A runoff coefficient is also defined to be the ratio of runoff to rainfall over a given period. In case of runoff analysis using triangular unit hydrograph method with rational formula's peak discharge, runoff coefficient is applied as this definition and same value mentioned above.

- Time of Concentration (Tc) : Time of concentration is defined as total of inlet time and flow time. Kirpich formula is utilized to estimate the inlet time and the flow time is calculated from assumed average flow velocity taking account of channel condition, bed slope, carrying capacity, etc.

- Rainfall intensity (i) : Average rainfall intensity in time of concentration is obtained from IDF curve formula that is adopted for the ONAS's planning study.

Basic conditions of rational formula mentioned above are summarized in Table 3.4.

(4) Basic conditions of storage function method

A storage function method is employed for flood runoff from each sub-basin and river channel. In general, there are some differences in runoff characteristics among basins. The parameters of storage function method can express those differences based on topographic data. This method has two main models, basin runoff model and river channel model, and each model has several parameters. Basic formulas and empirical formulas for each parameter are summarized in Table 3.5.

3.1.5 Establishment of Gauges

(1) Rainfall gauge stations

There are 56 rainfall gauge stations in and around the Greater Tunis and 16 stations in and around the Sousse area. Most of these stations are operated by D.G.R.E. And all observed data are also compiled by D.G.R.E. The location and condition of existing rainfall gauge stations were reviewed with collected data and information. Finally, four (4) rainfall gauge station sites in Greater Tunis and two (2) station sites in Greater Sousse were selected as shown on Fig. 3.3. The JICA provided four (4) rainfall gauges, and construction works for those stations were started at the end of April 1993, and completed by the end of May 1993. General descriptions of each rainfall gauge station are summarized in Table 3.6.

(2) Water level gauge stations

There are four (4) automatic water level gauge stations on the Oued Maliyan basin in Greater Tunis and two (2) stations on Oued Hammam basin in Sousse. The location and condition of existing water level gauges were checked through the field reconnaissance and collected data. Four (4) water level gauge station sites in Greater Tunis and one (1) station site in Sousse areas were selected as shown on Fig. 3.5. General description of existing stations and new gauge stations to be installed are summarized in Table 3.7.

3.2 Hydrological Studies in Greater Tunis

The study area contains following 7 river basins.

1) Oued Ennkhilet
2) Oued Greb
3) Oued Gariana
4) Oued Maliyan
5) Oued Magzette
6) Oued Bou Khamsa
7) Oued Ain Zerga

3.2.1 Climate

The project area lies among 36°0' and 37°0' of north latitude, and 9°30' and 10°20' of east longitude.

The monthly average mean temperature ranges from 11.6°C in January to 27.6°C in August at Tunis-Carthage (altitude 5 mNGT), and from 8.7°C in January to 27.0°C in July at Siliana (altitude about 430 mNGT). The average monthly maximum and minimum temperature are around 40°C in July and 4°C in January at Tunis- Carthage, and 42°C in July and 1°C in December at Siliana. The monthly temperature of recent 5 years are summarized in Table 3.8 and Fig. 3.6.

The average monthly relative humidity varies from 61.3% in July to 81.3% in January at Tunis-Carthage, and from 45.0% in July to 79.1% in December at Siliana and shown in Table 3.9 and Fig. 3.7.

The monthly sunshine duration ranges from 138.1 hours in January to 332.7 hours in July at Tunis-Carthage and from 130.0 hours in December to 323.4 hours in July at Siliana and shown in Table 3.10 and Fig. 3.8.

The annual average evapotranspiration in resent 5 years (1986 - 1991) is 1,196 mm. It has a high potential of monthly evapotranspiration (188 mm) in July and low potential (45 mm) in December and January. Table 3.11 shows 10-day, monthly and annual evapotranspiration and average monthly evapotranspiration and rainfalls in 5 years are plotted in Fig. 3.9.

3.2.2 Basin Analysis

Basin and sub-basin boundaries were drawn on the available topographic map for the major point of interest and the basin areas were measured. Catchment area of each river basin is summarized below and area of each sub-basins are shown in Table 3.12.

1) Oued Ennkhilet	17 km2
2) Oued Greb	19 km2
3) Oued Gariana	87 km2
4) Oued Maliyan	1,996 km2
5) Oued Magzette	7.0 km2
6) Oued Bou Khamsa	6.2 km2
7) Oued Ain Zerga	4.2 km2

Present and future land use conditions and those areas excluding Maliyan basin were also examined to clarify the basin runoff characteristics and obtain weighted runoff coefficients for rational formula (Ref. : Table 3.13).

3.2.3 Rainfall Analysis

Generally, rainfall characteristic in Tunis is that it has heavy rainfall within a few days in the midst of rain season (September to January) and not heavy but much rainfall with long duration in end of rain season. To know actual annual rainfall pattern, mean monthly rainfall at Tunis-Carthage and Siliana are illustrated in Table 3.14 and Fig. 3.10. It is seen that the basins receive much rainfall during the months from September to January, while a drier period is observed from June to August.

Stations AIN DJAJA PONT DU FAHS (40154), BIR M'CHERGA (40962), DOMAINE DECHAMUNE (42248), ROBAA GN (45416) and TUNIS CARTHAGE SM (47832) were selected, considering the location and data conditions, to study the annual and monthly rainfall characteristics with longer period. Monthly rainfall data were arranged in Table 3.15 and annual and average monthly rainfall was shown in Fig. 3.11 and Fig. 3.12, respectively.

Mean annual rainfall in the basin is about 380 mm to 540 mm. The average annual maximum daily rainfall in the basins varies from 29 mm to 108 mm. The recorded maximum daily rainfall is 252.5 mm in October 1969 at station SID ADAPT (46088).

3.2.4 Runoff Characteristics

The Oued Ennkhilet basin is involved in the Sebkhet Ariana basin, so all runoff in the Oued Ennkhilet basin flow to the Sebkhet Ariana. The Sebkhet Ariana is connected to the sea by a small channel but usually outlet of this channel is closed by the sand bar on sea coast. The Oued Greb basin lies in the northern west of the North Tunis lake. The runoff from this basin flow into the Tunis lake. The Oued Gariana basin is included in the Sebkhet Sijoumi basin. The Sebkhet Sijoumi basin is an inland basin and there is no outlet to the sea. The Oued Maliyan basin has the biggest catchment area in the Greater Tunis area and lies south to south-westward of Tunis. The runoff from this basin flow to the Gulf Tunis directly. All the Oued Magzette basin, Oued Bou Khamsa basin and Oued Ain Zerga basin have a small catchment area and face to the Gulf Tunis.

All 7 rivers in Greater Tunis area are called "Oued", so it means that river has little flow or no flow in dry season.

According to the study report on the Oued Maliyan in 1973, ten (10) water level gauge stations existed in the Oued Maliyan basin, but some of them were washed away by several floods after 1969. Four (4) water level gauge stations are still existing and three (3) stations among of them, Hamma Aval (K08), Thuburbo Majus (K18) and Bou Arada (K27), have been operated continuously. The collected discharge records in Maliyan basin are summarized in Table 3.16.

3.2.5 Flood Runoff Analysis

The purpose of the flood runoff analysis is to construct a flood runoff model of the each river basin based on the available hydrological data and calculate the probable flood runoff for flood control planning. Three (3) calculation models were applied for runoff analysis in Tunis study area considering with scale of basin area, availability of hydrological data, existing flood control facilities, planning concept, etc.

(1) Rational method

This method was applied for the Oued Magzette basin. River system model and calculation points on the model were determined as shown in Fig. 3.13. Calculation results of basic flood runoff at each calculation point are shown in Table 3.17 and the specific discharge on calculated basic flood runoff of 100-year return period at each point is plotted in Fig. 3.14.

(2) Triangular unit hydrograph method with rational formula's peak discharge

This method was applied for the Oueds Ennkhilet, Greb, Gariana, Bou Khamsa and Ain Zerga basins. River system model and calculation points on the model were determined as shown in Fig. 3.13.

The alternating block method was applied for the design hyetograph that is developed as center density distribution from an IDF curve with a condition that a time interval is equal to the time of concentration. Examples of typical design hyetograph in Tunis, developed in 60-min increments for 24-hour with 100-year and 10-year return period, are shown in Fig. 3.15.

Calculation results of basic flood runoff at each calculation point are shown in Table 3.17 and the specific discharge of 100-year and return period at each point is plotted in Fig. 3.14. Calculation results of peak discharge at each point in certain alternative plans are summarized in Table 3.18.

(3) Storage function method

This method was applied only for the Oued Maliyan basin, because of hydrological data in Maliyan basin such as rainfall hyetographs in the basin and discharge hydrographs at M'cherga dam are available for the calibration of flood runoff model. River system model and calculation points on the model were determined as shown in Fig. 3.13.

The observed hyetograph pattern in May 1973 and Sept. 1986 was applied for the design hyetograph pattern. The actual rainfall hyetographs in May 1973 and Sept. 1986 are shown in Fig. 3.16.

Basin mean daily rainfall was also studied to develop design rainfall for storage function model and 52 stations were selected for the calculation of basin mean daily rainfall. Results of this study show those correlation coefficients of many stations are very small. Because some observed daily rainfall shows the strange relation that one station has big daily rainfall compared with other stations around it or it has no rainfall but other stations around it have much rainfall. So this study was only used for reference.

Station Tunis-Manoubia (47836) was selected for representative station with good data condition instead of basin mean rainfall. Annual maximum daily rainfalls in 19 years (1968 to 1986) at this station were examined for probability analysis. Results of probability analysis are shown in Table 3.19 and Gumbel Method was utilized for further study. The ratio of the model hyetograph to the design rainfall in each return period based on the basin mean daily rainfall is also presented in Table 3.19.

The model calibration results in May 1973 and Sept. 1986 are shown in Table 3.20. The actual discharge hydrograph data observed at M'cherga Dam in May 1973 and calculated one are graphically shown in Fig. 3.17.

Calculation results of basic flood runoff at each calculation point are shown in Table 3.21 and the specific discharge of 100-year return period at each point are plotted in Fig. 3.18. Calculation results of peak discharge at each point in certain alternative plans are summarized in Table 3.22.

3.3 Hydrological Studies in Greater Sousse

Grater Sousse area contains following 4 river basins;

1) Oued Hammam
2) Oued Blibene
3) Oued Hallouf
4) Oued Hamdoun

3.3.1 Climate

The project area lies among 35°35' and 35°55' of north latitude, and 10°20' and 10°40' of east longitude.

The average monthly temperature ranges from 12.1°C in January to 27.9°C in August at Monastir (altitude 15 mNGT). The average monthly maximum and minimum temperature are around 40°C in July and August and 5°C in December and January. Monthly temperature of the recent 5 years are summarized in Table 3.8 and Fig. 3.6.

The average monthly relative humidity varies from 63.4% in July to 72.4% in January at Monastir and shown in Table 3.9 and Fig. 3.7.

The monthly sunshine duration ranges from 158.1 hours in December to 342.6 hours in July at Monastir and shown in Table 3.10 and Fig. 3.8.

The annual average evapotranspiration in resent 5 years (1986 - 1991) is 984 mm. It has a high potential of monthly evapotranspiration (141 mm) in July and low potential (42 mm) in January. Table 3.11 shows 10-day, monthly and annual evapotranspiration and average monthly evapotranspiration and rainfall in 5 years is plotted in Fig. 3.9.

3.3.2 Basin Analysis

Basin and sub-basin boundaries were drawn on the available topographic map for the major point of interest and the basin areas were measured. Catchment area of each river basin is summarized below and area of each sub-basin are shown in Table 3.12.

1) Oued Hammam	222 km2
2) Oued Blibene	15 km2
3) Oued Hallouf	12 km2
4) Oued Hamdoun	313 km2

Present and future land use conditions and those areas were also examined to clarify the basin runoff characteristics and obtain weighted runoff coefficients for rational formula (Ref. : Table 3.13).

3.3.3 Rainfall Analysis

Mean monthly rainfalls at Sousse are arranged as shown in Table 3.14 and Fig. 3.10. It is seen that the basins receive much rainfall during the months from November to January, while a drier period is observed from May to August.

Station KALAA SEGHIRA (73501) and MASAKEN DELG SM (74603) were selected, considering the location and data conditions, to study the annual and monthly rainfall characteristics with longer period. Monthly rainfall data were arranged in Table 3.23 and annual and average monthly rainfall were shown in Fig. 3.19 and Fig. 3.20, respectively. Mean annual rainfall in the basin is about 330 mm to 340 mm. The average annual maximum daily rainfall in the basins varies from 23 mm to 164 mm. The recorded maximum daily rainfall is 267.0 mm in Dec. 1973 at station KALAA KEBIRA (73509).

3.3.4 Runoff Characteristics

The Oued Hammam basin lies in the western area of the Sousse city and the Oued Hamdoun basin lies in the southern area. The areas in upper reaches of both basins are utilized as agricultural land and land slope is vary mild. It seems that the runoff coefficient in this area is small. The Oued Blibene basin and the Oued Hallouf basin have a small catchment and lie around the Sousse city.

There are two existing water level gauge stations in the Oued Hammam basin. These stations were installed at Dar et Caid (station Hammam Sousse) in 1990 and at Kalaa Srira (station Kalaa Sghira) in 1988 by D.G.R.E.. The collected water level records were arranged and peak water level in these stations are summarized in Table 3.24.

3.3.5 Flood Runoff Analysis

The purpose of the flood runoff analysis is to construct a flood runoff model of the each river basin based on the available hydrological data and calculate the probable flood runoff for flood control planning. Two (2) calculation models were applied for runoff analysis in Sousse study area considering with scale of basin area, availability of hydrological data, existing flood control facilities, planning concept, etc.

(1) Rational method

This method was applied for the Oued Blibene and Oued Hallouf basins. River system model and calculation points on the model were determined as shown in Fig. 3.21. Calculation results of basic flood runoff at each calculation point are shown in Table 3.25 and the specific discharge of 100-year return period at each point are plotted in Fig. 3.22.

(2) Triangular unit hydrograph method with rational formula's peak discharge

This method was applied for the Oued Hammam and Oued Hamdoun basins. River system model and calculation points on the model were determined as shown in Fig. 3.21.

The alternating block method was applied for the design hyetograph that is developed as center density distribution from an IDF curve with time interval is equal to the time of concentration. Examples of typical design hyetograph in Sousse, developed in 60-min increments for 24-hour with 100-year and 10-year return period, are shown in Fig. 3.23.

Calculation results of basic flood runoff at each calculation point are shown in Table 3.25 and the specific discharge of 100-year return period at each point are plotted in Fig. 3.22. Calculation results of peak discharge at each point in certain alternative plans are summarized in Table 3.26.

CHAPTER 4 URBAN DEVELOPMENT

4.1 Introduction

Over recent years the agglomerations of Greater Tunis and Sousse have witnessed a rapid growth in urban development and expansion as a result in an increase in population, a growth in industrial productivity and an improvement in transport and touristic facilities. This trend, however, has caused rapidly increasing spontaneous housing areas that do not comply with the required standards in terms of infrastructures, planning and cadastral points of view. As a result of all these, new urban development studies and projects have to be carried out to meet the arising socio-economic requirements and to set a new land use policy aiming at reducing the various disparities among the different Governorates in the study area.

4.2 Greater Tunis

The territory of Greater Tunis is the developed coastal plain that forms the Governorates of Tunis, Ariana and Ben Arous in the north-east region of Tunisia (See Fig.4.1). It includes a total of 45 Delegations and covers an area of 2,533 km2 that accommodates, at present, a total estimated population 1,769,600 of which 1,624,700 occupy the urban areas and 144,900 inhabit the rural areas.

At present most of the municipalities in Greater Tunis are provided with urban plans so as to face the increase in development and to accommodate the future growth in urban areas.

4.2.1 Present Land Use

A cursory review of the existing urban development in Greater Tunis shows that the urban area has been increasing over the past decade, with one quarter of the urban spread (approximately 1,600 ha) taking place on farmlands located on the outskirts of the cities of Tunis, Ariana and Ben Arous (See Fig.4.1).

To the South, the Tunis-Ben Arous section is dominated by the port, road transport and associated activities such as warehousing and light and heavy industries. To the North, the Tunis-Ariana section is marked with housing operations along the GP8 and with light to medium industries west of the airport.

The present land use in Greater Tunis is the result of an urban development that started to expand around the old medina some seventy years ago. The land use canvas depicted in

Fig.4.4 was constituted from aerial photographic maps and recent field reconnaissance to the study area. The composition of land use in Greater Tunis is shown in Table 4.1. The details of the present built-up urban areas in each of the three Governorates are presented in Table 4.2

A brief description of land use and composition in each Governorate is presented hereafter.

Governorate of Ariana

The urban areas cover around 122 km2 that accommodates around 80% of the total population of the Governorate.

Over the past two decades, the majority of the municipalities of the Governorate have witnessed two distinct types of urbanization trends.

The first one covers the formal housing projects that are being developed by private and public sectors. These housing projects occupy at present a total of 15.2 km2 that is expected to increase to 20 km2 in order to meet future demands on habitat for the next 10 years.

The second type involves the informal or the spontaneous settlements that have developed to fill the gap between supply and demand of habitat that was left unfilled by the formal housing operations. These settlements cover an area of 19.2 km2 and constitute one of the major points concerned by the flood protection study in the Government of Ariana for the simple fact that they have proliferated on the outskirts of municipalities in areas that are unfit for urban development such as agricultural lands, marshlands, oueds and flood plains. A typical example is the plain of Choutrana (1,800 ha) located south of Sebkhet Ariana, where spontaneous settlements suffer from frequent flooding during the rainy season.

The industrial zones represent another form of land use and they occupy an area of 366 km2.

Land use also includes the agricultural plains that cover an area of 1,053 km2. Among them only Choutrana suffers from serious flooding problems as it is located in a low laying flat area south of Sebkhet Ariana.

The green spaces such as parks, wadi, forests and pastures account for 333 km2. The social infrastructures cover, at present, an area of 6 km2 that are distributed among the twelve Delegations of the Governorate.

Land use in the Governorate of Ariana is also marked with an important water body (Sebkhet Ariana). Located on the north side of Ariana, Sebkhet Ariana is a natural pond that occupies a total area of 50 km2. It serves as the receiving body of storm water of Oued Ennkhilet, Canal Cometra and the drainage canals along the RVE501 road. The sebkhet also receives the sewage overflows from the waste water treatment plants of Choutrana and Coastal North at Soukra. At present the north-east corner of the sebkhet is being used as a land fills site for solid waste disposal.

Governorate of Tunis

At present, urban areas in the Governorate are saturated and account for 105 km2 where 10% of the nation's population live.

Since 1975, land use has developed at a particularly rapid rate in the municipal urban zones due to the improvement and the expansion of basic infrastructure utilities. This development, however, has followed two different trends. The first one consisting of the formal housing areas that cover 39 km2 or 60% of the present built-up area and which have expanded along major roads on the north and south sides of the Governorate. The second trend concerns the spontaneous habitats that have excessively proliferated to cover an area of 10.6 km2 of the present built-up area. Today, spontaneous settlements such as Dar Fadhel and Ain Zaghouan east of the airport, Mellassine and Saida Manoubia north of Sebkhet Sijoumi and west of Al Kram suffer from flooding problems that need to be resolved.

The industrial zones accounting for 5.8 km2 are located west of the airport and around the Tunis Lake and the port of Tunis.

The agricultural zones that represent another form of land use occupy an area of 100 km2. These zones are located west of Sebkhet Sijoumi and in the plain of Soukra.

The green areas such as the parks and the forests occupy an area of 15 km2.

The social infrastructure areas account for 9 km2.

Land use in the Governorate of Tunis is also characterized by two major water bodies, the Tunis Lake and the Sebkhet Sijoumi. These two bodies occupy 68 km2 and account for 24% of the total area of the Governorate. A brief description of each body is given hereafter.

1) Tunis Lake

Located on the east side of the Governorate, the wet land of Tunis Lake is split into two parts, the North Lake and the South Lake with approximate areas of 26 km2 and 16 km2, respectively.

In recent years, the North Lake has witnessed the implementation of important projects such as land reclamation along its banks, housing development (Al bouhira) on the north bank, the Ceinture Drainage Canal, dredging operations on the east side. The lake is connected to the sea by Canal Khayreddine and receives the storm water flows of Oued Greb and Oued Rouriche.

As for the South Lake, it is characterized by a number of operations such as the port of Tunis and the salt works on the south banks and the port of Rades. It also receives the storm water flows and the industrial effluents from the neighboring south areas of Jebel Jloud. At present, the east bank of the lake is expected to inundation due to run off flows from the Rades plain.

2) Sebkhet Sijoumi

The Sebkhet Sijoumi is a salty water body located almost in the center of the Governorate and covers an area of 26 km2. In past years, the sebkhet was concerned by a number of projects such as land reclamation and waste water treatment works. Unfortunately none of them was developed. Today, the sebkhet with its shallow depth water serves to collect the storm water from the Oued Gariana and the neighboring areas. It also receives raw waste water flows from Sidi Hssein Sijoumi and Hay Az-zouhour.

Governorate of Ben Arous

At present, the urban zones cover about 109 km2 of which 32% constitute the local built-up areas located in the municipalities of Ben Arous, Rades, Az-zahra, Hammam Lif, Boumhel, Megrine, Fouchana and M'hammadia.

Ben Arous has also witnessed the proliferation of spontaneous housing areas that, today cover an area of 5.2 km2 and are located at Sidi Mosbah, Az-zahra, Naasan, Hammam Lif, having areas suffer from flooding problems during rainy season due to their location in unsewered flat and depressed zones or along river beds such as Fouchana near Sijoumi, Wadi Traboulssia in Hammam Lif, Boumhel near the Auto route and MC33 road, Mornag at Sidi Saad and Khlidia.

The industrial zones in Ben Arous occupy 7.3 km2 that is located in three principal areas, Megrine, Bir El Kassaa and Borj Cedria.

The agricultural lands cover 358 km2 with the greater part located in the plains of Mornag and the remaining is shared between the municipalities of Fouchana and M'hamdia.

The green area, mostly forest reserves account for 220 km2. Most of which is located along the course of Oued Maliyan, and in the national park reserve.

The social infrastructure areas cover 3.3 km2. These areas are distributed among the 12 municipalities of the Governorate.

Due to its location and climatic conditions, the region of Greater Tunis does not receive more than 500 mm of average precipitation per year. Yet it still suffers from serious flood related problems. This phenomenon was observed during the rainy season of 1989-1990 where important parts of Ariana, Tunis and Ben Arous were exposed to significant flood events.

Even if some parts of the inundated zones are temporarily flooded during rainy incidents, still the remaining parts suffer from substantial floods such as the Choutrana and Soukra plains near Sebkhet Ariana and the plains of Rades South of Tunis Lake.

The present flood prone areas shown in Fig.4.5 have been identified on the basis of past flood records of 1989-1990, recent site reconnaissance and consultations with the concerned services. These areas were found to be located in fully developed urban zones and in bare and agricultural lands as well.

The concerned flood prone localities that were investigated, add up to 24 sites. A brief description of the problem came across at each site is given in Table 4.3.

The purpose of this exercise is to establish a flood risk database that can be used for the planning of future land use and which, on the long run, can help to reduce flood effects to an acceptable level.

4.2.2 Future Land Use

Over the past two decades, most of the communes in Greater Tunis have been provided with urban development projects and plans. Today, only a part of those projects is being implemented, and the greater part has not been executed and suffers from a number of deficiencies such as pending approvals, updating of projects to meet future demands and integration with the existing urban trend.

In this perspective, the need becomes imperative for an urban development plan that considers the existing urban development projects to satisfy future demands of land acquisition for new buildings, redevelopment and upgrading.

The urban development plan shown in Fig.4.6 was proposed by the District of Tunis in 1982. This plan provides, the following framework for the development of Greater Tunis:

- Reasonable land use in urban areas in order to cease the waste of space witnessed today,
- Control migration so as to establish a moderate population growth among the three Governorates,
- Creation of secondary urban centers to the south and to the north of the capital that will allow to absorb parts of the social and economic activities,
- Distribution of the industrial activities between the plenteous south (Ben Arous), the deficient west (Ksar Said) and their limited north (Ariana),
- Creation of new urban expansion areas to meet future population growth,
- Combat anarchic housing and rehabilitation and upgrading of spontaneous settlements,
- Control land use in agricultural zones that are susceptible to urban development (Mornag, Sijoumi, Soukra, Wadi-Ellil and Na'assen), and
- Protection of existing green spaces and reforestation of steepy slanting areas.

Future land use in the project area is to take into account the existing development plans and the framework mentioned above. The following development directions are believed to provide the future land use pattern in the three Governorates.

4.2.3 Recommendations on Urban Development

1) The control of urban development

- The urbanization of lands that require low capital cost for development and infrastructure facilities to create real estate reserves for urban expansion to the north-west at M'nihla and Ksar Said and to the south-west at Naassen and Fouchana.
- The restructuring of agricultural zones that can accommodates future areas such as the plains of Choutrana and Sora in Ariana and the south bank of Sebkhet Sijoumi in Tunis.
- The creation of new housing development areas along the north bank of Tunis Lake.

- The creation of new industrial zones in Manouba and in the North of Ariana in Mornaguia and Mornag in Ben Arous.
- The preservation of fertile and beneficial agricultural lands of Soukra and Mornaguia in Ariana and Mornag in Ben Arous.
- The protection and the improvement of the environment of Sebkhet Ariana and Sebkhet Sijoumi through a designed rehabilitation program.
- The cleanup and improvement work of Tunis Lake to safeguard its biological equilibrium.

The land reserves for urban expansion are about 8,400 ha that satisfies all future developments in Greater Tunis. The location of these reserves over the next two decades is presented in Table 4.4.

2) *Conceivable works at Sebkhet Ariana*

Sebkhet Ariana is the coastal lagoon situated between the estuary of Wadi Medjerda and the Cape of Gammarth in the municipality of Ariana. It occupies a total area of 50 km2. The hydrologic cycle of the sebkhet consists of two elements:

Inflows:
- rainfall precipitation
- flows of water courses and drainage canals
- sea water intrusion

Outflows:
- evaporation into the atmosphere
- infiltration into the substrata
- effluence into the sea

During the months of July and August, the outflows exceed the inflows and the sebkhet dries out leaving the entire water surface covered with a layer of salt.

Future land use around the Sebkhet Ariana is shown in Fig.4.6. As for the development of the sebkhet itself, a number of propositions can be contemplated as shown in Table 4.5.

3) Conceivable works at Sebkhet Sijoumi

Sebkhet Sijoumi is the inland lagoon located to the West of Tunis Lake between the GP3 and the MC39 roads. It occupies a total area of 37 km2. The hydrologic cycle of the Sebkhet consists of two elements:

Inflows:
- direct rainfall precipitation

- flows from water courses and drainage canals

Outflows: - evaporation into the atmosphere
- infiltration into the substrata

The average water depth of the sebkhet ranges among 40 cm to 50 cm. The evaporation from sebkhet exceeds the inflow during the months of July and August, and the entire surface of sebkhet dries out breing covered with a crust of salt.

Future land use along the west bank of the sebkhet is shown in Fig.4.5. As for the development of the sebkhet itself, the following proposition can be considered.

- Dredging of the bottom of the sebkhet to increase its storage capacity. Dredged materials can be used for land reclamation along the banks of the sebkhet and for the existing landfill site to be justified by feasibility study.

- Creation of recreational areas along the banks of the sebkhet and transferring the waterbody into a zone natural activities.

4) Proposed works for Tunis Lake

Located between the Mediterranean Sea and the old medina of Tunis, the Tunis Lake covers an area of 42 km2 and constitutes the larger water body in Greater Tunis. The lake is split into two parts:

5) The North Tunis Lake

The North Lake occupying an area of 26 km2 is located between the GP9 and the Express way and is in contact with the sea through the Canal Khayreddine. During the last decade, the North Lake has witnessed important reclamation works of 9 km2 along its northern bank where a housing project Al Bouhira was developed over an area of 150 ha. The remaining of the reclaimed lands will be developed considering the results of the Al Bouhira project.

Other projects can be considered for the water body itself such as:

- Dredging for additional land reclamation along the banks of the lake
- Fish farming on the east side of the lake near the Central Khayriddine
- Recreational activities such as sailing and wind surfing
- Salt works for the production of commercial salt.

6) The South Tunis Lake

The South Tunis Lake is smaller than the North Lake as it occupies an area of 16 km2 and is located in the lagoon area between the Mediterranean Sea to the east, the industrial zone to the south and the Port of Tunis and warehouses to the East. The only contact of the lake with the sea is on the east side through Canal Rades. At present the South Lake receives all the raw effluents of the southern industrial zones and the banks of the lake are being used as solid waste landfill sites.

Two years ago, the Ministry of Equipment and Housing had carried out a case study concerning the clean-up and the restoration of the South Lake. The recommendations stemming from the study are summarized below:

- Elimination of all points of discharge of industrial effluents.
- Dredging operations to increase the capacity of the lake.
- Enlarging Canal Rades to enhance water exchange with the sea.
- Creation of a platform of 930 ha along the southern bank of the lake for urban development use between the communities of Mergrine, Rades and the Port of Rades.
- Creation of new zones for recreational activities.

Evidently, all these projects need to be justified first by a feasibility study, cost and benefit analysis and market demand to establish an order of priority for the implementation of these projects.

4.3 Greater Sousse

Greater Sousse is the capital of the central-east region of Tunisia and is ranked the third largest conurbation in the country after Tunis and Sfax.

The metropolitan area is bound to the North by Oued Hammam and to the South by Oued Hamdoun, the territory of Greater Sousse stretches about 20 km along the seashore and is limited to the East by the Mediterranean Sea and to the West by the proposed Auto route.

The administrative structure shown in Fig.4.7 consists of the following centers:

- One regional metropole:	Sousse
- Three regional centers or medium towns:	Hammam Sousse, Kala'a Kebira, Musaken

- Two sub-regional centers or medium towns: Akouda, Kala'a Sghira
- Four local centers or small towns: Az-Zouhour, Zaouit Sousse, Riyadh Sousse, Ksiba

The topography of the area is characterized by the narrow coastal plain of Sousse to the North-east and by the gently ascending slopes towards the undulating plateau of the South and the depressed inland of Sebkhet Sidi El Hani to the South-west.

4.3.1 Present Land Use

For the two decades, Greater Sousse has witnessed a rapid increase of urban expansion. Between the years 1975 and 1993, the urbanization has gone up by 86%. This prosperous trend is the result of a population growth coupled with an increased industrial and agricultural productivity, transport development and major investments in the sector of tourism. It is forecasted that none of the aforementioned factors will change substantially soon to make the growth of Greater Sousse less dramatic.

The existing urban development is very much function of the growth that has been expanding in Greater Sousse for the last three decades.

Today, the agglomeration is witnessing the development of a number of urban centers that are radically spread to the West on the outskirts of the city of Sousse in the surrounding agricultural zones. This trend is in fact not well planned as it has led to the creation of new residential areas that are deprive of basic infrastructure facilities.

The present land use shown in Fig.4.8 is marked by two different aspects:

- The heavily urbanized coastal plain covering the existing residential, industrial and touristic activities along the shoreline. It stretches from the North to the South along the lower basin of Oueds Hammam, Blibene, Hallouf and Hamdoun.

- The modestly developed inland centers that are either located on the upper basins such as Kala'a Sghira, Az-zouhour, Zaouiet Sousse and Msaken, or spread over the intermediate basins such as Akouda, Messadine and Ksiba.

The composition of the present land use summarized in Table 4.6 was constituted from topographic maps, field reconnaissance to the site and consultation of the available urban development plans and reports of the study area.

At present, the urban zones add up to 3,415 ha. One half of these zones is located in Sousse and Hammam Sousse that constitute the lower basin area of the four oueds. About 10% of the urban zones occupy the intermediate basins. Whereas the remaining 40% are spread on the upper basins with Kalaa Kbira (10%) on Oued Kbir, Kalaa Sghira (6%) on Oued Kharroub, Az-zouhour with Riadh Sousse (6%) on Oued Hallouf and Msaken (18%) on Oued Hamdoun.

The agricultural lands that cover 12,713 ha stretch mainly south of the GP1 road with the lower basin area situated north of Hammam Sousse, the middle basin is located between the GP1 and Az-zouhour and the upper basin area on the higher plateau west of Az-zouhour.

The industrial zones are mainly spread along the major roads and cover about 900 ha. The greater parts of these zones are located in the lower basins of the four oueds on the northern entrance of Hammam Sousse (245 ha) and between Oued Hallouf and Oued Hamdoun (400 ha). The remaining industrial areas are found in the upper basin north of Kalaa Kbira (17 ha), and east of Kala'a Sghira (40 ha).

The green areas such as parks, forests and pastures add up to 749 ha and are mostly located along the beds of the four oueds.

Sebkhet Sousse is the only inland water body in the study area. It covers 80 ha and is situated south of Sousse between Oued Hallouf and Oued Hamdoun. It is not being exploited and dries out completely in the summer leaving a thin crust of salt on the surface.

The average annual rainfall precipitation in Greater Sousse does not exceed 370 mm. Nonetheless, exceptional storm events, such as the one of 1969 (700 mm), may occur and result in harmful floods.

Although a number of studies were carried out in the past to mitigate flood damages and to improve the protection of properties susceptible to inundation effects, today, the majority of the urban centers of Greater Sousse are still at risks of floods that are witnessed on the higher plateau, the intermediate basin and lower coastal areas as well.

Site visits and discussions with local authorities permitted to identify the major flood sensitive localities within the area of Greater Sousse. These are presented in Fig.4.9. A brief description of the encountered problems is given in Table 4.7.

Site investigations have also revealed that spontaneous settlements add up to 525 units and are distributed among six Delegations as shown in Table 4.8. A relocation program of these settlements is evidently imperative to carry out the rehabilitation works of the oueds and to avoid adverse accidents in rainy events.

4.3.2 Future Land Use

Greater Sousse is expected to be exposed to further developments on the demographic, industrial, agricultural, touristic and financial levels. To meet these objectives, Sousse and each of its surrounding urban centers had to be equipped with appropriate urban development projects and land use plans.

Today, most of these projects are being revised considering the new socio-economic requirements. In addition, the most recent Urban Development Master Plan for Sousse and Monastir was produced on March 1993, and the guide lines for the future development of the area of Greater Sousse are shown in the plan (Ref.:Fig.4.10).

4.3.3 Recommendations on Urban Development

The proposed composition of future land use is presented in Table 4.9. The recommendations provided in the Master Plan are summarized hereafter.

1) Housing Development

- Densification of land use by increasing urban densities (present density is 25 housing units per hectare) to reduce infrastructure cost.
- Control of housing problems by eliminating spontaneous settlements and improving the housing credit system.
- Limiting urban expansion to the area between Sousse and the deviation of the GP1 road.
- Creation of an intermediate agricultural zone west of the deviation of the GP1 road to limit the urban development in the middle basins area of the four oueds.
- Limiting housing construction in the upper basins to areas reserved for urban development to protect agricultural zones.

2) Industrial Development

- Creation of an industrial free zone of 9 ha at the port of Sousse.
- Rehabilitation of the existing industrial zones in Sousse and Kala'a Kbira and creation of new industrial areas in Msaken and Kala'a Sghira in the upper basins of the four oueds.

3) Agricultural Development

- Transformation of the lands west of Kala'a Kbira and Msaken in the upper basins into agricultural irrigated lands.

4) Road Development

- Deviation of the GP1 road to the South of Sousse.
- Completion of the road section of the GP12 between Moureddine and the MG100 road.
- Rehabilitation of the MC48 road that links Sousse to Kala'a Kbira.
- Creation of a new inter-urban road linking Kala'a Kbira to Kala'a Sghira and to Msaken.

CHAPTER 5 URBAN DRAINAGE

5.1 General

Urban drainage systems consist of storm water drainage system and sewerage system. The major purpose of the study is to check whether domestic and industrial waste water becomes a base flow of each river before flood occurs. If this flow is very minimal, then the flow will be neglected in determining design flood.

Reviewing data and information on storm water drainage system and sewerage system in both Greater Tunis and Sousse areas, and also through field reconnaissance and interview, it has been revealed that the inundation of urban roads is the most critical since before. It is judged that it comes from poor existing storm water drainage system. On the other hand, domestic water is mostly treated at sewer treatment plants and treated water is discharged directly into the sea through a canal system and one part of treated water is utilized as irrigation water. Industrial water is discharged to sewer and river passing nearby without sufficient treatment, but the discharge amount is very small and minimal.

5.2 Review of Existing Urban Drainage System

5.2.1 Data Collected

Besides the data and information on urban drainage collected by S/W Mission, the JICA Study Team tried to collect additional data/information from various sources. As a result, it was found that the studies and succeeding implementations of storm water drainage and sewerage systems in both Greater Tunis and Sousse areas had mainly been made to date in several steps by National Sanitation Agency (ONAS), which was once one department of MOEH. There exist much data and information relating to storm water drainage and sewerage systems which had been published in the past. However data and information collected during Phase 1 at the site are rather old one. Then the members of the JICA Study Team visited several times ONAS offices in Tunis and Sousse, and visited some local consultants who are well acquainted with the present conditions and future implementation plan of ONAS's projects. The JICA Study Team could obtain general information about it, but not the detailed data and information compiled in the form of reports and/or drawings.

MOEH is also implementing the storm water drainage projects in both Greater Tunis and Sousse areas. General features of such projects and several drawings were also collected.

To grasp the relation between water supply and urban drainage system, data concerning water supply were also collected from Water Authority (SONEDE). Water supply to urban and rural areas in the country is autonomously operated and managed by SONEDE since before. Stage-wise development of water supply system has been carried out to date, and now SONEDE is implementing the Eighth Plan which covers five years starting 1992 and ending 1996. Data that show the nation-wide rehabilitation and extension program in this Eighth Plan was obtained, however, area-wide program was not available.

5.2.2 Review of Data Collected

Data collected and information obtained through interviews to staff concerned of ONAS, SONEDE and MOEH, and some local consultants were examined.

It was noticed that storm water drainage and sewerage systems in urban areas in Greater Tunis area have been operated and managed, and rehabilitated by ONAS since before. Every five year, the review of Master Plan had been made, and now is in the Fourth Stage. Modified Master Plan and the Feasibility Study on priority projects are now under finalization, and the final reports will be issued by ONAS soon. The Study Team also requested ONAS to avail the latest data and information studied in the recent study, and MOEH requested ONAS to release it through an official channel, however, it has not been obtained yet. The JICA Study Team intends to consider the study results by ONAS to the maximum extent in the course of formulation of master plan for flood protection program.

In Greater Sousse area, storm water drainage and sewerage systems are also planned, operated and maintained by ONAS. Review of Master Plan was made in 1991/92 by ONAS. It has newly planned to extend the systems to meet the requirement.

As for water supply for both Greater Tunis and Sousse areas, the details of existing facility, supply capacity, served population, etc. are not available. Data obtained from SONEDE show only nation-wide water supply features. It is shown in the papers that:

- Situation at the end of Seventh Plan (1987-1991):

- Total quantity of water supplied	: 196 mil.m3
- Drinking water distribution	: Urban cities - 100 %
	: Rural areas - 33 %
- Served population	: 6,000,000 (73 % of total)

- Eighth Plan (1992-1996):

- Total quantity of water supplied : 217 mil.m3
- Drinking water distribution : Urban cities - 100 %
: Rural areas - 37 %
- Served population : 6,800,000 (76 % of total)

5.2.3 Field Reconnaissance and Findings

Field reconnaissance was made to grasp the actual situation of storm water drainage system and sewerage systems which are being operated by ONAS and MOEH by the JICA Study Team and MOEH's counterpart during the months of March to April, 1993. As a result, it was found the following:

(1) In the urban area, the demarcation of flood control project by MOEH and storm water drainage system by ONAS is not clearly determined. For instance, improvement of Oued Ennkhilet has been planned both by both ONAS and MOEH, and construction works are now under way by MOEH. Similar cases are also observed in Greater Sousse area.

(2) In Greater Tunis area, there exist four sewer treatment plants. Sewer water from central part of Tunis is collected by combined sewerage/drainage system, but remaining are collected by separated sewer pipe network laid and connected to these sewer treatment plants. In view of Tunisia's dry climate and it's limited water resources, the Ministry of Agriculture and some private owners are implementing projects to reclaim a part of treated waste water for irrigation purposes, and the other is discharged to the Mediterranean Sea at the north of Sebkhet Ariana through a canal system. From this viewpoint, it is judged that the quantity of waster water discharging into oueds in the study area is minimal.

(3) In Greater Sousse area, there exist two sewer treatment plants now. The Sousse South Plant (WWTP South) is discharging treated water into Oued Hallouf through pipe culvert. The Souse North Plant (WWTP North) is overloaded, and untreated sewer water is flowing into the sea at the river mouth of Oued Hammam. Moreover, at many places it was observed waste water is discharged into oueds, and it emits bad odor to the surrounding areas. The quantity of this sewer water is not known yet.

(4) As most parts of storm water drainage systems consist of underground structures such as pipes, concrete culvert, manhole, etc., it is rather difficult to grasp the actual situation without referring to detailed drawings of the systems. However it was observed at many places that inlets of such systems are heavily clogged by garbage disposed by local people living nearby. The staff concerned of ONAS Sousse explained the JICA Study Team that a basin of Oued

Maouar is the most problem area. Flood frequently occurs due to poor storm water drainage system. This Oued Maouar exists just between Oued Blibene and Oued Hallouf.

(5) On May 5/6, 1993, the JICA Study Team could have a chance to see the actual situation of storm water drainage system in urban area of central part of Tunis, when storm rainfall with about 100 mm in total occurred. It was observed many roads in the urban area were inundated to several tens centimeters because of poor storm water drainage system, but the duration of such inundation was not so long. It was also observed that many retention ponds existing along the river course are functioning well to mitigate the inundation of the area.

5.3 Present Condition at Greater Tunis and Sousse

5.3.1 Greater Tunis

(1) Existing drainage system and facility

Inventory of existing drainage systems and facilities operated and maintained by ONAS and MOEH has not been obtained.

(2) Urban drainage development plan

ONAS is now finalizing urban drainage development plan by reviewing the third Greater Tunis Sewerage and Drainage Project. It is expected the final results will be disclosed soon.

(3) Institution relating to drainage and water supply

Urban drainage systems in Greater Tunis area are mainly controlled by ONAS, and one part by MOEH. On the other hand, water supply system is fully managed by SONEDE, autonomous government agency under MOA. It seems that each government or autonomous agency is implementing projects independently without adjusting their plans each other.

5.3.2 Greater Sousse

(1) Existing drainage system and facility

Inventory of existing drainage system and facility in Greater Sousse area operated and maintained by ONAS and MOEH has not been obtained. The JICA Study Team requested ONAS and MOEH to provide relevant data.

(2) Urban drainage development plan

Grand Sousse Master Plan for urban drainage had been reviewed by ONAS in 1991/92, and the following storm water drainage network is projected to improve the existing system. The projected storm water drainage network is divided into four parts:

- For northern part: four (4) interceptor sewers, 6,200 m in total (one interceptor by MOEH.
- For the western part: three (3) interceptor sewers, and coastal interceptor sewers.
- The eastern part draining the area of the road to Manastir.
- The southern part for Sousse integrated in the basin of the Oued Hallouf: six(6) interceptor sewers, 9,500 m in total.

(3) Institution relating to drainage and water supply

Institution relating to drainage and water supply is just the same to that of Greater Tunis area, as described herein before.

5.4 Preliminary Design of Urban Drainage System

In urban area of both Greater Tunis and Sousse areas, it has frequently been observed that many urban roads were inundated during storm rainfall due to poor urban drainage system. It mainly comes from insufficient surface drainage system. To minimize the inundation of those urban roads, preliminary design of urban drainage system was made in consideration of the following:

- Peak discharge : 10 m3/s/km2 (0.1 m3/ha)
- Drain slope : S = 1/100 on average
- Type of drain : Rectangular ditch and box culvert (0.25m x 0.25m - 1.6m x 1.6m)
- Minimum lot area: 1 ha

As a result, the construction cost for urban drainage system is roughly estimated to be DT6,800/ha. It was taken into consideration in the study of flood protection program for respective river basins.

CHAPTER 6 ENVIRONMENT

6.1 Institutions, Laws and Regulations

6.1.1 Institutional Structure

The National Environmental Protection Agency (NEPA) created in 1988 and the Ministry of Environment and Land Use Planning established in 1991 are the primary institutions in charge of environmental management and protection in Tunisia. Decrees issued in February and April 1993 define the administrative structure, roles, and responsibilities of these institutions. Other institutions are:

(1) Institutions with a special mandate

These are agencies that are specifically responsible for environmental management in their respective sectors. These include various units of the Ministries of Health, Agriculture, Interior, Economy and Finance, as well as the municipalities, the National Commission on Environment (NCE), and over 30 NGOs.

(2) Institutions with an implicit mandate

These are institutions that are involved indirectly or partially in environmental management. They have a dual role and are specialized in a given area. These include ONAS, ONTT, SONEDE, ARRU etc.

(3) Support institutions

These provide important services for environmental efforts and include research institutions, teaching laboratories and teaching institutions.

6.1.2 Legislative and Regulatory Framework

The legislative and regulatory framework related to the environment in Tunisia is governed by a large number of legal texts and decrees. Three major comments are:

(1) The lack of an overall, integrated legal approach to environmental protection. There is no single Environmental Code but scattered texts (laws, decrees, decisions) dealing with a wide range of fields promulgated over a long time.

(2) The wide range of agencies responsible for environment. The creation of NEPA and the Ministry of Environment and Land Use Planning has not yet had any impact on coordination since the structure of other agencies still remains unchanged.

(3) The partial application of regulations. This is the result of the lack of staff and financial resources as well as a number of legal factors related to the ambiguities of lack of powers granted to the authorities for enforcement of the laws.

6.1.3 Decrees, Laws and Guidelines

Tunisian environmental legislation falls into three broad categories:

(1) for protection of the natural environment: soil, subsoil, forests, inland waterways, marine environment, air, flora and fauna;

(2) for protection of human settlements: conservation, archeological and historical heritage, national parks;

(3) for pollution control: waste, dangerous establishments, chemicals and dangerous substances, noise, harmful smells.

Some relevant laws, decrees, and guidelines concerning environment as related to this flood protection study are as follows:

(a) Forestry Code (1966; revised 1988). This is for protection of forest lands and fauna and flora resources.

(b) The Protection of Agricultural Land Code (1983).

(c) Urban Code (1979) and four procedural documents (1980) for urban development.

(d) Several texts for nuisance control dealing mainly with waste discharge, classified establishments, chemicals and noise levels.

(e) The Water Code was issued in 1975 for protection of inland waterways. Among other measures this code includes a series of prohibitions to prevent pollution of surface water and underground water. It also includes general provisions concerning urban waste water treatment and individual sanitation. The water code is one of the first laws to provide incentives by recommending that State financial aid for industrial development be linked to the obligation to provide adequate water treatment systems and to the "polluter pay principle" to finance waste water disposal and treatment facilities by means of graduated user charges.

(f) In 1985, decree No. 85-56 concerning "Regulation of Abandonment of Waste Water and Waste in the Environment" was enacted. This decree stipulated regulations regarding waste water and waste drained into the environment and penal provisions against the violation of regulation.

(g) The Tunisian Standard, N.T. 106.002, of "Environmental Protection - Waste Water Drained into the Oceans, Rivers and Sewers" was enacted in 1989. These standards stipulate the objects of application of waste water quality standard, analysis of water quality and method of analysis and the standard of waste water allowed to be drained into the sea, rivers and sewers. Some comments concerning these are:

(i) The fight against water pollution rests entirely on the strict norms of allowed discharges.

(ii) The applicable limits of pollutant emissions are fixed only on the basis of the concentration at the discharge point without taking into account the total volume of discharge. Tunisian norms in many cases when compared with international standards are excessively severe and are difficult to achieve taking into account the available technology.

(iii) There is still no inventory and classification of public waters based on water usage or ambient quality.

(h) Decree No. 91-362 was issued in 1991 concerning Impact Studies (Environmental Impact Assessment). This is to regulate the procedures for performing environmental impact studies as a prerequisite before commencing any project activities especially those related to industry, energy, transport and tourism activities. Environmental assessment procedures are not yet defined for various sector activities.

(i) International conventions related to environment ratified by Tunisia.

6.2 Existing Conditions

Tables 6.1 and 6.2 summarize the existing environmental conditions in the river basins of the Greater Tunis and Sousse study area, respectively. Water sampling was conducted at selected locations in the rivers of the study area to determine water quality and supplement field observations. Figs. 6.1 and 6.2 show the locations of the sampling stations and Tables 6.3 and 6.4 present the results.

6.3 Initial Environmental Examination (IEE)

6.3.1 Environmental Baseline Evaluation

This step includes an identification of the important environmental elements, an evaluation of their present condition, and an evaluation of their predicted future condition without the project. Table 6.5 indicates this evaluation for the Greater Tunis study area and Table 6.6 for the Greater Sousse study area.

The scale of importance is an arbitrary scale to evaluate the importance of each environmental element to the problem of flooding in the study area. The importance factor is thus dependent upon the characteristics of the specific areas of river basins and the nature (cause and degree) of flooding problems in them. In Tables 6.5 and 6.6, the importance ratings are given to each environmental element according to the following evaluation criteria:

Rating	Criteria
1 (not important)	un-related to or not affected by flooding
2 (important)	affected to some extent by flooding
3 (very important)	affected significantly by flooding
x (not clear)	may/may not be affected by flooding; further study may be necessary

The scale of present condition is an arbitrary measure to evaluate the current quality level of each environmental aspect determined to be important or very important in the importance rating above. The judgment is based on a comparison with conditions in the past. The scale of present condition evaluation in Tables 6.5 and 6.6 was decided by comparing the present condition with the environment state of the area twenty years ago as follows:

Rating	Criteria
1	worse quality than twenty years ago
2	almost same as twenty years ago
3	better quality than twenty years ago
x	rating not possible due to lack of data; further study may be necessary

The final phase of this baseline evaluation comprises an arbitrary scale determining what the future environmental condition would be without the proposed project. That is, what the environmental susceptibility to management is. The rating system for the predicted future condition in Tables 6.5 and 6.6 is as follows:

Rating	Without Project Impact
	(negative)
-3	high significance
-2	medium significance
-1	low significance
0	no significant impact
x	impact not clear; further study may be necessary
	(positive)
1	low significance
2	medium significance
3	high significance

The ratings of these three phases have been judged based on the environmental preconditions in the project area presented in the earlier section. Those environmental elements receiving an importance rating of 2 or 3 or x, and a present rating of 1 or x, or a future rating of x or +/- 2 to 3 are carried forward to the next evaluation step: environmental compatibility and decision matrix.

6.3.2 Environmental Compatibility and Decision Matrix

This step is an overall assessment designed to preview the possible future environmental disruptions and benefits from the proposed project.

The with project impact rating is the same as for the "future environmental condition without the project" in the Environmental Baseline Evaluation. Table 6.7 summarizes the results for the Greater Tunis study area and Table 6.8 for the Greater Sousse study area.

6.3.3 Environmental Impacts

Table 6.7 presents the results of the IEE for Greater Tunis study area and Table 6.8 for the Greater Sousse study area. The without project (structural measures) option is compared with the with project (structural measures) option. Each alternative plan is considered for each river basin for the with project option. Various structural measures considered are different for each river basin. In general, these include one or a combination of the following: river improvement works, new retention basin, rehabilitation of existing retention basin or dam, new diversion tunnel or channel, and new flood control dam.

(1) Without Project

Without the proposed structural measures, flooding in the Greater Tunis and Sousse study area would continue to cause considerable economic disruption and social hardship to a high proportion of the population, particularly spontaneous housing settlements living in the flood prone low lying areas. Eutrophication of rivers would continue, further impeding normal river flow and thereby increasing the flood prone area. Loss of agricultural crops would continue to occur in flooded agricultural area. Soil erosion and river bed erosion problems would persist. Risk of spreading of water borne diseases after flooding would be high as garbage, industrial waste water and domestic sewage is disposed into many rivers of the study area. Transportation disruption due to floods has been minimal mostly resulting in traffic delays in the past. However this could worsen if no flood control measures are taken with the ever increasing number of vehicles on the roads.

(2) With Project

As seen from Tables 6.7 and 6.8, the proposed structural measures under each alternative plan for each river basin largely lead to positive environmental impacts. The construction of new flood control structures or upgrading and rehabilitation of old structures itself does not result in negative impacts such as resettlement of population. However, in the case of the Choultrana Plain of Ariana in the Greater Tunis study area, the extensive proliferation of spontaneous housing in a low lying area itself is largely the cause of flooding by impeding natural drainage. The same is true in the case of spontaneous housing located in or near Oued Hammam in Sousse area (particularly severe in Oued Laya, near Kalaa Kebira), in the basin of Oued Hallouf (Cite El Ghodrane) and in the basin of Oued Hamdoun near M'Saken. Man made causes of flooding like spontaneous housing in flood prone area, construction of illegal poor culverts, and disposal of industrial waste water, domestic sewage and garbage into the drains need to be tackled by appropriate non-structural measures like defining and enforcing necessary regulations and policies.

Presently, the widespread spontaneous housing problem is being tackled based on a strategy of:

(a) Upgrading rather than the eradication of spontaneous settlements.

(b) Governmental interference in land development and infrastructure provision rather than in housing construction which is left to the household themselves.

(c) Adoption of development standards and levels affordable to low income groups.

(d) The abolition of subsidies in favor of a policy based on cost recovery and the application of actual costs as being the only option for a housing and infrastructure provision policy to meet the needs.

Two alternative plans for Oued Ennkhilet and Sebkhet Ariana, and Oued Gariana and Sebkhet Sijoumi propose land reclamation from Sebkhet Ariana and Sebkhet Sijoumi, respectively. The environmental impacts of land reclamation of the sebkhets need to be determined. Large number of wintering birds particularly flamingoes were seen on several days in March-April in the sebkhets. However, data of observations of type and numbers of wintering birds are lacking. Further, the value of this wildlife to the local population is also not clear. Studies on the appropriateness of the sebkhet ecosystem to support wintering birds to stay for extended periods have not been done. Both Sebkhet Ariana and Sebkhet Sijoumi are basins without overflows that accept rain water during the rainy period. This water is completely evaporated during the drought summer period. Thin sediments remain and the saltiness always increases. Because of the temporary complete drought of the sebkhets, various kinds of food necessary for wintering birds like flamingoes to feed cannot develop. Lake Ichkeul, a national park in the northern part of Tunisia of international significance, has an ecosystem very different from that of the sebkhets. It corresponds more to a freshwater lake than to a lagoon. It undergoes salinity changes which in turn supports various bio-types appropriate for various kinds of wintering birds in selected months of the year.

It is therefore necessary to study in more detail concerning the ecological value of wintering birds like flamingoes in the sebkhets to the local population, and to determine to what extent is the sebkhet ecosystem really capable of supporting wintering birds to come and stay for extended periods. On the basis of these results, the benefits of land reclamation in making increased land available for alleviating the housing shortage especially for low income groups, as well as for necessary resettlement of spontaneous settlements from flood prone areas could be evaluated.

Other major negative environmental impacts of land reclamation of Sebkhet Ariana and Sebkhet Sijoumi are not perceived. Loss of adjoining agricultural land to urbanization needs to be controlled by appropriate institutional measures.

The river improvement works would contribute to improving the river landscape and aesthetics especially since the rivers flow through densely populated urban areas. Prevention of accessibility is not important since the rivers are not used for any purpose. Riverine landscaping of Oued Hammam in Sousse area in the tourist zone is to be done carefully.

The proposed flood control dams and retention ponds in the various oueds would not cause any adverse environmental impacts as eutrophication and prolonged turbidity since water would be stored only during the flood periods.

The salinity of Oued Maliyan is a problem preventing its use for irrigation. Major tributaries of Oued Maliyan are Oued Kebir, Oued Djarabiah and Oued Hamma. In the middle reaches of Oued Maliyan (tributaries Oued Kebir and Djarbiah), the broad flat plain is expanded and an old saline lake exists. During floods, the drainage waters from this area cause the river salinity to rise. The effect of the change that could occur in the salinity of Oued Maliyan due to the proposed alternative flood control measures needs further study.

Along with the proposed structural measures keeping in view the causes of flooding and their negative environmental impacts, non-structural measures are necessary for:

(1) Controlling land use in flood plains for prevention of new spontaneous settlements in flood prone areas and for rehabilitation of existing spontaneous settlements. This can be done by appropriate land use zoning and effective implementation of land policies. Plans for housing zone development catering to low income communities need to be formulated.

(2) Prevention of water pollution due to garbage disposal and domestic and industrial waste water discharges into the drainage system and the oueds. Improved monitoring and strict enforcement of pollution control laws are necessary.

(3) Delaying runoff and increasing infiltration - thereby reducing the risk of flooding. These include watershed management activities (e.g. increasing vegetation cover particularly on slopes, improving agricultural practices, implementing erosion control measures etc.) and planting of vegetation along river banks to contain and reduce flooding.

(4) Prevent or prohibit certain types of structures from being built on the flood way and flood plain to reduce flood risk. This can be done through formulation and implementation of zoning ordinances.

(5) Development of a flood warning system and an evacuation plan for spontaneous housing settlements in vulnerable flood prone areas.

From the above, it is clear that compared with the wholly negative nature of the without project alternative, the social and natural environmental impacts of the proposed project alternatives in each river basin can be judged as being in general more positive than negative. Therefore the alternative plans proposed for each river basin are judged to be acceptable from the environmental point of view provided the major negative impacts mentioned above in specific river basins are addressed using the proposed non-structural measures.

6.4 Environmental Assessment in Selected Priority Projects

6.4.1 Greater Tunis Area

First priority: Oued Maliyan improvement (Oued Hamma river improvement including flood control dam project)

Major environmental aspects to be studied are:

1. Salinity control of Oued Maliyan water,
2. Riverine landscaping, and
3. Spontaneous housing settlements rehabilitation, resettlement and/or evacuation plans.

Second priority: Oued Ennkhilet improvement (lower reaches' channel improvement)

Major environmental aspects to be studied are:

1. Rehabilitation, resettlement and/or evacuation plans for spontaneous housing settlements in low lying Soukra Choultrana area, and
2. Environmental impacts of land reclamation of Sebkhet Ariana, particularly its effect on wintering birds population.

6.4.2 Sousse Area

First priority: Oued Hammam (channel improvement and one of the retarding basins in the upstream reach)

Major environmental aspects to be studied are:

1. Rehabilitation, resettlement and/or evacuation plans for spontaneous housing settlements in or near river bed, and
2. Riverine landscaping in coastal tourist zone.

Second priority: Oued Hallouf (channel improvement)

Major environmental aspects to be studied are:

1. Rehabilitation, resettlement and/or evacuation plans for spontaneous housing settlements in or near river bed, and
2. Riverine landscaping.

CHAPTER 7 RIVER AND FLOOD

7.1 General

Major floods recorded in Tunisia in recent years are those in the years 1969, 1973, 1986 and 1989. The 1969 flood was particularly severe, when officials estimated the damage at 12% of GDP and 300,000 people were affected throughout the country, with an estimated 500 deaths, and 70,000 houses were destroyed. To protect the residential properties and public facilities from these severe floods, some flood protection structural and non-structural measures are urgently required.

The study is to formulate the Master Plan of the flood protection for the seven oueds in Greater Tunis area and four oueds in Greater Sousse area. These river basins have the catchment area from 6 km^2 to 2,000 km^2 and have each characteristic and land use condition. In this Chapter, present river basin conditions, river improvement progress, flood conditions and characteristic for each river are described.

In order to estimate the existing flow capacity, non-uniform flow calculation is applied with the following conditions and assumptions;

(1) Roughness coefficient:	natural river	: 0.035
	concrete lining	: 0.025
(2) Initial water level:	sea level	: El.0.4 m
	Sebkhet Ariana	: El.0.8 m
	Sebkhet Sijoumi	: El.9.5 m
	Link Canal for Oued Greb	: El.0.7 m

7.2 Oueds in Greater Tunis Area

7.2.1 Oued Ennkhilet and Sebkhet Ariana

Oued Ennkhilet and Sebkhet Ariana basin as shown in Fig.7.1 is located at the north of Greater Tunis. Total catchment area of Oued Ennkhilet basin, other river basins that are flowing into Sebkhet Ariana, and Sebkhet Ariana itself is 124 km^2. Each area is as follows;

Catchment Basin	Area (km2)	Ratio(%)
Oued Ennkhilet	17.1	13.7
Other river	73.6	59.2
Sebkhet Ariana	33.7	27.1

Total:	124.4	100.0

Oued Ennkhilet is located at the west of this basin. Housing development in shore area of Sebkhet Ariana and at the hilly area is progressing. This would cause flooding problem. Outlet of Sebkhet Ariana into the sea has sometime clogged by sea wave and/or drifting sand.

Oued Ennkhilet is collecting the water from oueds and running down along the road RVE-533, and flow into the Sebkhet Ariana. River system model of the basin is shown in Fig.7.2. River improvement work has been continuing from the upstream reaches by the MOEH. First and second phases were executed during the years 1990 to 1992, and construction cost for this improvement was approximately estimated at 2.2 million DT. Concrete pipes and rectangular culvert are adopted for these sections. Location and typical section of the improved stretches are shown in Fig.7.3.

Along with this river improvement, Water and Soil Conservation Department of MOA constructed the small dam named Ain Snoussi in the tributary for flood control purpose. Principal features of this dam are as follows:

Catchment	: 1.12 km^2
Dam crest elevation	: El.103 m
Dam crest length	: 74 m
Dam embankment volume	: 5,500 m^3
Spillway crest elevation	: El.101.5 m
Spillway crest length	: 15 m
Flood water level (50-yr)	: El.102.4 m
Storage volume	: 40,000 m^3
Construction cost	: 26,000 DT

Drainage system improvement works in the other river basins are being carried out by ONAS, and three retarding basins were constructed to date along road GP-8.

MOEH had prepared a river improvement plan for the Oued Ennkhilet on March 1991 and is now implementing the project with the minor modification as described in the above. 50-yr flood is adopted for the river improvement plan. Rectangular-shaped concrete canal is proposed for the almost all stretches except downstream end. Location and typical sections are shown in Fig.7.3. Along with this MOEH's proposal, ONAS also studied the Oued Ennkhilet with 10-year flood.

As described in the above, three government agencies *MOEH, MOA* and *ONAS* have each flood control plan and implemented independently for the Oued Ennkhilet. Its demarcation is not clear and close coordination will be required in the future.

To grasp scale of inundation area under existing river condition, the flood runoff distribution at each return period was prepared based on the hydrological analysis in Chapter 3, which is shown in Fig.7.4. Peak discharges of flood runoff into Sebkhet Ariana at 100-year and 10-year return periods are 50 m^3/s and 24 m^3/s under present land use and 80 m^3/s and 40 m^3/s under future land use. The peak discharge of flood in the year 2020 is conceived to be increased up to 1.6 times of that of the present.

To formulate the future river improvement plan, estimate for flow capacity of existing river is necessary. Flow capacity of Oued Ennkhilet is estimated using non-uniform flow calculation based on the above flood runoff distribution. Their results are shown in Figs.7.5 and 7.6. It is obvious that main river has not enough flow capacity even for 1.05-year flood.

Then, flood inundation areas for each return period are assumed based on the above hydraulic analysis, topographical conditions and field reconnaissance. These inundation areas under both present and future land use conditions are presented in Table 7.1 and summarized below. Also, inundation area for 100-year flood under future land use is illustrated in Fig.7.7.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	326	396
10-year	157	191

The potential flood damage is increasing year by year due to recent urbanization, so that some flood control facilities are essential.

7.2.2 Oued Greb

Oued Greb is located between Oued Ennkhilet basin and Oued Gariana basin with a catchment area of 19 km^2 as shown in Fig.7.8. This basin is densely populated area and new housing development in the northern hilly area is rapidly progressing. Flood retarding basin has been constructed together with the housing development.

Oued Greb and its main tributary Oued Roriche are flowing down from northwest to southeast in parallel through the residential area known as El Menzah. Oued Greb has been flowing into the North Tunis Lake formerly. However Oued Greb and the adjacent oueds are now diverted to the South Tunis Lake through the Link Canal along the Liaison Nord-Sud road and pumping station with the capacity of 12 m^3/sec. This system was planned and implemented by ONAS to protect the North Tunis Lake from the pollution. There exist tidal control gates at the outlet of the North Tunis Lake and sea water is circulating now by tidal fluctuation. River system model of Oued Greb is shown in Fig.7.9.

River improvement work has been carrying out by ONAS for this Oued Greb. Channel protection works are basically divided by three types as follows;

Upper to middle reaches	: Concrete pipe or box culvert
Middle reaches	: Concrete lined trapezoidal or rectangular shape
Lower reaches	: Earth lined trapezoidal shape

There are eight (8) retarding basins in the Oued Greb basin as shown in Fig.7.10. It seems these basins are well functioning as flood preventing measures for further downstream reaches. However, garbage disposal into the river channel, especially at the outlet structures is a big problem. Periodical maintenance to remove disposed garbage is required. Principal features of retarding basins are as follows;

Retarding Basin	Capacity (m^3)	Water Depth (m)
Roriche Dam	43,000	1.5
ERO-3	18,200	2.4
ERO-3B	8,750	2.5
ERO-5	15,000	2.0
Greb Dam	47,000	2.9
EGU-4	25,000	2.4
EGU-7	33,000	2.35
Ennasr Basin	9,300	4.2
Total:	209,250	

ONAS is implementing the above flood control and river improvement works as the "Greater Tunis Sewerage and Drainage Project". 10-yr and 50-yr floods are applied for planning the river improvement and retarding basin, respectively. Construction of additional retarding basin and river improvement in the middle reaches are recommended for future implementation.

The flood runoff distribution for Oued Greb basin under existing river facilities is shown in Fig.7.11. Peak discharges of flood runoff into Link Canal along the North Tunis Lake at 100- year and 10-year return periods are 80 m^3/s and 28 m^3/s under future land use and 40 m^3/s and 14 m^3/s under present land use. The peak discharge of flood in the year 2020 is conceived to be increased up to double of that of the present. Fig.7.11 also shows that the existing eight (8) retarding facilities control flood runoff and peak discharge of 100-year flood is reduced from 120 m^3/s to 80 m^3/s at Link Canal.

Oued Greb and its main tributary Oued Roriche have been improved by ONAS. As the result of his effort, these rivers have flow capacity equivalent to 2- to 5-year flood as shown in Figs.7.12 and 7.13. In particular, middle reaches of Oued Roriche has 10-year flood capacity under future land use.

Since both rivers flow down along the gentle valley, inundation areas are not widely spread. These areas are presented in Fig.7.14 and Table 7.1, and is summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	112	159
10-year	34	82

As inundation areas include densely populated area named El Menzah, proper flood control plan is required.

7.2.3 *Oued Gariana and Sebkhet Sijoumi*

Oued Gariana and Sebkhet Sijoumi basin as shown in Fig.7.15 is located at the west of Greater Tunis. Total catchment area of Oued Gariana basin, other river basins that are flowing into Sebkhet Sijoumi, and Sebkhet Sijoumi itself is 241 km^2. Each area is as follows;

Catchment Basin	Area (km2)	Ratio (%)
Oued Gariana	86.5	35.9
Other river	128.8	53.4
Sebkhet Sijoumi	25.8	10.7
Total:	241.1	100.0

Oued Gariana is the biggest one flowing into the Sebkhet Sijoumi and is located at the northern area of this basin. Housing development in the northern hilly area is progressing. This would cause flooding problem in the downstream. There is no outlet from this basin. Old river course can be seen near Ben Arous, however, it is not functioning well at present.

Oued Gariana is collecting the rain water from oueds and flows down in the densely populated area. Agricultural areas are spreading in the upstream reaches. River system model of the basin is shown in Fig.7.16. River improvement works not only for the Oued Gariana but also for other oueds flowing into the Sebkhet Sijoumi have been carried out by ONAS. Rectangular or trapezoidal shaped channels with the concrete or wet masonry lining are basically applied in the middle to lower reaches. Concrete pipe or box culvert is adopted in the upper reaches of the improved section.

There are eight (8) retarding basins in the Oued Gariana basin as shown in Fig.7.17. These basins seem to be good flood preventing measures for further downstream reaches. However, garbage disposal problems are observed especially at the outlet structures. Principal features of retarding basins are as follows;

Retarding Basin	Capacity (m3)	Water Depth (m)
EBA-3	65,000	2.9
EBA-4	34,000	2.3
Ettamhden	14,000	3.2
EGE-3	48,500	1.85
EGE-2	48,000	1.7
Douar Hicher	37,000	4.2
EGE-6	59,000	2.15
EBA-2	53,000	1.2
Total:	358,500	

ONAS is implementing the above flood control and river improvement works as the "Greater Tunis Sewerage and Drainage Project". Construction of additional five (5) retarding basins, expanding of two (2) existing retarding basins and river improvement is planned for future implementation.

The flood runoff distribution for Oued Gariana basin under existing river facilities is shown in Fig.7.18. Peak discharges of flood runoff into Sebkhet Sijoumi at 100-year and 10-year return periods are 500 m^3/s and 210 m^3/s under future land use and 240 m^3/s and 80 m^3/s

under present land use. The peak discharge of flood in the year 2020 is conceived to be increased up to more than double of that of the present. Fig.7.18 also shows that the existing eight (8) retarding facilities control flood runoff and peak discharge of 100-year flood is reduced from 600 m^3/s to 500 m^3/s at Sebkhet Sijoumi.

Oued Gariana and almost all the tributaries have only flow capacity equivalent to 1- to 2-year flood as shown in Figs.7.19 and 7.20. In particular, downstream stretch from confluence between Oued Gariana and Tributary-2 has less than 1.05-year flood capacity. Inundation area around the confluence is, then, widely spread as shown in Fig 7.21 and Table 7.1, and is summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	227	412
10-year	153	278

The potential flood damage is increasing year by year due to recent urbanization, so those flood control facilities for entire river stretches are essential.

7.2.4 Oued Maliyan

Oued Maliyan as shown in Fig.7.22 is the biggest one in Greater Tunis area with river length and river basin area. Total catchment area of this basin is 1,996 km^2. Hilly or flat areas in the basin are mainly used as agricultural land. Major problems in this basin are flood inundation in the downstream reaches and salinity in river water. High saline water is not suitable for irrigation and the low flow is not used effectively.

Oued Maliyan is flowing down from southwest to northeast. Its major tributaries are Oued Kebir, Oued Djarabiah and Oued Hamma. In the middle reaches of Oued Maliyan, the broad and flat plain are expanded and some old sebkhets (saline lake) exist in this area. River system model of the basin is shown in Fig.7.23.

MOA constructed the Bir M'Cherga Dam in 1971 in the middle reaches for the flood control purpose, because the downstream agricultural areas have been often inundated by the flood water. Principal features of the Bir M'Cherga Dam are follows;

Catchment area	: 1,398 km^2
Dam volume	: 1,300,000 m^3
Dam height	: 41.5 m
Dam crest length	: 1,300 m

Dam crest elevation	: El.137.5 m
Flood control (100-yr)	: Peak inflow 1,700 m^3/s
	: Peak outflow 100 m^3/s
Flood control storage(100-yr)	: 113,000,000 m^3

Along with this Bir M'Cherga Dam, there exists Kebir Dam in the upper reaches. This Kebir Dam was constructed in 1920 and the first large dam in Tunisia. Main purpose was a water supply to Tunis when it was constructed, however this water supply function is now for only downstream towns. Approximately 60 to 70 % of storage volume are occupied by the sediments. In 1969, one of the biggest flood occurred and flood water reached at almost the dam crest, then MOA lowered the spillway crest by 1.5 m after this event for the dam safety.

In the downstream reaches, MOA has been constructing the river dike just along the ravine from river mouth to the confluence with the Oued Hamma. However no proper river improvement plan is available at this section.

Recent flood inundation has occurred at the confluence with the Oued Hamma to the downstream and major flood water was observed coming from the Oued Hamma as illustrated in Fig. 7.24. To control the flood water from the Oued Hamma and for the irrigation water supply, MOA has a plan to construct the Hamma Dam in the middle reaches. Principal features of this dam are follows;

Catchment area	: 123 km^2
Dam volume	: 1,060,000 m^3
Dam height	: 24 m
Dam crest length	: 1,200 m
Dam crest elevation	: El.108.4 m
Flood control (100-yr)	: Peak inflow 427 m^3/s
	: Peak outflow 145 m^3/s
Flood control storage(100-yr)	: 7,650,000 m^3
Water supply storage	: 8,000,000 m^3

The flood runoff distribution for Oued Maliyan basin under existing river facilities is shown in Fig.7.25. Peak discharges of flood runoff into the Mediterranean Sea at 100-year and 10-year return periods are 1,500 m^3/s and 750 m^3/s under both present and future land uses. Fig.7.25 also shows that flood control effect of Bir M'Cherga Dam extends to confluence to Oued Hamma but downstream stretch of Oued Maliyan is dominated by runoff from Oued Hamma.

The middle and upstream stretches of Oued Maliyan have sufficient flow capacity for more than 100-year flood but downstream stretch from confluence to Oued Hamma has 2- to 5-year flood capacity as shown in Figs. 7.26 and 7.27. Oued Hamma has around 1.05-year flood capacity.

Inundation occurs particularly at around confluence of Oued Maliyan and Oued Hamma and flood water flows down to downstream end of this basin since inland slope is slightly steep. These estimated flood areas are shown in Fig.7.28 and Table 7.1, and are summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	7,300	7,300
10-year	2,630	2,630

A remarkably extensive inundation area is conceivable although rapid urbanization has not progressed in this basin. It is desirable to carry out flood control as soon as possible.

7.2.5 Oued Mayzette

Oued Mayzette is located between the lower reaches of the Oued Maliyan and Ez Zahra town with a catchment area of 7 km^2 as shown in Fig. 7.29. Upper reaches named Oued Mornag flowed into the Oued Mayzette formerly, however this river is now diverted to the Oued Maliyan at GP-1 road. Densely populated area known as Ez Zahra is located on the right bank side in the downstream reaches, and this area has been often inundated due to poor drainage system and low lying area.

There is a natural river course in the downstream from GP-1 road and vast swamp areas are spreading near railway crossing. No river course exists in the upper reaches from GP-1 road. River system model of the basin is shown in Fig.7.30.

On the right bank, there is a river dike with a height of approximately 1 m to 1.5 m. No other river improvement work is observed. ONAS is preparing the drainage improvement plan for this basin, however this plan does not cover the main stream of Oued Mayzette.

There is no prospective retarding basin site, then river improvement plan only will be studied for formulating the Master Plan. Judging from the topographic and land use conditions, new river course along GP-1 road is selected as shown in Fig.7.31.

The flood runoff distribution for Mayzette basin under existing river facilities is shown in Fig.7.32. Peak discharges of flood runoff into the Mediterranean Sea at 100-year and 10-year return periods are 35 m^3/s and 18 m^3/s under future land use and 22 m^3/s and 12 m^3/s under present land use. The peak discharge of flood in the year 2020 is conceived to be increased up to around 1.6 times of that of the present.

Oued Mayzette flows down to river mouth changing its figure so many times and then flow capacity scatters from less than 1.05-year flood to more than 100-year flood as seen in Figs.7.33 and 7.34. Inundation area spreads upstream area of GP-1 road and railway as shown in Fig 7.35 and Table 7.1, and is summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	108	191
10-year	39	70

The potential flood damage is increasing year by year due to recent urbanization, so that flood control facilities are necessary.

7.2.6 Oued Bou Khamsa

River basin of the Oued Bou Khamsa is located in the upstream of the Ez Zahra with a catchment area of 6.2 km^2 as shown in Fig.7.36. Housing development in the hilly area is progressing. This would cause flooding problem. Densely populated area known as Ez Zahra is located on left bank in the lower reaches and this area has been often inundated due to poor drainage system and low lying area.

Oued Bou Khamsa is a short river with the earth lining and its length is approximately 800 m from MC-33E road to river mouth. Drainage culvert from the Oued Mellasine, which has a retarding basin in upper reaches, is connected to this river at the railway crossing. No river course exists in the upstream from MC-33E road. River system model of the basin is shown in Fig.7.37.

MOEH prepared a river improvement plan for the Oued Bou Khamsa on October 1988, however no river improvement work has been made to date. 50-yr flood is adopted for this plan. Rectangular-shaped channel or concrete pipe are proposed for the upper reaches and trapezoidal section is applied in the lower reaches. Location and typical sections are shown in Fig.7.38. Along with this MOEH's proposal, ONAS also studied river improvement of the Oued Bou Khamsa for 10-yr flood.

The flood runoff distribution for Oued Bou Khamsa basin under existing river facilities is shown in Fig.7.39. Peak discharges of flood runoff into the Mediterranean Sea at 100-year and 10-year return periods are 40 m^3/s and 18 m^3/s under future land use and 22 m^3/s and 10 m^3/s under present land use. The peak discharge of flood in the year 2020 is conceived to be increased up to double of that of the present.

Almost all the stretch of Oued Bou Khamsa has insufficient flow capacity even for 1.05-year flood as seen in Figs.7.40 and 7.41. Inundation area spreads between GP-1 road and railway as shown in Fig 7.42 and Table 7.1, and is summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	88	176
10-year	63	126

The potential flood damage is increasing year by year due to recent urbanization, so that flood control facilities are necessary.

7.2.7 Oued Ain Zerga

Oued Ain Zerga is located at Hammam Lif with a catchment area of 4.2 km^2 as shown in Fig.7.43. Housing development in the hilly and the coastal areas are rapidly progressing. Housing area along GP-1 road and the coastal zone has been often inundated due to poor drainage system and low lying area. Upstream reaches are covered by the forest of national park.

Oued Ain Zerga forms the ravine in middle to upper reaches, however there is no river course in the downstream from GP-1 road. River system model of the basin is shown in Fig.7.44.

MOEH prepared a river improvement plan for the Oued Ain Zerga in 1979 and is now constructing the river channel in the lower reaches. This river improvement with the total length of 1,120 m is scheduled to be completed in 1994. Box culvert with the dimension of 2.2 m x 0.8 m and 2.5 m x 0.6 m are applied under the town road. Location and typical sections are shown in Fig.7.45.

The flood runoff distribution for Oued Ain Zerga basin under existing river facilities is shown in Fig.7.46. Peak discharges of flood runoff into the Mediterranean Sea at 100-year and 10-year return periods are 35 m^3/s and 18 m^3/s under future land use and 22 m^3/s and 12

m^3/s under present land use. The peak discharge of flood in the year 2020 is conceived to be increased up to almost 1.6 times of that of the present.

All the stretches of Oued Ain Zerga have insufficient flow capacity even for 1.05-year flood as seen in Figs.7.47 and 7.48. Inundation area spreads low lands around GP-1 road as shown in Fig 7.42 and Table 7.1, and is summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	29	39
10-year	14	18

The potential flood damage is increasing year by year due to recent urbanization, so that flood control facilities are necessary.

7.3 Oueds in Greater Sousse Area

7.3.1 Oued Hammam

Oued Hammam basin is located at the northwestern and western region of the Greater Sousse with a catchment area of 222 km^2 as shown in Fig.7.50. Four major towns, i.e. Kalaa Srira, Kelaa Kebira, Akouda and Hammam Sousse are located along this oued and suffered from flood inundation from time to time. River basin is widely used as agricultural land, and its main product is olive. Very flat plain is spreading in the upstream reaches and river courses are not clear in these areas.

Oued Hammam is collecting the flood water from the tributaries such as Oued Laia, Oued M'Derraj, and Oued Guemgame, and flows down in the urbanized area. River system model of the basin is shown in Fig.7.51. Lower reaches are provided by dikes on both banks. Length of improved section is approximately 350 m and a bottom width is 56 m. River bottom has been placed by excessively large-sized rocks to cover exposed polluted stagnant water in river channel. This river improvement was carried out by the Ministry of Tourism under the guidance of MOEH. Upstream of this improved section has been left under natural condition in which flooding might occur easily.

MOEH prepared a flood control plan for the Oued Hammam in 1990. Flood control structures against 100-yr flood are recommended. Location and typical sections of these facilities are shown in Fig.7.52. Three small dams i.e., Laia Dam, M'Darrej Dam and Guemgame Dam located on each tributary are studied for flood control purposes.

The flood runoff distribution for Oued Hamma basin under existing river facilities is shown in Fig.7.53. Peak discharges of flood runoff into the Mediterranean Sea at 100-year and 10-year return periods are 200 m^3/s and 95 m^3/s under future land use and 170 m^3/s and 75 m^3/s under present land use. The peak discharge of flood in the year 2020 is conceived to be increased up to almost 1.2 times of that of the present.

Most of the downstream and upstream stretches of Oued Hammam have sufficient flow capacity for 100-year flood but middle reach around confluence to Oued Kebir has flow capacity equivalent to 1- to 5-year flood as shown in Figs.7.54 and 7.55. Most of the stretch of Oued Kebir and Oued M'darrej has sufficient flow capacity for 100-year flood, except confluence stretch to Oued Guemgame.

Inundation occurs at around confluence of Oued Hammam and Oued Kebir and flood water flows down to downstream end of this basin since inland slope is slightly steep. These estimated flood areas are shown in Fig.7.56 and Table 7.1, and is summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	270	320
10-year	127	150

The potential inundation area is extensive and it is increasing year by year. It is desirable to carry out flood control as soon as possible.

7.3.2 Oued Blibene

Oued Blibene basin is located at the west of Greater Sousse as shown in Fig. 7.57 with a catchment area of 15 km^2. Eastern area of the basin is occupied by the residential or commercial zone. On the other hand, vast agricultural land mainly olive field is spreading in the eastern area. Housing development in this agricultural area is progressing. This would cause flooding problem in the downstream reaches. This river is small , however it down-most reach is very important area for resort purpose. Careful flood control study is required.

MOEH has constructed its river channel in the lower-most reaches with concrete lined channel. Its improved length is 270 m with a bottom width of 10 m. However right bank is not yet constructed. This right bank will be constructed with some future development plan. There is earth-lined channel with dike between GP-1 and Touristic roads. Its length is approximately 430 m with a bottom width of 50 m. Location and typical sections are shown in Fig.7.59. Just upstream of it is almost same condition with the Oued Hammam and oued has been left under natural condition. There is a ravine with a height of 3 m to 4 m in the middle reaches, however no river course exists in the upstream agricultural area. Some small drainage improvement has been executed in the urban area by MOEH. River system model of the basin is shown in Fig.7.58.

MOEH prepared a preliminary river improvement plan on 1990. River improvement against 50-yr flood is proposed for main stream and 10-yr flood is proposed for upper reaches small channel. According to that study, no river improvement is required in the middle reaches because of enough flow capacity. This will be confirmed in the Study. ONAS also prepared the drainage plan for the upper reaches for 10-yr flood.

The flood runoff distribution for Oued Blibene basin under existing river facilities is shown in Fig.7.60. Peak discharges of flood runoff into the Mediterranean Sea at 100-year and 10-year return periods are 85 m^3/s and 40 m^3/s under future land use and 55 m^3/s and 26 m^3/s under present land use. The peak discharge of flood in the year 2020 is conceived to be increased up to almost 1.5 times of that of the present.

The most of the stretch of Oued Blibene and its tributary have sufficient flow capacity for 100-year flood as seen in Figs.7.61 and 7.62. Inundation occurs at downstream stretch from confluence to Tributary-2 as shown in Fig 7.63 and its area is shown in Table 7.1 and summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	23	31
10-year	13	17

The potential flood damage in this basin is conceived to be not serious.

7.3.3 Oued Hallouf

Oued Hallouf basin is located at the south of Greater Sousse as shown in Fig. 7.64 with a catchment area of 12 km^2. Northern area of the basin is residential and commercial zones of Greater Sousse. Urbanization of Sousse is spreading to the surrounding agricultural area of this basin. This would cause flooding problem in the downstream. This river is a small river. It may not be called as a river but just a drainage channel for domestic waste water. Polluted water with bad smell can be observed. Some countermeasures by some institutional means are essential.

Oued Hallouf has been left under natural condition and no river improvement has been implemented. There is a natural river course in the lower reaches, however no river course in the upper agricultural area. Some drainage improvement work has been made in the urban area by ONAS. River system model of the basin is shown in Fig.7.65.

MOEH prepared a river improvement plan on 1990 and 50-yr flood is adopted for this Oued Hallouf. Rectangular-shaped concrete channel is applied in the upper reaches and the trapezoidal section is proposed in the lower reaches. Location and typical sections are shown in Fig.7.66. ONAS also prepared the drainage plan for the upper reaches for 10-yr flood.

The flood runoff distribution for Oued Hallouf basin under existing river facilities is shown in Fig.7.67. Peak discharges of flood runoff into the Mediterranean Sea at 100-year and 10-year return periods are 130 m^3/s and 60 m^3/s under future land use and 70 m^3/s and 35 m^3/s under present land use. The peak discharge of flood in the year 2020 is conceived to be increased up to almost double of that of the present.

The downstream stretch of Oued Hallouf has flow capacity equivalent to more than 2-year flood as seen in Figs.7.68 and 7.69, but the upstream stretch is not developed yet as a flood drainage. Since Oued Hallouf flows down along the gentle valley, inundation area is not widely spread. This area is presented in Fig.7.80 and Table 7.1, and is summarized as below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	61	77
10-year	38	54

The potential flood damage is increasing year by year due to recent urbanization, so that flood control facilities are necessary.

7.3.4 Oued Hamdoun

Oued Hamdoun basin is located at the southwestern region of Greater Sousse with a catchment area of 313 km^2 as shown in Fig.7.71. Msaken that is the major town in this region is located at the center of this basin. Olive production and its processing are the main industry in this area. Very flat plain is spreading in the upstream reaches and river courses are not clear in the area. This river is also too much polluted by waste water from factories and a lot of garbage appear in its middle to lower reaches.

Oued Hamdoun is collecting the flood water from the tributaries such as Oued Melah, Oued Chergui, Oued Deiik, and Oued Grab, and flows down to the Mediterranean Sea. River system model of the basin is shown in Fig.7.72. There is no artificial flood control facility along the main stream.

The flood runoff distribution for Oued Hamdoun basin under existing river facilities is shown in Fig.7.73. Peak discharges of flood runoff into the Mediterranean Sea at 100-year and 10-year return periods are 240 m^3/s and 110 m^3/s under future land use and 220 m^3/s and 100 m^3/s under present land use. The peak discharge of flood in the year 2020 is conceived to be almost same as that of the present.

Almost all the stretch of Oued Hamdoun has flow capacity equivalent to more than 1.05 year flood as seen in Figs.7.74 and 7.75. The river reservation of Oued Hamdoun is relatively wide and inundation occurs along the reservation. These are shown in Fig 7.76 and its area is presented in Table 7.1 and summarized below.

	Flood Inundation Area (ha)	
Return Period	Present Land Use	Future Land Use
100-year	277	293
10-year	192	206

Since rapid urbanization is not progressed in this basin, potential flood damage in the year 2020 is conceived almost same as the present.

CHAPTER 8 FLOOD CONTROL PLAN

8.1 Conditions

Following basic design conditions and criterion are applied for preparing the flood control plan.

1) Basic design flood is to be taken at 100-yr flood for the all rivers and those secondary channels.
2) 10-yr flood is to be adopted for the tertiary or drainage channels.
3) Stage-wise development
   i) First step development is to be considered on the basis of 10-yr flood for river improvement.
   ii) Dam and retarding basin developments are to be considered on the basis of 100-yr flood even in the first step development.
   iii) River or channel width should be kept sufficient for 100-yr flood for future development.
   iv) Determination of the priority river stretches is based on that not to cause the adverse effect in the downstream reaches.

8.2 Preliminary Design of Flood Control Measures

For designing the river facilities and flood control dams, the following basic design criteria are applied, except for Hamma dam in Oued Maliyan, the basic design of which has already been completed.

(1) River Facilities
   i) Existing river course is adopted as much as possible.
   ii) Present river or ground profile is basically introduced for designing the river profile.
   iii) Deepening of river bed is basically introduced for urban rivers not to cause the inner water and the flood water level is kept lower or almost same with the ground level.
   iv) In case the flood water level is higher than the ground level, following freeboard is principally applied.

200 m^3/s > Design Discharge	: 0.6 m
500 m^3/s > Design Discharge >200 m^3/s	: 0.8 m
2,000 m^3/s > Design Discharge >500m^3/s	: 1.0 m

iv) River cross section is decided considering the land use condition along river course, existing structures, design flow velocity and etc. Typical cross sections are illustrated in Fig.8.1.

v) Non-uniform flow is applied for channel flow calculation. The following roughness coefficient is adopted.

n = 0.035............. for natural and earth lined river

n = 0.025............. for concrete lined river

n = 0.023............. for concrete lined tunnel

vi) Following initial water level is applied for channel flow calculation.

Sea level................................ El. 0.4 m

Sebkhet Ariana......................... El. 0.8 m

Sebkhet Sijoumi....................... El. 9.5 m

Link Canal for Oued Greb........... El. 0.7 m

(2) Retarding Basin and Dam

i) Flood control single purpose dam or retarding basin is planned except Hamma dam. Hamma dam scheme proposed by MOA is introduced without modification in this study.

ii) Surcharge water level (SWL) is estimated from the required flood control space of a 100-yr flood. Non-gated outlet structure is introduced in the Study.

iii) 1.2 times of calculated flood control space is adopted for design flood control space in considering the allowance.

iv) Topographical and geological points of view, earth fills type is introduced for dam or retarding basin dike. Slope of 1: 3.0 and 1: 2.5 are applied for upstream and downstream slopes respectively.

v) Non-gated overflow type is provided for spillway. 100-yr flood discharge without retarding effect is applied for this spillway.

8.3 Construction Cost

The construction cost for the alternative study of Master Plan was estimated on the basis of following conditions and assumptions.

(1) Estimate dateline

April 1993 when the time of cost survey in Tunisia was made.

(2) Exchange rate

US \$ 1.0 = DT 0.97 = Yen 110.0

(3) Unit construction cost

Unit construction cost of respective work item is estimated based on the prevailing cost of construction fields in Tunisia referring to collected cost data. Unit cost estimated for major construction work items is shown in Table 8.1.

(4) Estimated cost is expressed by US Dollar equivalent.

(5) Construction works will be conducted by selected contractor(s) through international and/or local competitive tender.

(6) Hamma dam proposed by MOA is planned for multipurpose dam of irrigation and flood control. Allocated construction cost is applied for flood control purpose.

(7) Construction cost of tertiary or urban drainage channels are assumed 6,800 DT/ha.

(8) First stage for 10-yr flood) and Second stage (for 100-yr flood) are assumed to be completed within the years 2000 and 2020, respectively.

(9) Following provisions are made for estimating the project cost;

- Miscellaneous works	: 15% of the sum of the estimated cost
- Preparatory works	: 8% of the sum of the estimated cost of the civil works including miscellaneous works
- Engineering services	: 10% of the direct construction cost
- Government administration	: 5% of the sum of the direct construction cost, land acquisition and compensation cost
- Contingency	: 15% of the all cost

8.4 Alternative Study

8.4.1 Oued Ennkhilet and Sebkhet Ariana

To formulate the Master Plan of the Oued Ennkhilet and Sebkhet Ariana, the following flood control plans are conceived as the alternative plans. There is a possibility to reclaim the water surface of the Sebkhet Ariana for housing or other land use. This idea is incorporated in the alternative plans;

1) ENK-1	: River improvement with Ain Snoussi Dam and Retarding Basin A. Sebkhet Ariana is remained as it is.
2) ENK-2	: River improvement with Ain Snoussi Dam. Sebkhet Ariana is remained as it is.
3) ENK-3	: River improvement with Ain Snoussi Dam, and with or without Retarding Basin A. Sebkhet Ariana will be reduced by half with widening of outlet structure.

4) ENK-4 : River improvement with Ain Snoussi Dam, and with or without Retarding Basin A. Sebkhet Ariana will be reduced as much as possible with widening of outlet structure.

Above alternative plans are illustrated in Fig.8.2.

At first, water level of Sebkhet Ariana is simulated by applying the 100-yr probable flood which was estimated in Chapter 3. The simulation is conducted by flood routine method under conditions of the present river facilities and future land use (Year 2020). An initial water level for the simulation is set at El. 0.4 m as same as sea water level. A storage volume curve of Sebkhet Ariana is prepared by using the topographical map of 1 : 25,000 scales. Surface area and effective storage volume above El. 0.4 m are as follows;

Area and Effective Storage Volume of Sebkhet Ariana

Elevation (m)	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Surface Area (km^2)	25.1	26.5	28.0	29.4	30.8	32.3	33.7
Effective Volume ($Mil.m^3$)	0.0	2.6	5.3	8.2	11.2	14.3	17.6

As illustrated in Fig.8.3, maximum water level during the flood reaches at around El. 0.72 m with the existing outlet structures. This level is less than the assumed allowable flood water level of Sebkhet Ariana (El. 0.8 m) which is judged from topographical map of 1 : 5,000 scale, survey result for Oued Ennkhilet and site reconnaissance. It is conceived that no flood damage in surrounding area of Sebkhet Ariana will occur under the above condition.

The simulation is also conducted for 3 cases that 30 %, 50 % and 70 % of surface area of Sebkhet Ariana is reduced by land reclamation. As shown in Fig.8.3, maximum flood water level in case of lake area reduction 30 % is lower than the El. 0.8 m, therefore this plan would not bring about the inundation problem along the shore area. On the other hand, flood water will exceeds the allowable water level in cases of 50 % and 70 % in early time of the flood, so that some improvement work at the existing outlet structure is necessary. Required improvement works and its project costs are as follows;

Items		Alternative ENK-3 (50 % Reduction)	Alternative ENK-4 (70 % Reduction)
Required Improvement Works			
- Connection canal,	Width (m)	10	60
	Length (m)	300	300
- New bridge,	Span (m)	16	71
Project Cost (DT)		302,000	1,556,000

On the basis of the hydrological analysis, the flood runoff distribution for each alternative cases is prepared. As shown in Fig.8.4, flood retarding effect by Ain Snoussi dam and Retarding Basin A is not expected at the lower reaches. However, these flood regulation facilities are located just upstream the densely populated area and good flood control effect is expected along there. River facilities that have the carrying capacity of 40 m^3/s to 65 m^3/s are required along RVE-533 road for 100-yr flood river improvement plan.

By applying the design criteria described before and flood runoff distribution, preliminary design and the construction volume estimate are executed for each alternative cases. After all, the construction costs are estimated by adopting the unit construction cost. Following table shows the comparison of construction cost for each alternative.

Construction Cost of Alternative Cases for Oued Ennkhilet

(Unit : 1,000 DT)

	Item	ENK-1	ENK-2
I	Preparatory Works	1,254	1,300
II	River Improvement	15,496	16,253
III	Dam or Retarding Basin	179	0
	Sub-Total of I to III	16,929	17,553
IV	Land Acquisition & Compensation	2,273	2,304
V	Engineering Service	1,693	1,755
VI	Government Administration	960	993
VII	Contingency	3,278	3,391
	Total	25,133	25,996
VIII	Urban Drainage (886 ha)	6,025	6,025

As shown in the above table, construction cost of Case ENK-1 is lower than the other. From the technical and economical points of view, this ENK-1 plan is selected for Master Plan of Oued Ennkhilet. Along with the above river improvement development, urban drainage works is required because rapid urbanization is progressing in this basin. Direct construction cost required for this urban drainage is estimated to be approximately 6 million DT until the year 2020.

Figs.8.5 and 8.6 show the plan and longitudinal profile with the sections of the selected alternatives. Earth lined section is applied in the lower reaches and box culvert is applied in the middle reaches considering the availability of river reserve. One lane box culvert is planned in the First stage (for 10-yr flood) and additional box culvert with the same dimensions is planed in the Second stage (for 100-yr flood) as shown in Fig.8.6. Construction of the Retarding Basin A is planned in the First Stage. Principal features of Oued Ennkhilet improvement plan are as follows;

Principal Features of Oued Ennkhilet River Improvement

Items	First Stage	Second Stage
I Length of River Improvement		
- Earth lining (m)	7,365	4,909
- Concrete rectangular (m)	0	2,456
- Box culvert (m)	3,671	3,671
Total (m)	11,036	11,036
II Construction Volume		
- Excavation (m^3)	201,000	143,200
- Embankment (m^3)	68,100	60,300
- Concrete (m^3)	22,650	27,950
III Dam and Retarding Basin		
- No.of new dam or retarding basin	1	0
- No.of exist.retarding basin to be expanded	0	0
- Total flood control storage (m^3)	25,500	0
- Total surface area (m^2)	5,100	0
- Total excavation (m^3)	5,150	0
- Total embankment (m^3)	9,800	0
III Urban Drainage (ha)	223	663

Required construction cost related to the above improvement works are shown in Table 8.2 and summarized as below;

Summary of Construction Cost for Oued Ennkhilet

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	656	598	1,254
II	River Improvement	8,020	7,476	15,496
III	Dam or Retarding Basin	179	0	179
	Sub-Total of I to III	8,855	8,074	16,929
IV	Land Acquisition & Compensation	1,914	359	2,273
V	Engineering Service	886	807	1,693
VI	Government Administration	538	422	960
VII	Contingency	1,829	1,449	3,278
	Total	14,022	11,111	25,133
VIII	Urban Drainage(Direct Const. Cost)		(886 ha)	6,025

8.4.2 Oued Greb

Judging from the topographic and land use conditions, the following flood control plans are conceived as the alternative cases for Oued Greb. Rehabilitation of existing dams and expanding of existing retarding basin are included in these cases;

1) GB-1 : River improvement with existing retarding basins.
2) GB-2 : River improvement with existing and additional retarding basins.
3) GB-3 : River improvement with existing and additional retarding basins, and rehabilitation and expanding of existing dams and retarding basins.

Above alternative plans are illustrated in Fig.8.7.

On the basis of the hydrological analysis, the flood runoff distribution for each alternative case is prepared. As shown in Fig.8.8, much flood retarding effect by existing and/or proposed retarding basins are expected at the downstream reaches. Comparing the alternative GB-1 and GB-3, peak runoff of GB-3 is approximately 80% of that of GB-1 at the junction with the Link Canal.

By applying the design criteria described before and flood runoff distribution, preliminary design and the construction volume estimate are executed for each alternative case. After all, the construction costs are estimated by adopting the unit construction cost. Following table shows the comparison of construction cost for each alternative.

Construction Cost of Alternative Cases for Oued Greb

(Unit : 1,000 DT)

	Item	GB-1	GB-2	GB-3
I	Preparatory Works	640	590	569
II	River Improvement	8,004	7,139	6,657
III	Dam or Retarding Basin	0	230	454
	Sub-Total of I to III	8,644	7,959	7,680
IV	Land Acquisition & Compensation	3,410	3,130	3,130
V	Engineering Service	864	796	768
VI	Government Administration	603	554	541
VII	Contingency	2,028	1,866	1,818
	Total	15,549	14,305	13,937
VIII	Urban Drainage (1,490 ha)	10,132	10,132	10,132

As shown in the above table, construction cost of Case GB-3 is the lowest among three alternatives. From the technical and economical points of view, this GB-3 plan is selected for Master Plan of Oued Greb. Along with the above river improvement development, much urban drainage works is also required in this river basin because rapid urbanization is progressing in the hilly area. Direct construction cost required for this urban drainage is estimated to be approximately 10 million DT until the year 2020.

Figs.8.9 and 8.10 show the plan and longitudinal profile with the sections of the selected alternatives. Earth lined section is applied in the lower reaches and rectangular section is applied in the middle reaches considering the availability of river reserve. River improvement works are not required in the middle reaches of Oued Roriche for the First Stage because these stretches have enough carrying capacity as shown in Fig.8.10. Construction of the Retarding Basin A and expansion of ERO-3 and ERO-5 are planned in the First Stage. Flood control effect by rehabilitation of Greb and Roriche Dams is negligibly small and that plan is not incorporated. Principal features of Oued Greb improvement plan are as follows;

Principal Features of Oued Greb River Improvement

Items	First Stage	Second Stage
I Length of River Improvement		
- Earth lining (m)	2,892	1,501
- Concrete rectangular (m)	933	5,270
- Box culvert (m)	1,412	1,412
Total (m)	5,238	8,183

II	Construction Volume		
	- Excavation (m^3)	40,500	117,400
	- Embankment (m^3)	10,000	0
	- Concrete (m^3)	6,480	22,230
III	Dam and Retarding Basin		
	- No.of new dam or retarding basin	1	0
	- No.of exist.retarding basin to be expanded	2	0
	- Total new flood control storage (m^3)	109,400	0
	- Total new surface area (m^2)	29,500	0
	- Total excavation (m^3)	60,800	0
	- Total embankment (m^3)	5,700	0
III	Urban Drainage (ha)	710	780

Required construction cost related to the above improvement works are shown in Table 8.3 and summarized as below;

Summary of Construction Cost for Oued Greb

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	171	398	569
II	River Improvement	1,689	4,969	6,657
III	Dam or Retarding Basin	454	0	454
	Sub-Total of I to III	2,314	5,367	7,680
IV	Land Acquisition & Compensation	1,670	1,460	3,130
V	Engineering Service	231	537	768
VI	Government Administration	199	341	541
VII	Contingency	662	1,156	1,818
	Total	5,076	8,861	13,937
VIII	Urban Drainage(Direct Const. Cost)		(1,490 ha)	10,132

8.4.3 Oued Gariana and Sebkhet Sijoumi

There is no outlet from this basin now as described before and this situation has a possibility to cause some flood problems along the lake shore of the Sebkhet Sijoumi. Furthermore no flood control study was carried out for this sebkhet to date. Judging from the topographic and land use conditions, the following alternative flood control plans are conceived. Diversion channel plans from the Sebkhet Sijoumi are included in these alternative plans. There is a possibility to reclaim the water surface for housing or other land use. This idea is also incorporated in the alternative plans;

1) GR-1 : River improvement with existing retarding basins.

2) GR-2 : River improvement with existing and additional retarding basins, including expansion of existing retarding basins.

3) GR-3 : Diversion tunnel to South Tunis Lake, with Sebkhet Sijoumi reduced 15 % or 30 %, with above GR-1 or GR-2 conditions.

4) GR-4 : Diversion channel to Oued Maliyan, with Sebkhet Sijoumi reduced 15 % or 30 %, with above GR-1 or GR-2 conditions.

Above alternative plans are illustrated in Fig.8.11.

At first, water level of Sebkhet Sijoumi is simulated for 100-yr probable flood, of which calculation is conducted by flood routine method under the conditions of present river facilities and future land use (Year 2020). A storage volume curve of Sebkhet Sijoumi that is applied for the calculation is quoted from a report "Bilan Hydrologique Du Lac Es Sejoumi, Mai 1992".

Area and Effective Storage Volume of Sebkhet Sijoumi

Elevation (m)	7.75	8.0	8.5	9.0	9.5	10.0
Surface Area (km^2)	0.0	8.7	23.5	25.0	26.5	28.0
Effective Volume ($Mil.m^3$)	0.0	1.1	8.9	21.0	33.9	47.5

For setting an initial water level of the calculation, long term simulation for Sebkhet Sijoumi water level is conducted based on 10-day rainfall and evaporation data reported in "Institut National De La Meteorologie" for 5 years from 1986 September to 1991 October. Prior to the simulation, runoff ratio of 0.2 as a common figure in the Mediterranean seaboard of North Africa is calibrated as shown in Fig.8.12. It seems that this figure is available for Sebkhet Sijoumi basin. The result of long term simulation is presented in Fig.8.13 and the initial water level is decided at El.8.86 m which is same as an annual mean high water level for 5 years simulation.

Then, the flood routine calculation is conducted on the above condition. Simulated maximum water level during the flood reaches at around El.9.5 m as shown in Fig.8.14. This level is just the same as assumed allowable flood water level of Sebkhet Sijoumi (El.9.5 m), which is judged from topographical map of 1 : 5,000 scale, survey result for Oued Gariana and site reconnaissance. It is conceived that no flood problem in surrounding area of Sebkhet Sijoumi will occur under the above condition.

The calculation is also made for the other 3 cases that 15 %, 30 % and 50 % of surface area of Sebkhet Sijoumi is assumed to be reduced by land reclamation. As shown in Fig.8.13, each initial water level for 3 cases is obtained at 9.12 m, 9.66 m, and 9.96 m, respectively. Maximum water level during the flood is, then, calculated and it is appeared that all cases require some new diversion facilities to control the flood water level to be within 9.5 m. The case of 50 % reduction is, however, not feasible from technical and economic points of view, so that the new facility is studied for 15 % and 30 % cases.

Conceivable new facilities are a new diversion tunnel to the Mediterranean Sea and a new diversion channel to Oued Maliyan as shown in Fig.7.15. On the basis of the above hydraulic analysis, both diversion plans are studied. As the result, following improvement works and project costs are required for the land reclamation project;

Items	Alternative Cases			
	GR-3-1 (Reduc.15%)	GR-3-2 (Reduc.30%)	GR-4-1 (Reduc.15%)	GR-4-2 (Reduc.30%)
Design Discharge (m^3/s)	11	92	11	92
Required Improvement Works				
- Diversion Tunnel, Diameter (m)	2.8	6.2	-	-
Length (m)	3,000	3,000	-	-
- Diversion Channel, Box Culvert				
Width (m)	-	-	3.1	6.1
Height (m)	-	-	2.7	3.2
No.of Lane	-	-	2	6
Length (m	-	-	6,000	6,000
Project Cost (DT)	7,916,000	29,616,000	20,891,000	112,896,000

On the basis of the hydrological analysis, the flood runoff distribution for each alternative cases is prepared. As shown in Fig.8.15, much flood retarding effect by existing and/or proposed retarding basins are expected at the downstream reaches. Comparing the alternative GR-1 and GR-2, peak runoff of GR-2 is approximately 80% of that of GR-1 at the Sebkhet Sijoumi.

By applying the design criteria and flood runoff distribution, preliminary design and the construction volume estimate are executed for each alternative case. After all, the construction costs are estimated by adopting the unit construction cost. Following table shows the comparison of construction cost for each alternative.

Construction Cost of Alternative Cases for Oued Gariana

(Unit : 1,000 DT)

	Item	GR-1	GR-2
I	Preparatory Works	4,372	4,088
II	River Improvement	54,647	45,642
III	Dam or Retarding Basin	0	5,462
	Sub-Total of I to III	59,019	55,192
IV	Land Acquisition & Compensation	25,830	23,172
V	Engineering Service	5,902	5,519
VI	Government Administration	4,242	3,918
VII	Contingency	14,249	13,170
	Total	109,242	100,971
VIII	Urban Drainage (6,088 ha)	41,398	41,398

As shown in the above table, construction cost of Case GR-2 is lower than that of GR-1. From the technical and economical points of view, this GR-2 plan is selected for Master Plan of Oued Gariana. Along with the above river improvement development, much urban drainage works is also required in this river basin because rapid urbanization is progressing in the hilly area. Direct construction cost required for this urban drainage is estimated to be approximately 41 million DT until the year 2020.

Figs.8.16 and 8.17 show the plan and longitudinal profile with the sections of the selected alternatives. Rectangular shaped concrete lined channel is planned for almost all stretches considering the availability of river reserves. Construction of the all new retarding basin and expansion of existing retarding basin are planned in the First Stage. Principal features of Oued Gariana improvement plan are as follows;

Principal Features of Oued Gariana River Improvement

	Items	First Stage	Second Stage
I	Length of River Improvement		
	- Earth lining (m)	1,548	757
	- Concrete rectangular (m)	12,688	13,894
	- Box culvert (m)	564	706
	Total (m)	14,800	15,357
II	Construction Volume		
	- Excavation (m^3)	423,000	401,000
	- Embankment (m^3)	0	0
	- Concrete (m^3)	92,200	70,800

III	Dam and Retarding Basin		
	- No.of new dam or retarding basin	5	0
	- No.of exist.retarding basin to be expanded	2	0
	- Total new flood control storage (m^3)	1,149,500	0
	- Total new surface area (m^2)	237,000	0
	- Total excavation (m^3)	607,500	0
	- Total embankment (m^3)	159,900	0
III	Urban Drainage (ha)	1,523	4,565

Required construction cost related to the above improvement works are shown in Table 8.4 and summarized as below;

Summary of Construction Cost for Oued Gariana

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	2,923	1,165	4,088
II	River Improvement	31,077	14,565	45,642
III	Dam or Retarding Basin	5,462	0	5,462
--	Sub-Total of I to III	39,462	15,730	55,192
IV	Land Acquisition & Compensation	12,812	10,360	23,172
V	Engineering Service	3,946	1,573	5,519
VI	Government Administration	2,614	1,304	3,918
VII	Contingency	8,825	4,345	13,170
	Total	67,659	33,312	100,971
VIII	Urban Drainage(Direct Const. Cost)		(6,088 ha)	41,398

8.4.4 Oued Maliyan

For formulating the Master Plan of the Oued Maliyan, the following flood control plans are conceived as alternative plans. There is a prospective flood retarding basin between Bir M'Cherga Dam and the confluence with Oued Hamma. This plan is taken into account for the alternative plans. With the development of the Sebkhet Sijoumi, there would be a possibility to construct the diversion channel to Oued Maliyan. This plan is also included in the alternative study.

1) ML-1 : River improvement with existing Dam.
2) ML-2 : ML-1 and Hamma Dam
3) ML-3 : ML-1 and Retarding Basin A
4) ML-4 : ML-1 with Hamma Dam and Retarding Basin A
5) ML-5 : Diversion Channel from Sebkhet Sijoumi with ML-1 to ML-4.

Above alternative plans are illustrated in Fig.8.18.

Among these alternative plans, diversion channel plan from Sebkhet Sijoumi (ML-5) is discarded since it was made clear that this plan is not economically feasible as discussed in Oued Gariana improvement plan.

On the basis of the hydrological analysis, the flood runoff distribution for each alternative case is prepared. As shown in Fig.8.19, much flood control effect by proposed Hamma Dam is expected at the downstream reaches. On the other hand, flood control effect by the Retarding Basin A is negligibly small because the flood peak runoff is already controlled by the Bir M'Cherga Dam which is located in the upstream.

By applying the design criteria and flood runoff distribution, preliminary design and the construction volume estimate are executed for each alternative case. After all, the construction costs are estimated by adopting the unit construction cost. Following table shows the comparison of construction cost for each alternative.

Construction Cost of Alternative Cases for Oued Maliyan

(Unit : 1,000 DT)

	Item	ML-1	ML-2	ML-3	ML-4
I	Preparatory Works	1,688	1,395	1,772	1,508
II	River Improvement	21,105	13,665	20,174	13,094
III	Dam or Retarding Basin	0	3,769	1,982	5,751
	Sub-Total of I to III	22,793	18,829	23,928	20,353
IV	Land Acquisition & Compensation	919	1,438	1,169	1,687
V	Engineering Service	2,279	1,883	2,393	2,035
VI	Government Administration	1,186	1,014	1,255	1,102
VII	Contingency	4,077	3,475	4,312	3,777
	Total	31,254	26,639	33,057	28,954
VIII	Urban Drainage (2,500 ha)	17,000	17,000	17,000	17,000

As shown in the above table, construction cost of Case ML-2 is the lowest among all alternatives. From the technical and economical points of view, this ML-2 which plan has a Hamma Dam scheme is selected for Master Plan of Oued Maliyan. Along with the above river improvement development, urban drainage works is also required in this river basin, especially left bank of Oued Maliyan. Direct construction cost required for this urban drainage is estimated to be approximately 17 million DT until the year 2020.

Figs.8.20 and 8.21 show the plan and longitudinal profile with the typical sections of the selected alternatives. Raising of existing diking system is planned for Oued Maliyan and widening of existing channel is planned for Oued Hamma. Construction of the Hamma Dam is planned in the First Stage. Principal features of Oued Maliyan improvement plan are as follows;

Principal Features of Oued Maliyan River Improvement

Items	First Stage	Second Stage
I Length of River Improvement		
- Earth lining (m)	29,400	29,400
II Construction Volume		
- Excavation (m^3)	927,000	390,600
- Embankment (m^3)	284,600	272,400
III Hamma Dam		
- Dam embankment (m^3)	1,060,000	-
- Dam height (m)	24	-
- Dam crest length (m)	1,200	-
- Flood control storage (m^3)	7,650,000	-
- Water supply storage (m^3)	8,000,000	-
III Urban Drainage (ha)	630	1,870

Required construction cost related to the above improvement works are shown in Table 8.4 and summarized as below;

Summary of Construction Cost for Oued Maliyan

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	1,065	330	1,395
II	River Improvement	9,540	4,126	13,665
III	Dam or Retarding Basin	3,769	0	3,769
	Sub-Total of I to III	14,374	4,456	18,829
IV	Land Acquisition & Compensation	1,276	162	1,438
V	Engineering Service	1,437	446	1,883
VI	Government Administration	783	231	1,014
VII	Contingency	2,681	794	3,475
	Total	20,551	6,088	26,639
VIII	Urban Drainage(Direct Const. Cost)		(2,500 ha)	17,000

8.4.5 Oued Mayzette

There is no prospective retarding basin site, then river improvement plan only is studied for formulating the Master Plan. On the basis of the hydrological analysis, the flood runoff distribution is prepared as shown in Fig.8.22.

By applying the design criteria and flood runoff distribution as mentioned above, preliminary design and the construction volume estimate are executed. Figs.8.23 and 8.24 show the plan and longitudinal profile with the channel sections. Earth lined embankment is applied in the lower reaches and rectangular shaped concrete lined channel is planned in the middle reaches. Box culvert type is introduced in the upper reaches. Single rectangular channel and box culvert are planned in the First Stage and same structures are planned to construct in the Second Stage. Principal features of Oued Mayzette improvement plan are as follows;

Principal Features of Oued Mayzette River Improvement

	Items	First Stage	Second Stage
I	Length of River Improvement		
	- Earth lining (m)	2,753	2,753
	- Concrete rectangular (m)	1,097	1,097
	- Box culvert (m)	1,234	1,234
	Total (m)	5,084	5,084
II	Construction Volume		
	- Excavation (m^3)	80,000	70,500
	- Embankment (m^3)	22,100	5,500
	- Concrete (m^3)	7,400	7,400
II	Urban Drainage (ha)	88	265

Required construction cost related to the above improvement works are shown in Table 8.6 and summarized as below;

Summary of Construction Cost for Oued Mayzette

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	211	198	409
II	River Improvement	2,642	2,473	5,115
III	Dam or Retarding Basin	0	0	0
	Sub-Total of I to III	2,853	2,671	5,524
IV	Land Acquisition & Compensation	333	333	665
V	Engineering Service	285	267	552
VI	Government Administration	159	150	309
VII	Contingency	545	512	1,058
	Total	4,175	3,933	8,108
VIII	Urban Drainage(Direct Const. Cost)		(353 ha)	2,401

As shown in the above table, urban drainage works is also required in this river basin. Direct construction cost required for this urban drainage improvement is approximately 2.4 million DT.

8.4.6 Oued Bou Khamsa

In this river basin also, there is no prospective retarding basin site, then river improvement plan only is studied for formulating the Master Plan. On the basis of the hydrological analysis, the flood runoff distribution is prepared as shown in Fig.8.25.

By applying the design criteria and flood runoff distribution as mentioned above, preliminary design and the construction volume estimate are executed. Figs.8.26 and 8.27 show the plan and longitudinal profile with the channel sections. Box culvert is basically introduced along the GP-1 road and MC-39 road since no enough river reserves is available. Single or double box culvert is applied in the First Stage and same structures are planned to construct in the Second Stage. Principal features of Oued Bou Khamsa improvement plan are as follows;

Principal Features of Oued Bou Khamsa River Improvement

Items	First Stage	Second Stage
I Length of River Improvement		
- Earth lining (m)	824	0
- Concrete rectangular(m)	0	824
- Box culvert(m)	2,068	2,068
Total(m)	2,892	2,892
II Construction Volume		
- Excavation(m^3)	51,300	51,100
- Embankment(m^3)	0	0
- Concrete(m^3)	7,400	7,400
III Urban Drainage(ha)	88	265

Required construction cost related to the above improvement works are shown in Table 8.7 and summarized as below;

Summary of Construction Cost for Oued Bou Khamsa

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	198	177	375
II	River Improvement	2,475	2,218	4,693
III	Dam or Retarding Basin	0	0	0
	Sub-Total of I to III	2,673	2,395	5,068
IV	Land Acquisition & Compensation	296	296	592
V	Engineering Service	267	240	507
VI	Government Administration	148	135	283
VII	Contingency	508	460	968
	Total	3,892	3,526	7,418
VIII	Urban Drainage(Direct Const. Cost)		(405 ha)	2,754

As shown in the above table, urban drainage works is also required in this river basin. Direct construction cost required for this urban drainage improvement is approximately 2.8 million DT.

8.4.7 Oued Ain Zerga

For formulating the Master Plan of the Oued Ain Zerga, following flood control plans are conceived as alternative plans. There are prospective flood retarding basins in the middle reaches. These plans are taken into account for the alternative plans.

1) AZ-1 : River improvement only.
2) AZ-2 : River improvement and Retarding Basin A.
3) AZ-3 : River improvement and Retarding Basin B.
4) AZ-4 : River improvement and Retarding Basin A and B.

Above alternative plans are illustrated in Fig.8.28.

On the basis of the hydrological analysis, the flood runoff distribution for each alternative case is prepared. As shown in Fig.8.29, approximately 40 % of flood peak runoff will be controlled by the retarding basins at the river mouth.

By applying the design criteria described before and flood runoff distribution, preliminary design and the construction volume estimate are executed for each alternative case. After all, the construction costs are estimated by adopting the unit construction cost. Following table shows the comparison of construction cost for each alternative.

Construction Cost of Alternative Cases for Oued Ain Zerga

(Unit : 1,000 DT)

	Item	AZ-1	AZ-2	AZ-3	AZ-4
I	Preparatory Works	434	252	227	246
II	River Improvement	5,416	2,670	2,269	2,177
III	Dam or Retarding Basin	0	477	564	894
	Sub-Total of I to III	5,850	3,399	3,060	3,317
IV	Land Acquisition & Compensation	956	210	820	640
V	Engineering Service	585	340	306	332
VI	Government Administration	340	181	194	198
VII	Contingency	1,160	620	657	673
	Total	8,891	4,750	5,037	5,160
VIII	Urban Drainage (103 ha)	701	701	701	701

As shown in the above table, construction cost of Case AZ-2 is the lowest among four alternatives. From the technical and economical points of view, this AZ-2 plan is selected for Master Plan of Oued Ain Zerga. Along with the above river improvement development, urban drainage works is also required because urbanization is progressing in this basin. Direct construction cost required for this urban drainage is estimated to be approximately 0.7 million DT until the year 2020.

Figs.8.30 and 8.31 show the plan and longitudinal profile with the sections of the selected alternatives. Box culvert is introduced under the existing road in the First stage (for 10-yr flood) and additional box culvert is also planned in the Second stage (for 100-yr flood) as shown in Fig.8.31. Construction of the Retarding Basin A is planned in the First Stage. Principal features of Oued Ain Zerga improvement plan are as follows;

Principal Features of Oued Ain Zerga River Improvement

Items	First Stage	Second Stage
I Length of River Improvement		
- Earth lining (m)	598	0
- Concrete rectangular (m)	124	722
- Box culvert (m)	687	687
Total (m)	1,409	1,409
II Construction Volume		
- Excavation (m^3)	29,700	32,400
- Embankment (m^3)	0	0
- Concrete (m^3)	1,500	7,200

III Dam and Retarding Basin		
- No.of new dam or retarding basin	1	0
- Flood control storage (m^3)	69,300	-
- Surface area (m^2)	16,000	-
- Excavation (m^3)	7,100	-
- Embankment (m^3)	31,300	-
III Urban Drainage (ha)	26	77

Required construction cost related to the above improvement works are shown in Table 8.8 and summarized as below;

Summary of Construction Cost for Oued Ain Zerga

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	131	121	252
II	River Improvement	1,156	1,514	2,670
III	Dam or Retarding Basin	477	0	477
	Sub-Total of I to III	1,764	1,635	3,399
IV	Land Acquisition & Compensation	198	12	210
V	Engineering Service	177	163	340
VI	Government Administration	99	82	181
VII	Contingency	336	284	620
	Total	2,574	2,176	4,750
VIII	Urban Drainage(Direct Const. Cost)		(103 ha)	701

8.4.8 Oued Hammam

For formulating the Master Plan of the Oued Hammam, following flood control plans are conceived as alternative plans. There are prospective flood retarding basins in the middle reaches in addition to M'Darrej Dam, Guemgame Dam and Laia Dam. These retarding basins are also taken into consideration of the alternative plans.

1) HM-1 : River improvement only.
2) HM-2 : River improvement and Guemgame Dam.
3) HM-3 : River improvement and M'Darrej Dam.
4) HM-4 : River improvement and Retarding Basin A.
6) HM-6 : River improvement and Retarding Basin B.
7) HM-7 : River improvement and all combination.

Above alternative plans are illustrated in Fig.8.32.

On the basis of the hydrological analysis, the flood runoff distribution for each alternative case is prepared. As shown in Fig.8.33, runoff distributions for each alternative case are varied due to the location of the flood retarding basins.

By applying the design criteria described before and flood runoff distribution, preliminary design and the construction volume estimate are executed for each alternative case. After all, the construction costs are estimated by adopting the unit construction cost. Following table shows the comparison of construction cost for each alternative.

Construction Cost of Alternative Cases for Oued Hammam

(Unit : 1,000 DT)

	Item	HM-1	HM-2	HM-3	HM-4	HM-5	HM-6	HM-7
I	Preparatory Works	363	386	372	457	471	425	530
II	River Improvement	4,531	3,959	4,323	3,902	4,184	2,673	1,362
III	Dam or Retarding Basin	0	854	322	1,807	1,692	2,638	5,256
	Sub-Total of I to III	4,894	5,199	5,017	6,166	6,347	5,736	7,148
IV	Land Acquisition & Compensation	474	1,170	1,145	1,367	2,890	4,139	10,416
V	Engineering Service	490	520	502	617	635	574	715
VI	Government Administration	269	319	309	377	462	494	879
VII	Contingency	920	1,082	1,046	1,280	1,551	1,642	2,874
	Total	7,047	8,290	8,019	9,807	11,885	12,585	22,032
VIII	Urban Drainage (2,224 ha)	15,124	15,124	15,124	15,124	15,124	15,124	15,124

As shown in the above table, construction cost of Case HM-1 is the lowest among seven alternatives. From the technical and economical points of view, this HM-1 plan is selected for Master Plan of Oued Hammam. Along with the above river improvement development, urban drainage works is also required because urbanization is progressing in this basin. Direct construction cost required for this urban drainage is estimated to be approximately 15 million DT until the year 2020.

Figs.8.34 and 8.35 show the plan and longitudinal profile with the sections of the selected alternatives. Earth lined type is introduced for this river considering the land use condition along Oued Hammam. Dam and retarding basin plans are not selected because those plans are not economical. Principal features of Oued Hammam improvement plan are as follows;

Principal Features of Oued Hammam River Improvement

Items	First Stage	Second Stage
I Length of River Improvement		
- Earth lining (m)	7,850	7,850
II Construction Volume		
- Excavation (m^3)	218,500	0
- Embankment (m^3)	26,200	54,000
III Urban Drainage (ha)	557	1,667

Required construction cost related to the above improvement works are shown in Table 8.9 and summarized as below;

Summary of Construction Cost for Oued Hammam

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	333	30	363
II	River Improvement	4,158	373	4,531
III	Dam or Retarding Basin	0	0	0
	Sub-Total of I to III	4,491	403	4,894
IV	Land Acquisition & Compensation	296	178	474
V	Engineering Service	450	40	490
VI	Government Administration	240	29	269
VII	Contingency	822	98	920
	Total	6,299	748	7,047
VIII	Urban Drainage(Direct Const. Cost)		(2,224 ha)	15,124

8.4.9 Oued Blibene

In this river basin, there is no prospective retarding basin site, then river improvement plan only is studied for formulating the Master Plan. On the Basis of the hydrological analysis, the flood runoff distribution is prepared as shown in Fig.8.36.

By applying the design criteria and flood runoff distribution as mentioned above, preliminary design and the construction volume estimate are executed. Figs.8.37 and 8.38 show the plan and longitudinal profile with the channel sections. Proposed river sections by MOEH are introduced in the lower reaches and bottle neck portion in the middle reaches are planned to be widened. Principal features of Oued Blibene improvement plan are as follows;

Principal Features of Oued Blibene River Improvement

	Items	First Stage	Second Stage
I	Length of River Improvement		
	- Earth lining (m)	828	828
	- Trapezoidal concrete lining (m)	337	337
	Total(m)	1,165	1,165
II	Construction Volume		
	- Excavation(m^3)	28,600	0
	- Embankment(m^3)	300	400
	- Concrete(m^3)	2,800	200
III	Urban Drainage(ha)	163	488

Required construction cost related to the above improvement works are shown in Table 8.10 and summarized as below;

Summary of Construction Cost for Oued Blibene

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	243	3	246
II	River Improvement	3,030	44	3,074
III	Dam or Retarding Basin	0	0	0
	Sub-Total of I to III	3,273	47	3,320
IV	Land Acquisition & Compensation	112	8	120
V	Engineering Service	328	4	332
VI	Government Administration	170	2	172
VII	Contingency	583	9	592
	Total	4,466	70	4,536
VIII	Urban Drainage(Direct Const. Cost)		(651 ha)	4,427

As shown in the above table, urban drainage works is also required in this river basin. Direct construction cost required for this urban drainage improvement is approximately 4.4 million DT.

8.4.10 Oued Hallouf

In this river basin also, there is no prospective retarding basin site, then river improvement plan only is studied for formulating the Master Plan. On the basis of the hydrological analysis, the flood runoff distribution is prepared as shown in Fig.8.39.

By applying the design criteria and flood runoff distribution as mentioned above, preliminary design and the construction volume estimate are executed. Figs.8.40 and 8.41 show the plan and longitudinal profile with the channel sections. Trapezoidal earth lining section is basically applied in the main stream. On the other hand, box culvert under road is introduced in the Tributary 3 because enough river reserve is not available. Principal features of Oued Hallouf improvement plan are as follows;

Principal Features of Oued Hallouf River Improvement

Items	First Stage	Second Stage
I Length of River Improvement		
- Earth lining (m)	3,900	3,900
- Box culvert (m)	1,359	1,359
- Trapezoidal concrete lining (m)	765	765
Total (m)	1,165	1,165
II Construction Volume		
- Excavation (m^3)	99,900	94,600
- Backfill (m^3)	57,900	20,600
- Concrete (m^3)	6,300	6,700
III Urban Drainage(ha)	238	792

Required construction cost related to the above improvement works are shown in Table 8.11 and summarized as below;

Summary of Construction Cost for Oued Hallouf

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	447	162	610
II	River Improvement	5,596	2,025	7,621
III	Dam or Retarding Basin	0	0	0
	Sub-Total of I to III	6,044	2,187	8,231
IV	Land Acquisition & Compensation	1,436	772	2,208
V	Engineering Service	604	219	823
VI	Government Administration	374	148	522
VII	Contingency	1,269	499	1,768
	Total	9,727	3,825	13,552
VIII	Urban Drainage(Direct Const. Cost)		(1,030 ha)	7,004

As shown in the above table, urban drainage works is also required in this river basin. Direct construction cost required for this urban drainage improvement is approximately 7 million DT.

8.4.11 Oued Hamdoun

Flood control plan is not available for this Oued Hamdoun main stream. Some drainage improvement plan for Msaken is prepared by MOEH. For formulating the Master Plan of the Oued Hamdoun, following flood control plans are conceived as alternative plans. There are prospective flood retarding basins in the middle reaches. These retarding basins are also taken into consideration of the alternative plans.

1) HD-1 : River improvement only.
2) HD-2 : River improvement and Retarding Basin A.
3) HD-3 : River improvement and Retarding Basin B.
4) HD-4 : River improvement and Retarding Basin A and B.

Above alternative plans are illustrated in Fig.8.42.

On the basis of the hydrological analysis, the flood runoff distribution for each alternative case is prepared. As shown in Fig.8.43, runoff distributions are varied due to the location of the flood retarding basins.

By applying the design criteria described before and flood runoff distribution, preliminary design and the construction volume estimate are executed for each alternative case. After all, the construction costs are estimated by adopting the unit construction cost. Following table shows the comparison of construction cost for each alternative.

Construction Cost of Alternative Cases for Oued Hamdoun

(Unit : 1,000 DT)

	Item	HD-1	HD-2	HD-3	HD-4
I	Preparatory Works	541	577	590	651
II	River Improvement	6,754	5,865	5,915	5,334
III	Dam or Retarding Basin	0	1,340	1,456	2,796
	Sub-Total of I to III	7,295	7,782	7,961	8,781
IV	Land Acquisition & Compensation	0	320	200	520
V	Engineering Service	730	779	796	878
VI	Government Administration	365	406	408	465
VII	Contingency	1,259	1,394	1,405	1,597
	Total	9,649	10,681	10,770	12,241
VIII	Urban Drainage (2,583 ha)	17,565	17,565	17,565	17,565

As shown in the above table, construction cost of Case HD-1 is the lowest among four alternatives. From the technical and economical points of view, this HD-1 plan is selected for Master Plan of Oued Hammam. Along with the above river improvement development, urban drainage works is also required because urbanization is progressing in this basin. Direct construction cost required for this urban drainage is estimated to be approximately 17.6 million DT until the year 2020.

Figs.8.44 and 8.45 show the plan and longitudinal profile with the sections of the selected alternatives. Earth lined type is introduced for this river considering the land use condition along Oued Hamdoun. Retarding basin plans are not selected because those plans are not economical. Principal features of Oued Hamdoun improvement plan are as follows;

Principal Features of Oued Hamdoun River Improvement

Items	First Stage	Second Stage
I Length of River Improvement		
- Earth lining section (m)	16,300	16,300
II Construction Volume		
- Excavation (m^3)	361,200	459,100
III Urban Drainage (ha)	596	1,987

Required construction cost related to the above improvement works are shown in Table 8.12 and summarized as below;

Summary of Construction Cost for Oued Hamdoun

(Unit : 1,000 DT)

	Item	First Stage	Second Stage	Total
I	Preparatory Works	330	211	541
II	River Improvement	4,114	2,640	6,754
III	Dam or Retarding Basin	0	0	0
	Sub-Total of I to III	4,444	2,851	7,295
IV	Land Acquisition & Compensation	0	0	0
V	Engineering Service	445	285	730
VI	Government Administration	223	142	365
VII	Contingency	767	492	1,259
	Total	5,879	3,770	9,649
VIII	Urban Drainage(Direct Const. Cost)		(2,583 ha)	17,565

CHAPTER 9 FORMULATION OF MASTER PLAN

9.1 General

Master plan study under Phase 2 (mid-May to mid-Aug., 1993) has been made in Japan in accordance with the basic approach described below. Work flow is shown in Fig.9.1. All data and information and the results of field reconnaissance and field investigation at the site during Phase 1 (end-Feb. to mid-May, 1993) were reviewed carefully and incorporated in the formulation of the master plan to the maximum extent.

9.2 Basic Approach

9.2.1 Objective River Basins

All the eleven rivers (oueds), seven rivers in the Greater Tunis area and four rivers in the Greater Sousse area, are subject to the master plan study as MOEH and the Study Team mutually agreed through the explanation of Inception Report.

9.2.2 Basic Design Condition

1) Design discharge for master plan

- for primary and secondary canals : 100-yr flood
- for other branches and inland (urban drainage) : 10-yr flood

2) Design discharge for 1st stage development

Stage-wise implementation is considered since whole development in one stage would require big initial investment cost. First stage work will be implemented with 10-year flood in consideration of optimum scale of the project, and in the future the second stage with more bigger flood will be considered.

3) Target year

With urban development, which will cause changes of land use and accordingly the risks of flood damage be increasing, target year will be set at the year 2020.

9.2.3 Hydrological Conditions/River and Drainage System

On the basis of the findings during Phase 1 field works, especially present problems encountered in each river and drainage system, hydrological analysis has been made. The following factors have been taken into account for hydrological analysis.

1) Design rainfall

- Area-Depth-Duration of rainfall

2) Design flood

- Flood runoff from rainfall
- Domestic and industrial waste waters and return flow from irrigation, which would usually be a base flow before flood occurs. It is judged this flow is negligibly small, then be neglected in determining design flood.
- Runoff coefficient is estimated from the hydrological data collected in the objective river basins and also from the results of studies made by government agencies such as ONAS and MOA. Data from other countries with similar nature is also considered.

3) Erosion/sedimentation

It was revealed no sufficient data concerning erosion and sedimentation are available in the objective river basins. Therefore, the current river condition and river profile surveyed during Phase 1 field works are only the base to judge erosion and sedimentation of rivers.

9.2.4 Socio-Economic/Urban Development Plan

Tunisian government and local government agencies have formulated various new economic development plans and some of urban development plans in the study area. These are taken into account for this study. Major factors to be considered are as listed below:

1) Present socio-economic condition and land use

2) Future socio-economic condition and land use

- illegal land use should be treated in such a way of institutional arrangement, and

- needs of land reclamation in lake shore area for both Sebkhet Ariana and Sebkhet Sijoumi will be taken into account.

9.2.5 Basic Flood Runoff Distribution

On the basis of the results of hydrological analysis and also present and future land use in the respective basins, basic flood runoff distribution diagram is prepared. This becomes the basic data for flood control plan, which includes flood runoff in each stretch of rivers and drainage system.

9.2.6 Initial Environmental Assessment

All the environmental factors related to the flood control and drainage projects are to be assessed in terms of present and future conditions without project, especially;

- illegal land use and resettlement of inhabitants, and
- possibility of land reclamation in lake shore area in view of environmental effect.

9.2.7 Flood Damages

All the flood and drainage problems are to be clarified. Major problems recognized in the objective areas are as described below:

1) Illegal land use on river course (house building etc.) is causing flood damages more serious.

2) Illegal land use in the lake shore area which causes flood damage more serious.

3) Disposal of garbage into the river course which causes discharge capacity of the river channel to decrease.

4) Shortage of discharge capacity/drainage capacity, which causes the flooding/stagnation in the surrounding area of river and drainage system.

Flood damages are estimated in the following viewpoints:

- population affected by flooding,
- infrastructure suffered from flooding,
- housing and properties suffered from flooding, and

- economic activities stagnation by flooding.

9.2.8 Alternative Countermeasures

Structural and non-structural measures are considered according to the nature of flood damages. Major components to be considered in alternative countermeasures are as follows.

1) Structural measures

- river channel improvement,
- flood regulation reservoir,
- flood retention pond, and
- flood diversion channel and/or short-cut channel.

2) Non-structural measures

- institutional arrangement to eliminate garbage disposal in the river course,
- delineation of river right-of-way, and
- delineation of lake shore lines.

These alternative countermeasures are assessed in terms of i) cost and benefit, and ii) environmental effect. If all alternatives have the same benefit, only project cost comparison is to be made.

9.2.9 Selection of Best Alternative Plan

Among the considered alternative countermeasures, the best alternative plan will be selected. The selection criteria are as follows:

- cost minimum alternative in case that all alternative brings the same benefit
- alternative with highest economic return in case of different benefit in conceived alternative

Best alternative plan selected as above is considered as "Master Plan" of the objective river/drainage system.