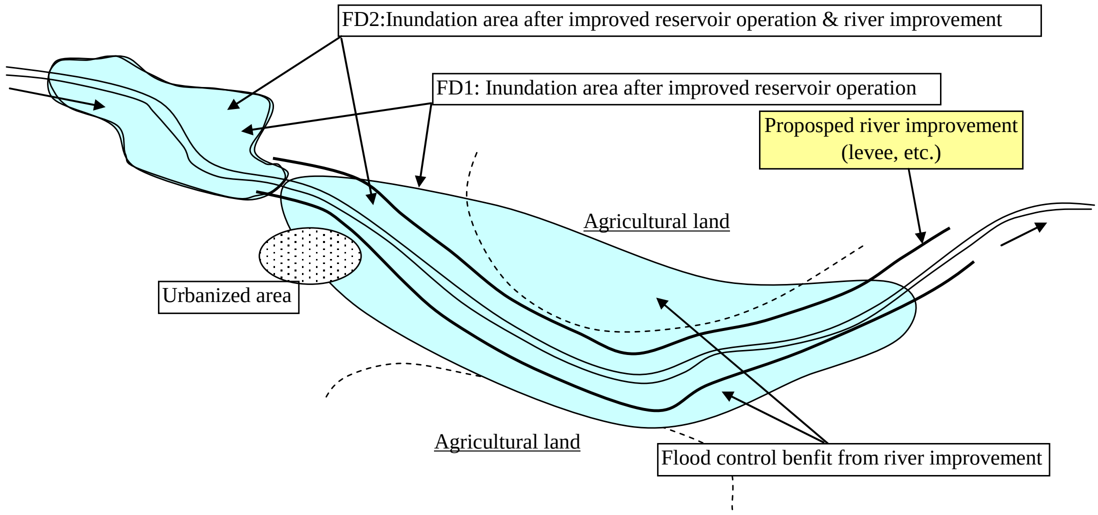
D4.3 Flood Control Benefit from River Improvement

D4.3.1 Basic Concept of Flood Control Benefit from River Improvement

(1) FD1: amount of flood damage in flood inundation areas after improved/coordinated reservoir operation at 4 existing and 3 planned reservoirs

(2) FD2: amount of flood damage in flood inundation areas after improved/coordinated reservoir operation at 4 existing and 3 planned reservoirs and river improvement

(3) Flood control benefit from river improvement = FD1 - FD2（see Figure below）



Source: the Study Team

Flood Control Benefit from River Improvement

D4.3.2 Composition of Flood Damage to be Estimated in Inundation Areas

The flood damage to be estimated is composed of direct and indirect flood damage as stated below:

(1) Direct flood damage
- Agricultural products
- Housing and household effects
- Depreciable assets and inventory stocks of industrial sectors
- Infrastructure

(2) Indirect flood damage
- Damage due to loss of business opportunities, interruption of public transportation, wage loss of employees, labor cost for cleaning houses, etc.

In this study, the amount of indirect flood damage is assumed to be 30% of the total amount of direct flood damage.

D4.3.3 Review of Flood Damage due to Past Major Floods

(1) Reference manual and baseline information

In order to estimate the flood damge based on the defferent scale of flood occurrence, following manual and related data/information were utilied:

1) "Manual on Economic Survey for Flood Control (Draft)", Ministry of Infrastructure, Land and Transport (MILT), Japan, April 2005 (latest version of the Manual) (to be referred to as "The Japanese Manual" hereinafter)
2) National Census in Tunisia, 2004
3) Flood damage records and related documents obtained from CRDAs
4) Results and collected information by "Flood Inundation and Damage Survey" conducted by ECO Resources in March 2007

It is noted that the Japanese Manual above is widely applied not only in Japan herself but also in the other countries, since the concept of methodology and attached information include universality in planning and design of flood control projects. Among the available data collected through DGBGTH/CRDAs, those from CRDA Manouba are most comprehensive and informative, which includes monetary damage information on agricultural crops and infrastructures connected with different flood events.

(2) Flood Damage in Past Major Floods in Mejerda River Basin

The Governorate Manouba, in particular El Battane-Jedeida area has been hit by devastated floods in seccessive years from 2003 to 2005. Total 35 kinds of documents were collected and analyzed, in particular the damage records as listed in **Table D4.3.1**. Further, some information are available in other Governorates such as in Ariana, Beja and Jendouba in the documents collectd through the "Flood Inundation and Damage Survey" conducted in March 2007. Those were further reviewed from the aspect of damaged area/location and monetary values of damaged crops through economic evaluation in Supporting Report I. **Table D4.3.2** shows the result of enumeration of the raw records extracted from the available documents.

D4.4 Preliminary Cost Estimate of River Improvement Works

D4.4.1 Probable Discharge Distribution

A diagram of distribution of flood peak discharges was prepared based on the simulation resutls of reservoir operation study as illustrated and shown in Section D3.4.1. Considering the preliminary design configuration of river imrovement works, distribution of flood peak discharges of different scale by menas of channel improvement is shown in the figure of Section 3.4.1. The size (bottom width) of the channel to be improved corresponding to probable discharges is listed in **Table D4.4.1**.

D4.4.2 Configulation of River Improvement with Related Structures

In each zone, river improvement works corresponding to probable floods (5, 10, 20 and 50 year floods) were worked out and construction costs were estimated. After the screening of possible structural measures, conceptual design of the structures, earth works including channel excavation and embankment of levee and miscellaneous works, such as revetment and sluiceway, etc. were prepared. The construction cost versus construction size curves (principal dimensions of related structures and earth wroks), total 50 categories of construction works were preapred.

In particular, four bypass routes and one retarding basin together with earth works such as low water channel excavation and embankment of levee were considered as possible structural measures as below:

Bypass channel	(Jendouba), Bou Salem, Mejez El Bab, El Battane
Flood retarding basin	(Jendouba), El Mabtouh

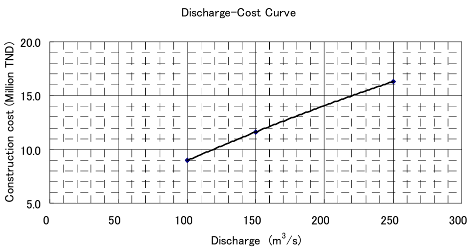
The baypass channel at Jendouba was eventually cancelled because the widening of river channel and levee construction revealed less costly than constrcution of the new bypass channel. In case of candidate site of retarding basin at Jendouba, it was finally discarded due to unfovarable topographic condition for control of outgoing discharge.

D4.4.3 Unit Cost and Bill of Quantity

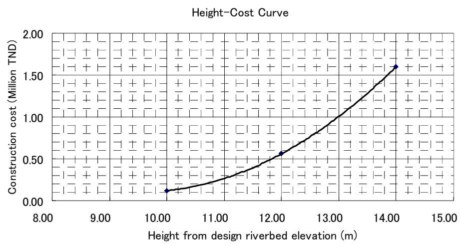
The unit cost of major work items are investigated in the recent projects implemented or under going by MARH and MEHAT. After the review and comparison of those collected data, the unit price was adjusted to be current rate for the current study. The bill of quantities of earth works and structures are preliminarily estimated based on the drawings of river profile and cross sections and plans, etc.

D4.4.4 Summary of Cost Estimate

In accordancee with the defferent size of the works in 50 categories the cost curvs were prepared for convenience of estimating the related cost depending on the magnitude of probable flood discharges and volume. By means of the cost curves, the direct construction cost was estimated as tabulated in **Table D4.4.1**. The following two figures show the cost curves for the El Mabtouh retarding basin and levee embankment as the samples of cost curves.



El Mabtouh Retarding Basin



Levee Embankment (MD281-MD251)

D4.5 Flood Control Benefit

D4.5.1 Damage to Agricultural Products

A unit damage rate of TND2,000/ha (Ref: T**able D4.3.2**) is applied based on the verification of actual damage to agricultural crops. In addition to this, the cost for soil conservation and rehabilitation of land (TND 400/ha) was added.

Damage = ∑{(Value per agricultural product) x R x Inundation area}

Damage rate : R

Agricultural Products

Item	Depth (m)	Duration of Inundation (days)			
		1 to 2	**3 to 4**	**5 to 6**	**More than 7**
Lowland Crop (root vegetable, pulse, pepo, wheat, etc.)	< 0.5	0.27	0.42	0.54	0.67
	0.5 - 0.99	0.35	0.48	0.67	0.74
	1.0 <	0.51	0.67	0.81	0.91

Source: "Manual on Economic Survey for Flood Control (Draft)", MILT, Japan, April 2005

D4.5.2 Damage to Housing and Household Effects

(1) Damage to housing

Damage = ∑{(Value per house) x R_d x V_h }

Where, R_{d1} : Damage rate

V_h : Number of house in inundation area

Note: - Unit value of house per m^2= TND 400/m^2 (A)

(based on the discussions with technical staff in DGBGTH subject to be verified)

- Average size of occupied ground area per house = 150 m^2/house (B)
- Value per house = (A) x (B) = TND 60,000/house

(If certain reliable data of the value is available by Governorate, they will be applied.)

- V_h = ∑ {(Inundation area/Area of Delegation) x P_d / 4.5^{*2}}

P_d : Population in Delegation subject to inundation areas

*2 : Average population per household in six Governorates subject to inundation (Ref: **Table 4.5.1**)

(2) Damage to household effects

Damage = ∑{(Value of total effects per household) x Rd2 x V}

Where: Rd2, Damage rate

Note: TND 18,035/household (Ref: **Tables D4.5.2**)

Damage rate

Housing and Household Effects

Item	Inundation Depth (m)				
	< 0.5	**0.5 - 0.99**	**1.0 - 1.99**	**2.0 - 2.99**	**3.0 <**
Houses (R_{d1})	0.092	0.119	0.266	0.380	0.834
Household Effects (R_{d2})	0.145	0.326	0.508	0.928	0.991

Source: Japanese Manual, April 2005

D4.5.3 Damage to Depreciable Assets and Inventory Stocks

(1) Damage to depreciable assets (Ref: **Tables D4.5.3** to **D4.5.6**)

Damage = ∑{(Inundation area/Area of Governorate) x V_d}

Where, Vd: Total value of depreciable assets by Governorate

(2) Damage to inventory stock (Ref: Table D4.5.3 to D4.5.6)

Damage = ∑{(Inundation area/Area of Governorate) x Vi}

Where, Vi: Total value of inventory stock by Governorate

Damage rate

Depreciable Assets and Inventory Stock

Item	Inundation Depth (m)				
	< 0.5	0.5 - 0.99	1.0 - 1.99	2.0 - 2.99	3.0 <
(a) Depreciable Assets	0.232	0.453	0.789	0.966	0.995
(b) Inventory Stock	0.128	0.267	0.586	0.897	0.982

Source: Japanese Manual, April 2005

D4.5.4 Damage to Infrastructure

TND400/ha (Ref: **Table D4.5.7**)

The damage to infrastructure is assumed to be irrigation network, rural road network, irrigation pumps, drainage network, drinking water supply facilities and pumping station, etc. The rate estimated in Governorate Ariana based on the flood damage in January 2003 is applied.

D4.5.5 Indirect Flood Damage

Damage = Total of Direct damage x 30%

Note: 30 %, Dominant proportion applied to other flood management studies (to be verified by further detailed economic analysis in the succeeding study stage)

In the Study Area, the indirect damage is assumed, such as the secondary damage and cost resulting from flood inundation, i.e.:

- Additional transport cost incurred because of long detours due to existing bridge and road closures
- Loss of product (output) due to the interruption of economic activities,
- Cost of evacuating people and urgent relief activities
- Cleaning up building/houses after the event, etc.

D4.5.6 Flood Damage with Project

It is presumed that certain inundation area will be remained even after implemnetation of the proposed project(s). As mentioned in Section 4.3, promising convination of structural measuress based on the distribution of flood peak discharge over the Mejerda River basin were assumed for estimation of the construction cost. With the proposed structure measures, the inundation analysis were worked out by the same manner as conducted without any structural measures (under present condition).

D4.5.7 Summary of Reduced Flood Damage

The results of reduction of flood damage i.e. “Without-“ condition minus With-“ condition are summarized as follows:

Summary of Reduction of Flood Damage

Unit: TND 1,000

Zone	5-Year	10-Year	20-Year	30-Year	40-Year	50-Year
U1	0	3,246	3,690	4,107	4,524	4,941
U2	4,920	11,916	21,619	23,489	25,359	27,229
M	0	1,531	3,026	3,627	4,228	4,829
D1	4,006	6,559	8,102	8,263	8,425	8,586
D2	9,169	23,029	27,604	29,099	30,595	32,090

Source:the Study Team

D4.6 Selection of Optimum Flood Protection Level

D4.6.1 Basic Condition

(1) Economic life for evaluation

The project life of the structural measures in the Master Plan to be proposed is set 50 years taking account the common nature of the large scale river improvement works such as by channel excavation, construction of bypass canal, retarding basin and relevant structures, etc.

(2) Discount rate

The discount rate of 12 % for the loss of opportunity cost in the country was applied to convert from direct cost and benfit to the yearly present values in the benefit-cost stream.

(3) Standard conversion factor (SCF)

In order to estimate the economic cost and benefit, a standard conversion factor of 88 % was applied. Since the unit pirces of the cost estimate includes Value Added Tax, the values after reduction of 18% (tax rate for most commodities in Tunisia) and the SCF was applied.

(4) Annuarized flood control benefit

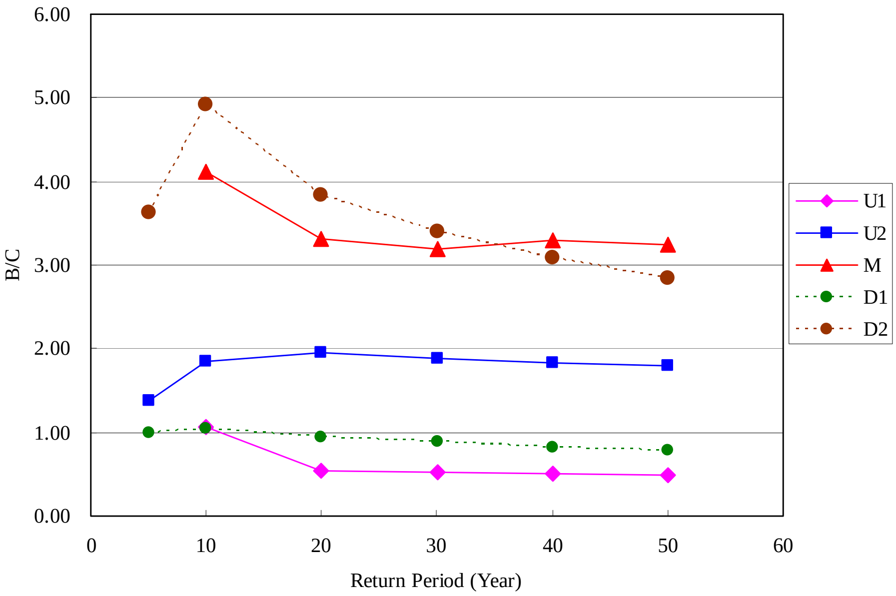
Based on the premises as above mentioned, annualized average benefit was estimated.

D4.6.2 Flood Protection Level

Following figure shows the results of B/C ratios for the five zones. Based on the results, a 10 year return period was selected as an optimum flood protection level of river improvement for each of U1, M, D1 and D2, because the selected return period has the highest B/C ratios for each zone. In the case of U2, a 20 year return period was selected. Detailed cost-benfit stream for each zone is attached in Data Book DD1.

Design Flood Discharge

Zone U1, M, D1, D2 → 10-year probability
Zone U2 → 20-Year probability



Source: the Study Team

Benefit – Cost Relationship by Zone (River Improvement Works)

CHAPTER D5 IMPLEMENTATION SCHEDULE OF RIVER IMPROVEMENT WORKS

D5.1 Work Quantity and Construction Period

In order to assess the required construction period for river improvement works in each zone, work quantity of major work items are summarized as follows:

Work Quantity of Major Items for River Improvement

Work Item	Zone U1 (10 yr)		Zone U2 (20 yr)		Zone M (10 yr)		Zone D1 (10 yr)		Zone D2 (10 yr)	
Total Length (km)	94.4		63.9		45.0*		83.6		65.0	
Channel excavation										
- Length (km)	48.2		42.7		12.9		81.2		63.8	
- Volume (1,000m^3)	4,230		13,100 (3,510)**		640		12,080 (2,650)**		10,040	
Embankment										
- Length (actual: km)	L	R	L	R	L	R	L	R	L	R
	2.3	2.9	34.8	32.7	4.2	3.2	36.7	33.9	29.4	26.5
- Volume (1,000m^3)	88		4,833 (241)***		128		848 (26)***		1,735 (1,128)**	
Disposal of excavated material										
- Volume (1,000m^3)	4,160		8,670		410		11,290		8,960	

Note: *, Distance for river cross section survey works
**, Work quantity for construction of bypass channel
***, Work quantity for construction of back levee along tributaries and retarding basin
Source: the Study Team

As seen in the table above, the work quantity of Zone M is rather small compared with others. From technical point of view, it is judged advantageous that Zone M together should be combined with Zone U1 as one component for implementation.

The critical path for construction works of the proposed project would be for levee embankment due to its construction procedure. Considering the target year of 2030of the proposed Master Plan, which has been set for completion of all works including fund arrangement, feasibility study, detailed design, EIA, land acquisition, etc. construction periods of each zone are preliminarily decided as follows:

(a) Zone D2 : 4 years
(b) Zone D1 : 3.5 years
(c) Zone U2 : 5 years
(d) Zone U1 + M : 2 years

D5.2 Period of Associated Activities

Aside from the construction period of river improvement works, the period of other associated works are assumed to set up the implementation schedule as follows:

(i) Preparatory works : 1 year
(ii) Feasibility study : 1.5 years
(iii) Environmental Impact Assessment : 1 year
(iv) Fund source arrangement : 1year
(v) Procurement of consulting services : 1 year

(vi) Detailed Design : 1.5 years
(vii) Prequalification, budding and procurement of constrictors : 9 months
(viii) Land acquisition : 2 ~ 4 years

D5.3 Implementation Schedule and Annual Disbursement Schedule

Based on the conditions as mentioned in previous sections, the implementation schedule if the river improvement works of each zone is individually conducted is set for subsequent economic analysis to assess its viability as presented in **Tables D5.3.1** and **D5.3.2**.

D5.4 Other Associated Cost for River Implement Works

The associated cost to be incurred for implementation of the proposed river improvement works, following conditions are applied. The estimated cost for implementation of the proposed river improvement works in the Master Plan is tabulated by zone in T**ables D5.3.3** to **D5.3.6**.

(1) Direct construction cost

Based on the actual works quantity and prevailing unit cost in Tunisia and international construction market, which were analyzed and enumerated through the preliminary design works, the direct construction cost was estimated. The proportion between foreign and local currencies were preliminarily decided taking into account the majority of cost of the proposed river improvement works by each zone (Ref: Supporting Report E).

(2) Land acquisition cost

In accordance with the layout of major structures, required land for construction works are computed. The average land value prevailing in the governorate in the Mejerda River basin was investigated and applied (Ref: Supporting Report E).

(3) Government administration cost

The administration cost to be incurred for management of the project by the executing agency is assumed 3 % of total cost of items, (1) Direct construction cost and (2) Land acquisition cost.

(4) Engineering services cost

The engineering services cost, which is required to carry out the detailed design and construction supervision, 10 % of the direct construction cost is applied.

(5) Physical contingency

The physical contingency, which should be considered unexpected usage of budget due to certain reason, 10 % of the total cost of items, (1) Direct construction cost, (2) Land acquisition cost, (3) Government administration cost and (4) Engineering services cost.

(6) Price contingency

As for the local currency, average value of consumer's price index between 2000 and 2008 (Institute National de la Statistique, INS), 3.2 % was applied. On the other hand, as for the foreign currency, 2.1 %, which was estimated at an average increase rate of consumer prices of G-7 Countries in 5 years from 2006 to 2010, was applied as follows:

Consumer's Price Index of G-7 Countries

Unit: %

2006	2007	2008	2009	2010	Average
2.0	1.9	2.6	1.8	2.0	2.1

Source: World Bank ("Global Outlook in Summary")

The concerned amount of the rates is the total of items, (1) Direct construction cost, (2) Land acquisition cost, (3) Government administration cost, (4) Engineering services cost, and (5) Physical contingency:

(7) Taxes

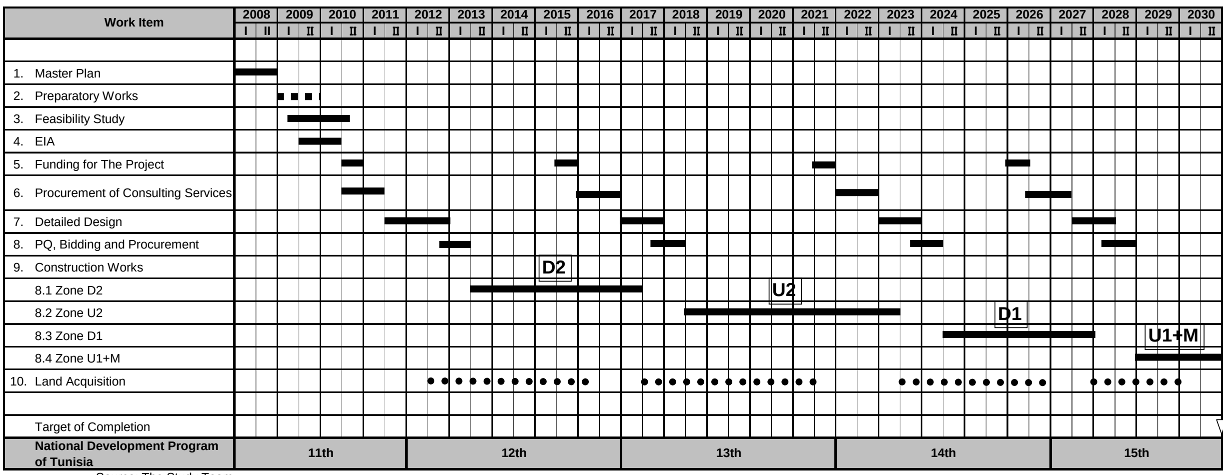
As for the taxes of commodities and services required for implementation of the proposed project, following conditions are introduced:

(i) Direct construction cost : 18 %

(ii) Government administration and engineering services costs : 10 %

D5.5 Overall Implementation Schedule of River Improvement Works

Based on the cost estimate of each zone obtained in Section D5.4, economic analysis was conducted and its results are presented in Supporting Report I. The sequence of implementation of the four zones (D2, D1, U2 and U1+M) was decided with consideration of the results of economic analysis and common procedure of channel improvement works. As the result of economic analysis, it would be apparently beneficial to commence from zone D2. As for the second zone, the economic indicators of zones D1 and U2 fall almost equivalent level. The sequence of U2, D1 and then U1+M was finally decided considering the priority of Bou Salem area (Zone U2) based on topographic and hydrological characteristics as well as people's demand in the area. In conclusion, following overall implementation schedule was proposed aiming at successful completion of the master plan by year 2030 as below:



Source: The Study Team

Overall Implementation Schedule of River Improvement Works

CHAPTER D6 COST ALLOCATION FOR FUTURE MULTIPURPOSE DAM PROJECT

D6.1 Methodology

D6.1.1 Objective

As discussed in Chapter D3, conducting optimum reservoir operation will be the first priority of structural measures in the Mejerda River. Remarkable flood control effect of major seven dams (four existing and one under construction, and two to be constructed in the future), have been identified in the reservoir operation study. Based on the study results, modified rules of the integrated reservoir operation for flood control are proposed in the current Study.

On the other hand, flood control benefit was estimated including the retarding effects by the improved reservoir operation with assuming various scale of floods into each reservoir. Theoretically, it is required to take account the cost for construction of dams for economic analysis for overall schemes planned in the Mejerda River basin with focusing flood control purposes.

Among the seven dams, Mellegue 2 and Tessa Dams are planned to be constructed in the future in accordance with the latest information of DGBGTH, MARH. Since those are both multipurpose dam projects, cost for flood control function shall be exclusively separated from total construction cost in certain appropriate manner. In case of Sarrath Dam, its cost can be treated as sunk cost, since implementation has been started already.

It should be noted that inundation analysis in the current study takes flood control effect by the optimum operation of major dams including those to be constructed in the future and derives river improvement plan accordingly. Therefore, the construction cost of the multipurpose dams should be accounted in due procedure in economic analysis of the proposed Master Plan.

In this context, this Chapter presents the study results on separation of the dam construction cost for overall economic analysis to assess affordability of the Master Plan in the Mejerda River basin.

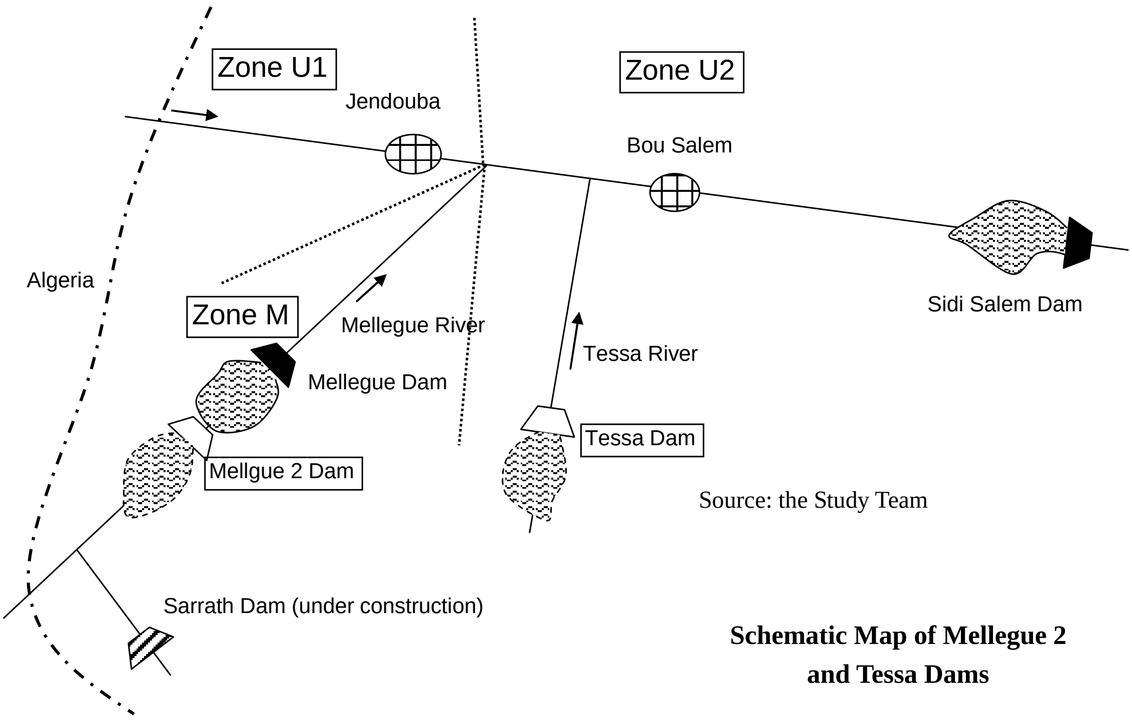
D6.1.2 Methodology

As the results of interview and discussions with DGBGTH, any rule for allocation of construction cost of multipurpose dams/reservoirs has not been established in Tunisia. Therefore, the standard/guideline available in Japan, which is commonly referred for dam engineering for planning and design in particular for multipurpose dam projects, was applied in this Study.

In case of Mellegue 2 Dam, the flood control function will contribute to the benefit in Zone M (through the Mellegue River) and U2 (Mejerda River) because of its location. After separation of the cost for flood control portion was conducted, it was further divided into two Zones (U2 and M) by means the proportion of the length of river reaches concerned as follows:

			Ratio
- Zone M	: 55 km (Mellegue 2 Dam ~ Confluence w/Mejerda)	:	0.60
- Zone U2	: 37 km (Confluence w/Mejerda ~U/S end of Sidi Salem)	:	0.40

Inundation analysis by MIKE FLOOD definitely shows an effect (reduction of inundation area) by Mellegue 2 Dam at downstream stretches of the confluence with the Mellegue River. Therefore, the river course belonging to Zone U2 was taken into account for allocation. In case of Tessa Dam, the estimated cost for flood control function was allocated 100% to Zone U2 considering the river system as illustrated below:

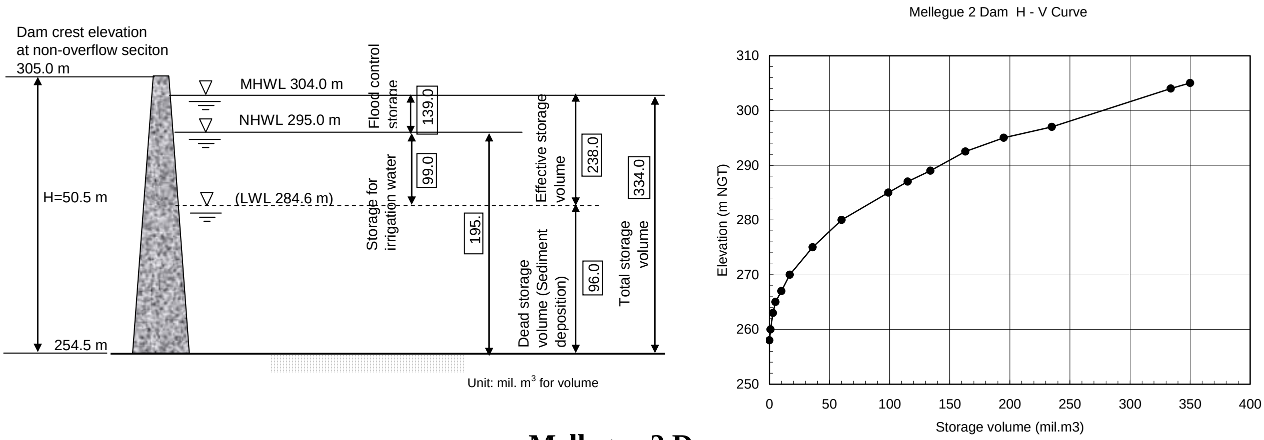


Source: the Study Team

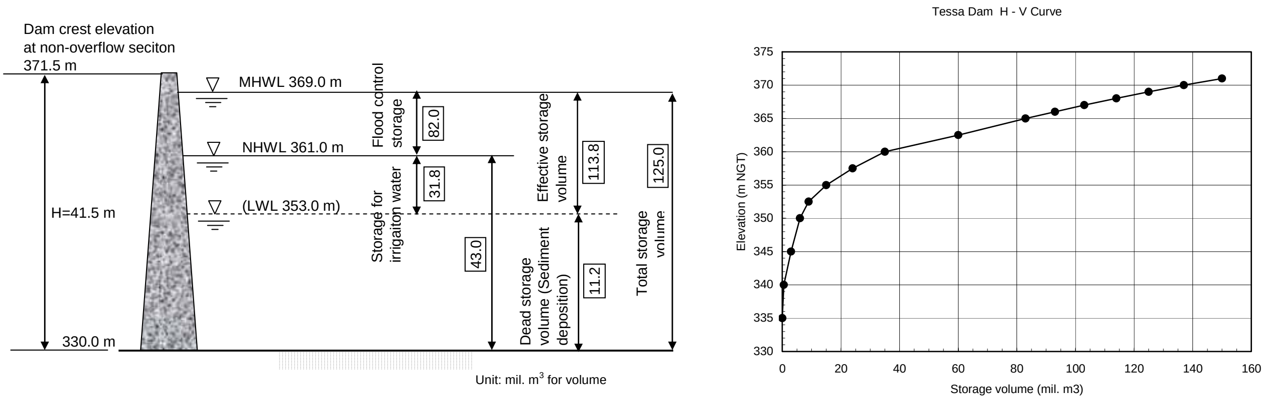
Schematic Map of Mellegue 2 and Tessa Dams

D6.2 Salient Feature of Selected Dams

The storage volume of the reservoir and corresponded water levels of the two dams were referred to in the studies of water balance and reservoir operation. Those figures are schematically shown with an elevation ~ storage volume curve as follows:



Mellegue 2 Dam



Tessa Dam

Distribution of Reservoir Storage of Mellegue 2 and Tessa Dams

(for cost allocation)

D6.3 Cost Allocation for Flood Control Function

The allocation of construction cost of Mellegue 2 and Tessa Dams are separated into proposed functions are tabulated as follows. Detailed process of computation and assumptions applied is shown in **Table 6.3.1**.

Sharing Cost Ratio between Functions on Mellegue 2 and Tessa Dams

	Description	Mellegue 2 Dam				Tessa Dam		
		Flood Control	Irrigation Water Supply	Hydroelectric Generation	Total	Flood Control	Irrigation Water Supply	Total
a	Substitute Dam Construction Cost	81.4	73.9	-	-	19.6	14.5	-
b	Valid investment cost	41.9	63.3	13.8	-	29.3	11.9	-
c	Smaller figure among a & b	41.9	63.3	13.8	-	19.6	11.9	-
d	Exclusive cost	0.0	0.0	5.0	-	0.0	0.0	-
e	c- d	41.9	63.3	8.8	114.0	19.6	11.9	31.5
f	Separated cost	41.1	54.4	4.3	99.8	11.5	7.0	18.5
g	Resudial benefit	0.8	8.9	4.5	14.2	8.1	4.9	13.0
h	Ratio of Item "g" (%)	6%	63%	32%	100%	62%	38%	100%
i	Allocated resudial cost	0.9	9.5	4.8	15.2	4.7	2.8	7.5
j	**Project cost to be shared**	**42.0**	**63.9**	**9.1**	**115.0**	**16.2**	**9.8**	**26.0**
k	Proportion of Project cost	36%	56%	8%	100%	62%	38%	100%

Source: the Study Team

The shared cost for flood control of Mellegue 2 Dam is further allocated into Zones U2 and M by means of the methodology as described in Clause D6.1.2 and below:

Zone U2 : Zone M = 40 : 60 = 16.8 mil : 25.2 mil. (total TND 42.0 mil.)

As the results of cost analysis as mentioned above, the direct construction cost of the two dams is eventually allocated into two Zones U2 and U1+M as follows:

Cost Allocation of Mellegue 2 and Tessa Dams by Zone

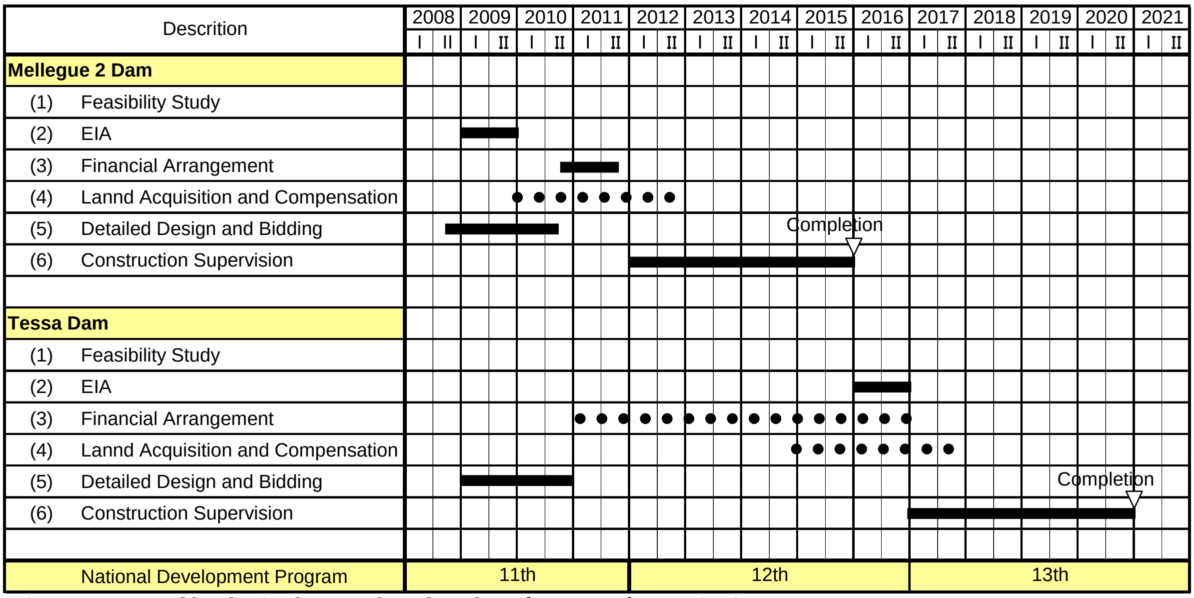
Unit: TND mil.

Name of dam	Zone U1+M	Zone U2	Total
Mellegue 2	25.2	16.8	42.0
Tessa	0.0	16.2	16.2
Total	**25.2**	**33.0**	**58.2**

Source: the Study Team

D6.4 Implementation Schedule

Based on the information from DGBGTH, the implementation schedule was duly confirmed in order to annually disburse the project cost for the economic analysis. The following schedule was set to assess the viability of overall project together with river improvement works as well as for the study of reservoir operation. In accordance with the implementation schedule, annual disbursement of the direct cost and other associated cost, such land acquisition and engineering services were estimated.



Source: Prepared by the Study Team based on the information from DGBGTH

Implementation Schedule of Mellegue 2 and Tessa Dams

D6.5 Other Associated Cost to be Shared

Other associated cost for implementation of the project aside from the direct construction cost, following assumptions was applied:

(1) Land acquisition cost

Surface area under the Normal High Water Level with prevailing land value of agricultural area and its sharing ratio was applied.

Mellegue 2 Dam: Reservoir area (at NHWL 304.0 m) = 1,764 ha x TND18,000/ha x 60%*
= TND 19.05 mil.
TND 19.05 mil. x 36%= TND 6.86 mil.
Zone M (60%) :TND 4.12 mil.

Zone U2 (40%): TND 2.74 mil.

Tessa Dam : Reservoir area (at NHWL 369.0 m) = 2,387 ha x TND 18,000/ha x 56%**
= TND 24.06 mil.

TND 24.06 mil. x 62 % = TND 14.92 mil → Zone U2 (100%)

Note: *, Assumed proportion of agricultural area in the reservoir area (GIS data not available)
**, Proportion of agricultural area in the reservoir area (based on GIS database)

(2) Government administration cost

3 % of (direct construction cost + land acquisition cost)

(3) Engineering services cost

10 % of (direct construction cost)

(4) Proportion of foreign and local currencies

F/C : L/C = 50 : 50

Tables D6.5.1 and **D6.5.2** present annual disbursement schedule for implementation of dam projects including direct construction cost and other associated costs for Zone U2 and U1+M respectively.

CHAPTER D7 FLOOD PLAIN REGULATION/MANAGEMENT

D7.1 Rationale of Flood Plain Regulation/Management

D7.1.1 Mejerda Flood Directive

As for the structural measures as proposed in the Mejerda River basin, the target scale of planning level has been set at 10-year probability for Zones D2, D1, U1 and M, and 20-year probability for Zone U2 respectively. Even if the proposed river improvement works would have been completed, needless to say, excess flood beyond the design scale might occur and cause certain extent of damage to properties in the basin.

In order to cope with such excess floods and to mitigate damage due to inundation, non-structural measures should be positively introduced in the Mejerda River basin, which can play vital roles in association with structural measures. However, the target scale for planning of flood plain regulation/management is not clearly defined neither in Tunisia nor other developed country at present.

In the Mejerda River basin, magnitude of 100-year probable flood is set as target scale for flood plain regulation/management plan, which should be handled by the responsible institution of river administration, MARH. To clearly show the target range is cognized quite essential in order to reasonably demarcate the responsibility of the governmental agencies concerned. This concept is highly recommended to infuse into flood control policy of the Mejerda River basin. Further, the excessive scale of flood would be beyond control by the responsible agency of river administration, but it should be handled by the disaster/risk management entity at nation's level, because such tremendous disaster will be treated as a sort national alert or state of emergency and requires to save human lives, which will be taken care by the Ministry of Interior or Civil Defense in case of Tunisia.

The above concept is desirable to introduce as "Mejerda Flood Directive", which is recommended as core concept of the flood control policy of the Mejerda River basin in the future.

D7.1.2 Trend in European Committees

The new "Flood Directive (January 2006)" of European Union shows a sort of current trend of flood management policy based on their lessons learnt empirically accumulated through past floods.

Europe suffered over 100 major floods between 1998 and 2004 including catastrophic floods along the Danube and Elbe Rivers in 2002[1]. These floods caused some 700 fatalities, the displacement of about a million people and insured economic losses totaling at least €25 billion. Flood events during summer 2005, in Austria, Bulgaria, France, Germany and Romania and elsewhere, has pushed these figures even higher.

Typical trends of flooding in current Europe is an increased flood risk and to greater

[1] According to the "Explanatory Memorandum of the "Proposal for a Directive of the European Parliament and of the Council on the assessment and management of floods, Commission of the European Communities, Jan.18, 2006"

economic damage from floods. Firstly, the scale and frequency of floods are likely to increase in the future as a result of global climate change, inappropriate river management and construction in flood risk areas. Second, there has been a marked increase in vulnerability due to the number of people and economic assets located in flood risk zones.

The objective of the Flood Directive is to reduce and manage flood-related risks to human health, the environment, infrastructure and property. The Directive adopted by the parliament and Council requires that Member States take a long-term planning approach to reducing flood risks in three stages, i.e. (i) to undertake a preliminary flood risk assessment, (ii) to develop flood hazard maps and flood risk maps, and (iii) to prepare flood risk management plans.

Further the Directive states that, in case of international river basins, Member States must coordinate so that problems are not passed on from one to another. All stakeholders must be given the opportunity to participate actively in the development and updating of the flood risk management plans. Risk assessments, maps and plans must furthermore be made available to the public.

This basic concept of EC can be referred to the current Study in particular for flood plain regulation/management. In fact, in Tunisia, the Public Hydraulic Domain (PHD) has been defined in the "Water Code" (1975) and actual delimitation of the boundaries is now undertaken by MARH. Since these activities can be recognized as a sort of flood zoning, its review was firstly done to set the appropriate direction and concept of flood plain regulation/management plan in the Mejerda River basin.

D7.2 Delimitation Works of Public Hydraulic Domains (PHD)

D7.2.1 Legislative Definition of Public Hydraulic Domain

The "Public Hydraulic Domain (PHD)" is defined to include the following water body in Article One in Chapter One of the "Water Code" in Tunisia[2]:

(i) All kinds of water courses and lands included in their free boards
(ii) Ponds constitutes on watercourses
(iii) All kinds of springs
(iv) All kinds of underground waters
(v) Lakes and Sebkhas (salted lakes)
(vi) Aqueducts, wells, and water in places for public use as well as their dependents
(vii) Navigation, irrigation or draining channels managed directly by the State or through delegation of authority (to a third party) for a public use as well as land uses which are located on their free board (vicinity) and their dependents.

Article 5 of the Code stipulates that the limits of water course are fixed by the water level flowing through bank full before overflowing. Article 40 of Chapter IV (Easements) stipulates that the riverside residents of the water courses, lakes and sebkhas (salted lakes) identified by the decree are compelled to as easement called by free board, within the

[2] Issued in Law No.16 of the year 1975 dated on March 31, 1975, and modified and completed by the texts particularly the order No.2606 for the year 2001 issued on November 09, 2001.

limits of 3 m width starting from the shore, aiming at allowing the free passing of the administrator's personnel and equipment. The easement do not allow for the right to indemnity. Further, inside the area under easement, any new construction work, any heightening of the fixed boundary, any plantation is subjected to a prior authorization from the Ministry of Agriculture and Water Resources. In order to materialize the concept of the "Water Code", in particular for the delimitation of PHD, following Official Gazettes have been published by MARH:

(i) Decree No.87-1202 of September 04, 1987, fixing the procedure of delimitation of water course, lakes and senkhas coming under the PHD

(ii) Decree No.89-1059 on July 27, 1989, modifying the Decree No.87-1202 in ove September 04, 1978

(iii) Circular for the attention of the Governors and Mayors of October 20, 2005, concerning the clarifications of the procedures relating to the delimitation of water courses, lakes and sebkhas falling under the PHD

Attached documents: "Guideline on the Procedure for the Delimitation of the PHD"

Aside from the regulations above mentioned, special rules are enacted by the "Town and Country Planning Code and Related Enforcement Laws" (modified/added to the law No.2003-78 issued on December 29, 2003). In accordance with the rules, it is forbidden to build in zones, which is not covered by an approved urban development plan, within 100 m from the boundaries of PHD. On the other hand, in zones covered by an approved development plan in rural area, it is forbidden to construct within 25 m starting from the boundaries of PHD.

D7.2.2 Delimitation Operation by DGRE, MARH

In the framework of the delimitation of the PHD, which objective is to achieve more precise delimitation and thus allowing for more refined definition of the PHD, the General Direction of Water Resource (DGRE) of MARH is mandated to conduct topographic and bathymetric surveys along with property surveys (parcellery surveys) of water courses and sebkhas throughout the different regions in the country.

In actual, the delimitation of PHD (drawing boundaries along the Mejerda River) is undertaking by Topographic and Cartography National Agency – Office de la Topographic et de la Cartographie (OTC) based on the agreement No.06M23 between DGRE and OTC. In fact, DGRE is supervising the works in compliance with the latest Circular of the Ministry.

According to the information provided by DGRE, delimitation works of PHD in the Mejerda River has been completed in total 292 km as of the end of year 2007 and is scheduled to be conducted for another 138 km in year 2008 as shown in the tables below:

Areas Delimitated as Public Hydraulic Domain by OTC

Governorate	Covered Area	Distance in km
Jendouba	Algerian border / Sidi Miskin	41.0
	Erraghay	26.0
	Sidi Miskin / Melka	50.0
	Melka / Beja	45.0
	Sub-total	162.0
	Mellegue / Road for El Kef	40.0
	Smida	4.0
	Sub-total	44.0
Beja	Jendouba Border / Sidi Ismail	30.0
Manouba	Borj Ettoumi / Jedeida	Not available
Ariana	Bejaoua / Kalaat El Andalous	51.0
Siliana	Mssouj	5.0
	Grand total	**292.0**

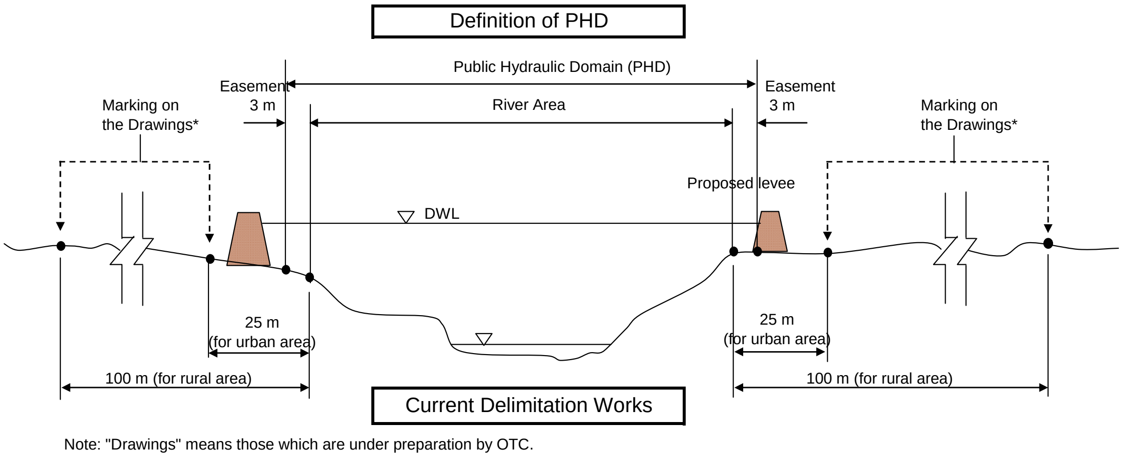
Source: DGRE, MAHR

Public Hydraulic Domain Delimitation Program for Year 2008

Governorate	Covered Area	Distance in km
Jendouba	Tessa Souk Essebt / Mejerda	20.0
Beja	Khalled	3.0
	Siliana	4.0
	Lahmer	1.5
	Sabbalet El Araneb	1.5
	Jnen Magraoui	2.0
	Beja	6.0
	Ain Hammam Siala	1.0
	Esseha	4.0
	Sub-total	23.0
Manouba	Borj Ettoumi	10.0
Ariana	Sebkhat Ariana	6.0
	Borj Ettoumi	6.0
	Oued Ettabla	2.0
	Ain Essnoussi	9.0
	El Hmada	7.0
	Sub-total	30.0
Siliana	Ettemrit	2.0
	Oued Siliana	40.0
	Sub-total	42.0
El Kef	Oued El Ain	5.0
	Ain Manous	3.0
	Izid Eddahmani	5.0
	Sub-total	13.0
	Grand total	**138.0**

Note: The information above for the Governorates subject to the Mejerda River basin is extracted from the data source.
Source: DGRE, MAHR

As far as confirmed on the drawings prepared by OTC based on the Agreement between DGRE and OTC for the delimitation works of PHD, the inherent definition of PHD in the "Water Code" and actual notation by OTC can be schematically illustrated with the proposed levee embankment in a section as follows. The clarification and redrawing of the boundary of PHD based on 3 m easement on each sheet (topographic maps with scale 1:2,000) is under way by the two agencies.



Relation between Definition of PHD and Current Delimitation Works (Conducting by DGRE and OTC)

D7.3 Basic Concept for Flood Plain Regulation/Management in Mejerda River Basin

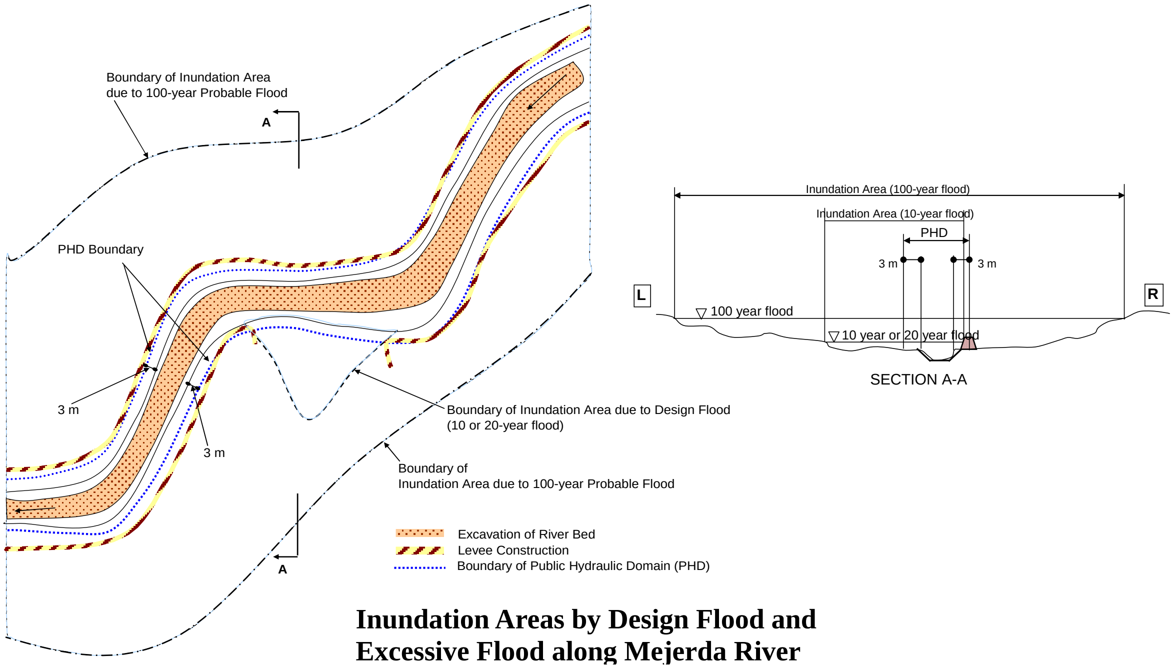
Flood hazard map or flood risk map has not yet been prepared in any river basin in Tunisia. Flood hazard map are related with the flood forecasting and warning system, and evacuation and flood fighting activities. In case of Mejerda River basin, delineating risk level of inundation of the region will become one of vital tools to mitigate vulnerability in the flood prone areas. In particular, taking account of dominant utilization of the land by agricultural cultivation, certain regulation of land utilization as well as restricting construction activities of new houses/buildings in riparian urban areas will be prerequisite in association with structural measures. Therefore, basic concept of flood plain regulation/management is set for enhancement of land use control in the aspect of flood disaster management in the flood prone areas by means of preparation and dissemination of flood risk maps.

D7.4 Target Risk Level for Plan Formulation

In order to delineate the boundary of affected area by the excessive flood, the inundation area by the 100-year probable flood was assumed taking account of the valuable resources as breadbasket of the country. When such a large scale (100-year) of flood occurs, the proposed levee system will not be able to accommodate the flood water in the channel and to prevent overtopping along the whole stretches of the mainstream. The proposed levee will be breached and destroyed due to such catastrophe.

Further, it is commonly reported that large scale of floods with torrential local rainfall, which cannot be presumed based on the historical trend of meteorological events, are occurring due mainly to global warming in many regions over the world. In this aspect, strategic control for future land use in the Mejerda River basin would become more crucial for sustainable development.

The relationship of the target areas as abovementioned is illustrated as follows:



Inundation Areas by Design Flood and Excessive Flood along Mejerda River

D7.5 Preliminary Analysis on Current Land Use in Flood Prone Areas

D7.5.1 Flood Prone Areas due to Design Flood Discharge (High Risk Zone)

(1) Characteristics of Inundation Areas

In the study of plan formulation of river improvement by inundation analysis, areas, where are allowed overtopping river banks and will remain inundation area to some extent, were carefully selected aiming at retention of flood peak discharge at downstream reaches. The hydraulic feature of those areas is summarized as below:

Hydraulic Conditions in Inundation Area by Design Flood Discharge

Zone	River Stretches where allows Overflowing	Location	Length of River Stretches (km)	Designed Flood Protection Level	Design Flood Discharge (m^3/s)	Present Flow Capacity (m^3/s)
U1	MU228~ MU215	U/S of Jendouba	6.4	10 year	570	250
U2	MU53~ MU80	D/S of confluence of Kasseb River	10.8	20 year	1,840	250
M	ME19~ ME106	D/S of Mellegue	20.8	10 year	410	200
D1	MD29~ MD24	U/S of Testour	1.7	10 year	410	350
D2	MD434~ MD447	Lower reach of floodway (Oued El Hmadha)	5.2	10 year	580	180

Source: the Study Team

As the results of the inundation analysis, the flood prone areas under the design flood discharge in five zones can be summarized by land use as tabulated below:

Estimated Flood Prone Area by Design Flood Discharge

Zone	River Stretches where allows Overflowing	Current Land Use in Flood Prone Area (ha)				
		Agricultural Area (non-irrigated)	Agricultural Area (irrigated)	Urban Area	Other Area	Total Area
U1	MU228~ MU215	348	93	5	26	472
U2	MU53~ MU80	411	614	10	5	1,040
M	ME19~ ME106	322	317	5	21	665
D2	MD29~ MD24	3,224	390	5	2,876	6,495
D1	MD434~ MD447	109	68	0	10	187

Source: the Study Team

(2) Expected Function of Inundation Area

Considering the hydraulic conditions and land use at upstream and downstream of the subject stretches allowing overflowing as indicated in the previous Clause, particular vital function of retarding effect is given from flood control aspect. In order to keep the flood protection level set for each zone, such distinct function should be individually noted as follows:

Expected Function for Flood Control in Inundation Area (below design flood discharges)

Zone	River Stretches where allows Overflowing	Expected Function for Flood Damage Mitigation
U1	MU228~MU215	To mitigate flood damage to the urban area of Jendouba by reducing flood peak discharge at upstream area.
U2	MU53~MU80	To reduce flood peak discharge, which propagates to downstream, by allowing local inundation after joining of flood water at outlet of Bou Salem Bypass Channel
M	ME19~ME106	To reduce flood peak discharge before joining with the Mejerda River by allowing overflow along the Mellegue River. Due consideration to protect the urban area of Jendouba will be required.
D2	MD29~MD24	To regulate the flood water level at El Battane weir (about km downstream) up to the existing elevation of road pavement on the weir (29.1m NGT), local inundation will be allowed at upstream of Testour.
D1	MD434~MD447	To allow overflowing of flood water at downstream of existing road bridge crossing over the floodway to the river mouth. Recommendation is made for reconstruction of the bridge and heightening of the approach road at both banks.

Source: the Study Team

D7.5.2 Flood Prone Areas due to Excessive Flood (100-year Probable Flood)

The flood prone area due to 100-year probable flood is preliminarily assessed based on the results of inundation analysis. **Figures D7.5.1** and **D7.5.2** show separately the flood prone areas in upstream and downstream of Sidi Salem dam. The following table presents current land use enumerated into four categories by each zone:

Estimated Flood Prone Area by Excess Flood

Zone	Urban Area affected	Current Land Use in Flood Prone Area (ha)				
		Agricultural Area (non-irrigated)	Agricultural Area (irrigated)	Urban Area	Other Area	Total Area
U1	Jendouba	2,725	1,976	156	130	4,987
U2	Bou Salem	4,046	7,810	468	26	12,350
M	Jendouba	4,160	5,684	660	83	10,587
D1	Mejez El Bab	1,602	4,950	182	42	6,776
D2	Tebourba, El Battane, Jedeida, Sidi Thabet	22,771	22,136	390	9,776	55,073

Source: the Study Team

In addition to the analysis of land use as shown in the above, affected population was estimated based on the proportion of subject areas to inundation and population density by each delegation. As the results, it was clarified that approximately a total of 143,000 people are residing in the flood prone area in the Mejerda River basin as shown below:

Estimated Affected Population by Excess Flood

Zone	Urban Area	Rural Area	Total
U1, U2 & M	49,474 (34.7%)	32,987 (23.1%)	82,461 (57.8%)
D1 & D2	25,443 (17.8%)	34,870 (24.4%)	60,313 (42.2%)
Total	74,917 (52.5%)	67,857 (47.5%)	**142,774 (100.0%)**

Source: the Study Team

D7.6 Draft Plan of Strengthening of Flood Plain Regulation/Management

D7.6.1 Outline of Draft Plan

The strengthening of flood plain regulation/management aims to contribute to reduce flood damage risk by better land use, which will be introduced considering potential of flood risk and sustainable urban and agricultural development in the flood prone areas. As explained in the previous section, flood inundation area under the 100-year probable (excessive flood) flood was delineated in this Study. Based on the outcome, the land use pattern focusing crop selection and planting/harvest pattern will be further analyzed and investigated in each zone or smaller unit like delegation.

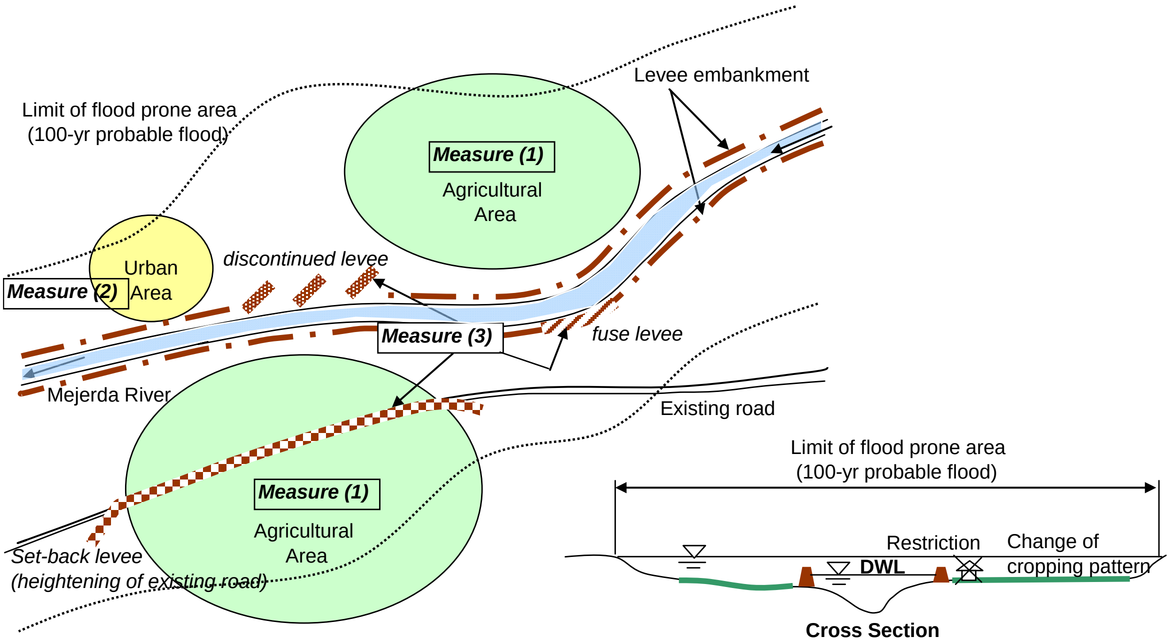
A manner and methodology for appropriate land use will be studied and guidelines are to be prepared in order to disseminate the practice to CRDAs or municipalities concerned. After preparation of the guidelines, actual application and evaluation of the recommended manner will be conducted. Further, in order to enhance the expected benefits of the plan, a series of training and seminars will be organized and conducted periodically.

In order to further mitigate damage due to excessive flood in the flood prone areas, appropriate allocation of the structures regulating over banked flow will be important in association with the flood plain regulation/management activities as abovementioned.

Those structures have different functions from ordinary dikes, which is constructed to protect against inundation, with guiding and controlling the flood flow after over banking. In this master plan, such structures are proposed to apply to mitigate flood damage against excessive flood.

The relationship between those structures and flood plain regulation/ management can be shown as follows:

Measure (1)	Promotion to convert flood-resistant crops in agricultural land
Measure (2)	Restriction of new house/building construction in urban area
Measure (3)	Construction of secondary levee (set-back levee), discontinued levee and fuse levee (regulating structures in flood plain)



Layout Image of Regulating Levee Structures in Flood Prone Area

(1) Secondary levee

1) Objective and effectiveness

Even if the constructed levee embankment is breached due to excessive flood, by means of delay of reaching flood flow, limitation of inundated area and reduction of inundated depth, protection of the important area and stretches and to secure required time and route of evacuation for the affected people are duly enhanced.

2) Layout plan

Considering the extent of flood prone areas along the Mejerda mainstream and network of existing road and railway, heightening of existing road aiming at avoiding interception of traffics (as well as securing evacuation route) during floods and protecting against increase of inundation areas by over banked flow would be effective.

3) Candidate sites

Taking account of the flood prone area and flood flow during experienced major floods in 1973, 2003 and 2004, following three sites (assuming heightening of existing road section) were selected for secondary levees. However, as for implementation, four issues as mentioned in this Clause shall be carefully examined.

Candidate Sites for Secondary Levee

Site	Length (km)	Expected effect (regulation of excessive floods)
El mabtouh	12.0	To protect the priority farm land from over banked flow due to excessive floods in El Mabtouh plain (left bank of the Mejerda River). To regulate the flow, which diffuses to north.
Sidi Thabet	7.0	To protect the irrigation area in Sidi Thabet against the over banked flow. To regulate the flow, which rushes to northeast and increase flood damage in the Kalaat Andarous area (right bank of El Hmada floodway)
Tebourba	3.0	To protect the irrigation areas between Tebrouba and Jedeida from flood flow, which over-top at downstream of the urban area (left bank), and to regulate the flow reaching to jedeida urban area

The location of the candidate sites above mentioned is shown in Figure 8.7.1.

(2) Discontinued levee

1) Objective and effectiveness

The destruction levee will enable decreasing flood water level, reduction of flow velocity and delay of propagation to downstream by means of conveying and retarding of the flood water temporarily in the plain. The levee itself has a function of training wall to lead over banked flow into the designated area. In the course of recession of flood and decreasing water level in the river channel, the over banked flow will return to the channel and inundation in the low plain will be diminished.

2) Layout plan

Taking account of current land use and extent of areas to be protected, the plural numbers of discontinued levee shall be constructed. The length of and angle to the river channel is to be determined based on the inundated land and location of protected land/structures and hydraulic conditions.

(3) Fuse levee

1) Objective and effectiveness

The fuse levee has function of over flowing and breaching itself in the designated location in order to prevent from breaching in other location and after then to avoid expansion of inundation area

2) Layout plan

In case that urban and agricultural area located at downstream, the fuse levee shall be located at upstream and allows inundation (such as natural retarding basin) while an excessive flood flows. Normally, the height of the fuse dike shall be kept as lower than existing levee and formed a structure, which is easily destructed after overflow by means of adjustment of levee material and making steeper of surface slope, etc.

Further, as for implementation, following four issues shall be emphasized:

- To prevent an increase of inundation damage at downstream area by using with other regulating structures in parallel (such as pumps and training canal, etc.)
- To consider compensation measures (resettlement of the people, heightening of residential land, compensation to actual flood damage, etc.) for the area, where inundation damage will be accelerated due to construction of the regulating structures.
- To clearly designate the area for construction of the structures as abovementioned and endangered area by inundation and disseminate the information for creating consensus to the local people
- To introduce, in addition to construction of such regulating structures, compensation rules for damaged farm land and/or flood insurance (as shown the concept proposed in the "Institutional and Organizational Capacity Development Plan" in this Master Plan).

D7.6.2 Component of Proposed Activities

Step 1: Preparation of GIS database and flood risk maps

(1) Delineation of flood prone areas

As the results of inundation analysis for 100-year probable flood, the flood prone area is estimated at approximately 89,800 ha in entire Mejerda River basin, which is 5.6 % of the total catchment of 15,830 km2 (in Tunisian territory). The boundary of the anticipated inundation area should be delineated based on the inundation and hydraulic analysis conducted in the current study on the GIS Database system. Topographic information such as longitudinal and cross sections obtained in the current Study will be utilized. The base map of topographic information will be 1:10,000.

(2) Updating of GIS database land use information

In the current JICA Study, GIS database system has been established and it was fully utilized for various study components. Therefore, it is recommended to utilize this database system after updating and adding information in particular for agricultural land use (crop pattern) and delineation of urban development zones. Since the current GIS system dose not cover the land use by crop classification, it will be favorably integrated in the database system in accordance with the planning concept.

(3) Preparation of flood risk map with zoning

The flood prone area (100-year probability) will be overlaid with 10 or 20-year probable inundation areas (under design flood discharge). Based on the results, the flood prone areas are basically divided into three zones: (i) restricted zone, (ii) protected zone, and (iii) potential cultivating zone, with preparation of zoning criteria to be applied.

<u>Step 2: Preparation of guidelines for formulation of land use plan</u>

(4) Analysis on improvement of land use (cropping) pattern based on current prevailing land use and future development policy/program

In MARH, DGPA (Direction of Agricultural Production) and AFVA are in charge for preparation of technical guideline/manual for land development, planting, harvesting and drainage system, etc. This information shall be integrated in terms of water-resistant crops for enhancement of future land use in the flood prone area.

(5) Clarification of development plan in urban areas

Within flood prone area of the Mejerda, urban areas are dispersed such as Jendouba, Bou Salem, Mejez El Bab, Tebrouba, El Battane, Jedeida and Kalaat Andalous, etc. As for some of the areas, development plans are under preparation by MEHAT and or municipal governments. It was confirm by the Study Team that urban development plans in Jendouba, Bou Salem and Mejez El Bab are being formulated and/or waiting for an official approval for implementation as of August 2008.

In particular for the flood prone area in urban areas, building codes as well as applicable development permission will be considered in the divided zones in the flood risk map.

(6) Preparation of guidelines

Following two kinds of guidelines will be prepared to disseminate the accumulated know-how to CRDAs and concerned local governments:

(i) Guideline for Flood Risk Mapping
To contain the procedure of inundation analysis, required data, input-output format, boundaries conditions, compilation of output and map legends, etc. The operation manual of inundation analysis by MIKE FLOOD, which has been prepared through the current Study, shall be referred.

(ii) Guideline for Enhanced Land Use Control for Urban and Rural Areas
To contain the source of GIS database, manner of updating and integration of data along land use control in terms of reduction of flood vulnerability

<u>Step 3: Dissemination of maps and guidelines to CRDAs and municipalities concerned</u>

(7) Dissemination, application, evaluation and validation of the flood risk maps and land use plan with guidelines

The prepared maps and guidelines shall be disseminated, applied, evaluated and validated in the other development plans of the subject areas, which are currently prepared or going to be prepared, aiming at effective utilization and successful realization of the plans. The lessons and comments accumulated through the activities in Steps 1 and 2 shall be fed back to the guidelines.

(8) Training and seminar

Various training and seminar will be organized periodically aiming at effective transfer of technical knowledge and capacity building through the activities through each component of activity. On-the-job training through the activities proposed herein shall be appropriately arranged.

D7.6.3 Key Issues for Implementation of Plan

The implementation of the proposed activities as mentioned in Clause D7.6.2 can be commenced as soon as possible in parallel with implementation of river improvement works to assure and enhance the project benefit expected. Further, the flood plain regulation/management cannot be separated from other non-structural measures in the aspect of disaster management of the vulnerable areas. Implementation of the plan together with FFWS, flood fighting and evacuation system, and capacity building of concerned institutions, etc. will be also essential considering effective infiltration and dissemination of basic concept of flood mitigation to not only governmental agencies but also local people.

On the other hand, the river improvement works proposed by the Study is aiming to complete by 2030. However, there might be possible to take longer period because of budget constraint. On the other hand, since those non-structural measures need fewer budgets, it is recommended to implement as early as possible in order to reduce flood vulnerability in the flood prone area.

Tables

Table D2.3.1 Flood Inundation and Damage Survey Resutls (Inundation and Flood Damage (1/2)

Farmers

No.	Code	Sample size	Year of Flood event	*1 Max Depth (cm)	Range (cm)	*1 Duration (days)	*1 Inundated Area (ha)	Major damaged crops	*1 Damaged value (TND)	*2 Received compensation
1	NB	4	2003, 2000	33	20~40	5	17	vegetable, cereal	7,150	0/4
2	JN	19	1973, 2000	88	10~300	12	6.8	olive, cereal	8,314	3/19
3	BS	10	2003, 1973	50	20~100	21	1.5	olive, vegetable, cereal	3,850	6/10
4	SI	10	2003	95	30~180	19	4.1	olive, cereal	7,555	2/10
5	ZA	5	2003	154	40~300	44	4.4	olive, cereal	6,330	0/5
6	TS	20	2003, 1973	75	20~400	15	1.9	pomegrate, other crops	18,281	1/20
7	SL	30	1973, 2003	295	80~500	76	2.2	other crops	48,667	16/30
8	MB	7	2003, 1973	159	50~300	39	1.9	vegetable, cereal	15,871	3/7
9	EH	20	2003, 1973	148	80~300	55	28.5	olive, vegetable, cereal	44,550	10/20
10	TB	9	1973, 2003	78	40~100	33	2.9	other crops	66,056	7/9
11	JD	10	1973, 2003	101	50~250	35	5.6	vegetable, cereal, other crops	84,120	10/10
12	EB	15	1973, 2003	107	50~200	27	4.3	cereal, other crops	16,547	9/15
13	CS	20	2003, 1973	82	15~250	35	7.6	vegetable, cereal	9,625	1/20
			Average	113		32.0	6.8		25,917	

Note: *1, Average value of answers
*2, (numbers of answer who received / total numbers of respondents)

Residents

No.	Code	Sample size	Year of Flood event	*1 Max Depth (cm)	Range (cm)	*1 Duration (days)	*1 Inundated Area (m2)	Major damaged properties	Damaged value (TND)	*2 Received compensation
1	NB		2003	9 house respondents replied that no flood water reached to their house.					Not applicable	-
2	JN		1973, 2000	88	10~200	8	183	partial damage of house (tiling, window, crack of wall), furniture, cereals, etc.	Not applicable	4/16
3	BS		2003, 1973	143	40~290	9	382	partial damage of house (tiling, window, crack of wall), furniture, etc.	Not applicable	16/20
8	MB		2003, 1973	125	10~350	19	286	partial damage of house (tiling, window, wall), furniture, etc.	Not applicable	13/20
10	TB		2003, 1973	100	30~200	32	122	partial damage of house (tiling, window, crack of wall), furniture, cereals, etc.	Not applicable	3/8
11	JD		2003, 1973	109	40~220	38	128	partial damage of house (tiling, window, crack of wall), furniture, cereals, etc.	Not applicable	7/9
12	EB		2003, 1973	90	30~150	17	108	partial damage of house (tiling, window, crack of wall), furniture, etc.	Not applicable	4/5
			Average	109		21	202			

Note: *1, Average value of answers
*2, (numbers of answer who received / total numbers of respondents)

Source: Results of "Flood Inundation and Damage Survey" coducted by Eco Ressources Inc., under the present JICA Study

Table D2.3.1 Flood Inundation and Damage Survey Resutls (Inundation and Flood Damage (2/2)

Shops

No.	Code	Sample size	Year of Flood event	Max Depth (cm) *1	Range (cm)	Duration (days) *1	Inundated Area (m2) *1	Major damaged properties	Damage rate (%) *1	Interuption period (days) *1	Damaged value (TND) *3	Received insurance *2	Received compensation *2
2	JN		2000, 2003	80	20~180	11	74	chair and oterh material	88	19	438	0/4	0/4
3	BS		2003	109	20~200	10	34	refregirator, raw material, engine, icebox, hair dryermado	38	28	734	0/8	5/8
8	MB		2003	160	7~60	25	189	refregirator, office	21	80	22,200	0/7	4/7
10	TB		2003	43	25~60	15	190	no answer	10	23	1,625	0/2	0/2
11	JD		2003	100	100	45	30	Refrigerator	10	45	225	0/1	1/1
			Average	98		21	103		33	39	5044		

Note: *1, Average value of answers
*2, (numbers of answer who received / total numbers of respondents)
*3, Answers of unit shall be verified (uncertain).

Industries

No.	Code	Sample size	Year of Flood event	Max Depth (cm) *1	Range (cm)	Duration (days) *1	Inundated Area (m2) *1	Major damaged properties	Damage rate (%) *1	Interuption period (days)	Damaged value (TND) *1	Received insurance *2	Received compensation *2
2	JN		2000	120	120	2	400	motors	-	45	18,000	1/1	0/1
3	BS		2003	100	80~120	4	40	raw materila	60	34	3,750	1/2	1/2
8	MB		2003	148	50~220	34	98	engines, tools and materials	20	60	18,500	0/6	1/6
10	TB		2003	60	60	30	140	engine	15	30	3,600	0/1	0/1
			Average	107		18	170		32	42	10,963		

Note: *1, Average value of answers
*2, (numbers of answer who received / total numbers of respondents)

Source: Results of "Flood Inundation and Damage Survey" coducted by Eco Ressources Inc., under the present JICA Study

Table D2.3.2 Flood Inundation and Damage Survey Resutls (Flood Protection Measures) (1/2)

Farmers

No.	Code	Mind for self-help or preparedness for next flood		Secured properties in past flood		Repetition of damage if flood hits		Change of daily life for preparedness of next flood		Lessons learnt (majority and dominant comments)	Existing flood control structures near your house, do you know?		Most important structure for flood protection (numbers of answer as the highest priority)				
		Possitive	Negative	Yes	No	Yes	No	Yes	No		Yes	No	Construction of structures	Early warning	Proper instruction	Supporting manpower	Evacuation assistance
1	NB	2	2	0	4	2	2	0	2	・Flood is daingerous. If we do not find the suitable ways to escape from it, the losses would be extremely severe. ・We must evacuate as fast as possible.	0	4	4	0	0	0	0
2	JN	9	10	0	19	19	0	0	19	・Need to move away the most important properties. ・Flood streaming in the river is very high. ・When it dose happen we lose many things.	0	19	0	5	2	0	12
3	BS	0	10	0	10	10	0	0	10	・We must be careful when it rains. ・We are trying our best to save our crops, but still do not have any solution to cope with floods. ・Flood is a threat that will make us suffer unless we find the suitable solutions.	6	4	8	0	0	0	2
4	SI	3	7	0	10	10	0	0	10	・To face the situation with courage and patience. ・Flood is big problem and not easy to face.	0	10	0	7	1	0	2
5	ZA	1	4	0	5	5	0	0	5	・Floods are serious threat. ・Flood is a big problem and not to face.	0	5	0	1	0	1	3
6	TS	5	15	0	20	20	0	0	20	・We must be careful especially when it rains. ・When it does happen we lose so many things.	1	19	0	18	0	0	2
7	SL	15	15	0	30	30	0	0	30	・Flood streaming in the river is very rough. ・Flood makes in danger our lives and products.	0	30	4	25	0	0	1
8	MB	0	7	0	7	7	0	0	7	・Floods are serious threat. ・We are unable to face floods.	0	7	7	0	0	0	0
9	EH	1	19	0	20	20	0	0	20	・Floods are very severe, there must be a solution to stop their danger. ・Floods are main cause of our losses in the last few years.	0	20	20	0	0	0	0
10	TB	3	6	0	9	9	0	0	9	・Floods are serious threat. ・Floods may make us homeless.	0	9	0	9	0	0	0
11	JD	6	4	0	10	10	0	0	10	・Floods are threat that will make us suffer unless we find the suitable solutions. ・When floods happen we lose so many things.	0	10	0	9	0	0	1
12	EB	8	7	0	15	14	1	0	14	・We must be careful especially when it rains. ・Flood streaming in the river is very rough.	0	15	0	15	0	0	0
13	CS	4	16	0	20	20	0	0	20	・Flood are very harmful. ・Floods are very dangerous. Most important thing is to protect our lives.	0	20	10	10	0	0	0
	Total	57	122	0	179	176	3	0	176		7	172	53	99	3	1	23
		32%	68%	0%	100%	98%	2%	0%	100%		4%	96%	30%	55%	2%	1%	13%

Source: Results of "Flood Inundation and Damage Survey" coducted by Eco Ressources Inc., under the present JICA Study

Table D2.3.2 Flood Inundation and Damage Survey Resutls (Flood Protection Measures) (2/2)

Residents

No.	Code	Mind for self-help or preparedness for next flood		Secured properties in past flood		Repetition of damage if flood hits		Change of daily life for preparedness of next flood		Lessons learnt (majority and dominant comments)	Existing flood control structures near your house, do you know?		Most important structure for flood protection (numbers of answer as the highest priority)				
		Possitive	Negative	Yes	No	Yes	No	Yes	No		Yes	No	Construction of structures	Early warning	Proper instruction	Supporting manpower	Evacuation assistance
1	NB	0	11	Not applicable		0	11	0	11	・We shall predict dangers if floods are string enough to threaten our lives.	0	11	11	0	0	0	0
2	JN	6	10			0	16	0	16	・Floods are very dangerous and unrespectable when they happen.	0	16	0	10	0	0	6
3	BS	6	14			0	20	0	20	・We cannot cope with flood. We have to find a fundamental solution.	11	9	16	1	0	1	2
8	MB	1	19			0	20	0	20	・Floods are serious dangers.	0	20	20	0	0	0	0
10	TB	1	7			0	8	0	8	・Floods make in danger our lives and products.	0	8	0	8	0	0	0
11	JD	7	2			0	9	0	9	・We must be careful especially when it rains.	0	9	0	7	0	0	2
12	EB	1	4			0	5	0	5	・Floods are threat that will make us suffer unless we find the suitable solutions.	0	5	0	5	0	0	0
	Total	22	67			0	89	0	89		11	78	47	31	0	1	10
		25%	75%			0%	100%	0%	100%		12%	88%	53%	35%	0%	1%	11%

Shops

No.	Code	Mind for self-help or preparedness for next flood		Secured properties in past flood		Repetition of damage if flood hits		Change of daily life for preparedness of next flood		Lessons learnt (majority and dominant comments)	Existing flood control structures near your house, do you know?		Most important structure for flood protection (numbers of answer as the highest priority)				
		Possitive	Negative	Yes	No	Yes	No	Yes	No		Yes	No	Construction of structures	Early warning	Proper instruction	Supporting manpower	Evacuation assistance
2	JN	1	3	Not applicable		4	0	0	4	・Floods are serious danger.	0	4	0	1	1	0	2
3	BS	2	6			8	0	2	6	・We must move as far as possible to save our properties.	6	2	7	0	0	0	1
8	MB	0	7			7	0	0	7	・W cannot cope with floods, we have only to escape whenever it happens.	0	7	7	0	0	0	0
10	TB	0	2			2	0	0	2	・Floods make us danger our lives and products.	0	2	0	2	0	0	0
11	JD	0	1			1	0	0	1	・Floods are serious threat.	0	1	0	1	0	0	0
	Total	3	19			22	0	2	20		6	16	14	4	1	0	3
		14%	86%			100%	0%	9%	91%		27%	73%	64%	18%	5%	0%	14%

Industries

No.	Code	Mind for self-help or preparedness for next flood		Secured properties in past flood		Repetition of damage if flood hits		Change of daily life for preparedness of next flood		Lessons learnt (majority and dominant comments)	Existing flood control structures near your house, do you know?		Most important structure for flood protection (numbers of answer as the highest priority)				
		Possitive	Negative	Yes	No	Yes	No	Yes	No		Yes	No	Construction of structures	Early warning	Proper instruction	Supporting manpower	Evacuation assistance
2	JN	1	0	Not applicable		1	0	0	0	・To face the situation with courage and patience	0	1	0	1	0	0	0
3	BS	0	2			2	0	0	2	・We are unable to face floods ourselves and we need help.	2	0	2	0	0	0	0
8	MB	0	6			6	0	0	6	・We must find a fundamental solution to reduce floods' danger.	0	6	6	0	0	0	0
10	TB	0	1			1	0	0	1	・Flood is a big problem and not easy to face.	0	1	0	1	0	0	0
	Total	1	9			10	0	0	9		2	8	8	2	0	0	0
		10%	90%			100%	0%	0%	100%		20%	80%	80%	20%	0%	0%	0%

Source: Results of "Flood Inundation and Damage Survey" coducted by Eco Ressources Inc., under the present JICA Study

Table D2.3.3 Flood Inundation and Damage Survey Resutls (Evacuation and Early Warning (1/2)

Farmers

No.	Code	Evacuation experiences in past			Source of information for evacuation					Did you hear any warning for evacuation?			Do you know evacuation plan?		Do you know where and how to evacuate?		Do you think the evacuation plan is necessary?		Have you participated in the evacuation drill?	
		Yes	(Year)	No	Police	Imada Office	Delegation Office	Governorate Office	Myself	Yes	No	No answer	Yes	No	Yes	No	Yes	No answer	Yes	No
1	NB	1	2000(1)?	3	0	0	0	0	1	0	3	1	0	4	2	2	4	0	0	4
2	JN	14	1973(6), 2000(8)	5	0	0	1	3	10	0	5	14	4	15	17	2	16	3	1	18
3	BS	6	2003(6)	4	0	0	3	0	3	0	3	7	1	9	6	4	10	0	1	9
4	SI	9	2003(9)	1	0	0	0	2	7	2	8	0	2	8	10	0	8	2	2	8
5	ZA	1	2003(1)	4	0	0	0	0	1	0	5	0	0	5	3	2	5	0	1	4
6	TS	5	2003(5)	15	0	2	0	0	3	3	17	0	3	17	19	1	17	3	0	20
7	SL	30	2003(30)	0	1	10	0	0	19	12	18	0	12	18	30	0	18	12	5	25
8	MB	5	1973(1), 2003(4)	2	0	4	1	0	0	2	0	5	2	5	7	0	5	2	2	5
9	EH	20	2003(20)	0	0	1	2	0	17	0	0	20	1	19	20	0	19	1	1	19
10	TB	9	1973(2), 2003(7)	0	0	0	0	0	9	0	9	0	0	9	9	0	9	0	0	9
11	JD	10	2003(10)	0	0	10	0	0	0	10	0	0	10	0	10	0	0	10	0	10
12	EB	15	1973(1), 2003(14)	0	0	0	0	0	15	0	15	0	0	15	15	0	15	0	1	14
13	CS	16	2003(16)	4	0	0	6	1	9	1	10	9	0	20	20	0	20	0	0	20
	Total	141		38	1	27	13	6	94	30	93	56	35	144	168	11	146	33	14	165
		79%		21%	1%	19%	9%	4%	67%	17%	52%	31%	20%	80%	94%	6%	82%	18%	8%	92%

Residents

No.	Code	Evacuation experiences in past			Source of information for evacuation					Did you hear anywarning for evacuation?			Do you know evacuation plan?		Do you know where and how to evacuate?		Do you think the evacuation plan is necessary?		Have you participated in the evacuation drill?	
		Yes	(Year)	No	Police	Imada Office	Delegation Office	Governorate Office	Myself	Yes	No	No answer	Yes	No	Yes	No	Yes	No	Yes	No
1	NB	0	-	11	0	0	0	0	0	0	11	0	0	11	11	0	11	0	0	11
2	JN	13	1973(3), 2000(9), 2003(1)	3	0	0	0	7	6	5	8	3	8	8	14	2	11	5	7	9
3	BS	18	2003(18)	2	0	0	7	7	4	1	1	18	3	17	13	7	17	3	4	16
8	MB	19	1973(1), 2003(18)	1	17	0	0	0	2	0	1	19	2	18	12	8	18	2	2	18
10	TB	6	1973(1), 2003(5)	2	0	0	2	0	4	3	5	0	3	5	8	0	5	3	2	6
11	JD	9	2003(9)	0	0	7	0	0	2	7	1	1	7	2	9	0	2	7	1	8
12	EB	3	2003(3)	2	0	0	1	0	2	0	4	1	0	5	4	1	5	0	0	5
	Total	68		21	17	7	10	14	20	16	31	42	23	66	71	18	69	20	16	73
		76%		24%	25%	10%	15%	21%	29%	18%	35%	47%	26%	74%	80%	20%	78%	22%	18%	82%

Source: Results of "Flood Inundation and Damage Survey" coducted by Eco Ressources Inc., under the present JICA Study

Table D2.3.3 Flood Inundation and Damage Survey Resutls (Evacuation and Early Warning (2/2)

Shops

No.	Code	Evacuation experiences in past			Source of information for evacuation					Did you hear anywarning for evacuation?			Do you know evacuation plan?		Do you know where and how to evacuate?		Do you think the evacuation plan is necessary?		Have you participated in the evacuation drill?	
		Yes	(Year)	No	Police	Imada Office	Delegation Office	Governorate Office	Myself	Yes	No	No answer	Yes	No	Yes	No	Yes	No	Yes	No
2	JN	2	2000(2)	2	0	0	0	0	2	0	4	0	0	4	4	0	4	0	0	4
3	BS	7	2003(7)	1	0	0	3	2	2	0	1	7	0	8	6	2	8	0	4	4
8	MB	7	2003(7)	0	0	1	0	0	6	0	0	7	0	7	5	2	7	0	0	7
10	TB	2	2003(2)	0	0	0	0	0	2	1	1	0	1	1	2	0	1	0	0	2
11	JD	1	2003(1)	0	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0
	Total	19		3	0	2	3	2	12	2	6	14	2	20	18	4	20	0	5	17
		86%		14%	0%	11%	16%	11%	63%	9%	27%	64%	9%	91%	82%	18%	100%	0%	23%	77%

Industries

No.	Code	Evacuation experiences in past			Source of information for evacuation					Did you hear anywarning for evacuation?			Do you know evacuation plan?		Do you know where and how to evacuate?		Do you think the evacuation plan is necessary?		Have you participated in the evacuation drill?	
		Yes	(Year)	No	Police	Imada Office	Delegation Office	Governorate Office	Myself	Yes	No	No answer	Yes	No	Yes	No	Yes	No	Yes	No
2	JN	1	2000(1)	0	0	0	0	0	1	0	1	0	0	1	1	0	1	0	0	1
3	BS	2	2003(2)	0	1	0	1	0	0	0	0	2	0	2	2	0	2	0	2	0
8	MB	5	2003(5)	1	0	0	2	0	4	0	1	5	0	6	6	0	6	0	0	6
10	TB	1	2003(1)	0	0	0	0	0	1	0	1	0	0	1	1	0	1	0	0	1
	Total	9		1	1	0	3	0	6	0	3	7	0	10	10	0	10	0	2	8
		90%		10%	10%	0%	30%	0%	60%	0%	30%	70%	0%	100%	100%	0%	100%	0%	20%	80%

Source: Results of "Flood Inundation and Damage Survey" coducted by Eco Ressources Inc., under the present JICA Study

Table D2.5.1 Major Issues of Flood Protection and Possible Structural Measures (For Preliminary Setting of Alternatives) (1/2)

Location	Mejerda US				Mellegue DS	Mejerda and Mellegue Confluence
	Approx. 6 km DS from Ghardimaou ～ Confluence of Rarai*	**Jendouba Bridge**	**Jendouba City and Its Suburbs**	**Bou Salem City and Its Suburbs**	**Confluence of Mellegue ~ Approx. 22km US Left Bank**	**Approx. 2 km to the North from the Mellegue bridge (Route No.6)**
Principal Feature of Watershed and River Channel	・Extensive meandering ・Formed as a valley with high river bank (10m ~ 15m or more) and continued down to Jendouba		・Low lying area is located around Jendouba and forms topography where flooded water likely concentrate there. ・If flood peak discharges of the Mejerda River can be retarded before rushing into Jendouba, the countermeasure would be effective.	・Dike has been constructed in river channel at US and DS of Bou Salem Bridge by Ministry of Equipment (June to July 2007). ・It is not only obstruction of flow but also deteriorating proper function of automatic water level gauges. Remedial measure is urgently required.	・Steep slope is formed at river bank with at least 4~5m in height. At DS a valley is formed with reaching to 10～15m as same as the Mejerda. ・Riverbed material is composed by 5~15cm in diameter of gravel and seems to be maintained the riverbed conditions before construction of Mellegue Dam. It seems that fine material has been washed to DS and acetated siltation there.	・Relatively low populated area with natural vegetation (brushes)
				・Drainage improvement project is on-going by Ministry of Equipment. Approx. 50 % has been completed. Project cost is approx. TND 5.0 mil.		
Flooding Conditions	・Inundated along the main road in 1973	・Max. water level was 14.6 m (Gauge Height) in 1973 flood (upper surface of bridge girder).	・Almost entire area of Jendouba City (approx. 3,000 ha) was inundated in 1973.	・Almost entire area of Bou Salem City was inundated due to 2003 flood. ・Overtopped at left bank of DS areas of the Bou Heurtma River.	・Overtopped at same location when floods occurred both in 1973 and 2000, and flooded water ran into lowly undulated areas along old river course of the Mejerda. It eventually joined with the Mejerda again at just US of confluence.	・Deep river channels of both main river; bank areas often at lower level - natural flood plain
	（Approx. 600 ha of farmland was inundated）	(Max gauge level is 14.0 m)		・The railway bridge crossing over the Bou Heurtma River is disrupting flow. ・Prevention from overtopping of the Bou Heurtma River is one of key points for protection of Bou Salem City.	・There is a concrete box culvert crossing main road (Route No.6) which has a function of drainage canal. However, it is clogged by heavy silt and garbage (approx. 2 km bound to Jendouba from Mellegue Bridge).	
	・Backwater into the Rarai seems to be influenced in inundation. ・Overbanked flow from Mejerda comes through flood plain between Mejerda and Rarai Rivers to Rarai - ca 4 km US from confluence	・Overtopped from low banks (right and left) at US of bridge site		・A pumping station for irrigation (P0) exists at just DS of confluence of the Mejerda and Bou Heurtma. As for tapping water there, water level is raising by steel sheet piling across the river and it affects to US water level. Steel sheet piling weir is partially broken - reconstruction or replacement by movable structure is recommended.		
				・Dike and huge layer of sediment in Bou Salem (at gauging station) causes backwater during flood up to confluence with Bou Heurtma River. River channel maintenance is required urgently.		
Flood Damage	Agricultural crop and farmland	Road, bridge, house, farmland	House, household effects, agricultural crops, farmland, road, railway	House, household effects, agricultural crops, farmland, road, railway	Agricultural crops and farmland	Agricultural crop and farmland
Possible Countermeasures	・Short-cut ・Dike ・Retarding basin ・Combinations of the above ・Area US of confluence of Mejerda and Rarai to let in current conditions - as natural retardation basin. Dikes (cutting of natural flood plain area) could get worse flood conditions downstream, esp. in Jendouba	・(In case of flow capacity is small at bridge section) Additional span(s) can be provided at left bank with box culvert, etc. ・Channel excavation (namely DS of the town) ・Removing some old concrete structure (flow obstacle) from river channel - situated directly in bridge cross section.	・Retarding basin (approx. 500 ha) ・Short-cut ・Dike ・Cobination of the above	・Channel excavation of the Bou Heurtma River (vegetation maintenance), dike along the Bou Heaurtma, improvement of railway bridge and intake structure of pumping station ・Channel excavation of the Mejerda River ・Dike (location and size according to simulation results)	・Dike (+ revetment) - old field road should be used partially as a base of levee construction ・Channel excavation ・Short-cut ・Retarding basin (approx.60 ha)	・Two smaller retardation basins are proposed for protection downstream area (Bou Salem)
Notable Issues to be Considered		・After 2003 flood, drainage canal was constructed by Municipality of Jendouba.		・Influence of Bou Heurtma Dam located at US shall be considered for river improvement of Bou Heartma itself (minimal ecological discharge will be assessed).		

Source: The Study Team

Table D2.5.1 Major Issues of Flood Protection and Possible Structural Measures (for Preliminary Setting of Alternatives) (2/2)

Location	Mejerda MS		Mejerda DS			
	DS of Sidi Salem Dam ~ Testour ~ Slougia*	Medjez El Bab	Medjez El Bab ~ El Herri Weir ~ Laroussia Dam	Tebourba～Jedeida	Confluence of Chadrou～ Tobias Movable Weir	Tobias Movable Weir ~ River Mouth (Floodway)
Principal Feature of Watershed and River Channel	・Lowly undulated along the river course and formed moderate hilly topography.	･The old bridge (Andalous) constructed in 17th Century seems to be disruption of river flow. ･The ground elevation in the City is low, and in particular, near the rotary at right bank side of the old bridge. ･There is a gentle hill with 20~30 m in height at south side of the City. Construction of new floodway might be possible if the route could avoid crossing the hill.	･Shortcuts are proposed in El Herri area - appropriate location to be confirmed	・The causes of inundation between Tebourba and Jedeida might be lack of flow capacity in the Mejerda River itself, in particular, at DS of El Battane Weir, and US and DS of Jedeida Old Bridge (decrease of flow section due to siltation at riverbed is significant).	･The river width is about 50 to 70 m (distance between shoulders of river banks). There is low dike (less 2.0 m high) partially along the stretch. According to DGBGTH, river improvement of the Mejerda in these stretches has been started during French occupation in 1910's. Short-cutting was realized at least three stretches as far as confirmed on topographic maps (scale of 1:25,000). Crescent-shaped lakes are remained. ･The large drainaged area around El Mabtouh is natural flood plain.	・Construction of Tobias Movable Weir was completed in 1990, and the pumping station, which is operated by SECADENORD, was constructed in 1991. ・The original river course of the Mejerda was reformed by narrowed trapezoidal section with concrete lining of bottom and side slopes. New floodway stretches about 8.0 km from Tobias Movable Weir to the river mouth.
		・Discharge capacity in the vicinity of Andalous bridge was increased ca from 180 m3/s up to 250 - 300 m3/s by measures (dredging) in year 2005. ONAS already prepared some proposal for flood protection of town in the future.		･According to Laroussia dam operator vegetation in river channel was significantly cut in about 8 km long river reach near Jedeida (to be confirmed the location) in year 2004 => Laroussia dam operator appreciated positive effect of this cutting.	･The riverbed material is mainly composed of fine sand and bank erosion looks not so serious with thick vegetation. ･Outlet gate from El Mabtouh drainage channel is destroyed - unable to move.	･Inundation area toward the north plain from Utique and Galâat Landalous was in the sea during B.C. 2nd Century..
Flooding Conditions	・Inundation was extended in a belt along the main road between Testour and Mejez El Bab due to 1973 flood.	・Overtopping at US left bank of new bypass road occurred due to 2003 flood. The flooded water crossed the new road and rushed into the center of the city.	・Inundation area was extended as a belt along the main road between Mejez El Bab and Tebrouba in 1973.	・The wide areas between Testour and Jedeida were inundated due to 1973 flood. Especially overtopping occurred and inundation area was extended at DS of El Battane Weir in 2003 flood.	・According to the inundation areas due to 1973 flood, overtopping might have been occurred at various locations at left bank side (bank height or height of dike shall be confirmed by river cross sections).	・Although flooding conditions in these stretches due to floods of 2004 and 2005 are not confirmed yet, confirmation would be required.
		・Overtopped at DS both banks of the old bridge. ・At around 4 km DS of the old bridge, overtopping occurred at first meandering stretches of the Mejerda.	・It is reported that the flood in 2003 has not affected to Larrousia Dam (total design discharge of three gates is 250 m3/s: to be confirmed).	・Inundation has occurred at both sides of river banks between Jedeida Old Bridge and confluence of the Chafrou River in 2004 flood.		
		･Inudation happened along the two creeks which join at left bank with the Mejerda. However, the inundation area was not so extended due to relatively high ground elevation. ･The left bank flood plain is also flooded by backwater from drainage system (not		･Especially, flow capacity between El Battane and El Henna (Jedeida) is quite small and its countermeasure will be essential. ･There is really huge layer of sediment and dense vegetation in river coarse in DS of El Battan weir/bridge => significant decre		
				･MAHR mentioned that the fast growing-up of vegetation in the most of stretches is serious problem in order to maintain flow capacuty and smooth current.		
Flood Damage	Agricultural crops, farmland and road	House, household effects, agricultural crops, farmland, road, factory, pipeline	House, household effects, agricultural crops, farmland, road	House, household effects, agricultural crops, farmland, road	House, household effects, agricultural crops, farmland, road, irrigation canal and appurtenant structures	House, household effects, agricultural crops, farmland, road, irrigation canal and appurtenant structures
Possible Countermeasures	・Channel improvement ・Dike	・Channel improvement ・New floodway (approx. 3.8 km) ・Dike (overtopped section) ・Sluiceways (at outlet of tributaries)	・Channel improvement ・Dike ・Short-cut	・River improvement (dredging, widening) ・Dike ・Bypass channel (Approx. 1.3 km for bypass of El Battane Weir - to be evaluated by MIKE Flood)	･River improvement (dredging) ･Dike ･River training works (US right bank side of Tobias Weir) ･Large area around El Mabtouh to be let as natural flood plain, only local protection (dikes) of settled areas ･Reconstruction of outlet gate from El Mabtouh drainage canal	・River improvement ・Dike ・Reconstruction of old Mejerda channel downstream Tobias weir (new connection with existing Mejerda river channel) also for flood protection use
Notable Issues to be Considered		･The new floodway will require resettlement of 40 to 50 households (to be confirmed). Provision of siphon (about 280 m long) will be one of option to mitigation the adverse effect to the local people.	・River improvement at US and DS of El Herri will require due care of height of the weir. The current riverbed formation at US might be affetced by this structure.		･Although low lying areas likely suitable for retarding basin exists in fact, retarding flood peak discharge seems not essential in these stretches. Rather importance should be given how much water can be stored in terms of quantity. It will be verified through topographic survey.	
					･Since Tobias Movable Weir will become to be control point in hydraulics, its affect to flow capacity (and also influence of road bridge to Galâat Landalous) shall be examined. ･Confirmation on flow capacity of DS canal and Tobias Movable Weir shall be made.	

Source: The Study Team

Table D3.6.1 Principal Features of Proposed River Improvement

Zone D2

I. Mejerda River				
1) Levee 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^3
	Fascine mattress type		2,400	m^2
5) Renewal of existing bridge			3	Location
6) Heightening of existing railway bridge			1	Location
7) Heightening of existing road			4,600	m
II. El Mabtouh Retarding Basin				
1) Inlet channel	Improvement of existing channel		9,130	m
	New 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 max
6) Overflow dike of inlet channel (with stop log		Length	80	m

Zone D1

I. Mejerda River				
1) Levee 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^3
	Fascine mattress type		2,700	m^2
5) Renewal of existing bridge			1	Location
II. Majez El Bab Bypass Channel				
1) Length		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

Zone U2

I. Mejerda River				
1) Levee 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^3
	Fascine mattress type		3,300	m^2
5) Renewal of existing aqueduct with foot bridge			1	Location
II. Bou Salem Bypass Channel				
1) Length		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) Levee embankment			3,721	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	
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^3
	Fascine mattress type		1,500	m^2

Zone M

I. Mellegue River				
1) Levee embankment				
a) Length				
Whole river stretches under planning			8,895	m
Actual construction plan of embankment			7,405	m
Actual construction length		(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.

Table D4.3.1 Available Documents relevant to Flood Damage and Restoration Works in Governorate Manouba (1/3)

Ref. No.	Main Subject	Flood Event Concerned	Type of Document	Date Issued	Sent from	Sent to	Number of Page	File Type
Doc 1	A report about the meeting of the Regional Committee of disasters fighting of the Governorate Manouba organized from Feb 9,2005. The report describe all the improvements done up to Feb 20, 2005.	Feb. 2005	Report	February 20, 2003	The Governorate of Manouba	***	4	Word
Doc 2	A report about the damages occurred on the Governorate of Manouba after the rainfall of Feb & March 2005 and especially damages that concern the soil and water conservation sector.	Feb. 2005	Report	no date	***	***	1	Word
Doc 3	Report about the damages caused by the floods of Mejerda & Chafrou rivers in Manouba, a list of the damaged farmers.	Feb. 2005	Report	March 7, 2005	The President of the Agricultural information Cell-Manouba	Regional Delegate of the Agricultural Development	5	Excel
Doc 4	Report including 6 sheets describing the agricultural damages in Manouba caused by: floods, stagnated water, wind, cold and landslides. The sheet n° 7 summarize the others.	Feb.2005	Report	March 7, 2005	The Regional Delegate of the Agricultural Development-Manouba	The General Director of the Agricultural Productivity-Manouba	10	Excel
Doc 5	Survey of the black points where Mejerda overtopped in Feb 2005 and the submerged areas + A Xl file containing the list of the damaged farmers and the kind of their plantations (Battane :village of Halfaoui).	Feb.2005	Report	Feb 21, 2005	CRDA Manouba -The unit of the agricultural Information	***	2	Excel
Doc 6	The improvement made by the CRDA-Manouba and the progress of the 2004 maintenance program. The report includes 12 sheets.	- (river channel improvement works after Jan. 2003 flood)	Report	August 19, 2004	1^{st} & the 2^{nd} fromThe Regional Delegate of the Agricultural Development of Manouba	1^{st} The Governor of Manouba 2^{nd} The Secretary of the State to the Minister of Agriculture, Environment and Water Resources in charge of the water resources and fishing	12	Excel
Doc 7	An invitation for the meeting supervised by the Secretary of the State to the Minister of Agriculture and Water resources on Tuesday August 31, 2004 at 9 o'clock.	(after Jan. 2003 flood)	Letter	August 28,2004	The Minister Office Chief (by procuration from the Minister) Mr. Abdelhakim Khaldi	The Regional Delegate of the Agricultural Development-Manouba	1	Word
	A meeting leaded by The Secretary of State of water resources and fishing= the excavation of the rivers and the protection of the towns from floods	(after Jan. 2003 flood)	Meeting minutes	August 31,2004	***	***	4	Word
Doc 8	With this letter a copy of the meeting minute is joined "to inform the CRDA Chief and to follow the meeting instructions".	(after Jan. 2003 flood)	Letter	September 11,2004	The First Delegate (by procuration from the Governor of Manouba) Mr. Sadok SAIDII	The Regional Delegate of the Agricultural Development-Manouba	1	Word
	The meeting of the Regional Committee to cope with disasters and organizing rescue presided by the Governor of Manouba	(after Jan. 2003 flood)	Meeting minutes	September 20 ,2004	***	***	13	Word
Doc 9	Flooded areas in the Governorate of Manouba- Village that need an urgent works to preserve water and soil	Jan. 2003?	A3 map-3maps of the flooded areas-Report-Sheet	****	CRDA Manouba	***	6	Word
Doc 10	The influence of the strong rainfall of 11,12 and 13 December 2003 on the agricultural lands and infra-structures in Manouba	Dec. 2003	A preliminary report +2 sheets	December 15, 2003	CRDA Manouba	***	5	Word
Doc 11	A list of the farmers having a damaged lands by Chafrou and Mejerda Floods-January 2004	Jan. 2004	A list of the farmers and the damaged plantations	January 2004	CRDA Manouba	***	10	Excel
Doc 12	The distribution of the flooded areas by Chafrou and Mejerda rivers on January 2004	Jan. 2004	Sheet	January 16, 2004	CRDA Manouba	***	1	Excel
	The agricultural damages of the inundation of Mejerda in Manouba on January 2004	Jan. 2004	Report	January 16, 2004	CRDA Manouba	The Minister of Agriculture, Environment and Water Resources	3	Word
Doc 13	The damage caused by the inundation of Mejerda river on December 2003 and January 2004, Costs and the improvement done by the CRDA to cope with floods	Jan. 2004	Report (including 4 sheets & 3 photos)	January 28,2004	CRDA Manouba	***	10	Word
	Flooded lands-damages-maintenance works done on 2003-the improvement of the CRDA to cope with floods	Jan. 2004	4 sheets (the previous report)	January 28,2004	CRDA Manouba	***	1	Excel
Doc 14	A list of the used materials and vehicles to cut the trees on Mejerda river (Manouba)	Sep.2003?	Report	September 29,2005	The Chief of the Forests District	The Chief of CRDA-Manouba		Word
Doc 15	4 sheets describe progress of the works and improvement done by the CRDA to cope with floods and disasters. Detailed work progress from September to October 2003.	(after Jan. 2003 flood)	4 Sheets	7 & 9 October 2003	CRDA Manouba	***	4	Excel

Table D4.3.1 Available Documents relevant to Flood Damage and Restoration Works in Governorate Manouba (2/3)

Ref. No.	Main Subject	Flood Event Concerned	Type of Document	Date Issued	Sent from	Sent to	Number of Page	File Type
Doc 16	A report that describe the current projects and the planned one	(after Jan. 2003 flood)	Report	August 25,2003	CRDA Manouba-Section of Water & Rural Equipment-District of the Maintenance of the Hydrological Equipments	***	2	Word
Doc 17	A project description: the reparation of the damaged equipments of the water and soil protection	(after Jan. 2003 flood)	Project Card	September 2003	CRDA Manouba- Section of water and soil protection	***	1	Word
Doc 18	A project description: the reparation of the damaged forestry equipments	Sep. 2003	Project Card	September 25, 2003	CRDA Manouba-Forests Section	***	1	Word
Doc 19	A report talking about the body of the animals killed by flood of Sep. 2003 -Manouba	Sep. 2003	Report	September 20,2003	CRDA Manouba	***	16 content is repeated	Word
Doc 20	A summary report of the damages caused to the corps and livestock by September 2003 inundation in Manouba	Sep. 2003	Report	September 23, 2003	CRDA Manouba	The Minister of Agriculture, Environment and Water Resources	1	Word
	A summary report of the damages caused to the corps and livestock by September 2003 flood in Manouba	Sep. 2003	Report	September 23, 2003	CRDA Manouba	The Minister of Agriculture, Environment and Water Resources	6	Excel
Doc 21	A synthetic report including all the damages caused by September 2003 flood	Sep. 2003	Report	October 1st, 2003	CRDA Manouba	***		Word
Doc 22	The places where the water stagnates in the Delegation of Oued Ellil	Sep. 2003	Report	October 7, 2003	Mr. The Delegate of Oued Ellil	Mr. The Governor of Manouba	2	Word
Doc 23	The damages that affected the hydrological equipments in the irrigated perimeter of Manouba	Jan. 2003	Report	February 22,2003	The Regional Delegate of the Agricultural Development of Manouba	The General Director of the Rural Engineering and Water Exploitation	3 (the third is repeated)	Word
Doc 24	Damages the affected the Hydrological Equipments and materials	Jan. 2003?	Report	March 1st, …the year isn't clear	CRDA Manouba-The section of Water and Rural Equipment-The district of Maintenance of the Hydrological Equipments	***	1	Word
Doc 25	This document describe the procedures to do for the body of the dead animals	Jan. 2003?	A technical notice	no date	Health Ministry-Direction of Hygiene, Milieu and environment protection	***	2	Word
Doc 26	9 sheets describing the damages caused by flood and the financial cost of the damage	Jan. 2003	Sheets	January 2003	***	***	7(the 2last pages are repeated)	Excel
Doc 27	The subsidiary unit created in the Regional Committee to avoid and cope with floods and rescue organization in Manouba	?	Report	no date	The Governorate of Manouba-Political affairs section	***	2	Word
Doc 28	This report proposes to acquire a materials (pumps, vehicles) to use during inundations	Dec. 2003	Report	December 2003	***	***	1	Word
Doc 29	This report explains the improvement done by the CRDA Manouba to cope with January 2003 inundation.	Jan. 2003	Report	September 23, 2003	The Regional Delegate of the Agricultural Development of Manouba	The Minister of Agriculture, Environment and Water Resources	2	Word
Doc 30	A list of the damaged farmers and theirs lands (heavy rainfall of 17 and 18 September 2003)	Sep. 2003	Report	September 20,2003	The Chief of the Regional Union of Agriculture and Fishing in Manouba	The Regional Delegate of the Agricultural Development-Manouba	1	Word
Doc 31	A report about the damage of the plantations after the heavy rainfall (September 2003)	Sep. 2003	Report	September 21, 2003	The Chief of the Agricultural information-Manouba	The General Director of CRDA of Manouba & The Chief of the Information and the improvement of the Agricultural production	1	Word
	A sheets describing the list of farmers, their damaged plantations, by hectares.	Sep. 2003	Sheets	September 21, 2003	The Chief of the Agricultural information-Manouba	The General Director of CRDA of Manouba & The Chief of the Information and the improvement of the Agricultural production	3	Excel
Doc 32	A detailed report about the inundations of January 2003 in Manouba and the ways to solve the problems	Jan.2003	Report	no mentioned	The National technical committee	***	21	Word

Table D4.3.1 Available Documents relevant to Flood Damage and Restoration Works in Governorate Manouba (3/3)

Ref. No.	Main Subject	Flood Event Concerned	Type of Document	Date Issued	Sent from	Sent to	Number of Page	File Type
Doc 33	The impact of 2003 inundation on the aquifer in Manouba	Jan.2003	Report	not mentioned	Mr. Abdessatar BEN KESSIM-Chief of the Water resources Section	***	5	Word
Doc 34	Inundation of 2003 in Manouba	Jan.2003	Report	not mentioned	CRDA Manouba	***	6	Word
	An appendix of the previous report (Doc 34)	Jan.2003	2 Sheets	not mentioned	CRDA Manouba	***	1	Excel
Doc 35	A report that describes the agricultural damages in the Governorate of Manouba caused by 2003 inundations	Jan.2003	Report	February 2003	Ministry of Agriculture-The committee of evaluation of the agricultural damages of the inundations in the Governorate of Manouba	***	17	Word
	16 Sheets including the damages of all the sectors (livestock, agriculture, construction…)	Jan.2003	Sheets	February 2003	Ministry of Agriculture-The committee of evaluation of the agricultural damages of the inundations in the Governorate of Manouba	***		Excel

Table D4.3.2 Background Information of Flood Damage to Agricultural Crops (1/2)

1. Flood Inundation and Damage Survey, March 2007 (under current JICA Study)
(Simple statistic enumeration of answers from the respondents as "Farmers")

No.	Area	Sample size	Year of Flood event	Max Depth (cm) *1	Range (cm)	Duration (days) *1	Inundated Area (ha) *1	Major damaged crops	Damaged value (TND) *1	Damaged value (TND/ha)	Received compensation *2
1	Nebeur	4	2003, 2000	33	20~40	5	17.0	vegetable, cereal	7,150	421	0/4
2	Jendouba	19	1973, 2000	88	10~300	12	6.8	olive, cereal	8,314	1,223	3/19
3	Bou Salem	10	2003, 1973	50	20~100	21	1.5	olive, vegetable, cereal	3,850	2,567	6/10
4	Sidi Ismail	10	2003	95	30~180	19	4.1	olive, cereal	7,555	1,843	2/10
5	Zone Amont	5	2003	154	40~300	44	4.4	olive, cereal	6,330	1,439	0/5
6	Testour	20	2003, 1973	75	20~400	15	1.9	pomegrate, other crops	18,281	9,622	1/20
7	Slouguia	30	1973, 2003	295	80~500	76	2.2	other crops	48,667	22,121	16/30
8	Mejez El bab	7	2003, 1973	159	50~300	39	1.9	vegetable, cereal	15,871	8,353	3/7
9	El Herri	20	2003, 1973	148	80~300	55	28.5	olive, vegetable, cereal	44,550	1,563	10/20
10	Tebrouba	9	1973, 2003	78	40~100	33	2.9	other crops	66,056	22,778	7/9
11	Jedeida	10	1973, 2003	101	50~250	35	5.6	vegetable, cereal, other crops	84,120	15,021	10/10
12	El Battan	15	1973, 2003	107	50~200	27	4.3	cereal, other crops	16,547	3,848	9/15
13	Chaouat- Sidi Thabet	20	2003, 1973	82	15~250	35	7.6	vegetable, cereal	9,625	1,266	1/20
		179	Average	113		32	6.8		25,917	**3,798**	

Note: *1, Average value of answers
*2, (numbers of answer who received / total numbers of respondents)

2. Flood Inundation and Damage Survey, March 2007 (under current JICA Study)
- Irrigated land (灌漑農地) **581.22** /ha (Yr 2006 price) (based on the answers from farmers in Governorate Beja in Jan. 2003 Flood and of
- Dry farm land (乾燥農地) **240.34** /ha (Yr 2006 price) Governorate Jendouba in May 2000 Flood)

3. Information from CRDA Manouba (collected by Study Team)

3.1 Damaged value caused by Jan. 2003 flood (Ref:Doc 26)
(Damaged area: not specifically mentioned, but supposed to be the total in whole Governorate Manouba)

Damaged Item	Damage Area	Value per ha	Damaged Value (TND)	
Crops (A)				
Dry cereals	2,233	600	1,339,800	
Irrigated cereals	810	1,350	1,093,500	
Green fodder	1,045	750	783,750	
Other cereals	54	480	25,920	
Potatoes	77	4,500	346,500	
Artichoke	535	4,500	2,407,500	
Other leguminous	93	1,000	93,000	
Sub-total	4,847	13,180	6,089,970	
Fruits tree (B)				
Completely destroyed	110	3,000	330,000	
Partially destroyed	1,600	2,000	3,200,000	
Sub-total	1,710	5,000	3,530,000	
Total	6,557	=(A)+(B)	9,619,970	=(A)+(B)
			1,467	(TND/ha)
Cattle (C)				
Sheep	250	120	30,000	
Cow	24	800	19,200	
Fowl	683	3	2,049	
Hives of bees	418	100	41,800	
Rabbits	112	5	560	
Sub-total	1,487	1,028	93,609	
Restoration works (D)	Unit (?)	Cost for repair		
Well excavation	8	400	3,200	
Pumps (reparation)	211	100	21,100	
Irrigation canal	11,320	5	56,600	
Equipment for spot irrigation	161	2,000	322,000	
Stables and poultry farms	27	100	2,700	
Sub-total	11,727	2,605	405,600	
Total			10,119,179	=(A)+(B)+(C)+(D)

Damage to agricultural products
= (1,467+400) x 1.0964 = 2,047
= **2,000 /ha**
(2007 price)

3.2 Damage caused by over banking small rivers in Manouba, Oued Ellil and Doua Hicher occurred in September 2003 (Ref: Doc 20)

Delegation	Number of affected farmers	Damaged area (vegetable, ha)	Other leguminous	Damaged value TND	Damaged value TND/ha
Manouba	13	18.2	9.25	9,375	515
Oued Ellil	12	26.3	7.80	22,725	864
Douar Hicher	4	9.4	5.10	7,155	761
Total	29	53.9	22.15	39,255	**728**

Note: The report mentions that inundation depth was about **40 cm** based on the flood marks remained.

3.3 Areas having the priority of improvement of the irrigation facilities and soil conservation (Ref: Doc 9)
(due to December 2003 flood)

	Delegation	Area for land improvement (ha)	Priority area for urgent improvement (ha)	Cost (TND 1,000)
1	Tebourba	6,500	4,000	4,200
2	El Battan	1,600	1,000	1,040
3	Jedeida	500	1,000	600
4	Mournaguia	2,800	500	1,320
5	Bourj El Amri	3,500	500	1,600
6	Oued Ellil	1,500	1,000	1,000
7	Manouba	100	0	40
	Total	16,500	8,000	**9,800**

Unit ratio : **TND 400/ha** applied

Table D4.3.2 Background Information of Flood Damage to Agricultural Crops (2/2)

3.4 Damage caused by overtopping from Mejerda River channel occurred in February 2005 (Ref: Doc 4)

(Damaged areas: Delegations of Bourj El Amri, Tebourba, Jedeida, Mornaguia, Oued Ellil and El Battan)

Damaged Plantation/Crops	Damaged Area		Number of Farmers	Cost of Damage (TND)	Damaged value (TND/ha)
	Ha	% of Damage			
Large-scale farming					
Cereals	1,963	40 - 70	272	392,600	200
Fodder plant	836	40 - 70	160	133,760	160
Leguminous					
Potato	22	50	2	129,000	6,000
Artichoke	19	100	14	95,000	5,000
Various	22	60	22	6,600	300
Fruit Trees	242	-	61	-	
Olive trees	4	-	3	-	
Total	**3,108**			756,960	**265**

Source: CRDA Manouba

4. Information from CRDA Jendouba

4.1 Damaged value caused by May 2000 Flood

Item	Damage area (ha)	% of Damage	Damaged value (TND)	
Irrigated cereal	635	-	560,000	
Forage	125	95	164,000	
Dry fruits	180	-	50,000	
Vegetables	287	50 - 75	515,000	
Industrial plantation (tobacco, sugar cane)	34	75	70,000	
Fruit trees (citrus, grapes, olives)	31	70	15,000	
Total	**1,292**		1,374,000	**1,063** (TND/ha)

Source: CRDA Jendouba

Note: Primary and supplementary aids with value of TND 356,400 were provided to supply 818 small-scale farmers **(ave. TND 436/person)**.

4.2 Damaged area caused by Jan. 2003 Flood

A technical commission evaluated the damages agricultural area in Governorate Jendouba after flood in January 2003 as follows:

Plantation	Damaged area (ha)
Cereals	2,400
Green forage	340
Dry fruits	25
Vegetables	70
Potatoes	20
Fruit trees	145
Total	3,000

Source: CRDA Jendouba

Table D4.4.1 Configulation of River Improvement Works by Probable Discharges (1/2)

Scale of River Improvement

Zone	Return period	Peak Discharge (m3/s)	Existing Flow Capacity (m3/s)	River Cross Section No.	Flood Retarding Basin		River Channel Excavation			Embankment				Bypass Channel			Embankment (along Bypass)		Revetment
										Left		Right							
					Peak Q (m3/s)	Volume (mil. m3)	Discharge (m3/s)	Bottom width (m)	Length (km)	Height (m)	Length (km)	Height (m)	Length (km)	Discharge (m3/s)	Bottom width (m)	Depth (m)	Height (m)	Length (km)	
U1	5-Year	520	200	MU317~MU306	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5-Year	370	200	MU248~MU211	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	5-Year	370	200	MU210-MU165	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	10-Year	790	200	MU329~MU306	—	—	790	10	12.4	—	—	—	—	—	—	—	—	—	—
	10-Year	570	200	MU248~MU211	—	—	570	15	18.9	—	—	—	—	—	—	—	—	—	—
	10-Year	570	200	MU210-MU165	—	—	570	10	16.4	—	—	—	—	—	—	—	—	—	—
	20-Year	1,150	200	MU329~MU306	—	—	1,150	15	12.4	—	—	—	—	—	—	—	—	—	—
	20-Year	820	200	MU248~MU211	—	—	820	20	18.9	—	—	—	—	—	—	—	—	—	—
	Jendouba B													250	25	6.0			
	20-Year	820	200	MU210-MU165	—	—	570	35	16.4	—	—	—	—	—	—	—	—	—	—
	50-Year	1,830	200	MU329~MU306	—	—	1,830	25	12.4	—	—	—	—	—	—	—	—	—	—
	50-Year	1,310	200	MU248~MU211	—	—	1,310	25	18.9	—	—	—	—	—	—	—	—	—	—
	Jendouba B													530	55	6.0			
	50-Year	1,310	200	MU210-MU165	—	—	780	50	16.4	—	—	—	—	—	—	—	—	—	—
M																			
	5-Year	120	120	MG1~MG8	—	—	120	—	1.6	—	—	—	—	—	—	—	—	—	—
	10-Year	410	120	MG1~MG52	—	—	410	15	12.9	—	—	—	—	—	—	—	—	—	—
	20-Year	1,100	120	MG1~MG112	—	—	1,100	25	26.9	—	—	—	—	—	—	—	—	—	—
	50-Year	2,420	120	MG1~MG112	—	—	2,420	35	26.9	—	—	—	—	—	—	—	—	—	—
U2	5-Year	490	200	MU123~MU164	—	—	490	20	16.6	—	—	—	—	—	—		—	—	—
	Bou Salem B	640	400	MU80~MU122	—	—	640	30	14.9	—	—	—	—	—	—	—	—	—	—
	5-Year	680	250	MU36~MU79	—	—	680	35	16.7	—	—	—	—	—	—	—	—	—	—
	5-Year	680	200	MU1~MU35	—	—	680	—	14.3	○		○	—	—	—	—	—	—	—
	Bou Heurtma	40	—	—	—	—	—	—	—	—		—		—	—	—	—	—	—
	10-Year	890	200	MU123~MU164	—	—	890	25	16.6	—	—	—	—	—	—	—	—	—	—
	Bou Salem B	1,110	400	MU80~MU122	—	—	810	50	14.9	○		○		—	—	—	—	—	—
	10-Year	1,140	250	MU53~MU79	—	—	1,140	50	10.4	—	—	—	—	—	—	—	—	—	—
	10-Year	1,140	250	MU36~MU52	—	—	1,140	—	15.9	○		○		—	—	—	—	—	—
	10-Year	1,140	200	MU1~MU35	—	—	1,140	—	14.3	○		○		—	—	—	—	—	—
	Bou Heurtma	40	—	—	—	—	—	—	—		4.6		4.6	—	—	—	—	—	—
	20-Year	1,490	200	MU123~MU164	—	—	1,490	40	16.6	○		○					—	—	—
	Bou Salem B	1,800	400	MU80~MU122	—	—	1,100	50	14.9	○		○		700	25	8.0	—	—	—
	20-Year	1,840	250	MU52~MU79	—	—	1,840	50	10.4	—	—	—	—	—	—	—	—	—	—
	20-Year	1,840	250	MU36~MU52	—	—	1,840	—	15.9	○		○		—	—	—	—	—	—
	20-Year	1,840	200	MU1~MU35	—	—	1,840	—	14.3	○		○		—	—	—	—	—	—
	Bou Heurtma	40	—	—	—	—	—	—	—		6.9		6.9	—	—	—	—	—	—
	50-Year	3,330	200	MU123~MU164	—	—	3,330	50	16.6	○		○		–	–	–	–	–	–
	Bou Salem B	3,570	400	MU80~MU122	—	—	1,970	50	14.9	○		○		1,600	50	8.0	○	–	–
	50-Year	3,870	250	MU53~MU79	—	—	3,870	50	10.4	—	—	—	—	—	—	—	—	—	—
	50-Year	3,870	250	MU36~MU52	—	—	3,870	—	15.9	○		○		—	—	—	—	—	—
	50-Year	3,870	200	MU1~MU35	—	—	3,870	—	14.3	○		○		—	—	—	—	—	—
	Tessa	—	—	TS1-TS72	—	—	—	—	—	—	—	2.0	16.4	—	—	—	—	—	—
	Bou Heurtma	300	—	—	—	—	—	—	—		8.6		8.6	—	—	—	—	—	—

Costruction Cost

Unit:TND mil.

Flood Retarding Basin	River Channel Excavation	Embankment	Bypass Channel		Revetment	Total	Economic Cost (0.82*0.88)
			Excavation	Embankment			
—	—	—	—	—	—	0.00	
—	—	—	—	—	—	0.00	
—	—	—	—	—	—	0.00	
						0	**0.00**
—	5.78	—	—	—	—	5.78	
—	8.66	—	—	—	—	8.66	
—	15.00	—	—	—	—	15.00	
						29.44	**21.24**
—	8.52	—	—	—	—	8.52	
—	12.77	—	—	—	—	12.77	
—	—	—	22.30	—	—	22.30	
—	23.40	—	—	—	—	23.40	
						66.99	**48.34**
—	11.11	—	—	—	—	11.11	
—	16.66	—	—	—	—	16.66	
—	—	—	36.00	—	—	36.00	
—	35.70	—	—	—	—	35.7	
						99.47	**71.78**
—	0.42	0	—	—	—	**0.42**	**0.30**
—	2.82	1.21	—	—	—	**4.03**	**2.91**
—	3.64	6.24	—	—	—	**9.88**	**7.13**
—	5.46	11.64	—	—	—	**17.1**	**12.34**
—	13.27	—	—	—		13.27	
—	10.20	—	—	—	3.00	10.20	
—	7.13	—	—	—	—	7.13	
—	0.00	0.91	—	—	—	0.91	
—	—	0.05	—	—	—	0.05	
						34.56	**24.94**
—	19.00	0.00	—	—	—	19.00	
—	21.71	0.70	—	—	3.40	25.81	
—	12.10	0.00	—	—	—	12.10	
—	0.00	0.96	—	—	—	0.96	
—	0.00	2.93	—	—	—	2.93	
—	—	0.10	—	—	—	0.10	
						60.90	**43.95**
—	26.00	1.94	—	—	—	27.94	
—	21.71	1.86	28.00	—	3.80	55.37	
—	12.10	0.00	—	—	—	12.10	
—	0.00	1.75	—	—	—	1.75	
—	0.00	4.43	—	—	—	4.43	
—	—	1.54	—	—	—	1.54	
						103.13	**74.42**
—	34.36	3.37	—	—	—	37.73	
—	21.71	3.27	40.02	3.00	4.20	72.20	
—	12.10	—	—	—	—	12.10	
—	0.00	3.97	—	—	—	3.97	
—	0.00	9.60	—	—	—	9.60	
—	—	2.92	—	—	—	2.92	
—	—	6.36	—	—	—	6.36	
						144.88	**104.55**

Table D4.4.1 Configulation of River Improvement Works by Probable Discharges (2/2)

Scale of River Improvement

Zone	Return period	Peak Discharge (m3/s)	Existing Flow Capacity (m3/s)	River Cross Section No.	Flood Retarding Basin		River Channel Excavation			Embankment				Bypass Channel			Embankment (along Bypass)		Revetment
										Left		Right							
					Peak Q (m3/s)	Volume (mil. m3)	Discharge (m3/s)	Bottom width (m)	Length (km)	Height (m)	Length (km)	Height (m)	Length (km)	Discharge (m3/s)	Bottom width (m)	Depth (m)	Height (m)	Length (km)	
D1	5-Year	420	350	MD1-MD-64	–	–	420	10	20.8	–	–	–	–	–	–	–	–	–	–
	5-Year	420	350	MD65-MD116	–	–	420	10	17.1	–	–	–	–	–	–	–	–	–	–
	Mejez El Bab B	360	350	MD117-MD132	–	–	360	20	4.2	–	–	–	–	–	–	–	–	–	–
	5-Year	360	180	MD133-MD194	–	–	360	20	19.3	–	–	–	–	–	–	–	–	–	–
	5-Year	360	300	MD195-MD252	–	–	360	20	21.2	–	–	–	–	–	–	–	–	–	–
	10-Year	610	350	MD1-MD-64	–	–	610	20	20.8	○	○	○	○	–	–	–	–	–	–
	10-Year	610	350	MD65-MD116	–	–	610	20	17.1	○	○	○	○	–	–	–	–	–	–
	Mejez El Bab B	540	350	MD117-MD132	–	–	360	20	4.2	○	○	○	○	190	15		–	–	–
	10-Year	540	180	MD133-MD194	–	–	540	25	19.3	○	○	○	○	–	–	–	–	–	–
	10-Year	540	300	MD195-MD252	–	–	540	25	21.2	○	○	○	○	–	–	–	–	–	–
	20-Year	890	350	MD1-MD-64	–	–	890	25	20.8	–	–	–	–	–	–	–	–	–	–
	20-Year	890	350	MD65-MD116	–	–	890	25	17.1	–	–	–	–	–	–	–	–	–	–
	Mejez El Bab B	820	350	MD117-MD132	–	–	360	20	4.2	–	–	–	–	460	50		–	–	–
	20-Year	820	180	MD133-MD194	–	–	820	30	19.3	–	–	–	–	–	–	–	–	–	–
	20-Year	820	300	MD195-MD252	–	–	820	30	21.2	–	–	–	–	–	–	–	–	–	–
	50-Year	2,330	350	MD1-MD-64	–	–	2,330	30	20.8	–	–	–	–	–	–	–	–	–	–
	50-Year	2,330	350	MD65-MD116	–	–	2,330	30	17.1	–	–	–	–	–	–	–	–	–	–
	Mejez El Bab B	2,250	350	MD117-MD132	–	–	540	20	4.2	○	○	○	○	1,710	70		–	–	–
	50-Year	2,250	180	MD133-MD194	–	–	2,250	40	19.3	–	–	–	–	–	–	–	–	–	–
	50-Year	2,250	300	MD195-MD252	–	–	2,250	40	21.2	–	–	–	–	–	–	–	–	–	–
D2	5-Year	340	800	MD253-MD281	–	–	340	Non-imp't	9.6	–	–	–	–	–	–	–	–	–	–
	El Battane B	340	700	MD282-MD290	–	–	340	Non-imp't	2.2	–	–	–	–	–	–	–	–	–	–
	5-Year	340	350	MD291-MD328	–	–	340	Non-imp't	10.5	–	–	–	–	–	–	–	–	–	–
	5-Year	300	250	MD329-MD356	–	–	300	20	9.5	–	–	–	–	–	–	–	–	–	–
	El Mabtouh RB	300	250	MD357-MD410	–	–	300	20	18.9	–	–	–	–	–	–	–	–	–	–
	5-Year	290	200	MD411-MD433	–	–	200	–	7.1	–	–	–	–	–	–	–	–	–	–
	5-Year	440	200	MD434-MD477	–	–	200	–	5.2	–	–	–	–	–	–	–	–	–	–
	10-Year	490	800	MD253-MD281	–	–	490	Non-imp't	9.6	–	–	–	–	–	–	–	–	–	–
	El Battane	490	700	MD282-MD290	–	–	490	Non-imp't	2.2	–	–	–	–	–	–	–	–	–	–
	10-Year	490	350	MD291-MD328	–	–	490	20	10.5	–	–	–	–	–	–	–	–	–	–
	10-Year	470	250	MD329-MD356	–	–	470	25	9.5	○	○	○	○	–	–	–	–	–	–
	El Mabtouh RB	470	250	MD357-MD410	170	86	300	25	18.9	○	○	○	○	–	–	–	–	–	–
	10-Year	460	200	MD411-MD433	–	–	200	–	7.1	–	–	–	–	–	–	–	–	–	–
	10-Year	650	200	MD434-MD477	–	–	200	–	5.2	–	–	–	–	–	–	–	–	–	–
	20-Year	820	800	MD253-MD281	–	–	820	Non-imp't	9.6	–	–	–	–	–	–	–	–	–	–
	El Battane	820	700	MD282-MD290	–	–	490	20	2.2	–	–	–	–	330	20	–	–	–	–
	20-Year	820	350	MD291-MD328	–	–	820	25	10.5	○	○	○	○	–	–	–	–	–	–
	20-Year	800	250	MD329-MD356	–	–	800	30	9.5	○	○	○	○	–	–	–	–	–	–
	El Mabtouh RB	800	250	MD357-MD410	250	86	550	30	18.9	○	○	○	○	–	–	–	–	–	–
	20-Year	780	200	MD411-MD433	–	–	200	–	7.1	–	–	–	–	–	–	–	–	–	–
	20-Year	930	200	MD434-MD477	–	–	200	–	5.2	–	–	–	–	–	–	–	–	–	–
	50-Year	2,190	800	MD253-MD281	–	–	2,190	20	9.6	–	–	–	–	–	–	–	–	–	–
	El Battane	2,190	700	MD282-MD290	–	–	1,470	30	2.2	○	○	○	○	720	50	–	–	–	–
	50-Year	2,190	350	MD291-MD328	–	–	2,190	35	10.5	○	○	○	○	–	–	–	–	–	–
	50-Year	2,160	250	MD329-MD356	–	–	2,160	35	9.5	○	○	○	○	–	–	–	–	–	–
	El Mabtouh RB	2,160	250	MD357-MD410	580	86	1,580	35	18.9	○	○	○	○	–	–	–	–	–	–
	50-Year	2,070	200	MD411-MD433	–	–	200	–	7.1	–	–	–	–	–	–	–	–	–	–
	50-Year	2,250	200	MD434-MD477	–	–	200	–	5.2	–	–	–	–	–	–	–	–	–	–

Source: The Study Team

Costruction Cost

Unit:TND mil.

Return period	River Cross Section No.	Flood Retarding Basin	River Channel Excavation	Embankment	Bypass Channel		Revetment	Total	Economic Cost (0.82*0.88)
					Excavation	Embankment			
5-Year	MD1-MD-64	—	6.00	—	—	—	—	6.00	
5-Year	MD65-MD116	—	4.00	—	—	—	—	4.00	
Mejez El Bab B	MD117-MD132	—	2.57	—	—	—	—	2.57	
5-Year	MD133-MD194	—	12.70	—	—	—	—	12.70	
5-Year	MD195-MD252	—	13.80	—	—	—	—	13.80	
								39.07	**28.19**
10-Year	MD1-MD-64	—	10.30	0.48	—	—	—	10.78	
10-Year	MD65-MD116	—	7.20	0.18	—	—	—	7.38	
Mejez El Bab B	MD117-MD132	—	2.57	0.12	11.50	—	—	14.19	
10-Year	MD133-MD194	—	14.00	1.12	—	—	—	15.12	
10-Year	MD195-MD252	—	14.50	0.20	—	—	—	14.70	
								62.17	**44.86**
20-Year	MD1-MD-64	—	12.20	—	—	—	—	12.20	
20-Year	MD65-MD116	—	12.00	—	—	—	—	12.00	
Mejez El Bab B	MD117-MD132	—	2.60	—	17.02	—	—	19.62	
20-Year	MD133-MD194	—	19.10	—	—	—	—	19.10	
20-Year	MD195-MD252	—	19.40	—	—	—	—	19.40	
								82.32	**59.40**
50-Year	MD1-MD-64	—	15.00	—	—	—	—	15.00	
50-Year	MD65-MD116	—	14.70	—	—	—	—	14.70	
Mejez El Bab B	MD117-MD132	—	2.57	2.40	19.20	—	—	24.17	
50-Year	MD133-MD194	—	26.00	—	—	—	—	26.00	
50-Year	MD195-MD252	—	26.50	—	—	—	—	26.50	
								106.37	**76.76**
5-Year	MD253-MD281	–	–	–	–	–	–	0.00	
El Battane B	MD282-MD290	–	–	–	–	–	0.50	0.50	
5-Year	MD291-MD328	–	–	–	–	–	4.00	4.00	
5-Year	MD329-MD356	–	12.60	–	–	–	–	12.60	
El Mabtouh RB	MD357-MD410	–	6.00	–	–	–	–	6.00	
5-Year	MD411-MD433	–	–	–	–	–	–	0.00	
5-Year	MD434-MD477	–	–	–	–	–	–	0.00	
								23.10	**16.67**
10-Year	MD253-MD281	–	–	–	–	–	–	0.00	
El Battane	MD282-MD290	–	–	–	–	–	0.50	0.50	
10-Year	MD291-MD328	–	6.30	–	–	–	4.70	11.00	
10-Year	MD329-MD356	–	13.80	1.10	–	–	–	14.90	
El Mabtouh RB	MD357-MD410	12.90	7.00	1.42	–	–	–	21.32	
10-Year	MD411-MD433	–	–	–	–	–	–	0.00	
10-Year	MD434-MD477	–	–	–	–	–	–	0.00	
								47.72	**34.43**
20-Year	MD253-MD281	–	–	–	–	–	–	0.00	
El Battane	MD282-MD290	–	1.70	–	8.40	–	0.60	10.70	
20-Year	MD291-MD328	–	7.20	–	–	–	5.30	12.50	
20-Year	MD329-MD356	–	15.40	0.51	–	–	–	15.91	
El Mabtouh RB	MD357-MD410	16.30	8.30	5.51	–	–	–	30.11	
20-Year	MD411-MD433	–	–	–	–	–	–	0.00	
20-Year	MD434-MD477	–	–	–	–	–	–	0.00	
								69.22	**49.95**
50-Year	MD253-MD281	–	2.00	–	–	–	–	2.00	
El Battane	MD282-MD290	–	2.40	0.24	11.40	–	1.00	15.04	
50-Year	MD291-MD328	–	8.80	2.80	–	–	6.10	17.70	
50-Year	MD329-MD356	–	17.80	1.13	–	–	–	18.93	
El Mabtouh RB	MD357-MD410	35.90	9.80	9.47	–	–	–	55.17	
50-Year	MD411-MD433	–	–	–	–	–	–	0.00	
50-Year	MD434-MD477	–	–	–	–	–	–	0.00	
								108.84	**78.54**

Table D4.5.1 Population and Number of Household by Delegation

Gouvernorats	Delegation	Population Male	Population Female	Population Total	Household	Population per Household	
Ariana	L'Ariana Ville	49,101	48,586	97,687	27,468	3.556	
Ariana	Soukra	46,081	43,070	89,151	21,590	4.129	
Ariana	Raoued	31,453	29,443	60,896	14,276	4.266	
Ariana	Kalaât El Andalou	11,976	11,069	23,045	4,709	4.894	
Ariana	Sidi Thabet	9,900	9,504	19,404	4,215	4.604	
Ariana	Cité Ettadhamen	40,245	38,066	78,311	17,119	4.575	
Ariana	El Mnihla	27,937	25,815	53,752	11,950	4.498	4.4
Mannouba	Mannouba	26,038	25,360	51,398	12,230	4.203	
Mannouba	Douar Hicher	39,590	36,369	75,959	15,652	4.853	
Mannouba	Oued Ellil	29,332	29,212	58,544	12,325	4.750	
Mannouba	Mornaguia	17,946	17,183	35,129	7,225	4.862	
Mannouba	Borj Amri	8,158	8,026	16,184	3,275	4.942	
Mannouba	Djedeida	20,611	19,716	40,327	8,334	4.839	
Mannouba	Tebourba	20,621	20,429	41,050	8,203	5.004	
Mannouba	El Battane	8,737	8,584	17,321	3,506	4.940	4.8
Bizerte	Bizerte Nord	38,247	36,987	75,234	19,240	3.910	
Bizerte	Zarzouna	12,424	12,004	24,428	6,563	3.722	
Bizerte	Bizerte Sud	23,093	22,134	45,227	9,837	4.598	
Bizerte	Sedjnane	21,184	20,972	42,156	8,954	4.708	
Bizerte	Djoumine	17,787	17,426	35,213	6,755	5.213	
Bizerte	Mateur	23,826	23,736	47,562	10,655	4.464	4.4
Béja	Béja Nord	33,949	33,522	67,471	15,867	4.252	
Béja	Béja Sud	19,151	19,245	38,396	8,890	4.319	
Béja	Amdoun	11,221	11,263	22,484	4,765	4.719	
Béja	Nefza	25,795	27,400	53,195	12,045	4.416	
Béja	Teboursouk	12,559	11,768	24,327	5,317	4.575	
Béja	Tibar	5,202	5,307	10,509	2,560	4.105	
Béja	Testour	16,470	16,302	32,772	7,340	4.465	
Béja	Goubellat	8,407	7,976	16,383	3,086	5.309	
Béja	Medjez El Bab	19,891	19,073	38,964	8,714	4.471	4.5
Jendouba	Jendouba	34,395	34,202	68,597	15,189	4.516	
Jendouba	Jendouba Nord	21,542	22,653	44,195	9,516	4.644	
Jendouba	Bou Salem	17,587	18,474	36,061	8,330	4.329	
Jendouba	Tabarka	22,696	22,798	45,494	10,497	4.334	
Jendouba	Ain Draham	19,974	20,398	40,372	9,228	4.375	
Jendouba	Fernana	25,819	26,871	52,690	11,595	4.544	
Jendouba	Ghardimaou	32,771	35,184	67,955	14,336	4.740	
Jendouba	Oued Meliz	8,949	10,066	19,015	4,361	4.360	
Jendouba	Balta - Bou Aouar	20,168	22,061	42,229	9,825	4.298	4.5
Le Kef	Kef Ouest	15,095	14,856	29,951	7,107	4.214	
Le Kef	Kef Est	20,198	20,258	40,456	10,028	4.034	
Le Kef	Nebeur	13,792	14,536	28,328	6,255	4.529	
Le Kef	Sakiet Sidi Yousse	10,169	10,358	20,527	4,645	4.419	
Le Kef	Tajerouine	14,893	15,766	30,659	7,155	4.285	
Le Kef	Kalâat Snan	8,014	8,440	16,454	3,828	4.298	
Le Kef	Kalâat Khasbah	3,535	3,818	7,353	1,744	4.216	
Le Kef	Djerissa	5,507	5,791	11,298	2,787	4.054	
Le Kef	El Ksour	8,606	8,494	17,100	3,451	4.955	
Le Kef	Dahmani	15,340	15,409	30,749	6,609	4.653	
Le Kef	Es-Sers	12,618	13,297	25,915	5,498	4.714	4.4
						Average	4.5

Table D4.5.2 Value of Household Effects

Household Effects

(per Household)

	Per Capita GDP (US$)*1	I/H Effects (2004 1000 Yen*2	2004 US$	2004 Dinar	2007 Dinar
JAPAN	**34,023**	**14,927**	122,827		
TUNISIA	**3,313**	1,454	11,960	16,449	18,035

Exchange Rate Used (20 121.529 JPY/US$ 1.3753 TND/US$

Source *1: Per Capita GDP= Data refer to the year 2007. World Economic Outlook Database-October 2007, International Monetary Fund

*2: "Manual on Economic Survey for Flood Control Project (Draft)", MILT, Japan, April 2005

Note: The value of household effects per household is assumed proportionate to the per capita GDP.

Consumer Price Index

2004	112.0	
2005	113.6	
2006	119.5	
2007	122.8	1.0964

Source : Institut National de la Statistique (INS)

Table D4.5.3 Value of Depreciable Assets and Inventory Stock per Labor by Industrial Sector

	Industry	JAPAN*1 2004 (Yen 1,000/person) Depreciable Assets	Inventory Stock	TUNISIA 2007 (TND/person) Depreciable Assets	Inventory Stock
1	Mines	9,248	2,415	11,174	2,918
2	Construction	1,390	4,169	1,679	5,037
3	Manufacturing	4,350	5,071	5,256	6,127
4	Gas, Petrolium, & Water/Electricity Suppl	125,211	2,314	151,283	2,796
5	Transport and Communication	7,627	658	9,215	795
6	Commerce	2,176	2,727	2,629	3,295
7	Real Estate	3,667	465	4,431	562
8	Real Estate	19,893	12,093	24,035	14,611
9	Service	3,667	465	4,431	562
10	Public	3,667	465	4,431	562

Source *1: "Manual on Economic Survey for Flood Control Project (Draft)", MILT, Japan, April 2005

Note: The value of depreciable assets and inventory stock per labor per is assumed proportionate to the per capita GDP.

Table D4.5.4 Number of Labors by Industrial Sector and by Governorate

	1	2	3	4	5	6	7	8	9	10
Governorate	Mines	Construction	Manufacturing	Gas, Petrolium, & Water/Electricity Supply	Transport and Communication	Commerce	Banking and Finance	Real Estate	Service	Public
Ariana	67	963	25,847	1,668	10,468	17,129	4,306	0	14,561	40,308
Manouba	28	760	20,270	1,138	6,043	9,504	1,048	0	7,079	26,885
Bizerte	21	1,821	39,272	1,518	6,990	11,592	684	0	6,894	33,251
Béja	45	414	7,477	585	3,526	7,925	286	0	3,974	19,980
Jendouba	14	497	5,969	699	4,375	8,831	355	0	5,926	23,466
Le Kef	577	1,029	4,155	408	3,187	5,596	143	0	2,875	19,807
Total	752	5,484	1,035,974	50,770	34,589	60,577	6,822	0	441,046	1,355,693

Source: Enumerated by JICA Study Team to convert to the same categories in Japanese Manual based on the National Census in 2004

Table D4.5.5 Total Value by Governorate

Governorate	Depreciable Assets (TND)	Inventory Stock (TND)
Ariana	794,226,399	266,076,485
Manouba	516,079,445	187,072,429
Bizerte	715,129,322	320,782,565
Béja	289,720,353	92,196,247
Jendouba	333,438,513	90,357,271
Le Kef	236,944,590	67,259,822
Total	2,885,538,621	1,023,744,819

Source: Enumerated based on Tables 4.4.3 and 4.4.4

Table D4.5.6 Damage Rate for Estimate of Damage to Depreciable Assets and Inventory Stock

Item	Inundation Depth < 0.5 m	0.5-0.99 m	1.0-1.99 m	2.0-2.99 m	3 m <
(a) Depreciable Assets	0.232	0.453	0.789	0.966	0.995
(b) Inventory Stock	0.128	0.267	0.586	0.897	0.982

Source Manual on Economic Survey for Flood Control Project (Draft), MILT, Japan, April 2005

Table D4.5.7 Background Information of Flood Damage to Infrastructure

1. Governorate: Jendouba

1.1 Damage due to flood on May 26 and 27, 2000

Type of Facilities to be repaired	Estimated Cost for Repair (TND)
Pumping station (Sidi Ismail)	11,000
Agricutural trails	100,000
Irrigation Network	6,000
Drainage network	50,000
Other Equipment	5,000
Total	**172,000**

Source: CRDA Jendouba

1.2 Damage due to flood in January to February 2003

Type of Facilities to be repaired	Estimated Cost for Repair (TND)
Irrigation pumps	60,000
Irrigation netwrok	80,000
Rural roads	300,000
Drainage network	600,000
Drinking water supply network	586,000
Soil and water conservation	525,000
Hill dams	145,000
Ground water reacharge	55,000
Forest roads	480,000
Total	**2,831,000**

Source: CRDA Jendouba (Collected through "Flood Inundation and Damage Survey")

2. Governorate : Manouba

2.1 Damage due to flood during December 14, 15 and 16, 2003 and January 4 until 14, 2004

Damaged Area	Damaged Facilities	Contents of Damage	Quantities	Cost for restoration (TND1,000)
Bourj Ettoumi	Pumping Station	Erosion of Mejerda River bank at entrance of the station	50 m	50,000
Road from El Henna to Ezzouwaya	El Chaouat drainage canal	Damage to earth dike of the canal	50 m	10,000
Entraqnce of Jedeida	Chafrou and Mejerda Rivers	Erosion of the earth dike	2,500 m on both sides	50,000
Jedeida	Irrigation canals	Destruction of canals	3 km	15,000
Jedeida	Agricultural trails	Holes and accumuration of debis and sediment	5 km	35,000
Jedeida	Drainage canals	Deposit of sediment	15 km	45,000
Jedeida	Repair of equipment	-	3 pumps, 1 truck, 1 dredger machine, 1 tractor, 1 generating set	25,000
Total				**230,000**

Source: CDRD Manouba

Inudation area : Total 2,227 ha **TND 103/ha**

3. Governorate: Ariana

3.1 Damage due to flood occurred in January 2003

Type of Facilities to be repaired	Damaged Length (km)	Estimated Cost for Repair (TND)
Rural roads	40.0	60,000
Drainage canal	60.0	80,000
Irrigation network	16.5	300,000
Pumping station	-	600,000
Small dams	-	586,000
Total		**1,626,000**

Source: CRDA Ariana (Collected through "Flood Inundation and Damage Survey")

Inundation area: Total 4,000 ha (estimated by Study Team) **TND 407/ha** **→ TND400/ha**

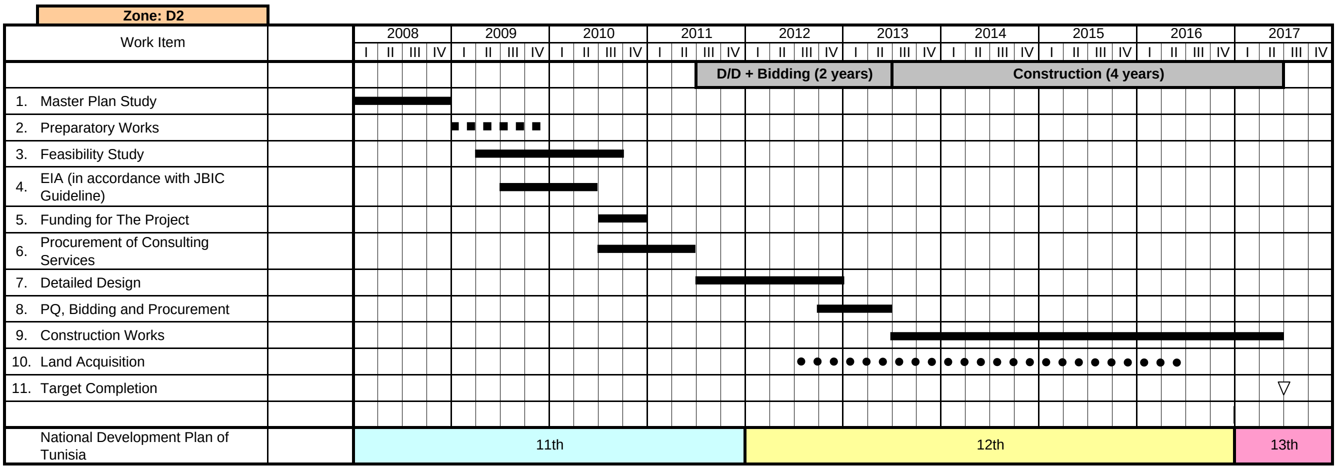
(in Governorate Ariana) (To be applied)

3.2 Damage due to flood occurred in September to December 2003

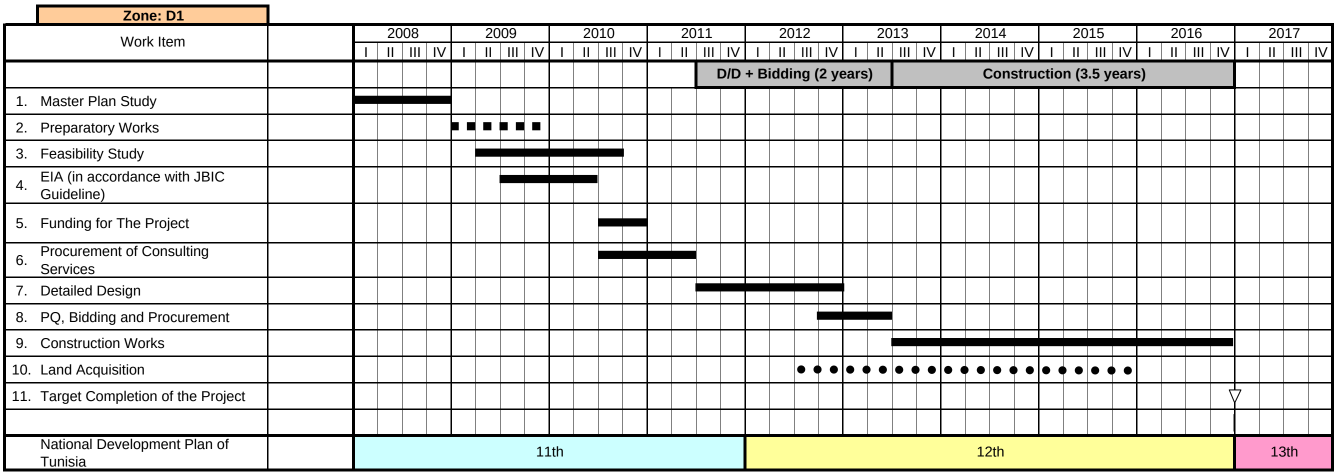
Type of Facilities to be repaired	Damaged Length (km)	Estimated Cost for Repair (TND)
Rural roads	41.0	352,000
Drainage canal	72.0	148,000
Tributary improvement	16.5	420,000
Hill dams	-	445,000
River dredging	-	30,000
Forest roads	-	35,000
Reforestation	-	50,000
Urban forestation and green zone cleaning	-	315,000
Total		**1,795,000**

Source: CRDA Ariana (Collected through "Flood Inundation and Damage Survey")

Table D5.3.1 Implementation Schedule of Mejerda River Flood Management Project (Zones D2 and D1)



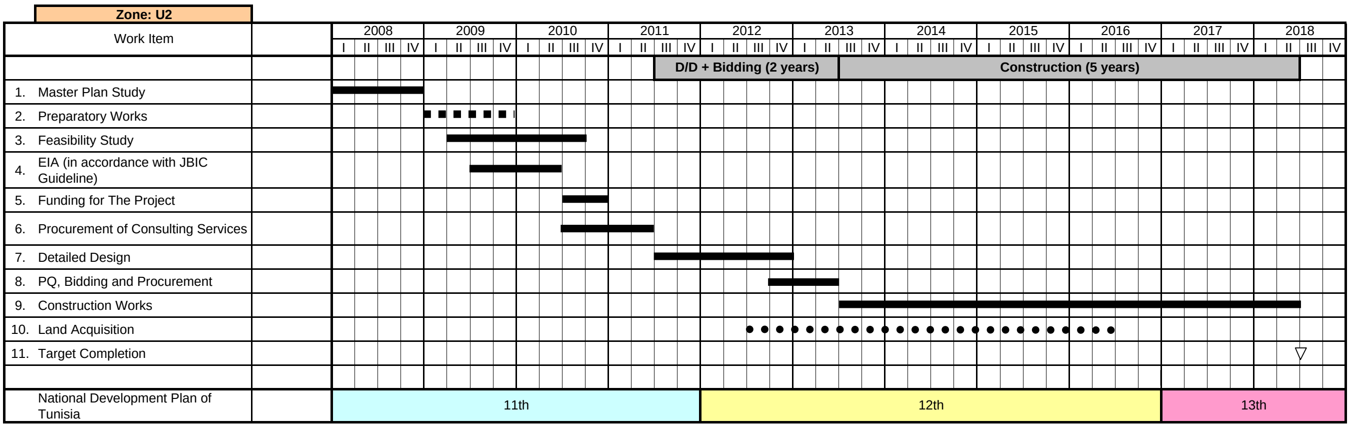
	Annual disbursement rate	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
(1)	Direct construction cost	-	-	-	-	-	10%	25%	30%	25%	10%	100%
(2)	Land acquisition	-	-	-	-	20%	30%	30%	20%	-	-	100%
(3)	Administration cost	-	-	-	5%	10%	15%	20%	20%	20%	10%	100%
(4)	Engineering services	-	-	-	15%	25%	10%	15%	15%	15%	5%	100%
(6)	Physical contingency	-	-	-	10%	10%	10%	20%	20%	20%	10%	100%



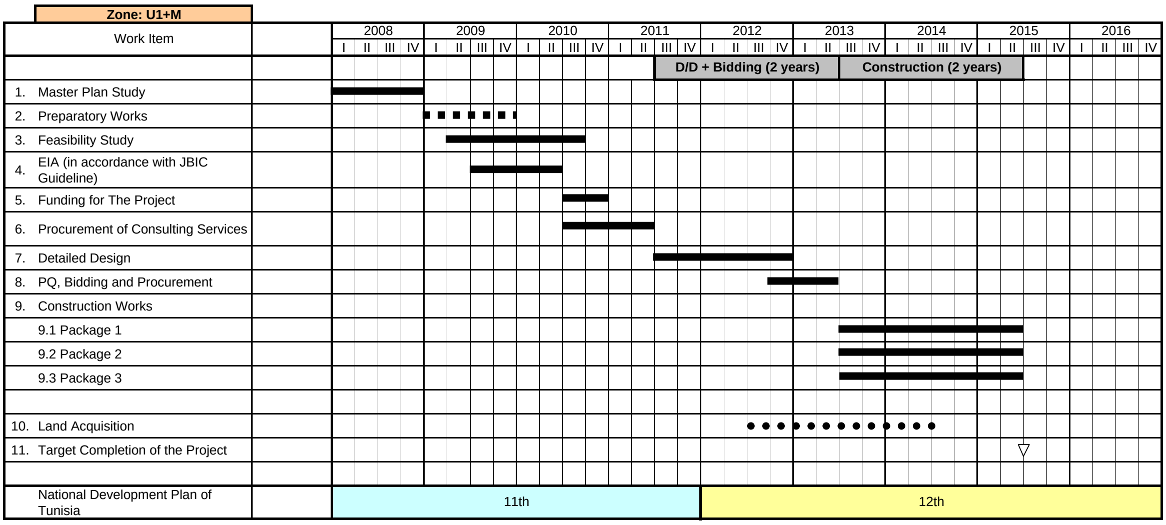
	Annual disbursement rate	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
(1)	Direct construction cost	-	-	-	-	-	15%	30%	30%	25%	-	100%
(2)	Land acquisition	-	-	-	-	20%	30%	30%	20%	-	-	100%
(3)	Administration cost	-	-	-	10%	15%	20%	20%	20%	15%	-	100%
(4)	Engineering services	-	-	-	15%	25%	10%	20%	15%	15%	-	100%
(6)	Physical contingency	-	-	-	10%	15%	20%	20%	20%	15%	-	100%

Source: JICA Study Team

Table D5.3.2 Implementation Schedule of Mejerda River Flood Management Project (Zones U2 and U1+M)



Annual disbursement rate		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
(1)	Direct construction cost	-	-	-	-	-	10%	20%	20%	20%	20%	10%	100%
(2)	Land acquisition	-	-	-	-	20%	30%	30%	20%	-	-	-	100%
(3)	Administration cost	-	-	-	10%	10%	10%	15%	15%	15%	15%	10%	100%
(4)	Engineering services	-	-	-	15%	20%	10%	10%	10%	15%	15%	5%	100%
(6)	Physical contingency	-	-	-	5%	10%	15%	15%	15%	15%	15%	10%	100%



Annual disbursement rate		2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
(1)	Direct construction cost	-	-	-	-	-	30%	50%	20%	-	100%
(2)	Land acquisition	-	-	-	-	20%	40%	40%	-	-	100%
(3)	Administration cost	-	-	-	20%	20%	25%	25%	10%	-	100%
(4)	Engineering services	-	-	-	25%	30%	15%	20%	10%	-	100%
(6)	Physical contingency	-	-	-	20%	20%	25%	25%	10%	-	100%

Source: JICA Study Team

Table D5.3.3 Project Cost for Zone D2 (Financial Cost)

D2

Unit:TND1,000

Description	FC TND	LC TND	Total Cost TND equiv.	Total Cost US$ equiv.	Total Cost Yen 10^3 equiv.	2011 FC	2011 LC	2012 FC	2012 LC	2013 FC	2013 LC	2014 FC	2014 LC	2015 FC	2015 LC	2016 FC	2016 LC	2017 FC	2017 LC
(1) Construction cost (Base cost)	27,428,000	41,142,000	68,570,000	58,557,000	6,253,000	0	0	0	0	2,743	4,114	6,857	10,286	8,228	12,343	6,857	10,286	2,743	4,114
1.1 River Improvement	27,428,000	41,142,000	68,570,000	58,557,000	6,253,000	0	0	0	0	2,743	4,114	6,857	10,286	8,228	12,343	6,857	10,286	2,743	4,114
1.2 FFWS																			
(2) Land Acquisition	0	9,265,000	9,265,000	7,912,000	845,000	0	0	0	1,853	0	2,780	0	2,780	0	1,853	0	0	0	0
(3) Government Administration	0	2,335,000	2,335,000	1,994,000	213,000	0	117	0	234	0	350	0	467	0	467	0	467	0	234
3% of (1) + (2)																			
(4) Engineering Services	2,743,000	4,114,000	6,857,000	5,856,000	625,000	411	617	686	1,029	274	411	411	617	411	617	411	617	137	206
10% of (1)																			
(5) Subtotal (1)+(2)+(3)+(4)	30,171,000	56,856,000	87,027,000	74,319,000	7,936,000	411	734	686	3,115	3,017	7,655	7,268	14,149	8,640	15,280	7,268	11,370	2,880	4,553
(6) Physical Contingency	3,017,000	5,686,000	8,703,000	7,432,000	794,000	41	73	69	312	302	766	727	1,415	864	1,528	727	1,137	288	455
10% of (5)																			
(7) Sub-Total (5)+(6)	33,188,000	62,542,000	95,730,000	81,751,000	8,730,000	453	807	754	3,427	3,319	8,421	7,995	15,564	9,504	16,808	7,995	12,507	3,168	5,009
(8) Price Contingency	5,106,000	14,586,000	19,692,000	16,816,000	1,796,000	29	80	65	460	363	1,436	1,062	3,238	1,488	4,146	1,446	3,584	652	1,642
FC:2.1% and LC:3.2% of (7)						(.064)	(.099)	(.087)	(.134)	(.11)	(.171)	(.133)	(.208)	(.157)	(.247)	(.181)	(.287)	(.206)	(.328)
(9) Sub total (7)+(8)	38,294,000	77,128,000	115,422,000	98,567,000	10,526,000	482	887	820	3,887	3,682	9,857	9,057	18,802	10,992	20,954	9,441	16,091	3,820	6,650
(10) Taxes	0	18,152,000	18,152,000	15,501,000	1,655,000	0	138	0	243	0	1,723	0	4,299	0	5,283	0	4,579	0	1,887
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	16,937,000	16,937,000	14,464,000	1,545,000	0	0	0	0	0	1,589	0	4,100	0	5,078	0	4,367	0	1,803
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	1,215,000	1,215,000	1,038,000	111,000	0	138	0	243	0	133	0	199	0	205	0	212	0	84
R: Rate of price contingency																			
Grand Total	**38,294,000**	**95,280,000**	**133,574,000**	**114,068,000**	**12,181,000**	**482**	**1,026**	**820**	**4,130**	**3,682**	**11,580**	**9,057**	**23,101**	**10,992**	**26,237**	**9,441**	**20,669**	**3,820**	**8,537**

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 40 : 60
(c) Base year for counting of price contingency is June 2008.

Source: The Study Team

		2011		2012		2013		2014		2015		2016		2017	
		3	3	4	4	5	5	6	6	7	7	8	8	9	9
		FC	LC												
		2.1%	3.2%												
Civil work	(1)	0%	0%	0%	0%	10%	10%	25%	25%	30%	30%	25%	25%	10%	10%
Land acqui	(2)	0%	0%	0%	20%	0%	30%	0%	30%	0%	20%	0%	0%	0%	0%
Admi cost	(3)	0%	5%	0%	10%	0%	15%	0%	20%	0%	20%	0%	20%	0%	10%
Consul service	(4)	15%	15%	25%	25%	10%	10%	15%	15%	15%	15%	15%	15%	5%	5%
Physical Conti	(6)	10%	10%	10%	10%	10%	10%	20%	20%	20%	20%	20%	20%	10%	10%

Table D5.3.4 Project Cost for Zone D1 (Financial Cost)

D1

Unit:TND1,000

Description	FC TND	LC TND	Total Cost TND equiv.	Total Cost US$ equiv.	Total Cost Yen 10^3 equiv.	2011 FC	2011 LC	2012 FC	2012 LC	2013 FC	2013 LC	2014 FC	2014 LC	2015 FC	2015 LC	2016 FC	2016 LC
(1) Construction cost (Base cost)	29,682,000	36,278,000	65,960,000	56,328,000	6,015,000	0	0	0	0	4,452	5,442	8,905	10,883	8,905	10,883	7,421	9,070
1.1 River Improvement	29,682,000	36,278,000	65,960,000	56,328,000	6,015,000	0	0	0	0	4452	5442	8905	10883	8905	10883	7421	9070
1.2 FFWS																	
(2) Land Acquisition	0	6,657,000	6,657,000	5,685,000	607,000	0	0	0	1,331	0	1,997	0	1,997	0	1,331	0	0
(3) Government Administration 3% of (1) + (2)	0	2,179,000	2,179,000	1,861,000	199,000	0	218	0	327	0	436	0	436	0	436	0	327
(4) Engineering Services 10% of (1)	2,968,000	3,628,000	6,596,000	5,633,000	602,000	445	544	742	907	297	363	594	726	445	544	445	544
(5) Subtotal (1)+(2)+(3)+(4)	32,650,000	48,742,000	81,392,000	69,507,000	7,423,000	445	762	742	2,565	4,749	8,237	9,498	14,042	9,350	13,195	7,866	9,941
(6) Physical Contingency 10% of (5)	3,265,000	4,874,000	8,139,000	6,950,000	742,000	45	76	74	257	475	824	950	1,404	935	1,319	787	994
(7) Sub-Total (5)+(6)	35,915,000	53,616,000	89,531,000	76,457,000	8,165,000	490	838	816	2,822	5,224	9,061	10,448	15,446	10,285	14,514	8,652	10,935
(8) Price Contingency FC:2.1% and LC:3.2% of (7)	5,237,000	11,935,000	17,172,000	14,664,000	1,566,000	32 (.064)	83 (.099)	71 (.087)	379 (.134)	572 (.11)	1,546 (.171)	1,388 (.133)	3,213 (.208)	1,611 (.157)	3,581 (.247)	1,565 (.181)	3,134 (.287)
(9) Sub total (7)+(8)	41,152,000	65,551,000	106,703,000	91,121,000	9,731,000	521	921	887	3,201	5,796	10,607	11,836	18,659	11,895	18,095	10,217	14,068
(10) Taxes	0	17,260,000	17,260,000	14,740,000	1,574,000	0	146	0	247	0	2,434	0	4,966	0	5,080	0	4,387
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	16,112,000	16,112,000	13,759,000	1,469,000	0	0	0	0	0	2,293	0	4,733	0	4,885	0	4,201
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	1,148,000	1,148,000	980,000	105,000	0	146	0	247	0	141	0	233	0	195	0	186
R: Rate of price contingency																	
Grand Total (9) + (10)	**41,152,000**	**82,811,000**	**123,963,000**	**105,861,000**	**11,305,000**	**521**	**1,067**	**887**	**3,447**	**5,796**	**13,041**	**11,836**	**23,626**	**11,895**	**23,175**	**10,217**	**18,455**

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 45 : 55
(c) Base year for counting of price contingency is June 2008.

		2011		2012		2013		2014		2015		2016	
		3	3	4	4	5	5	6	6	7	7	8	8
		FC	LC										
		2.1%	3.2%										
Civil work	(1)	0%	0%	0%	0%	15%	15%	30%	30%	30%	30%	25%	25%
Land acqui	(2)	0%	0%	0%	20%	0%	30%	0%	30%	0%	20%	0%	0%
Admi cost	(3)	0%	10%	0%	15%	0%	20%	0%	20%	0%	20%	0%	15%
Consul service	(4)	15%	15%	25%	25%	10%	10%	20%	20%	15%	15%	15%	15%
Physical Conti	(6)	10%	10%	15%	15%	20%	20%	20%	20%	20%	20%	15%	15%

Table D5.3.5 Project Cost of Zone U2 (Financial Cost)

U2

Unit:TND1,000

Description	FC	LC	Total Cost			2011		2012		2013		2014		2015		2016		2017		2018	
	TND	TND	TND equiv.	US$ equiv.	Yen 10^3 equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	35,607,000	43,520,000	79,127,000	67,572,000	7,216,000	0	0	0	0	3,561	4,352	7,121	8,704	7,121	8,704	7,121	8,704	7,121	8,704	3,561	4,352
1.1 River Improvement	35,607,000	43,520,000	79,127,000	67,572,000	7,216,000	0	0	0	0	3,561	4,352	7,121	8,704	7,121	8,704	7,121	8,704	7,121	8,704	3,561	4,352
1.2 FFWS																					
(2) Land Acquisition	0	12,724,000	12,724,000	10,866,000	1,160,000	0	0	0	2,545	0	3,817	0	3,817	0	2,545	0	0	0	0	0	0
(3) Government Administration 3% of (1) + (2)	0	2,756,000	2,756,000	2,354,000	251,000	0	276	0	276	0	276	0	413	0	413	0	413	0	413	0	276
(4) Engineering Services 10% of (1)	3,561,000	4,352,000	7,913,000	6,757,000	722,000	534	653	712	870	356	435	356	435	356	435	534	653	534	653	178	218
(5) Subtotal (1)+(2)+(3)+(4)	39,168,000	63,352,000	102,520,000	87,549,000	9,349,000	534	928	712	3,691	3,917	8,880	7,478	13,370	7,478	12,097	7,656	9,770	7,656	9,770	3,739	4,845
(6) Physical Contingency 10% of (5)	3,917,000	6,335,000	10,252,000	8,755,000	935,000	53	93	71	369	392	888	748	1,337	748	1,210	766	977	766	977	374	485
(7) Sub-Total (5)+(6)	43,085,000	69,687,000	112,772,000	96,304,000	10,284,000	588	1,021	783	4,060	4,308	9,768	8,225	14,707	8,225	13,307	8,421	10,747	8,421	10,747	4,113	5,330
(8) Price Contingency	7,163,000	17,230,000	24,393,000	20,831,000	2,225,000	38	101	68	545	472	1,666	1,092	3,059	1,288	3,283	1,523	3,080	1,732	3,522	950	1,973
FC:2.1% and LC:3.2% of (7)						(.064)	(.099)	(.087)	(.134)	(.11)	(.171)	(.133)	(.208)	(.157)	(.247)	(.181)	(.287)	(.206)	(.328)	(.231)	(.37)
(9) Sub total (7)+(8)	50,248,000	86,917,000	137,165,000	117,135,000	12,509,000	625	1,122	851	4,605	4,780	11,434	9,318	17,766	9,513	16,590	9,944	13,827	10,153	14,270	5,063	7,303
(10) Taxes	0	21,297,000	21,297,000	18,187,000	1,942,000	0	177	0	232	0	1,971	0	3,945	0	4,072	0	4,258	0	4,394	0	2,248
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	19,864,000	19,864,000	16,963,000	1,811,000	0	0	0	0	0	1,834	0	3,785	0	3,906	0	4,031	0	4,160	0	2,147
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	1,433,000	1,433,000	1,224,000	131,000	0	177	0	232	0	137	0	160	0	165	0	226	0	234	0	101
R: Rate of price contingency																					
Grand Total (9) + (10)	**50,248,000**	**108,214,000**	**158,462,000**	**135,322,000**	**14,451,000**	**625**	**1,299**	**851**	**4,837**	**4,780**	**13,405**	**9,318**	**21,712**	**9,513**	**20,661**	**9,944**	**18,085**	**10,153**	**18,664**	**5,063**	**9,551**

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 45 : 55
(c) Base year for counting of price contingency is June 2008.

		2011		2012		2013		2014		2015		2016		2017		2018	
		3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10
		FC	LC														
		2.1%	3.2%														
Civil work	(1)	0%	0%	0%	0%	10%	10%	20%	20%	20%	20%	20%	20%	20%	20%	10%	10%
Land acqui	(2)	0%	0%	0%	20%	0%	30%	0%	30%	0%	20%	0%	0%	0%	0%	0%	0%
Admi cost	(3)	0%	10%	0%	10%	0%	10%	0%	15%	0%	15%	0%	15%	0%	15%	0%	10%
Consul service	(4)	15%	15%	20%	20%	10%	10%	10%	10%	10%	10%	15%	15%	15%	15%	5%	5%
Physical Conti	(6)	5%	5%	10%	10%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	10%	10%

Table D5.3.6 Project Cost for Zone U1 + M (Financial Cost)

Unit:TND1,000

Description	FC	LC	Total Cost			2011		2012		2013		2014		2015	
	TND	TND	TND equiv.	US$ equiv.	Yen 10^3 equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	10,510,000	10,510,000	21,020,000	17,950,000	1,917,000	0	0	0	0	3,153	3,153	5,255	5,255	2,102	2,102
1.1 River Improvement	10,510,000	10,510,000	21,020,000	17,950,000	1,917,000	0	0	0	0	3,153	3,153	5,255	5,255	2,102	2,102
1.2 FFWS															
(2) Land Acquisition	0	2,790,000	2,790,000	2,383,000	254,000	0	0	0	558	0	1,116	0	1,116	0	0
(3) Government Administration	0	714,000	714,000	610,000	65,000	0	143	0	143	0	179	0	179	0	71
3% of (1) + (2)															
(4) Engineering Services	1,051,000	1,051,000	2,102,000	1,795,000	192,000	263	263	315	315	158	158	210	210	105	105
10% of (1)															
(5) Subtotal (1)+(2)+(3)+(4)	11,561,000	15,065,000	26,626,000	22,738,000	2,428,000	263	406	315	1,016	3,311	4,605	5,465	6,760	2,207	2,279
(6) Physical Contingency	1,156,000	1,507,000	2,663,000	2,274,000	243,000	26	41	32	102	331	461	547	676	221	228
10% of (5)															
(7) Sub-Total (5)+(6)	12,717,000	16,572,000	29,289,000	25,012,000	2,671,000	289	446	347	1,118	3,642	5,066	6,012	7,436	2,428	2,506
(8) Price Contingency	1,626,000	3,223,000	4,849,000	4,141,000	442,000	19	44	30	150	399	864	798	1,547	380	618
FC:2.1% and LC:3.2% of (7)						(.064)	(.099)	(.087)	(.134)	(.11)	(.171)	(.133)	(.208)	(.157)	(.247)
(9) Sub total (7)+(8)	14,343,000	19,795,000	34,138,000	29,153,000	3,113,000	308	490	377	1,268	4,040	5,930	6,810	8,983	2,808	3,125
(10) Taxes	0	5,372,000	5,372,000	4,588,000	490,000	0	81	0	96	0	1,525	0	2,593	0	1,076
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	5,013,000	5,013,000	4,281,000	457,000	0	0	0	0	0	1,462	0	2,514	0	1,038
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	359,000	359,000	307,000	33,000	0	81	0	96	0	64	0	80	0	39
R: Rate of price contingency															
Grand Total (9) + (10)	**14,343,000**	**25,167,000**	**39,510,000**	**33,741,000**	**3,603,000**	**308**	**571**	**377**	**1,364**	**4,040**	**7,455**	**6,810**	**11,576**	**2,808**	**4,201**

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 50 : 50
(c) Base year for counting of price contingency is June 2008.

		2011		2012		2013		2014		2015	
		3	3	4	4	5	5	6	6	7	7
		FC	LC								
		2.1%	3.2%								
Civil work	(1)	0%	0%	0%	0%	30%	30%	50%	50%	20%	20%
Land acqui	(2)	0%	0%	0%	20%	0%	40%	0%	40%	0%	0%
Admi cost	(3)	0%	20%	0%	20%	0%	25%	0%	25%	0%	10%
Consul service	(4)	25%	25%	30%	30%	15%	15%	20%	20%	10%	10%
Physical Conti	(6)	20%	20%	20%	20%	25%	25%	25%	25%	10%	10%

Table D6.3.1 Allocation of Cost for Future Dam Construction Projects in Mejerda River Basin

Unit: TND mil.

	Description	Mellegue 2 Dam: Flood Control	Mellegue 2 Dam: Irrigation Water Supply	Mellegue 2 Dam: Hydroelectric Generation	Mellegue 2 Dam: Total	Tessa Dam: Flood Control	Tessa Dam: Irrigation Water Supply	Tessa Dam: Total
a	Substitute Dam Construction Cos	81.4	73.9	-	-	19.6	14.5	-
b	Valid investment cost	41.9	63.3	13.8	-	29.3	11.9	-
c	Smaller figure among a & b	41.9	63.3	13.8	-	19.6	11.9	-
d	Exclusive cost	0.0	0.0	5.0	-	0.0	0.0	-
e	c- d	41.9	63.3	8.8	114.0	19.6	11.9	31.5
f	Separated cost	41.1	54.4	4.3	99.8	11.5	7.0	18.5
g	Resudial benefit	0.8	8.9	4.5	14.2	8.1	4.9	13.0
h	Ratio of Item "g" (%)	6%	63%	32%	100%	62%	38%	100%
i	Allocated resudial cost	0.9	9.5	4.8	15.2	4.7	2.8	7.5
j	**Project cost to be shared**	**42.0**	**63.9**	**9.1**	**115.0**	**16.2**	**9.8**	**26.0**
k	Proportion of Project cost	36%	56%	8%	100%	62%	38%	100%
					115.0			26.0

Background information

	Mellegue 2 Dam	Tessa Dam
a. Substitute Dam Construction Cost		
(1) Flood control dam	・Required storage: 139 + 96 = 235 mil. m3 → 297 .0m ・Height:297.0 - 254.5 = 42.5m ・Sectional area of cross section of dam body Full scale dam : 1/2 x 50.5 x 50.5 = 1,275.1m2 (100%) (U/S 1:0.2, D/S 1:0.8) Substitute dam: 1/2 42.5 42.5 = 903.1 m2 (70.8%) ・Construction cost Full scale dam : TND115.0 mil Substitute dam: 115.0 x 0.708 = **TND 81.4 mil.**	・Required storage: 82 0 + 11.2 = 93.2 mil. → 366.0 m ・Height:: 366.0 - 330.0 = 36.0 m ・Sectional area of cross section of dam body Full scale dam: 1/2 x 41.5 x 41.5 x 0.85 = 732.0 m2 (100%) (U/S 1:0.0, D/S 1:0.85) Substitute dam: 1/2 x 36.0 x 36.0 x 0.85 = 550.8 (75.2 %) ・Construction cost Full scale dam: TND 26.0 mil. Substitute dam: 26.0 x 0.752 = **TND 19.6 mil.**
(2) Irrigation dam	・Required storage: 99 + 96 = 195 mil.m3 → 295.0 m ・Height: 295.0 - 254.5 = 40.5 m ・Sectional area of cross section of dam body Full scale dam : 1,275.1 m2 (100%) Substitute dam: 1/2 x 40.5 x 40.5 = 820.1 (64.3 %) ・Construction cost Substitute dam: 115.0 x 0.643 = **TND 73.9 mil.**	・Required storage: 31.8 + 11.2 = 43.0 mil.m3 → 361.0m ・Height: 361.0 - 330.0 = 31.0m ・Sectional area of cross section of dam body Full scale dam: 732.0 m2 (100%) Substitute dam: 1/2 x 31.0 x 31.0 x 0.85 = 408.4 (55.8 %) ・Construction cost Substitute dam: 26.0 x 0.558 = **TND 14.5 mil.**
b. Valid investment cost		
(1) Flood control dam	・Average annual benefit Flood control benefit in Zone M estimated by inundation analysis: TND4,829,000 (50-year return period, present value) shall be allocated to 3 dams, i.e. (a) Sarrath, (b) Mellegue 2 and (c) Mellegue as follows: Flood control storage / Proportion / Annual benefit (TND1,000) (a) 27.6 mil. m3 / 10.3 % / 497 (b) 139.0 / 51.5 / 2,487 (c) 103.1 / 38.2 / 1,845 Total 269.7 / 100.0 / 4,829 ・Annual cost Assumed 3 % of direct constructin cost (5 years for construction period)→ 115.0 x 0.03 x1/5 = TND0.69 mil. 0.69 x (61.5/115.0) x 1/2 = TND 0.18 mil. ・Valid investment cost (2.487 - 0.18)/ 0.05478* = **41.9 mil.** (Note:*, Capital Recovery Factor (interst 5.0%, period 50 years)	It is assumed to estimate based on the proportion of flood control storage volume with Mellegue 2 dam. ・49.7 x (82.0/139.0) = **TND 29.3 mil.**
(2) Irrigation dam	・Average annual benefit Value of agricultural products (in 2006) = TND 1,263/ha/ year (Average of 3 governorates, i.e. Jendouba, El Kef and Beja) Further assumed 30% under the 2006 price for long term average = TND 884/ha/year Irrigable area is assumed 70% of due to hydrological cycle and 20% of ratio of net annual benefit per farmer 884 x (29,451 ha x 0.7) x 0.2 = TND 3.645 mil/year ・Annual cost: TND 0.18 mil./year ・Valid investment cost: (3.645 - 0.18)/0.05478 = **TND 63.3 mil.**	It is assumed to estimate based on the proportion of irrigation water storage volume with Mellegue 2 dam. ・37.2 x (31.8/99.0) = **TND 11.9 mil.**
(3) Hydropower dam	・Average annual benefit (value for kW and kWh of alternative power plant with same output) 10,000 kW x TND 107.73x 1.2 + 16,000,000 kWh x TND0.0511 x1.2 = TND 1.58mil. ・Annual cost: TND 0.33 mil./year ・Valid investment cost (1.58 - 0.33)/(0.0838 x (1+0.4x0.07x3)) = **TND13.76 mil.**	
c. Separated cost		
(1) Flood control dam	・ Storage volume for other function: 334 - 139 = 195 mil.m3 ・ Construction cost : H=295 - 254.4 = 40.5 → TND 73.9 mil ・ Separated cost : 115.0 - 73.9 = **TND 41.1 mil.**	・ Storage volume for other function: 125.0 - 82.0 = 43.0 mil.m3 ・ Construction cost : H=361.0 - 330.0 = 31.0 m → TND 14.5 mil ・ Separated cost : 26.0 - 14.5 = **TND 11.5 mil.**
(2) Irrigation dam	・ Storage volume for other function: 334 - (99 + 96 x 0.9 (for sand pocket)) = 148.6 mil.m3 ・ Construction cost : H=290.8 - 254.4 = 36.3 m → TND 60.6 mil ・ Separated cost : 115.0 - 60.6 = **TND 54.4 mil.**	・ Storage volume for other function: 125.0 - (31.8 + 11.2 x 0.9 (for sand pocket)) = 84.2 mil.m3 ・ Construction cost : H= 365.1 - 330.1 = 35.1 m → TND 19.0 mil ・ Separated cost : 26.0 - 19.0 = **TND 7.0 mil.**
(3) Hydropower dam	Since Mellegue 2 dam has no exclusive storage for hydro power, defference between 6 hours for peak (max) and average is assumed as separated storage. ・Max discharge: 25.0 m3/s (at Mellegue dam) ・Average discharge: 8.0 m3/s (assumed one third of max value) ・Storage for hydro power: (25.0-8.0) x 6 hrs x 3,600 = 367,200 m3 ・Storage volume for other function: 334.0 - 0.37 = 333.63 mil.m3→ H=303.97 - 254.5 = 49.47 m → TND110.7 mil. ・Separatd cost: 115.0 - 110.7 = **TND 4.3 mil**	

Table D6.5.1 Project Cost of Zone U2 with Dam Construction (Financial Cost)

U2

Unit:TND1,000

Description	FC	LC	Total Cost			2008		2009		2010		2011		2012		2013		2014	
	TND	TND	TND equiv.	US$ equiv.	Yen 10^3 equiv.	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	16,500,000	16,500,000	33,000,000	28,181,000	3,009,000	0	0	0	0	0	0	0	0	1,680	1,680	2,520	2,520	2,520	2,520
(Mellegue 2)	8,400,000	8,400,000	16,800,000	14,347,000	1,532,000	0	0	0	0	0	0	0	0	1680	1680	2520	2520	2520	2520
(Tessa)	8,100,000	8,100,000	16,200,000	13,834,000	1,477,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2) Land Acquisition	0	17,660,000	17,660,000	15,081,000	1,611,000	0	0	0	0	0	822	0	1,096	0	822	0	0	0	0
(Mellegue 2)	0	2,740,000	2,740,000	2,340,000	250,000	0	0	0	0	0	822	0	1,096	0	822	0	0	0	0
(Tessa)	0	14,920,000	14,920,000	12,741,000	1,361,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(3) Government Administratior	0	1,520,000	1,520,000	1,298,000	138,000	0	29	0	152	0	181	0	59	0	88	0	88	0	88
(Mellegue 2)	0	586,000	586,000	500,000	53,000	0	29	0	59	0	88	0	59	0	88	0	88	0	88
(Tessa)	0	934,000	934,000	798,000	85,000	0	0	0	93	0	93	0	0	0	0	0	0	0	0
3% of (1) + (2)																			
(4) Engineering Services	1,650,000	1,650,000	3,300,000	2,818,000	301,000	42	42	330	330	288	288	0	0	126	126	168	168	126	126
(Mellegue 2)	840,000	840,000	1,680,000	1,435,000	153,000	42	42	168	168	126	126	0	0	126	126	168	168	126	126
(Tessa)	810,000	810,000	1,620,000	1,383,000	148,000	0	0	162	162	162	162	0	0	0	0	0	0	0	0
10% of (1)																			
(5) Subtotal (1)+(2)+(3)+(4)	18,150,000	37,330,000	55,480,000	47,378,000	5,059,000	42	71	330	482	288	1,291	0	1,155	1,806	2,716	2,688	2,776	2,646	2,734
(6) Physical Contingency	1,815,000	3,733,000	5,548,000	4,738,000	506,000	46	63	363	747	317	684	0	0	139	189	185	251	139	189
(Mellegue 2)	924,000	1,257,000	2,181,000	1,863,000	199,000	46	63	185	251	139	189	0	0	139	189	185	251	139	189
(Tessa)	891,000	2,476,000	3,367,000	2,875,000	307,000	0	0	178	495	178	495	0	0	0	0	0	0	0	0
10% of (5)																			
(7) Sub-Total (5)+(6)	19,965,000	41,063,000	61,028,000	52,116,000	5,565,000	88	134	693	1,229	605	1,975	0	1,155	1,945	2,904	2,873	3,027	2,785	2,922
(8) Price Contingency	3,406,000	10,787,000	14,193,000	12,120,000	1,294,000	0	0	15	39	26	128	0	114	169	390	315	516	370	608
(Mellegue 2)	1,162,000	2,212,000	3,374,000	2,881,000	308,000	0	0	7	15	11	80	0	114	169	390	315	516	370	608
(Tessa)	2,244,000	8,575,000	10,819,000	9,239,000	987,000	0	0	7	24	14	49	0	0	0	0	0	0	0	0
FC:2.1% and LC:3.2% of (7)						(.)	(.)	(.021)	(.032)	(.042)	(.065)	(.064)	(.099)	(.087)	(.134)	(.11)	(.171)	(.133)	(.208)
(9) Sub total (7)+(8)	23,371,000	51,850,000	75,221,000	64,236,000	6,859,000	88	134	708	1,268	630	2,103	0	1,269	2,113	3,294	3,187	3,544	3,154	3,530
(10) Taxes	0	8,895,000	8,895,000	7,596,000	811,000	0	6	0	38	0	48	0	13	0	781	0	1,200	0	1,236
(Mellegue 2)	0	4,133,000	4,133,000	3,529,000	377,000	0	6	0	15	0	23	0	13	0	781	0	1,200	0	1,236
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	3,958,000	3,958,000	3,380,000	361,000	0	0	0	0	0	0	0	0	0	755	0	1,168	0	1,206
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	176,000	176,000	150,000	16,000	0	6	0	15	0	23	0	13	0	27	0	32	0	31
(Tessa)	0	4,762,000	4,762,000	4,067,000	434,000	0	0	0	23	0	25	0	0	0	0	0	0	0	0
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	4,467,000	4,467,000	3,815,000	407,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	295,000	295,000	252,000	27,000	0	0	0	23	0	25	0	0	0	0	0	0	0	0
R: Rate of price contingency																			
Grand Total (9) + (10)	**23,371,000**	**60,745,000**	**84,116,000**	**71,832,000**	**7,670,000**	**88**	**141**	**708**	**1,306**	**630**	**2,152**	**0**	**1,282**	**2,113**	**4,076**	**3,187**	**4,744**	**3,154**	**4,767**

Description	2015		2016		2017		2018		2019		2020		2021	
	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	1,680	1,680	0	0	1,620	1,620	2,430	2,430	2,430	2,430	1,620	1,620	0	0
(Mellegue 2)	1680	1680	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	1620	1620	2430	2430	2430	2430	1620	1620	0	0
(2) Land Acquisition	0	4,476	0	5,968	0	4,476	0	0	0	0	0	0	0	0
(Mellegue 2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	4,476	0	5,968	0	4,476	0	0	0	0	0	0	0	0
(3) Government Administratior	0	88	0	93	0	187	0	187	0	140	0	140	0	0
(Mellegue 2)	0	88	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	93	0	187	0	187	0	140	0	140	0	0
3% of (1) + (2)														
(4) Engineering Services	84	84	0	0	122	122	162	162	122	122	81	81	0	0
(Mellegue 2)	84	84	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	122	122	162	162	122	122	81	81	0	0
10% of (1)														
(5) Subtotal (1)+(2)+(3)+(4)	1,764	6,328	0	6,061	1,742	6,404	2,592	2,779	2,552	2,692	1,701	1,841	0	0
(6) Physical Contingency	92	126	0	0	134	371	178	495	134	371	89	248	0	0
(Mellegue 2)	92	126	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	134	371	178	495	134	371	89	248	0	0
10% of (5)														
(7) Sub-Total (5)+(6)	1,856	6,454	0	6,061	1,875	6,776	2,770	3,274	2,685	3,063	1,790	2,089	0	0
(8) Price Contingency	291	1,592	0	1,737	386	2,221	640	1,212	690	1,268	507	959	0	0
(Mellegue 2)	291	488	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	1,104	0	1,737	386	2,221	640	1,212	690	1,268	507	959	0	0
FC:2.1% and LC:3.2% of (7)	(.157)	(.247)	(.181)	(.287)	(.206)	(.328)	(.231)	(.37)	(.257)	(.414)	(.283)	(.459)	(.31)	(.554)
(9) Sub total (7)+(8)	2,147	8,046	0	7,798	2,261	8,996	3,410	4,486	3,375	4,331	2,297	3,048	0	0
(10) Taxes	0	858	0	21	0	910	0	1,386	0	1,414	0	983	0	0
(Mellegue 2)	0	858	0	0	0	0	0	0	0	0	0	0	0	0
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	829	0	0	0	0	0	0	0	0	0	0	0	0
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	28	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	21	0	910	0	1,386	0	1,414	0	983	0	0
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	0	0	0	0	852	0	1,319	0	1,361	0	936	0	0
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	0	0	21	0	59	0	67	0	53	0	47	0	0
R: Rate of price contingency														
Grand Total (9) + (10)	**2,147**	**8,903**	**0**	**7,819**	**2,261**	**9,907**	**3,410**	**5,872**	**3,375**	**5,745**	**2,297**	**4,032**	**0**	**0**

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 45 : 55
(c) Base year for counting of price contingency is June 2008.

Table D6.5.2 Project Cost of Zone U1+M with Dam Construction (Financial Cost)

U1+M

Unit:TND1,000

Description	FC	LC	Total Cost			2008		2009		2010		2011	
	TND	TND	TND equiv.	US$ equiv.	Yen 10^3 equiv.	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	12,600,000	12,600,000	25,200,000	21,520,000	2,298,000	0	0	0	0	0	0	0	0
(Mellegue 2)	12,600,000	12,600,000	25,200,000	21,520,000	2,298,000	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0
(2) Land Acquisition	0	4,120,000	4,120,000	3,518,000	376,000	0	0	0	0	0	1,236	0	1,648
(Mellegue 2)	0	4,120,000	4,120,000	3,518,000	376,000	0	0	0	0	0	1,236	0	1,648
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0
(3) Government Administratior	0	880,000	880,000	751,000	80,000	0	44	0	88	0	132	0	88
(Mellegue 2)	0	880,000	880,000	751,000	80,000	0	44	0	88	0	132	0	88
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0
3% of (1) + (2)													
(4) Engineering Services	1,260,000	1,260,000	2,520,000	2,152,000	230,000	63	63	252	252	189	189	0	0
(Mellegue 2)	1,260,000	1,260,000	2,520,000	2,152,000	230,000	63	63	252	252	189	189	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0
10% of (1)													
(5) Subtotal (1)+(2)+(3)+(4)	13,860,000	18,860,000	32,720,000	27,941,000	2,984,000	63	107	252	340	189	1,557	0	1,736
(6) Physical Contingency	1,386,000	1,886,000	3,272,000	2,794,000	298,000	69	94	277	377	208	283	0	0
(Mellegue 2)	1,386,000	1,886,000	3,272,000	2,794,000	298,000	69	94	277	377	208	283	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0
10% of (5)													
(7) Sub-Total (5)+(6)	15,246,000	20,746,000	35,992,000	30,736,000	3,282,000	132	201	529	717	397	1,840	0	1,736
(8) Price Contingency	1,743,000	3,318,000	5,061,000	4,322,000	462,000	0	0	11	23	17	120	0	172
(Mellegue 2)	1,743,000	3,318,000	5,061,000	4,322,000	462,000	0	0	11	23	17	120	0	172
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0
FC:2.1% and LC:3.2% of (7)						(.)	(.)	(.021)	(.032)	(.042)	(.065)	(.064)	(.099)
(9) Sub total (7)+(8)	16,989,000	24,064,000	41,053,000	35,058,000	3,744,000	132	201	540	740	414	1,960	0	1,908
(10) Taxes	0	6,200,000	6,200,000	5,295,000	565,000	0	10	0	23	0	34	0	19
(Mellegue 2)	0	6,200,000	6,200,000	5,295,000	565,000	0	10	0	23	0	34	0	19
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	5,936,000	5,936,000	5,069,000	541,000	0	0	0	0	0	0	0	0
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	264,000	264,000	225,000	24,000	0	10	0	23	0	34	0	19
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	0	0	0	0	0	0	0	0	0	0	0	0
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	0	0	0	0	0	0	0	0	0	0	0	0
R: Rate of price contingency													
Grand Total (9) + (10)	**16,989,000**	**30,264,000**	**47,253,000**	**40,353,000**	**4,309,000**	**132**	**211**	**540**	**763**	**414**	**1,994**	**0**	**1,927**

Description	2012		2013		2014		2015		2016		2017		2018		2019		2020		2021	
	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC
(1) Construction cost (Base cost)	2,520	2,520	3,780	3,780	3,780	3,780	2,520	2,520	0	0	0	0	0	0	0	0	0	0	0	0
(Mellegue 2)	2520	2520	3780	3780	3780	3780	2520	2520	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2) Land Acquisition	0	1,236	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(Mellegue 2)	0	1,236	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(3) Government Administratior	0	132	0	132	0	132	0	132	0	0	0	0	0	0	0	0	0	0	0	0
(Mellegue 2)	0	132	0	132	0	132	0	132	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3% of (1) + (2)																				
(4) Engineering Services	189	189	252	252	189	189	126	126	0	0	0	0	0	0	0	0	0	0	0	0
(Mellegue 2)	189	189	252	252	189	189	126	126	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10% of (1)																				
(5) Subtotal (1)+(2)+(3)+(4)	2,709	4,077	4,032	4,164	3,969	4,101	2,646	2,778	0	0	0	0	0	0	0	0	0	0	0	0
(6) Physical Contingency	208	283	277	377	208	283	139	189	0	0	0	0	0	0	0	0	0	0	0	0
(Mellegue 2)	208	283	277	377	208	283	139	189	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10% of (5)																				
(7) Sub-Total (5)+(6)	2,917	4,360	4,309	4,541	4,177	4,384	2,785	2,967	0	0	0	0	0	0	0	0	0	0	0	0
(8) Price Contingency	253	585	472	775	555	912	436	732	0	0	0	0	0	0	0	0	0	0	0	0
(Mellegue 2)	253	585	472	775	555	912	436	732	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FC:2.1% and LC:3.2% of (7)	(.087)	(.134)	(.11)	(.171)	(.133)	(.208)	(.157)	(.247)	(.181)	(.287)	(.206)	(.328)	(.231)	(.37)	(.257)	(.414)	(.283)	(.459)	(.31)	(.554)
(9) Sub total (7)+(8)	3,170	4,945	4,781	5,316	4,732	5,296	3,221	3,698	0	0	0	0	0	0	0	0	0	0	0	0
(10) Taxes	0	1,172	0	1,800	0	1,855	0	1,287	0	0	0	0	0	0	0	0	0	0	0	0
(Mellegue 2)	0	1,172	0	1,800	0	1,855	0	1,287	0	0	0	0	0	0	0	0	0	0	0	0
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	1,132	0	1,752	0	1,808	0	1,244	0	0	0	0	0	0	0	0	0	0	0	0
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	40	0	48	0	46	0	43	0	0	0	0	0	0	0	0	0	0	0	0
(Tessa)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1) 18% of ((1) x 1.1+(1) x 1.1 x R)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2) 10% of (((3) + (4))x1.1 +((3)+(4)) x1.1xR)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
R: Rate of price contingency																				
Grand Total (9) + (10)	**3,170**	**6,117**	**4,781**	**7,116**	**4,732**	**7,151**	**3,221**	**4,985**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Note: (a) Exchange rates applied to conversion of the currencies are : US$ 1 = TND 1.171 = Yen 106.79 based on prevailing rate in June 2008
(b) Proportion of construction cost is : FC : LC = 45 : 55
(c) Base year for counting of price contingency is June 2008.