JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF EQUIPMENT AND HOUSING
THE REPUBLIC OF TUNISIA

THE STUDY
ON
FLOOD PROTECTION PROGRAM
FOR
GREATER TUNIS AND SOUSSE

PART II

FEASIBILITY STUDY
ON
OUED ENNKHILET

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PART II FEASIBILITY STUDY

II-1 Oued Ennkhilet

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CHAPTER 1 SOCIO- ECONOMIC BACKGROUND

1.1 Introduction

General socio-economic data for the Governorate is presented in Part 1 Master Plan Study (Chapter 1).

The Oued Ennkhilet is located in the Delegation of North Ariana, which contains about one third of the total population of the Governorate. Potential flooding will affect areas within the Districts of Raoued, Borj Louzir and Soukra/Chotrana, which are the main expansion areas for urban development from the town of Ariana. Data on these areas is considered below in Chapter 10.

The following general trends of significance for the study areas should be noted:

*Ariana is an important Industrial, Commercial and Administrative Centre. The consequences of flooding will have an impact on all these areas.

*Ariana is a major urban expansion zone for Tunis, with constructed areas increasing rapidly in recent years at a growth rate of 6.4% (from 70,200 buildings in 1984 to 94,900 in 1989). It had a net positive migration of 53,500 persons between 1984 and 1989, by far the largest amount in the District of Tunis.

*Development has been largely uncontrolled, resulting in a large amount of anarchic construction and spontaneous housing.

*A major consequence has been that these areas are badly served in terms of basic social infrastructure

1.2 Population

There has been a significant increase in population in recent years, with a rate of growth of 5.9% between 1984 and 1991. .In 1991 Ariana contributed 31 % of the population of the District of Tunis. By 1996, this is expected to increase to 34%.

According to projections made by ONAS for North Ariana, (which includes Ariana town and the expansion areas to the north), population growth rates are expected to gradually reduce from 6.45% p.a. to 3.3% between 2006 and 2011.. Despite further falls in

growth rates beyond 2011, population in 2020 is expected to be in the region of 358 000. Density of population was estimated at 85 persons per hectare in 1990 , and is expected to increase to 140 persons per hectare in 2020. The average Household size is 5.2 for urban areas and 5.9 for rural areas

In North Ariana, the urban areas increased from 23 ha in 1975 to more than 500 by 1990. This rapid growth and the lack of control over construction has resulted in rapid increase in spontaneous housing, which houses one third of the population and occupies nearly 50% of the "rural" areas. In certain areas, spontaneous housing accounts for nearly 65%.

Population changes are reflected in the radical changes expected in land use in the flood prone areas. At present it is estimated that residential areas occupy one- third of these areas directly flooded by the Oued Ennkhilet; this ratio is expected to increase to over 90% by the year 2020.

1.3 Infrastructure

Two major roads run through the Study area. These are the RVE 533 and the GP 8. The former will be badly affected by potential flooding from the Oued Ennkhilet. The GP 8 which is a major artery for Tunis had an estimated flow of 25,000 vehicles per day.

Due to the anarchic construction newly developed urban areas consisting of spontaneous housing, are badly served with basic infrastructure and social facilities. The ONAS treatment plant is located in the flood prone area, and ONAS has major plans to improve the network in these areas.

1.4 Economic Activities

1.4.1 Industry

Flooding will have a direct impact on facilities located within the zone, but will indirectly affect economic activities through its impact on the residential population, much of which commutes to neighboring areas and to Tunis.

The Governorate of Ariana is mainly commercial/services based with an important industrial sector: In 1989 , services accounted for 47% of employment, followed by Industry with 35.8%. The flood prone area is an important commercial and industrial

one. The large industrial area of Charguia lies within the Commune of Ariana. The structure of Industrial activities in the Delegation are shown in Table 1.1 . The majority of the industry is textile and leather.

1.4.2 Agriculture

Crops grown in the flood prone areas include winter crops, vegetables, cereals, cotton animal foodstuffs, and root crops. However, its importance is rapidly declining ,particularly in the Chotrana and Raoud areas, due to the large loss of land to urbanization, but also to the increasing salinity of the soil due to rising water tables as a result of bad drainage. As noted in Chapter 10, in the projections of land use, agriculture will be virtually non-existent in the flood prone area in the future.

CHAPTER 2 TOPOGRAPHY AND GEOLOGY

2.1 General

The Master Plan study on seven oueds in the Greater Tunis area was carried out during end-Feb. and end-Aug.1993 (Phases 1 and 2) at both the site in Tunis and also in Tokyo Japan. As a result, the case of Oued Ennkhilet was finally determined as the most recommendable one on which the feasibility study be made as Phase 3 work at the site during the period of end-Sept. 1993 to beg-Feb. 1994.

For the Oued Ennkhilet, the following flood protection measures are being planned.

- Retarding basins in the upstream area
- Channel improvement by box culvert in the middle reach area
- Levee embankment in the downstream reach area

The geotechnical investigation was made to clarify the embankment material for the retarding dam and levee and the foundation conditions at the dam sites. The location of investigated spots in the Oued Ennkhilet basin is shown on Fig.2.1.

2.2 Topography and Geology

The topography of the basin is largely divided into the two, one is gently sloped hills and the other is alluvial plain. The maximum height of hill is about 240 m above the sea level.

The geology of the hills consists of the marl, clay-stone, limestone and their weathered soils aged from the Cretaceous to the Neocene, and some parts of them are being developed as quarry sites for sand and gravel materials for construction purposes in the Greater Tunis area. The alluvial plain is composed of sand layer covered with clayey soil layer varying its thickness from a few tens centimeters to a few meters.

2.3 Investigation Works

Field reconnaissance for the entire basin was made , and two boring sites of TR1 and TR3 for the dam foundation, three sites of TR1, TR2 and TR4 for dam embankment material and three sites of TL1, TL2 and TL3 for the levee embankment material were finally selected. The location of selected investigation sites is shown on Figs.2.2 - 2.5.

Geotechnical investigation works were sublet to the local contractor "Geotechnique Tunisie", and the field works were carried out by the contractor during October and November 1993 under the supervision of an Expert of the JICA Study Team.

At each boring site, three core borings were sunk to 10 meters deep with the standard penetration test at one meter depth interval in the soil layer and the in-situ permeability test at five meters depth interval.

At six (6) sites for the embankment material, the disturbed samples were taken from the test pit (three meters depth). Samples taken were tested at the laboratory of the contractor on the following six (6) items:

- Natural moisture content
- Specific gravity
- Gradation
- Liquid and plastic limits
- Compaction
- Permeability

The core boring results are shown on Figs.2.6-2.11. On the figures of boring log, the standard penetration test result is also shown. The in-situ permeability test result are shown in Table 2.1. According to these logs, the left abutment of proposed dam site at TR1 (Boring No. SC1) consists of the talus deposit of clayey soil with a few boulders having N-values from 44 to 70. The riverbed (Boring No. SC2) and the right abutment (Boring No. SC3) consist of the talus deposit to about five (5) meters deep and the bed rock of marl with thin sandstone seams. The N-values of talus deposits range from 42 to 97. The in-situ permeability test showed the permeability coefficients lower than 2×10^{-6} cm/sec. The left abutment of TR3 (Boring No. SC4) consists of the clayey talus deposit with a few boulders and some gravels. The N-values range from 44 to 89. The riverbed (Boring No. SC5) consists of the clayey talus from the ground surface to 3.5 m deep, the clayey residual soil layer from 3.5 m to 5.5 m deep and the bed rock of limestone and sandstone. The N-values of the talus and residual soil layers range from 42 to 83. The right abutment (Boring No. SC6) consists of the clayey talus deposit layer of 1.5 m thick and the clayey residual soil below it. The N-value of talus deposit is 36 and the N-values of residual soil layer range from 61 to 100. The in-situ permeability test showed the permeability coefficients lower than 5×10^{-7} cm/sec.

The stratification of embankment materials at six (6) sampling sites (TR1, TR2, TR3, TL1, TL2, and TL3) are shown on Figs.2.12 and 2.13. TR1 consists of the clayey soil layer to 2.5 m deep and the layer of pebble with clay below it. TR3 consists of the layer of clayey soil with some gravel to 2 m deep and the weathered marl below it. TL1

consists of the medium sand to 0.9 m and coarse sand below it. TL2 consists of the clayey soil layer. TL3 consists of the clay layer to 2.4 m and the medium sand layer below.

The Laboratory soil and rock test results are shown in Table 2.2. The all soil of TR1, TR2 and TR3 is classified into CL by the Unified Soil Classification of ASTM, that of TL1 is classified into SP, and that of TL2 and TL3 is classified into CH. The natural moisture contents of TR1, TR2 and TR3 range from 3 % to 12 % which are 6 - 10 % lower than their respective optimum moisture content. Those of TL1, TL2 and TL3 range from 17 % to 26 % which are 4 - 10 % higher than their respective optimum moisture content. The compressive strength were recorded at 72 bars (73.4 kg/cm2) on the sample of boring No. SC3 and 228 bars (232.6 kg/cm2) on that of Boring No. SC6.

2.4 Interpretation of Investigation Result

1) Foundation of Dam

The dams for the retarding basins is considered to be a homogeneous earth fill type. The standard penetration test shows N-values much more than 30, the in-situ permeability test shows the values much lower than 10^{-5} cm/sec, and the other sites not investigated are estimated quite similar to TR1 and TR2 from the reconnaissance result. Therefore the subsurface of each proposed retarding dam site is judged to have sufficient bearing capacity and imperviousness as a dam foundation.

2) Embankment material

The soil materials around the proposed dam site are classified into CL having the moisture contents lower than their optimum moisture content. Consequently these material is judged to be available for the dam embankment without any serious trouble except moistening them near to their optimum moisture content. An upstream slope of 1v : 2.5h and a downstream slope of 1v : 2.0h are recommended for the homogeneous earth fill dam within 10 m high.

The soil materials around the proposed levee section except the sand in the downstream end stretch are available for the embankment though they are not superior, and some drying treatment may be required. The sand is classified into SP and judged to be very erodible. Accordingly the levee embankment of sand will requires the clay lining. Slope of 1v : 2h is recommended for the both sides of levee embankment.

CHAPTER 3 HYDROLOGY

3.1 Runoff Analysis

3.1.1 Methodology

Basically, the same method applied for the M/P stage is considered in the runoff analysis in Oued Ennkhilet and Sebkhet Ariana basin to this F/S stage. The rational method is utilized for the determination of basic flood runoff in consideration of the basin scale and availability of hydrological data. Basic conditions on the rational formula is described as below.

(1) Runoff coefficient

The classification of runoff coefficient in Oued Ennkhilet and Sebkhet Ariana basin is reviewed in accordance with the detail future land use plan. Following runoff coefficients for various land use types are determined taking account of the M/P study, standard of Japan and USA, available topographic map and present and future land use map.

Land Use Type	Present Land Use Condition	Future Land Use Condition
Urban center, Commercial, High density residential areas :	0.6	0.8
Low density residential areas :	0.5	0.6
Industrial areas :	0.6	0.6
Agricultural lands, Open spaces :	0.2	0.2
Water surface :	1.0	1.0

(2) Time of concentration

The time of concentration is defined as a total of inlet time and flow time. The travel time of surface flow (overland flow and/or undefined channel) in the uppermost basin on each branch is calculated as the inlet time and the Kirpich formula is utilized to estimate the inlet time. The flow time is calculated from assumed average flow velocity in the channel taking account of channel condition, bed slope, carrying capacity, etc.

(3) Rainfall intensity

Average rainfall intensity in time of concentration is obtained from IDF (Intensity-Duration-Frequency) curve formula that was studied by "Institut National De La Meteorologie" based on the rainfall record in 21 years (1970 to 1990) at the station of Tunis-Carthage. Basic conditions of rational formula mentioned above is summarized in Table 3.1. On the other hand, the unit hydrograph method with rational formula's peak discharge is used to develop runoff hydrographs for storage design and evaluation of existing flood control facilities and flood damages. In this method, a runoff coefficient is defined to be the ratio of runoff to rainfall over a given time period and the same values mentioned above are adopted for runoff coefficient.

3.1.2 Runoff Simulation Model

(1) Drainage basin

The drainage area of Sebkhet Ariana is 117.53 km2 and contains Oued Ennkhilet basin, Canal Choutrana basin, other 10 river basins (Basin No.61 to 70) and Sebkhet Ariana itself (Basin No.80). Oued Ennkhilet basin has a catchment area of 17.12 km2 and this basin is divided into 40 sub-basins (Basin No.1 to 40) to examine into the details of flood runoff on secondary and tertiary channels. Canal Choutrana basin has a catchment area of 9.43 km2 and this basin is also divided into 4 sub-basins (Basin No. 51 to 54).

(2) Land use

Present and future land use condition is reviewed on each river basin and sub-basin with newest land use information and areas in the each river basin and sub-basin are classified into 5 zones according to the hydrological viewpoints. The weighted runoff coefficient for the rational formula under the present and future land use condition is calculated on each river basin and sub-basin.

The drainage area and its weighted runoff coefficient of each river basin and sub-basin are shown in Table 3.2.

(3) River system model

The river system model is made for runoff analysis taking account of the present river system and alternative plans, and calculation points are also determined at the point of

interest on the river system model. River system model and calculation points of Oued Ennkhilet and Sebkhet Ariana basin is shown in Fig. 3.1.

3.1.3 Rainfall Analysis

(1) Hydrologic design scale

Following basic condition are used for the design rainfall.

- Design scale for basic flood runoff : 100-year return period
- Design scale for 1st stage development : 10-year return period
- Evaluation of flood damage : 1.05, 2, 5, 10, 25, 50, 100-year return period

(2) Design hyetograph

Design hyetograph is utilized to obtain runoff hydrographs by the unit hydrograph method with rational formula's peak discharge.

The alternating block method is applied for the design hyetograph that is developed as center density distribution from an IDF curve with time interval equal to the time of concentration.

(3) Duration of design rainfall

Duration of design rainfall is adopted as 24 hours based on the requiring duration for the storage design in consideration of the longest time of concentration in Oued Ennkhilet and Sebkhet Ariana basin.

3.1.4 Flood Runoff Analysis

(1) Basic flood runoff

The Basic flood runoff for 1.05, 2, 5, 10, 25, 50, 100-year return period and present and future land use condition is calculated without any existing flood control facilities. Results of calculated basic flood runoff in Oued Ennkhilet and Sebkhet Ariana basin at each calculation point are shown in Tables 3.3 and 3.4, respectively. The design basic flood runoff distribution is determined based on these calculated results.

The runoff hydrographs from each sub-basin at each calculation point are also calculated by the unit hydrograph method with rational formula's peak discharge. Fig. 3.2 shows the same sample results of the calculated synthetic hydrograph at a certain calculation point. These hydrograph is used for the storage design and evaluation of flood control facilities.

(2) Existing flood control facilities

The Ain Snoussi Dam is an existing flood control facility in Oued Ennkhilet basin and the flood control effects by this dam is evaluated with the runoff simulation model. Calculation results under the condition with existing flood control facilities are shown in Table 3.5.

The runoff hydrographs from each sub-basin at each calculation point considering the existing flood control facilities are also calculated by the unit hydrograph method with rational formula's peak discharge. Fig. 3.3 shows the same sample results of the calculated synthetic hydrograph at a certain calculation point. These runoff hydrograph is used for the storage design and estimation of flood damages.

(3) Alternative study

Following diversion plans and combinations of those plan are examined for alternative study. The flood runoff for each alternative plan is calculated in accordance with each river system model.

- Diversion 3 Plan
- Diversion 4 Plan
- Diversion 5 plan
- Combination of Diversion Plans 1 and 3
- Combination of Diversion Plans 2 and 3
- Combination of Diversion Plans 3 and 4
- Combination of Diversion Plans 3 and 5
- Combination of Diversion Plans 3, 4 and 5

The river system models of each diversion plan listed above are shown in Figs 3.4 to 3.11 and calculation results of peak flood runoff at each critical calculation point on each diversion plan are summarized in Tables 3.6 to 3.13.

The runoff hydrographs from each sub-basin at each critical calculation point are also calculated by the unit hydrograph method with rational formula's peak discharge and these hydrograph is used for the storage design with each diversion plan.

3.2 Riverbed Material Investigation

3.2.1 General

Riverbed material investigation in Oued Ennkhilet basin was carried out for the purpose of clarifying a characteristic of riverbed material in the basin. Samples of riverbed material were taken at 6 spots in Oued Ennkhilet basin as shown in Fig 3.12.

3.2.2 Riverbed Material

Specific gravity of each sample is about 2.68 and grain size d50 (grain size that passing percentage is 50%) ranges from 0.002 mm to 0.02 mm. Results of riverbed material investigation are summarized below and results of gradation test are plotted in Fig. 3.13 on each sampling spot.

Sampling spot	Specific gravity (g/cm3)	d50 (mm)
T 1 (+ 0.3 km)	2.66	0.0220
T 2 (+ 2.9 km)	2.68	0.0080
T 3 (+ 2.1 km)	2.68	0.0060
T 4 (+ 4.9 km)	2.68	0.0070
T 5 (+ 5.3 km)	2.68	0.0016
T 6 (+ 6.2 km)	2.67	0.0026

CHAPTER 4 LAND USE PLAN

4.1 Introduction

It deals with a feasibility study focusing on present and future land use plan in the study area of Ariana Community including Sebkhet Ariana within the Governorate of Ariana and La Marsa Community in the Governorate of Tunis. Under the present land use plan, several phenomena are observed in these areas such as predominance of spontaneous settlements (illegal settlements) and expansion of urbanization in the agricultural zones and flood inundated zones. Many habitants have suffered damages from flood inundation by building their houses in the form of illegal way inside inundated zones and agricultural zones. In this aspect, the delimitation of the study area was determined by a catchment area basis against flood inundation. The study area is partially located in two governorates that have different zoning regulations. In this regard, the presentation of the land use plan was made Ariana Community and La Marsa Community, respectively. This chapter herewith aims to clarify present and future land use plan with a target year of 2000 in a short term and 2020 in a long term.

4.2 Ariana Community

4.2.1 General

The Governorate of Ariana comprises 8 administrative delegations : Ariana, North Ariana, Sidi Thabet, Ettadhamen, Monouba, Mornaguia, Tebourba and Kalaat El Andalous. The study area is situated within two delegations that involve Ariana and Ariana North (hereinafter referred to Ariana Community). Inasmuch as controlling the management, the Ariana Community was divided into 6 areas as shown Figure 4.1. In terms of all the locations of the area are indicated in Figure 4. 5.

4.2.2 The Site

The whole site of the study area occupies a total area of 117.5km2. The delimitation of study area was determined based on the criteria of catchment area against flood inundation. Nevertheless, the area is approximately overlapping with the administrative sectors of the Ariana Delegation and the Ariana North Delegation. Considering the urbanization that is more subject to administrative delimitation, the study of land use plan was conducted in terms of regional context that is not absolutely confined to the catchment area basis.

4.2.3 The Development of Urbanization

Ariana Community had been a small agglomeration, composed of Ariana Center and El Menzah until 1975. The Community doubled in 1980 and has extended 5 times in area at present as illustrated in Figure 4.2. In 1980, the Ariana area extended by the creation of Superior Ariana and zone of Cite Ettaamir toward the Southwest. The El Menzah has extended to high-density and mixed residential patterns. At the same time, North Ariana has witnessed the new phenomenon of unplanned urbanization by creating spontaneous housing. From 1980 to 1985, the Community evolved according to the land use plan approved in 1981 by the Governorate of Ariana in defining non-urbanized zones in the Community. As the urbanization to the South has been saturated, the urban expansion of Ariana Community has taken place only to the North in the form of anarchic way. The urbanized area in the Ariana Community has reached 5 times larger from 1985 to 1989. The half of the expansion was taken place in the area that are not planned by the land use development plan in 1981. Along with this expansion, some problems are observed in this Community. The major obstacle is the surrounding areas of the Sebkhet Ariana that is flood inundation zones.

4.2.4 Present Land Use Plan

In order to comprehend the distribution of the present land use pattern, the Community is classified to several zones. Under the present land use plan of Ariana Community, the proportion of the land use in the study area are composed of residential, commercial, administrative/institutional, industrial, agricultural, green area, open space and the Sebkhet Ariana as shown in Fig. 4.3 and Table 4.1.

The Sebkhet Ariana and its Surrounding Areas

The Sebkhet Ariana is located in the upper part of the study area that covers approximately 36.5km2. As this sebkhet lacks communication with the Mediterranean sea, it causes flood inundation around the sebkhet during the rainy season. When the sebkhet is saturated, the water can be discharged to the sea crossing over the roads in Gammarth.

Urban Center Area

The zone of Ariana Center and all the agglomerations of El Menzah and Superior Ariana constitute most important urbanized area with high density in the Great Tunis area. The expansion takes the formation of urbanization in various residential types in the Ariana Community.

The Zone of Choutrana

The Choutrana area occupies about 17.6km2 of which 3.0km2 is prone to inundation and the rest of 14.6km2 is not. Of this 14.6km2, 2.9km2 is occupied by the authorized housing of La Gazahla and Borj Louzir. The rest of the area (11.7km2) is distributed for agricultural use (7.6km2) and spontaneous housing (4.0km2).

The Zone of Soukra plain

This zone extends from the GP8 and along the RV533 until reaching the Sebkhet Ariana in the North and Gammarth in the East. The majority of this zone is composed of agricultural fields covering 9.0km2 (80%) in Soukra area in terms of study area. Moreover, a big occupation of spontaneous settlements accounting for 6.0km2 in a total area of Soukra is one of the most serious problems in this Community. Furthermore, this zone surrounded by the Sebkhet Ariana is considered as a flood inundation zone due to insufficient drainage network facilities and poor discharge capacity of the Sebkhet Ariana water to the sea.

The Zone of Raoued

In this zone, 10.1km2 (33%) of the area accounts for agricultural fields and 9.0km2 (30%) of the area is open space in the total area of 30.2km2. The zone is already occupied by the spontaneous housing areas in the agricultural fields along the RVE 546. With having much open space in this zone, urban expansion will be occurred as a form of new residential zone.

4.2.5 Flood Inundation Zone

The flood inundation zone in this Community creates great constraints to urbanization. This is because the ground water flows close to the ground level. Moreover, this Community has absence of natural slopes and poor drainage facilities. This phenomenon is witnessed conspicuously along the Oued Ennkhilet and in flat agricultural zones of Ariana North and Soukra as illustrated in Fig.4.7. In this aspect, the zone suffers flood inundation, particularly during the rainy season due to the increase of water level in the lowest part of the agricultural plain. Furthermore, the occupation of spontaneous settlements around the Sebkhet Ariana is one of major reasons of flood inundation. According to the source from MOEH, the flood inundation zones are indicated as follows ;

- Around the ONAS purification plant in Choutrana.
- Between the ONAS canal toward Raoued and RVE 533 up to the cross with RVE546.

- North of the Sebkhet Ariana area.
- All the low lands in the North of Raoued all along the ONAS canal.

4.2.6 Problems to be Addressed

1. One of the most conspicuous aspect observed in this area is spontaneous settlements. Those spontaneous housing areas have been constructed particularly in the flood inundation zones, surrounding the Sebkhet Ariana that are endangered not only existence of urban property but ecological equilibrium of the sebkhet and its surrounding areas.

2. With the rapid expansion of the new town development from the Ariana Center toward northern part, the Community has witnessed with poor traffic linkage to the old city of Ariana.

3. The agricultural zones of Ariana North and Soukra show lack of basic infrastructures and insufficient socio-collective facilities. Also, these zones are susceptible to flood inundation because of the problems of insufficient drainage system and weak water evacuation capability as well as the proximity of ground water level to the ground surface.

4. The Sebkhet Ariana has a poor flow of water into the sea. This is because insufficient facilities of the evacuation canals and stagnation of the water. Moreover, it is observed saturation occurs by used water from ONAS purification plant.

5. The spatial distribution and formation of urban fabric are not balanced in this Community. As an illustration, the old central city shows high density and spontaneous settlements have poor structures.

4.2.7 Future Land Use

The future land use plan is illustrated in Figure 4.4, according to the future land use development plan by the MOEH. In addition, Table 4.2 depicts the future land use proportion in the study area. Table below shows the increase of built-up urban areas to meet the future needs of the Community. Under the future land use plan of the Ariana Community, the proportion of the land use in the study area incorporates residential, commercial, administrative/ institutional, recreational, agricultural, green area, inundated zones and the Sebkhet Ariana.

	Residential	Commercial	Administra-tive / Institutional	Recreational	Industrial	Total
Raoued	2.7km2	0.05km2	0.25km2	1.3km2	-	4.3km2
Ariana Superior	1.3km2	-	0.2km2	2.5km2	-	4.0km2
Bori Louzir	3.0km2	0.05km2	0.2km2	0.15km2	-	3.4km2
Ariana Medina	0.2km2	-	-	-	-	0.2km2
Soukra	0.4km2	-	-	0.2km2	- 0.1km2	0.5km2
La Marsa	2.5km2	-	0.1km2	0.8km2	0.45km2	3.85km2
Total	10.1km2	0.1km2	0.75km2	4.95km2	0.35km2	16.25km2

Source: Calculated by the study team

Urbanized Area

The urbanized zones are composed of various forms in urban fabrics. The development has been undertaken in different ways in this zone compared to that of Ariana Center. Accordingly, some problems occurred with the urbanization of these new towns should be solved by providing efficient countermeasures as follows;

- to control spontaneous housing expansion and plan for the solution of the existing spontaneous settlements.
- to allow smooth linkage from new town to the old city of Ariana through efficient traffic network.
- to offer well-balanced distribution of public facilities in the Community.
- to promote basic infrastructure facilities particularly drainage and sewage network system.
- to provide public parks in Community to enhance the quality of life.

The Zone of Soukra

This zone will be allocated for a mixed urban zone with activities and residential areas for the closeness to the recreational park of Soukra. This zone will be relocated as a mixed area that incorporates medium-density housing and unpolluted industries. The land that can be urbanized in the North of the recreational park is allocated to low-density housing. The North of the areas linked to the Sebkhet Ariana will be maintained as a zone of agricultural preservation.

The Zone of Ariana North and Choutrana plain

The whole area of 18.0km2 allows to allocate the area of 9.0km2 for future urbanization after excluding the flood inundated zone of 1.5km2, the large public

facilities of 4.0km2, existing spontaneous settlements of 3.0km2 and the plots authorized or to be authorized of 3.5km2 in " La Gazahla". Nevertheless, this area requires a revision of study concerning spatial reorganization and planned road network to consider the evolution of spontaneous habitats and to integrate the continuation of the planned road X20 through Soukra and Choutrana plain as shown in Fig.4.6.

The Zone of Raoued

The zone is planned to a new urban project. It will integrate existing houses, surrounding areas of Sebkhet Ariana and flood inundation areas. This new zone will incorporate as follows;

- The medium-density housing zones, suitable for individual housing or isolated collective housing.
- The zones of dense housing toward seaside and suitable for collective housing.
- The zone between touristic area and residential area is planned for the commercial center in Raoued where the RVE546 cross.
- New residential area with isolated housing pattern will be created along the sea.

4.2.8 Flood Inundation Zone

The new construction will be prohibited in this zone as shown in Fig.4.7 to prevent urban properties from flood damage. The existing houses and buildings in this zone will be maintained but the habitants will not obtain any authorization for extension. As a countermeasure of eliminating these spontaneous settlements, the supplying of public housing for illegal inhabitants is required. Moreover, provision of new infrastructure facilities against flood damage such as retention ponds, irrigation and sewage system is necessary to minimize damages. In order to reduce the damages from the flood inundation, several methods are recommended as follows;

- to prevent the discharge of used water by the ONAS purification plant.
- to maintain the drain at the level of the agricultural plains.
- to reinforce outlet facility of the Sebkhet Ariana to allow smooth discharge to the sea.
- to improve drainage system and secure retarding ponds against possible flood damage.
- to halt spontaneous settlements in the zone.
- to maintain agricultural protection zones in Choutrana to promote the function of hydraulic structures such as drains and canals.

4.3 La Marsa Community

4.3.1 General

Community of La Marsa is an unique one in the Greater Tunis area with attractive points with high-quality natural environments and historic places. The Community of La Marsa is characterized as follows;

- A modest population growth
- A waste of space by low-density
- Good housing conditions but accompanied with the development of spontaneous housing
- Good socio-collective facilities but required better spatial distribution and improvement
- A central area of local characteristic that is not adapted to the regional context
- Centrifugal tendencies of urbanization in agricultural lands
- A potential of tourist activities that may offer a new characteristic of the community

4.3.2 The Development of Urbanization

La Marsa Community shows predominance of isolated housing on a big plots. This form of urbanization that has prevailed during the last 20 years led to extensive spread in urban fabric as illustrated in Fig.4.2. This uncontrolled urban development became an origin of centrifugal dynamics of the urbanization in this Community. With the saturation of the zone in the sea front, urbanization reaches to the area situated between Bou Seelsla and RVE550. Also, the area between the GP9 and MC33 and the zone of Sidi Daoud are boosting to urbanization. The pressure of urbanization also exists mainly along the GP9, GP10 and in the West of RVE550 where Slama is located. Along with that, the zone of Harrouch, which was defined as an agricultural zone by the land use plan in 1981 is subject to the development of spontaneous housing areas. The spatial dynamics of urbanization mainly in the outskirt of the Community such as Sidi Daoud, Bhar Lazrag and Gammarth area involves spontaneous housing problems.

4.3.3 The Site

La Marsa Community is located in western part of the study area that occupies in an area of 25.1km2 as shown in Fig.4.1. The northwest of the site is linked with the Sebkhet Ariana. La Marsa has been evolved on the lands surrounded by 2 hills towards the South of Community where the land is completely flat.

4.3.4 Present Land Use

For the better understanding of present land use distribution, the study area in La Marsa Community is classified to several zones. Under the present land use plan of the La Marsa, the proportion of the land use in the study area incorporates residential, commercial, administrative/institutional, industrial, recreational, agricultural, green area and open space as shown in Fig.4.3 and Table 4.1.

Residential zone in La Marsa Community covers about 6.4km2. The characteristic of residential zone is predominance of isolated housing on the plots that surfaces are large, ranging 500m2 to 1,000m2. This phenomenon has led to inefficient land use in the form of low density and waste of space. In addition, the anarchic housing represents 21% of the residential sector. In 1988, the area of spontaneous housing was estimated as 0.9km2 in this Community.

Commercial zone accounts for of 0.2km2. This zone is mainly located in central town of La Marsa and the other local commercial centers are in Gammarth and Sidi Daoud. Nevertheless, the structures and facilities of the zone do not correspond with the regional scale of the Community.

Administrative and institutional zones are also partially allocated in La Marsa Community, covering in an area of 0.4km2. The administrative zone including municipal office, embassy and guest house is mainly located in the central area. The institutional areas consist of schools, colleges, craft centers and hospitals.

Industrial activity zone in La Marsa covers an area of about 0.1km2 in the entrance of the Community along the GP9. Recently, coherent plan was elaborated by the MOEH that aims at creating activities, matching residential characteristic of its surrounding areas.

Recreational zone covers an area of approximately 0.5km2 including sports/ entertainment facilities and touristic places.

Agricultural zone incorporates three sub-divisions in the plain of Soukra, Gammarth and Sidi Daoud covering in an area of about 8.1km2 . The area between the RVE550 and GP9 and the area in South of Bou Seesla have reserved for vegetable agriculture. Also, the hillside of Gammarth has developed the arboriculture and the plain of Sidi Daoud has cultivated cereal product.

In La Marsa, green areas occupy in an area of 4.5km2. Most of green area is located in the natural forests in Gammarth and Harrouch.

4.3.5 Problems to be Addressed

1. The Community also contains disordered spontaneous housing areas in the outskirts of the Community. The proportion of anarchic habitats in La Marsa is 21% in an total area of 0.7km2 in 1988. Furthermore, most of these spontaneous settlements are located in the agricultural zone in Harrouch , Gammarth , Bhar Lazrag and Sidi Daoud near the GP9.

2. The population in La Marsa increases by a thousand of persons each year. This incorporates approximately 200 houses on the assumption that one household has five family members. Nevertheless, the annual space consumption is about 20ha that concerns average density is 1 house per 1 ha. Although this disparity is different from the areas in the Community, it implies the waste of space.

3. One of the phenomena in the Community is the expansion of urbanization in the agricultural zone. As an illustration, the areas of Sidi Daoud and mainly along the GP9 and GP10 are witnessed for new constructions. Also, the Bhar Lazrag area is observed the invasion of urbanization.

4. The central areas provide only local level for visitors rather than regional level in terms of functions and facilities that create saturation and much congestion.

5. The wide flood inundated zone around Sebkhet Ariana covers all the northwestern part of the Community. Moreover, as the built-up areas are situated in the upper side of the catchment area, this causes the flow and stagnation of rainwater in the flat zone, where is located in downstream and near the GP9.

4.3.6 Future Land Use

Like Ariana Community, the uncontrolled urban expansion by the spontaneous habitats is one of serious problems. In this sense, the future land use plan was made to minimize anarchic housing development and to optimize the land use by presenting southern limit of urbanization to the RVE550. Figure 4.4 illustrates the future land use development plan. In addition, Table 4.2 shows the land use proportion in the study area.

Despite of much attractions in the Community, the central area remains as a local level with small scale compared to expansion of Community development. Therefore, it requires a planning to redevelop the central area in the context of the regional scale.

Concerning the residential zones, it is imperative to optimize the urban land use by rearranging and reducing the area of a plot to 400m2 for the balanced land divisions. The average density will be 18-20 houses per one ha to reduce the waste of land and make the most of existing infrastructure facilities. Furthermore, the social housing operation program is proposed on an area of 0.3km2 in Harrouch by the PDU. This implementation of the project will reduce centrifugal tendencies of urbanization resulting from spontaneous housing.

Recreational zone occupies an area of 1.3 km2 involving sports /entertainment facilities, urban green parks and touristic places. In this zone, an urban park will be created in an area of 0.2km2 in Gammarth green area. The other recreational zone includes sports facilities covering in an area of 0.3km2 near Sidi Daoud along the GP9. In addition, the touristic areas involve three sectors in an area of 0.8km2 that are Gammarth, Chott El Ghaba and Chott Errih along the seaside. The development program of touristic zone is proposed in an area of 5.3km2 for next 15 years.

The major agricultural zone is located in the South of the RVE550. Nevertheless, the agricultural predominance in these areas is threatened by the pressure of urbanization. In this sense, it is necessary to control these areas to use as a reserved zone to meet the demands of the Community for long-term urbanization.

The green zone involves natural green areas and facility green areas. The natural green area is mainly composed of natural forests in Gammarth. The green area with facilities contains recreational urban parks along the GP9.

The urbanization has been arisen mainly in the zone of Bhar Larzag and Harrouch that are situated between the Gammarth area and the RVE 550. This unplanned expansion toward agricultural zone leads to an improper utilization of land and unnecessary infrastructure cost. To optimize and rationalize the land use, the urbanization should be limited to the southern part to the RVE 550 in La Marsa Community.

4.4 Conclusion

The development of Ariana Community has problems in urbanization. This is mainly because of inundated zones and spontaneous settlements. The problem of spontaneous

housing is closely interrelated to the flood damages because much of spontaneous settlements are created in agricultural zones or flood inundation zones where are susceptible to flood inundation . To settle these problems, the authority must control the expansion of anarchic habitats particularly in the flood inundated zones and offer social housing program for the spontaneous habitants as a countermeasure of eliminating the existing spontaneous housing problems. Furthermore, well-balanced spatial distribution of social facilities and basic infrastructures should be provided in accordance with urbanization to meet the demands of the residents.

CHAPTER 5 URBAN DRAINAGE

5.1 General

Urban drainage systems in the study area 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 the Oued Ennkhilet before flood occurs. In case this flow is very minimal, then the flow will be neglected in the design flood runoff analysis.

Reviewing data and information on storm water drainage system and sewerage system in Greater Tunis and area, and also through the 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 such treated water is utilized as irrigation water at he north shore of the Sebkhet Ariana. Industrial water from the light industries in the area is discharged to the existing sewerage system and oueds passing nearby without sufficient treatment, but the discharge amount is very small and minimal.

5.2 Existing Urban Drainage System

Data Collected:

Besides the data and information on urban drainage system collected by S/W Mission, the JICA Study Team tried to collect additional data/information from various sources. It was found that the studies and succeeding implementations of storm water drainage and sewerage systems in the Oued Ennkhilet basin had mainly been made as a part of systems in the Greater Tunis area in several steps to date by National Sanitation Agency (ONAS), which was before 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 Phases 1 and 2 at the site are rather old one. Then the members of the JICA Study Team visited several times ONAS offices in Tunis, and visited a local consultant who is 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 the study area. 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 study area 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 from 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.

Review of Data Collected:

Data collected and information mainly obtained during the Phase 1 through interviews to staff concerned of ONAS, SONEDE and MOEH, and some local consultants were examined again. Storm water drainage and sewerage systems in the study area have been operated and managed, and rehabilitated by both MOEH and ONAS since before. Review of Master Plan had been made every five year by ONAS, and now is in the Fourth Stage. The JICA Study Team was informed that modified Master Plan and the Feasibility Study on priority projects which cover whole the Greater Tunis area are now under finalization by ONAS, and the final reports will be issued by the end of November 1993. The Study Team requested ONAS through MOEH to avail the latest data and information studied in the recent study, however, it has not been obtained eventually.

As for water supply for the Greater Tunis area, the details of existing facility, supply capacity, served population, etc. are not available. Data obtained from SONEDE show only nation-wide water supply features. However it is judged that the amount of this water supply will not affect the flooding problem in the area.

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 Phase 3 study period. Major findings are as follows.

(1) In the study area, the demarcation of flood control project by MOEH and storm water drainage system by ONAS is not clearly determined. It is found the improvement of the Oued Ennkhilet has been planned and implemented by both MOEH and ONAS, and construction of concrete box culverts are now under way along the RVE 533 by MOEH.

(2) In Greater Tunis area, there exist four sewer treatment plants. Sewer water from the study area is mainly collected by combined sewerage/drainage system, but some part are collected by separated sewer pipe network laid and connected to one of these sewer treatment plants locating at southern shore of the Sebkhet Ariana. 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 the Oued Ennkhilet is minimal.

(3) 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. Inundation frequently occurs due to poor storm water drainage system.

(4) The JICA Study Team could have a chance to see the actual situation of storm water drainage system in the study area, when storm rainfall with about 100 mm in total occurred May 6, 1993. It was observed several roads and flat agricultural lands spreading at the shore line of the Sebkhet Ariana were inundated to several centimeters because of poor storm water drainage system, however the duration of such inundation was not so long. It was also observed that many retention ponds existing along the river course were functioning well to mitigate the peak flood runoff.

5.3 Present Condition at the Site

(1) Existing drainage system and facility

Inventory of existing drainage systems and facilities operated and maintained by ONAS and MOEH has not been released to the JICA Study Team.

(2) Urban drainage development plan

MOEH informed that 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 in near future.

(3) Institution relating to drainage and water supply

Urban drainage systems in the 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, an autonomous government agency under the MOA. It seems that each government or autonomous agency is implementing projects independently without adjusting their plans each other.

5.4 Preliminary Design of Urban Drainage System

In the urbanized area of the Oued Ennkhilet basin, it has been observed that some 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, it is recommended such urban drainage system should be planned and implemented by ONAS in collaboration with MOEH. Due to limited and insufficient data and information, the preliminary deign of urban drainage system in the study area was not carried out if the frame of feasibility study.

CHAPTER 6 ENVIRONMENTAL IMPACT ASSESSMENT

6.1 Background

An Initial environmental examination (IEE) was carried out as part of the master plan study. Details are enumerated in Chapter 6 of the Master Plan Report (Part I). The present chapter presents a more detailed environmental impact assessment (EIA) for the flood control measures proposed in the selected priority project. The contents of this chapter supplement the IEE and provide more detailed information of some environmental aspects determined to be of importance in the Oued Ennkhilet basin.

The study area considered for the environmental study includes not just the basin boundary for the Oued Ennkhilet and Sebkhet Ariana, but also the areas surrounding Sebkhet Ariana. In particular, the Raoued area in the North of the Sebkhet Ariana and the Soukra-Choultrana plain West of the Sebkhet Ariana are included considering their proximity to the Oued Ennkhilet and the Sebkhet Ariana.

6.2 Existing Conditions

Table 6.1 of the Master Plan Report summarizes the existing environmental conditions in the Oued Ennkhilet and the Sebkhet Ariana and surrounding area in terms of the general economic development in the river basin, problem of flooding and causes, environmental problems and water quality of oued or sebkhet. Taking into account the results of the IEE and environmental problems specific to the river basin, more detailed information concerning relevant environmental aspects with respect to the problem of flooding is presented here.

6.2.1 Physical Environment

(a) Geography and Site Location

The Ariana plain covers 12,000 ha and spreads around 12 km in length and 6 km in width. The average attitude is 8 to 10 m, and progressively sloping towards the East (5 m at Ennkhilet; 4 m at Borj Maala). A large part of this area is occupied by the plain of Soukra, situated at the bottom of a depression. The Soukra is bordered to the East by the hills of Carthage and Gammert, and in the West by the Pliocene hills that start at the plateau of Belvedere in an area 1.5 km north of Ariana in the small solid mass of Djebel Nahli, whose highest point hardly crosses 236 m. The meridian limit is the Tunis lake at

the level of low ground semi-inundable areas of Charguia and A'Aouina. In the North, the Soukra plain after narrowing to less than 0.5 km width between the hills of the West and the Sebkhet Ariana, rejoins the valley of the Medjerda.

(b) Slope

Fig. 6.1 presents the slope map of the study area. Following four categories are identified:

(1) Areas with slope between 5 and 10 % are found at the foothills of Jebel Nahli.

(2) Areas having slope between 0.5 and 5 % are situated in the West in the Gazelle sector.

(3) Areas having slope between 0 and 0.5 % spread over a large part of the plain of Soukra-Choultrana.

(4) Areas having 0 % slope located very near the Sebkhet Ariana.

It is seen that the study area is dominated by significant low laying areas prone to flooding and consequent difficulties in drainage.

(c) Ground water Location and Difficulty in Drainage

One of the major problems of the study area is the problem of drainage and shallow level of ground water. Due to the position of the closed basin between the hills of the East and those of the West, ground water drains with difficulty towards Sebkhet Ariana and Tunis Lake. Further, the ground water level is very shallow and in the rainy season in many areas in the lowest part of the Soukra plain, it is difficult to distinguish the ground water upper level from the lower level of surface water. This is a big handicap for the development of agriculture (market gardens and big cultivation) and for urban development. Fig. 6.2 presents the ground water location map for the study area. The following three categories are delineated:

(1) Level < 10 m: This zone is found West of the Raoued (Gazelle) route. The water is of good quality for irrigation.

(2) Around a large band of 70 m parallel to the Raoued route, the depth of the layer is between 5 and 7 m.

(3) In the rest of the zone, the layer is lower than 5 m. It is lower than 2 m in certain sectors notably in the outskirts and in the area surrounding Sebkhet Ariana. Ground water found at less than 5 m depth is typically soft (water) at the top, and dirty in the deep end. It can be utilized for plants with a shallow root system.

(d) Sebkhet Ariana

This is a lagoon covering a surface area of 3,100 ha whose level is sometimes lower than that of the seas. The Sebkhet is fed by rainfall over its area, by storm waters originating in the surrounding sloping basins, underground infiltration from the sea and by discharge of waste waters of the North. A more detailed discussion about the Sebkhet ecosystem and characteristic is presented in the next section.

6.2.2 Ecological Environment

Terrestrial Flora and Fauna: Sebkhet Sijoumi, Sebkhet Ariana and Tunis lake (including the North and South Lake of Tunis) constitute important wetlands of local and national importance, and is a popular site for wintering and migrating birds from Europe and the Middle East. Data about the flora and fauna in each of these wetlands, type, numbers and habits of wintering birds coming to these wetlands, the ecosystem prevalent in each of these wetlands, as well as the importance of these wetlands to the local population was collected. A non-governmental organization named "The Friends of the Birds" established in 1975 in Tunis provided significant information. Discussions with many members of this association as well as with several academic staff of the University of Tunis were held by the JICA Study Team to determine and assess the value of the flora and fauna in these wetlands. Since the three wetlands are so near each other, local ornithologists and ecology experts consulted were of the opinion that in assessing the importance of the flora and fauna of these wetlands, they should be considered collectively. Wintering bird populations have been observed to move from one to the other.

Table 6.1 presents specific information about various aspects for each of these wetlands that helps one understand the ecological value of these wetlands to the local community. Although the legal status of these wetlands is still unprotected, hunting is totally prohibited. Wintering bird population numbers change year to year and from one wetland to another. Factors like salinity of the water, availability of food in the wetlands, climate and numerous other factors affect their preference and choice. For example, it has been reported that in recent years after the North Lake of Tunis was cleaned up with the construction of the ONAS's canal, wintering bird numbers are seen to be decreasing there. The birds seem to prefer the polluted waters of the South Lake of Tunis. This is perhaps because the cleaned lake environment does not allow adequate development and growth of micro fauna and flora in the water on which the birds feed upon. Table 6.2 presents data on the type (species), and number of birds spotted in the three wetlands in

or around Tunis in the last five years (1989 to 1993). Major wintering birds include waders, flamingoes and dabbling ducks.

6.2.3 Human Use and Living Environment

(a) Urbanization

Ariana is characterized by three important phenomena, namely the dominance of spontaneous housing, the great use of agricultural land for urbanization, and significant environmental damage in the plain of Soukra and Sebkhet Ariana. All these have close relationship with the problem of flooding in the study area. These three problems need to be addressed adequately keeping both short and long terms needs of the entire population of the commune. From 1975 to 1985 the spontaneous housing figure reached 53 % in Ariana commune. Fig. 6.3 indicates the urbanization in Ariana commune in the year 1975, 1980, 1985 and 1988-89. The urbanization phenomena largely occurred on agricultural lands and green spaces. Until 1985, the plain of Soukra used more than 5,000 ha of urban space gained from agricultural lands. In Raoued and Soukra about 80 % of the agricultural parcels are inferior to 5 ha. Parcels inferior to 2 hectares represent 49 % of the total area. This land structure indicates problems in land control and encourages splitting of parcels and the increase of spontaneous constructions.

Fig. 6.4 shows the urbanization tendencies and the natural constraints. Many spontaneous constructions were made on flood prone areas around Sebkhet Ariana, which is harmful to the ecological equilibrium of the lake and its surroundings as well as to the urban patrimony itself. Urbanization is accomplished in three different ways:

(1) Planned urbanization according to regulations such as in Ariana center, El Menzah etc.

(2) An unplanned, but authorized urbanization such as in La Gazette and Zitouna.

(3) A spontaneous urbanization such as that of Borj Lonzir, Dar Fadhal, and Choultrana etc.

These phenomena recur in the absence of an agricultural and peri-urban policy in the District of Tunis, in spite of the existence of a map of agricultural classification issued in March 1985. From Fig. 6.3 it is seen that in Ariana commune the urbanization is spreading by a cluster phenomenon. Existing urban land use and future urban land use (in target year 2010) are presented in an earlier chapter. The present section focuses on the negative impacts of spontaneous settlements that constitute as much as 50 % of the urban settlements in Ariana commune. Negative impacts include:

(1) Negative impacts on the aesthetic appearance of cities.

(2) Poor functioning of spontaneous neighborhoods due to haphazard development without consideration of future population inflows or vehicle traffic. Labyrinth street systems develop which have difficult access and there is a rise in problems in terms of services, maintenance and emergency aid.
(3) A substantial use of land area. The density rate of spontaneous settlements is less than a half the rate for formal settlements.
(4) Costly infrastructure provision, particularly for sanitation systems. General layout is disorganized and primary networks are obliged to travel over large distances.
(5) Limited municipal services. In most of the illegal spontaneous settlements in the Soukra-Choultrana plain in Ariana, there is no sanitation or storm water drainage system. Households simply use cesspools or throw the waste water into the streets. The Oued Ennkhilet receives significant waste water from surrounding spontaneous communities lacking a sanitation system. These spontaneous settlements in Ariana are a major factor in the pollution caused by untreated domestic waste water.
(6) Hazards for the population of spontaneous settlements from hazards such as floods, electrocution, explosions, toxic waste poisoning, etc.

(b) Agriculture

The Choultrana plain constitutes land of good soil favorable for annual cultivation and market cropping. About 80 % of the area is occupied by annual crops and the rest of the area is used for various kinds of fruit trees. Nevertheless, the agronomic potentialities of the zone are limited and difficult to exploit due to the ever increasing illegal spontaneous settlements on one hand, and the feeble slope of the area that results in accumulation and stagnation for extended periods of rainwater originating in the Djebel Nahli. Thus, the agricultural land is flooded by water in winter and spring and their exploitation becomes very difficult without drainage and sanitation facilities.

The Soukra plain covers an area of over 1,286 ha with a topography slightly inclined towards the sea. The soils are sandy with very low retention capacity and have an airy structure. The average depth is around 2 m. It rests on a brown calcium soil, which forms the support of a dirty ground water layer that becomes increasing shallow towards the Sebkhet Ariana and limits agricultural development significantly. In spite of these limitations, about 1,146 ha is used for cultivation, about 100 ha for urban settlements and the remaining 40 ha is barren land. An important part of the plain is occupied by the irrigated perimeter of the Soukra. About 644 ha areas are irrigated by the purified waste water of Charguia station and 266 ha area irrigated by the water from surface wells. The crop choices are limited to the arboriculture that pose no health risk.

(c) Problems Created by Construction of and/or lack of Social Amenities and Municipal Facilities

The National Sanitation Agency (ONAS) has constructed two waste water treatment stations, the Charguia station and the station on the north coast side in 1977, and another new treatment station in Choultrana in 1986. The Choultrana station treats 90,000 m^3/d of waste water and is joined together to the Charguia station by a conduit of 2,000 mm, and with the north coastal station by an open canal of total length 5 km. While ONAS maintains that the canal is watertight and permeable, other technical experts affirm that it is impermeable and creates obstacles to the flow of water from the plain towards the Sebkhet Ariana, which is already a problem due to the natural slope and ground water conditions. Field investigations by the JICA Study Team confirmed this. Further, very often, ONAS diverts the flow of untreated or partially treated waste water directly into the sebkhet due to poor waste water flow control into the Choultrana station. The return of this untreated waste water from the sebkhet towards the plain feeds into the ground water and causes the water to stagnate for long periods, thereby endangering many agricultural crops.

A review of statistical data of Ariana commune indicates that the Soukra and Raoued remain disadvantageous compared with the rest of the commune. Only about 3 % of the urban settlements are connected to primary sewerage networks. There is no primary sewerage network in the Soukra and Raoued areas. Also more than 50 % of the dwellings in Raoued have no waste water collection system or even on site treatment facilities like septic tanks. All the households' waste water is discharged superficially outside the homes, causing pollution and posing significant health hazard particularly when flooding occurs. In Raoued, more than 30 % of households have no drinking water while in the Soukra this figure is about 22 %. Significant number of spontaneous settlements in Raoued and Soukra also do not have electricity. In North Ariana, except for some roads, most roads are not suitable for motor vehicles because of flooding problems, especially around the sebkhet.

6.3 Without Project Impacts

Without the proposed structural measures for flood protection, flood damage would continue to cause considerable economic disruption and social hardship to many of the populations, particularly spontaneous housing settlements living in the Soukra-Choultrana plain of Ariana. The Master Plan Report as well as a subsequent chapter of this report presents an assessment of the flood damage cost that would be incurred without the project. Damage assessment has been made for the 100-year return period.

Damage for intervening years has been made on a pro-rata basis according to areas flooded. The basis for the flood damage is past flooding history, the present land use, future land use and various socio-economic data. Damage has been assessed based on the following aspects:

(1) Damage to housing and residential property.
(2) Loss of income by residents/industrial employees.
(3) Damage to factories.
(4) Damage to agricultural areas.
(5) Road damage.
(6) Traffic delays.
(7) Increased vehicle operating costs.

It is seen that damage to property and income losses resulting from traffic delays together constitute over 90 % of the possible flood damage under both present and future land use conditions. Again, the delineated boundary for flood damage assessment is only the basin of Oued Ennkhilet. The large plain of Soukra-Choultrana is not included in this damage assessment. As seen in the description of existing conditions, significant flooding problems as well as environmental problems exist in this area. Flood damage to this large protected agricultural area and to the large number on spontaneous settlements in them would be very significant, as also observed in the past. Additional problems of risk of spread of waterborne diseases after floods are also very high in this area and in the northern part of Ariana near Sebkhet Ariana where there are no sanitation or adequate drainage facilities.

6.4 With Project Impacts

Table 6.3 presents the EIA matrix for the during construction and post construction periods.

6.4.1 Proposed Structural Measures

The flood control alternative measures considered in the Master Plan Study for the Oued Ennkhilet and Sebkhet Ariana areas were reviewed in detail in the feasibility study. The structural measures considered include: one or a combination of the following: river improvement works, new retarding basin, rehabilitation of existing retarding basin or dam, new diversion channel, and new flood control dam. The alternatives considered are:

(a) Retarding basins and small flood protection dams less than 7 m in height in upstream hilly areas in combination with multipurpose retarding basins in available open spaces in the urban areas in the middle reaches, and minimum river improvement

works downstream. This strategy of keeping river improvement works as less as possible is considered as future land use plan of the area proposes expansion and upgrading of existing road No. 533 along which Oued Ennkhilet is located. This could make river improvement works very costly though technically feasible.

(b) Retarding basins and small flood protection dams of less than 7 m height in upstream hilly areas in combination with some retarding basins in open spaces of urban areas, and channel improvement with new diversion channel to the Sebkhet Ariana in the downstream section using existing drains as far as possible. This alternative assumes that open spaces in the urban areas are not available for use as retarding basins.

The proposal put forward in the master plan of reclaiming land from the Sebkhet Ariana for development is discarded. The sebkhet would be maintained in the existing natural state allowing the annual natural fluctuation in water level to continue. Natural outlet of the Sebkhet Ariana to the Mediterranean Sea blocked by sand dunes would be maintained the same way. When flooding occurs, depending on the need, bulldozers would be used to clear the channel to allow flow of water from the sebkhet into the sea. Again, the natural accumulation of sand at the outlet opening would be allowed to continue.

6.4.2 Negative Impacts

The sites considered for the new flood control structural measures do not involve any resettlement or relocation of population. Negative impacts due to the proposed structural measures in the post construction period are not perceived. During the construction period, possible negative impact could be temporary erosion and siltation due to large scale earthworks for retention basin, diversion channel and river improvement works. To minimize this negative effect, appropriate construction methods should be undertaken with due environmental considerations. Table 6.4 presents possible negative impacts during construction works along with recommended mitigation measures.

6.4.3 Positive Impacts

Since the Sebkhet Ariana is going to be preserved in its natural state with no land reclamation planned, the wintering bird population would be unaffected. This needs to be considered as a very positive impact or benefit to the local population that has been determined to value the flora and fauna significantly.

The multi-purpose retention ponds considered in open spaces of the urban areas will provide a temporary storage during flooding. Under normal circumstances they would be used for recreational purposes like a sports field by the people. Along the perimeter of

these retarding basins, suitable green buffer zone would be established by reforestation and plantings. A variety of indigenous trees and shrubs may be introduced to regenerate the natural environment from the existing barren land condition. The diversion channel considered will be neatly landscaped with grass turf and lined with rows of trees. Pedestrian walkways will be provided along the channel and at some strategic locations, small plazas will be built to enhance riverine landscape. River improvement works would contribute to prevention of eutrophication and significant improvement of riverine landscape and aesthetics, especially since the Oued Ennkhilet flows through densely populated urban areas. For enhancement of riverine landscape, appropriate forms of pedestrian walkways, and resting plazas with focal gardening suitable for residential and commercial areas need to be considered. Riverine landscape needs to be improved by improvement of river revetments, clearing of river reserve, improvement of river reserve, provision of pedestrian ways and resting areas, provision of walkways on bridge branches, conservation of natural vegetation, riverine improvement in conjunction with the development of nearby commercial and residential areas, harmonized design and characteristic allocation for riverine facilities and structures, and consideration for pedestrian walkways with link up to adjacent plaza and park through riverside area.

Thus from the above, it is clear compared with the wholly negative nature of the without project alternative, the environmental impacts of the proposed project structural measures are very beneficial. From an environmental point of view, the project is determined to be sound with no negative impacts. However, several environmental problems discussed in detail earlier will continue to persist until and unless suitable environmental mitigation and monitoring measures are also formulated and implemented along with the proposed structural measures. This is discussed in the next section.

6.5 Environmental Mitigation and Monitoring Measures

Table 6.4 gives the environmental mitigation measures to minimize negative impacts during the construction period. In the post-construction period, environmental mitigation and monitoring measures are necessary in addition to the proposed structural measures for reducing and controlling floods. These need to address the following issues:

(a) Formulation and implementation of land use plan. This is for preservation of green areas, agricultural areas and protected areas, preventing new spontaneous housing in flood prone areas and rehabilitation of existing spontaneous settlements. Appropriate land use planning and effective implementation of policies are necessary. Plans for housing zone development catering to low income communities need to be formulated.

(b) Prevention of water pollution due to garbage disposal and domestic and industrial waste water discharges into the drainage system, streets and the river. Improved and regular monitoring as well as strict enforcement of pollution control laws is necessary. Garbage and solid waste collection system need to be improved. Appropriate screening facilities need to be provided at strategic locations along the river.

(c) Monitoring of flora and fauna in the Sebkhet Ariana and other wetlands in the Tunis area should be more regular and continued. NGOs should be assisted in carrying out more detailed research on wintering birds. The Sebkhet Ariana has good potential as a eco-tourism and educational site for this aspect.

(d) Watershed management activities and planting of vegetation along river banks should be undertaken in order to delay runoff and increase infiltration, thereby reducing the risk of flood.

(e) A study needs to be carried out to determine in detail the changes in the ground water levels and their effect on flooding in the Soukra-Choultrana area due to the construction of the ONAS's canal. Suitable environmental management strategies can then be formulated.

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

(g) Development of a flood warning system and an evacuation cum management plan for settlements or population in vulnerable flood prone areas.

(h) Formulating plans for provision of appropriate drainage and sanitation facilities for all of the study area.

(i) Environmental education and public awareness program for conservation of oued and sebkhet environment should be formulated and implemented by making maximum use of mass communication media.

CHAPTER 7 RIVER AND FLOOD

7.1 General

For the last some tens years, the Oued Ennkhilet basin and surrounding low laying area of the Sebkhet Ariana have been suffered from recurrent flood inundation because of its topographical condition and insufficient drainage system. Flood inundation problem becomes a serious social problem for those areas year by year. One of the major causes is judged to be an urbanization by housing development especially in the hilly area. It is found the housing development in the area is not well controlled by the government agency concerned. Eventually this would bring about flooding problem in the downstream reaches. It is therefore urgently required to solve this flood problem by some effective means.

7.2 Sebkhet Ariana and Oued Ennkhilet Basins

The Sebkhet Ariana basin with a catchment area of 117.53 km2 locates at the North of Greater Tunis area as shown in Fig.7.1. This basin is bounded by the Rous el Hraieg Mountains in the West and by the steep cliff along the Mediterranean Sea in the East. GP-9 and GP-10 roads are also in the watershed boundary in the South of this basin. Urban area is spreading in southwestern area of the basin around Ariana town and eastern end known as La Marsa as described in Chapter 4. Urbanization around Ariana town will expand to RVE-543 road in near future.

The Sebkhet Ariana with the area of 36.46 km2 occupy the northern part of this basin. The Sebkhet Ariana is a very shallow lake and almost dries up during a summer season. On the other hand, lake water sometime rises during rainy season and causes the inundation problem to the agricultural area spreading along the shore of the lake. Clogging by drifting sand at the outlet mainly bring out this problem, hampering the smooth discharge of lake water to the sea.

As shown in Fig.7.1, many rivers or small canals flow into the Sebkhet Ariana. The Oued Ennkhilet, Choutrana basin and La Marsa basin (Basin No.63) are the major basins among them. Each catchment area is as follows;

Catchment Basin	Area (km2)	Ratio (%)
Oued Ennkhilet	17.12	14.6
Choutrana	9.43	8.0
La Marsa	15.33	13.0
Other rivers	39.19	33.4
Sebkhet Ariana	36.46	31.0
Total	117.53	100.0

There is the ONAS's sewage canal along the shore line of the Sebkhet Ariana and many rivers including the above rivers are crossing with it. It is observed that these river cross sections at crossing points are not sufficient to convey the flood water from upstream and causes the inland inundation problem. Some countermeasures for these points, for example, widening and deepening of the existing rivers are required urgently.

The Oued Ennkhilet locates at the West of the Sebkhet Ariana basin as shown in Fig.7.2. Rapid urbanization along the GP-8 and RVE-533 roads are progressing now. The Oued Ennkhilet is collecting the flood water from the Rous el Hraieg Mountains and running down along the RVE-533 road, and finally flow into the Sebkhet Ariana. It travels some 8 km in the basin from South to North. Left tributaries have steep slope from 1/50 to 1/150 and those river bottom widths are from 2 to 3 meters. On the other hand, river slope of the main stream is very gentle and its slope varies from 1/800 to 1/1,500. Upper stretches are improved with the concrete box culvert, and open channels with the bottom width of approximately 10 m are running in the lower stretches.

7.3 Flood Runoff Distribution

To grasp the scale of inundation area and the flood discharge capacities of the existing river, the flood runoff distribution of each return period is firstly prepared under the existing river conditions. The Oued Ennkhilet basin is further divided into sub-basins considering the topographical conditions, future flood control plans and existing flood control facilities. Fig.7.2 shows the divided sub-basins of the Oued Ennkhilet and neighboring Choutrana basin, and Fig.7.1 shows the other river basins which flow into the Sebkhet Ariana.

The flood runoff discharges are studied based on the divided sub-basins and river system models, which is described in Chapter 3, with due consideration of the present and future land use conditions, which are obtained from the present and future land use plans.

The flood runoff distribution for all river basins in the Sebkhet Ariana basin is shown in Fig.7.3. Flood peak discharges from major rivers to the Sebkhet Ariana without flood retarding facilities are obtained as follows;

River Basin	Catchment Area (km2)	Present land use 100-yr	Present land use 10-yr	Future land use 100-yr	Future land use 10-yr
Oued Ennkhilet	17.12	50 m^3/s	24m^3/s	85 m^3/s	45 m^3/s
Choutrana	9.43	26	14	45	22
La Marsa	15.33	45	22	65	35

The peak discharge to the Sebkhet Ariana from each river is conceived to be increased up to approximately 1.8 times for the Oued Ennkhilet, 1.7 times for the Choutrana basin and 1.5 times for the La Marsa basin respectively in future due to a rapid urbanization.

There is a retarding basin named as Ain Snoussi Dam that is located at the just upstream of the residential area. Flood runoff discharges that are controlled by this retarding basin are also studied. Figs.7.4 and 7.5 show the flood runoff distributions of the Oued Ennkhilet with and without the Ain Snoussi Dam. Following flood control effects are expected under future land use condition as follows;

Location	without Ain Snoussi 100-yr	without Ain Snoussi 10-yr	with Ain Snoussi 100-yr	with Ain Snoussi 10-yr
Outlet to Sebkhet Ariana	85 m^3/s	45m^3/s	85 m^3/s	40 m^3/s
at Junction with Canal R2	70	35	65	35
Downstream end of Canal G1	28	14	24	12
at GP-8 road on Canal G1	20	9	12	6

7.4 Flood Discharge Capacity

To formulate the future river improvement plan, estimation of the existing river capacity is necessary. Flow capacity of the existing the Oued Ennkhilet is estimated by using uniform and non-uniform flow calculation based on the above flood runoff distribution.

Their results are illustrated in Figs.7.6 and 7.7. It is obvious that the Oued Ennkhilet main stream has insufficient discharge capacity to convey the flood water even for 1.05-yr flood under future land use conditions. This means some river improvement work is

urgently required for the Oued Ennkhilet, because housing developing is now rapidly progressing in the western area of this oued.

7.5 Floods and Inundation

Flood inundation areas are assumed based on the above hydraulic analysis, topographical conditions and field reconnaissance. Fig. 7.8 shows the assumed flood prone area for 100-yr flood under the future land use condition. As illustrated in the figure, the flood inundation area is divided to two areas. One is the flood inundation area in the Oued Ennkhilet basin, the other is the flood inundation area in the Choutrana basin. Latter flood inundation area is partly affected by the flood water that is overflowed RVE-533 road from the Oued Ennkhilet main stream. Flood inundation area and duration are shown in Table 7.1

Flood duration along RVE-533 road is assumed approximately to be 8 hours, however long flood duration approximately 5 days to one week is assumed at the low laying area near RVE-543 road because of its topographic conditions.

7.6 Present River Facilities

River improvement work has been proceeding from the upstream reaches by the MOEH to solve the flood inundation problems in the Oued Ennkhilet basin. First and second phases were executed during the years 1990 to 1992, and the construction cost for this improvement works was approximately estimated at 2.2 million DT. In addition to these improvement works, third phase is on-going now. Concrete pipes and rectangular culvert are adopted for these improved sections. Those locations and typical sections are shown in Fig.7.9.

In addition to those river improvement works, Water and Soil Conservation Department of MOA recently constructed the Ain Snoussi Dam in the tributary for flood control purpose as described before. Principal features of this dam are as follows;

Catchment area	1.12 km2
Dam crest elevation	El.103 m
Dam crest length	74 m
Dam embankment volume	5,500 m3
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 m3

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

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. Rectangular shaped concrete canal is proposed for the almost all stretches except downstream end. Location and typical sections are shown in Fig.7.9. In addition to this MOEH's proposal, ONAS also studied the river improvement of the Oued Ennkhilet with 10-year flood.

As described in the above, three government agencies such as MOEH, MOA and ONAS have each flood control plan and implemented independently for the Oued Ennkhilet. Its demarcation is not clearly defined, and close coordination is required.

CHAPTER 8 COMPARATIVE STUDY ON ALTERNATIVE PLANS

8.1 General

This chapter deals with a formulation of conceivable alternative plans for various flood control measures and the selection of the most recommendable plans. For the formulation of alternative plans, 10-year probable flood is applied since this flood probability has been utilized for the design of river facilities by MOEH, and all the existing river facilities can not be used for 100-year probable flood even though all the conceivable measure is mobilized. After the compartive study, 100-yr probable flood was taken into consideration for the feasibility study on the best plan selected in the comparative study.

The upstream stretch of the Oued Ennkhilet main stream runs along the RVE-533 road and most of which has already been improved and rehabilitated by concrete box culvert. The flow capacity of these existing culverts is estimated to be in the order of 3.0 m3/s to 6.5 m3/s, and it will not be enough to discharge the flood runoff of 10-year probability (20 m3/s to 30 m3/s) in the future, as housing development in the area is newly progressing and the residential area is spreading to upstream direction accordingly. However, the river improvement work for this stretch is not easy since the residential and commercial areas are developing rapidly, particularly at the site along the RVE-533 road. To avoid rehabilitation work of the existing culvert, it is necessary to construct not only a new diversion channel but also several retarding basins which regulate and mitigate a peak discharge of the flood of respective magnitude.

Considering the above, alternative plans of flood control measures for the Oued Ennkhilet are to be studied based on the following three (3) kinds of basic plans.

i) River Improvement Plan :
This is a plan to improve the river stretch which has not enough flow capacity for 10-year probable flood, without any diversion channel or retarding basin. In this plan, all the existing concrete box culvert along the RVE 533 road is to be rehabilitated and the flood is directly flown down into the Sebkhet Ariana.

ii) River Improvement + Diversion Channel Plan :
This is a plan to divert flood runoff of the Oued Ennkhilet main stream to downstream with diversion channel(s). Trans-basin diversion channel is also considered, that is, to divert flood runoff from the Oued Ennkhilet basin to the adjacent basin of the Choutrana. In this plan, flood runoff of the main stream is

decreased to some extent, then it is not necessary to rehabilitate some part of stretches with the existing concrete box culvert.

iii) River Improvement + Diversion Channel + Retarding Basin Plan :
This is a plan to construct several retarding basins in addition to diversion channel. It aims to evade the rehabilitation of the existing concrete box culvert as much as possible.

Some minor tributaries or tributaries where only some spots are required to be improved are discaarded in the feasibility study.

8.2 Design Criteria of Flood Control Measures

For the formulation of river improvement plan and design of river facilities, the following basic design criteria are applied.

(1) River Improvement Plan

i) Designed river profile follows present river or ground profile, basically.

ii) Present river course are to be remained as it is to the maximum extent.

iii) Deepening of riverbed is basically introduced for the stretches so that the flood water level is to be kept lower than that of the present condition, or almost the same with the ground level nearby.

iv) River cross section is decided considering the land use condition along the river course, existing structures, design flow velocity, etc.

v) In case the flood water level is higher than the ground level, following freeboard is principally applied :

50 m3/s > Design discharge : Hf= 0.6 m
50 m3/s ≤ Design discharge : Hf= 0.3 m

vi) Non-uniform flow analysis is applied for designed channel flow calculation. The following roughness coefficient of Manning's formula is adopted. :

n = 0.035 : for natural or earth-lined river channel
n = 0.025 : for concrete-lined river channel
n = 0.023 : for concrete-lined pipe.

vii) Following initial water level is applied for channel flow calculation :

Sea level : EL.0.4 m
Sebkhet Ariana : EL.0.8 m

(2) Design of River Facilities

i) Five (5) kinds of open channels in total and a concrete box culvert are applied for the design section of river stretch. These typical cross sections are shown in Fig. 8.1.

ii) Riverbed width of earth lined section is at least 2.0 m.

iii) The site inspection road is basically applied for both sides of the river, of which width is 3.0 m.

iv) Bridge (Refer to Fig. 8.1)

Freeboard to soffit level : Same as river improvement plan

Length of one span : At most 20 - 25 m

(3) Design of Retarding Basin

i) To decide dimension of the retarding basin, flood routine calculation is carried out. A formula applied for the calculation is as follows:

$$I - O = \frac{dS}{dt}$$

where, I : Inflow to the retarding basin,
O : Outflow from the outlet (orifice) of retarding basin,
S : Storage volume of the retarding basin, and
t : time (corresponding to unit time of hydrograph).

This continuity equation is solved using the Ekdahl's numerical calculation method.

ii) The outflow discharge from the outlet (orifice) of retarding basin is calculated as follows:

* $H \leq H_L + 1.2\ D$:

$$Q = 1.7\ B\ (H - H_L)^{3/2}$$

* $H_L + 1.2\ D < H < H_L + 1.8\ D$

Q is calculated by interpolation between $1.7\ B\ (1.2\ D)^{3/2}$ and $C\ D\ B\sqrt{2.6\ g\ D}$

* $H_L + 1.8\ D \leq H$:

$$Q = C\ D\ B\sqrt{2\ g\ (H - H_L - 0.5D)}$$

where, Q : Outflow discharge from the orifice,
H : Water level,
H_L : Elevation at bottom of the orifice,
D : Height of the orifice,
B : Width of the orifice, and
C : Coefficient of discharge (=0.6).

iii) Width or height of the orifice is taken for at least 0.2 m to prevent the orifice from clogging by garbage disposal.

iv) Following minimum freeboard is applied.

- Dam type retarding basin : 0.6 m
- Pond type retarding basin : 0.3 m

v) The bottom elevation of the orifice is set at 0.1 m higher than the bed elevation of the retarding basin. The sedimentation on the retarding basin is assumed to be taken out by periodical maintenance works.

vi) The flow area of the pipe connected to the orifice is taken at less than 3/4 of sectional area of the pipe to convey outflow safely.

8.3 Formulation of Alternative Plan

8.3.1 Finding of Candidate Site of Retarding Basin and Diversion Channel

Retarding basins and diversion channels are planned so as to mitigate flood runoff particularly for the upstream stretch of the Oued Ennkhilet main stream, since rehabilitation of the stretch is not easy and may have social problems. The candidate sites of these facilities are found based on such point of view.

The candidate site of the retarding basin is picked up from the 1/5000 scale topographic map. In the hill side area, dam type retarding basin site is seeked and its dam axis is decided through the site reconnaissance by the JICA Study Team. The topographic survey was also carried out for these dam type sites to estimate a storage volume of each site. In the flat plain area, unoccupied land or agricultural land in the vicinity of the Oued Ennkhilet main stream are seeked for the pond type retarding basin site, locations of which were also confirmed through the site reconnaissance.

15 sites (A to N2) in total are picked up for the candidate sites of retarding basin, and those sites are shown in Fig. 8.2. The retarding basin J2 was discarded as it was identified that the house development was proceeding at the site. These sites are studied in the following section, and the retarding basins that contribute to minimize the river improvement cost for the Oued Ennkhilet will be selected for the further alternative plan study.

Route of the diversion channels are also picked up from the 1/5000 scale topographic map. These diversion channels are located inside of the Oued Ennkhilet basin except Diversion Channel No.3. The Diversion Channel No.3 diverts flood runoff into the adjacent Choutrana basin. Most of the upstream stretch of this channel is required to be newly constructed but an existing ONAS drainage canal can be commonly used as the downstream stretch.

Then, the routes of four (4) diversion channels (No.2 to No.5) in total are picked up, and their locations are confirmed through the site reconnaissance. The longitudinal survey is also conducted for the routes. Their locations are presented in Fig. 8.2. The Diversion Channel No.1 was discarded as the retarding basin J2, which is an exit of the No.1, was

identified to be not available because of house development as explained above. These four diversion channels are well utilized for the alternative plan study.

8.3.2 Screening of Effective Retarding Basin

(1) *Methodology of Screening*

The screening for selection of effective retarding basin is conducted in the following manner.

i) To prepare 10-year probable flood hydrograph at each retarding basin site.
ii) To study dimension of each retarding basin with a minimum size of orifice necessary for regulating 10-year probable flood volume, and to estimate construction cost.
iii) To study flood runoff distribution for each river stretch when each retarding basin is constructed individually. The river stretch is schematically presented in Fig. 8.3.
iv) To estimate cost saving amount of the river improvement cost due to construction of such retarding basin.
v) To select effective retarding basins in comparison with construction cost of retarding basin and reduction of the river improvement cost.

10-year probable flood hydrographs at each retarding basin site are estimated in Chapter 3 by applying rational method under existing river condition in future land use. Referring to the storage curve (H-V curve) at each site, the dimension of each retarding basin is decided so as it can regulate the estimated flood runoff accordingly. And for the dam type retarding basin, overflow depth of 1.0 m over the spillway is applied for exceeded probable flood. Construction cost of the retarding basin is, then, estimated based on the work quantity calculated.

Flood runoff distribution in case with the retarding basin is calculated through flood routine analysis. The result of the calculation is shown in Table 8.1 and it is appeared that some of the dam type retarding basins located in the hill side are not so efficient to decrease peak flood runoff of the Oued Ennkhilet main stream. By applying the flood runoff distribution for respective river stretches, river improvement cost in case with retarding basin is estimated and then cost balance is calculated comparing with the cost without a retarding basin.

(2) Result of Screening

The construction cost of retarding basin and savings of the river improvement cost for each case are presented in Table 8.2, and are compared each other for the selection of effective retarding basin.

The table shows that each construction cost of Retarding Basins - A, G and J1 is much cheaper than the corresponding river improvement cost. It is judged that the construction of these retarding basins has an advantage for the river improvement work.

As for the Retarding Basins - I, L and M, river improvement cost without them is cheaper than the case with retarding basin, when they are constructed individually. However, these retarding basins locating at just upstream of the existing concrete box culvert are remained for further alternative plan study. Because, it is considered that the combination plan with the other retarding basin may become more effective than the individual case.

The remained Retarding Basins - B, C, D, E, F, H, K, N1 and N2 have no advantages for the river improvement work from hydrological and economical view points. These candidates of retarding basin are then discarded.

8.3.3 Formulation of Alternative Plan

The alternative flood control plans for the Oued Ennkhilet basin are formulated along the basic three (3) principles written in Chapter 8.1. Four (4) diversion channels and seven (7) retarding basins including the existing Ain Snoussi Dam are the finally selected facilities. The river system model for the alternative study is illustrated in Fig. 8.4.

(1) River Improvement Plan

Only one plan is conceivable for this principle. Almost all the present river course including existing concrete box culvert along the RVE-533 road is required to be improved for 10-year probable flood. The schematic diagram of this plan is illustrated in Fig. 8.5. The flood runoff distribution for each river stretch on this plan is calculated and is shown in Table 8.3.

(2) River Improvement + Diversion Channel Plan

The Diversion Channel No.3 is a trans-basin diversion, and it conveys all the flood runoff from the upstream stretch of the Oued Ennkhilet main stream to the adjacent

Choutrana basin. Applying this diversion channel, river improvement cost is decreased for the Oued Ennkhilet downstream basin, but that for the Choutrana basin is increased. The project cost of the Oued Ennkhilet flood control project includes the increased cost required for the additional improvement work in the Choutrana basin.

The Diversion Channel No.2 is planned to be directly connected with the Diversion Channel No.3 to convey flood runoff from upstream stretch of Canal C3. This diversion decreases improvement cost for upstream stretch of E9 of the Oued Ennkhilet. This plan is studied in a combination with the Diversion Channel No.3.

The Diversion Channel No.4 starts from just downstream of the Canal G1 and conveys all the flood runoff from upstream basin to the Canal C1. The improvement work for the Canal C1 now running through the undeveloped area is more economical, and has less social problem than for the main stream along the RVE-533 road. The Diversion Channel No.5 starts from just downstream of the Canal G2 and will function as same as the Diversion Channel No.4.

The combination of each diversion plan is considered in addition to the individual plan to decrease flood runoff of the Oued Ennkhilet main stream. There are four (4) conceivable combination plans, which are Diversion Channels No.2 & 3, No.3 & 4, No.3 & 5 and No.3, 4 & 5. The schematic diagrams for these plans are illustrated in Fig. 8.5. Then, the flood runoff distributions for total seven (7) diversion plans are calculated. These are shown in Table 8.3.

(3) River Improvement + Diversion Channel + Retarding Basin Plan

There are six (6) retarding basins and four (4) diversion channels for the alternative study. The alternative plans using these facilities are to be formulated so as it enables the present river facilities be remained as much as possible. From this view point, Diversion Channel No.3 is essential for the river stretch from E7 to E8, since there is no conceivable alternative facility instead of this.

The Diversion Channel No.3 separates the Oued Ennkhilet basin at the downstream end of the river stretch E9, then alternative plans are separately formulated for the upstream basin and the downstream basin.

In the upstream basin, all the retarding basins (G, I and J1) are necessary for river stretches C4, E9 and E10, however, Retarding Basins I and J1 are located at near the GP-8 road, and it may be difficult to acquire the land for such retarding basin.

Accordingly, an alternative plan without these two (2) retarding basins is also studied, although the existing concrete box culvert at river stretches of E9 and E10 (under GP-8 road) must be rehabilitated. Following three (3) alternative plans are formulated for the upstream basin, and these schematic diagrams are shown in Fig.8.6.

Alternative U-1	Retarding Basins G, I & J1 + Diversion Channel No.3
Alternative U-2	Retarding Basins G, I & J1 + Diversion Channels No.2 & 3
Alternative U-3	Retarding Basins G + Diversion Channel No.3

In the downstream basin, Retarding Basin L or Diversion Channel No.4 is necessary for the river stretch E6, and Retarding Basin M or Diversion Channel No.5 is necessary for the river stretch E4. Also, Retarding Basin A is an economic facility and there is no other justifiable plan instead of this. Then, the following six (6) alternative plans are finally formulated for the downstream basin and these schematic diagrams are shown in Fig.8.7.

Alternative D-1	Retarding Basins A, L & M
Alternative D-2	Retarding Basins A & L
Alternative D-3	Retarding Basins A & L + Diversion Channel No.5
Alternative D-4	Retarding Basins A & M + Diversion Channel No.4
Alternative D-5	Retarding Basin A + Diversion Channel No.4
Alternative D-6	Retarding Basin A + Diversion Channels No.4 & No.5

The flood runoff distributions for total nine (9) diversion and retarding basin plans are calculated for each river stretch . These are shown in Table 8.4.

8.4 Selection of Alternative Plan

The direct construction cost and land acquisition cost are estimated for each river stretch of all the alternative plan based on the flood runoff distribution. These costs for each river stretch is not summed up when the flow capacity of the stretch satisfies the flood runoff considered. The land acquisition cost is not counted for in case the land is owned by the government. Among all, the least cost plan is selected as the most economical one since it is considered the benefit created by such flood control plans is common.

These estimated costs are presented in Tables 8.5 and 8.6 and are summarized in Table 8.7. The cost of river improvement plan (Alt. Div.0) only is estimated to be DT 9.66 million. The most economical plan consisting of river improvement and diversion channel plan is Alt. Div.3,4&5 (Diversion Channels No. 3, 4 and 5 plan), of which cost is DT 7.76 million. As for the combination of river improvement, diversion channel, and

retarding basin plan, Alt U-1 (Retarding Basins G, I & J1 and Diversion Channel No.3) for the upstream basin and Alt D-5 (Retarding Basin A and Diversion Channel No.4) for the downstream basin are the most economical one. The cost of this combination plan is estimated to be DT 6.64 million.

Then, it is appeared that the plan with Retarding Basins A, G, I & J1 and Diversion Channels No.3 & 4 is the most economical plan among all the flood control alternative plan. By applying this flood control plan, it is not necessary to rehabilitate most of the existing river facilities, and this plan has less social problems than the other plans. This plan is considered as the most reasonable plan.

The design flood distribution for the selected flood control plan is estimated for first stage (10-yr flood) and second stage (100-yr flood) as shown in Fig.8.8. Location of river improvement works for both stages are illustrated in Figs.8.9 and 8.10 respectively. The principal features for both stages are introduced in the next Chapter 9.

CHAPTER 9 SELECTED FLOOD CONTROL PLAN

9.1 General

Through the comparative studies in the previous chapter, Diversion No.3, Diversion No.4, Retarding Basins A, G, I and J1 are recommended to be included in the flood control plan for the Oued Ennkhilet Basin. Considering these flood control facilities, further preliminary design for flood control plan is executed.

Following basic design conditions and criterion are applied for the preparation of 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) River or channel width should be kept sufficient for 100-yr flood for future development.

   iii) Determination of the priority river stretches is based on that not to cause the adverse effect in the downstream reaches.

9.2 Preliminary Design

For designing the river facilities and the retarding basins, the basic design criterion that is described in the pervious chapter is applied. In addition to that design criteria, following criteria and conditions are introduced;

1) Crossing facilities such as bridge and ONAS's sewage system are to be considered on the basis of 100-yr flood principally even in the first stage development.

2) Land acquisition and compensation are to be considered on the basis of 100-yr flood even in the first stage development.

3) Location of embankment dike, if required, is to be considered on the basis of 100-yr flood even in the first stage development.

4) Existing concrete culvert is remained as much as possible. In case the design flood discharge is bigger than the double of the existing discharge capacity, new concrete culvert is to be adopted, demolishing the existing small-sized culvert. On the other hand, additional culvert is to be introduced in parallel with the existing one, in case that design flood discharge is less than the double of existing discharge capacity.

By applying the design criteria as described before and flood runoff distribution, preliminary design and the work quantity estimate are executed for each canal. Figs 9.1, 9.2 and 9.3 show the general plan, longitudinal profile and typical cross sections of the selected river improvement plan respectively. Layout plan and outlet structure for retarding basins A, G, I and J1 are shown in Figs.9.4 to 9.7, and those hydraulic characteristics are shown in Figs. 9.8 and 9.9. Dimensions of new bridges are illustrated in Fig.9.10.

Flood water level of the Sebkhet Ariana is simulated by applying the 100-yr probable flood (Ref.: Chapter 3). The simulation is conducted by the flood routine method in conditions of the present river facilities and future land use (2020). The land reclamation is not considered. An initial water level for the simulation is set at EL.0.4 m, which is the annual average of monthly maximum sea water level. In addition to this, allowance of 20 % is added to the 100-yr flood discharge for the safety side simulation.

A storage volume curve of the Sebkhet Ariana is prepared by using the newly obtained cross sectional survey data on the sebkhet. Surface area and effective storage volume above mean sea water level (EL.0.0 m) are as follows;

Area and Effective Storage Volume of the Sebkhet Ariana

Elevation (m)	0.0	0.2	0.4	0.6	0.8	1.0	1.2
Surface Area (km2)	18.4	20.1	23.3	28.0	30.6	32.5	34.4
Effective Volume (Mil.m3)	0.0	3.8	8.2	13.3	19.2	25.5	32.2

This storage volume curve is almost same as the previous one that was applied in the Master Plan. As a result, the maximum flood water level reaches at around EL.0.72 m as shown in Fig.9.11. This level is lower than the assumed allowable flood water level of the Sebkhet Ariana (EL.0.8 m) which is judged from topographic map of 1/5000 scale, survey result for the Oued Ennkhilet and site reconnaissance. It is conceived that no flood damage in the surrounding area of the Sebkhet Ariana will occur under the above condition, therefore periodical maintenance for the outlet of the Sebkhet Ariana is recommended during rainy season.

In addition to the above, the simulation is also conducted for two (2) cases. The first case assumes that an initial water level of the Sebkhet Ariana is higher than the maximum sea water level of 0.4 m. An initial water level is varied from 0.4 m to 0.6 m by 0.05 m interval. The second case assumes the decrease of storage capacity of the Sebkhet Ariana by the sediment deposits. A sediment yield of 500 m3/yr/km2 is applied to estimate

sedimentation volume, which is applied for the design of Bir M'cherga Dam based on the data observed at the existing Kebir Dam. The simulated results are shown below.

Assumed initial W.L (EL.m)	0.40	0.45	0.50	0.55	0.60
Max. Water Level (EL.m)	0.72	0.76	0.80	0.84	0.87
Dead Storage/1 (Mill. m3)	8.2	9.5	10.8	12.0	13.3
Dead Period/2 (year)	202	234	266	296	328

/1 : Storage volume between EL.0 m and the assumed initial water level
/2 : Estimated period that the dead storage is filled with sediment deposit

From the above table, it is appeared that maximum water level of the Sebkhet Ariana during 100-yr flood will not exceed the assumed allowable flood water level of 0.80 m when the initial water level is lower than 0.50 m. Also, it is conceived that it takes more than 200 years until the dead storage of the Sebkhet Ariana will be filled with the sediment deposit. Judging from these results, widening or improvement of the outlet from the Sebkhet Ariana to the Mediterranean Sea is not required for the time being.

The outlet to the Mediterranean Sea is often clogged by the drifting sand. To solve this problem, following counter-measure are conceived;

1) To construct the jetty
2) To introduce the Sand Flashing System with combination of gates and pumps
3) To maintain the outlet by periodical dredging or excavation

Since the sedimentation and erosion are generally occurred on the each side of a jetty, there is a possibility to cause a big change of coast line. This coastal area is now developing for the resort area and new hotel is constructed there. Then careful study is necessary for this plan. It will take a time to realize a jetty construction as there exist insufficient data and information to make such study in detail.

Combination of some pumps and gates are required to flash the sand mechanically. This plan may not cause an environmental problem at coast line, however not only huge construction costs but also much running cost is required to maintain this Sand Flashing System.

The most simple and recommended practical measure to keep this outlet open would be to carry out a periodical excavation. Only one swamp bulldozer of D-6 crass is required for this purpose.

9.3 Principal Features of Selected Plan

9.3.1 Oued Ennkhilet Main Stream

River improvement is required in the lower reaches, stretches No.E-1 and E-2, and upper most stretch for first stage. Remaining middle reaches along RVE-533 road have a sufficient discharge capacity for 10-yr design flood, and no additional river improvement is required. However, almost all stretches are necessary to be improved in the second stage.

Trapezoidal earth-lined section is applied in the lower reaches from RVE-533 road to the Sebkhet Ariana, because an enough space is available at the site. Rectangular concrete box culvert is applied for the stretches along RVE-533 road considering the land availability.

Two road bridges for RVE-543 and RVE-533 are necessary to be constructed in the first stage. Principal features for each stretches of this river are as follows;

Oued Ennkhilet Main

Stretch E-1 (from Sebkhet Ariana to junction with Canal C1)

First Stage

(1)	River improvement	Design discharge : 40 m3/s Type : trapezoidal earth-lining Bottom width : 21 m Length : 1,115 m Excavation : 25,700 m3 Embankment : 22,200 m3 Bank protection : 60 m on both bank
(2)	Bridge for RVE-543 Road	Width : 12 m Length : 50 m
(3)	Drainage Sluice way	1 no

Second Stage

(1)	River improvement	Design discharge : 75 m3/s Type : trapezoidal earth-lining Bottom width : 40 m Length : 1,115 m Excavation : 21,200 m3

Stretch E-2 (from junction with Canal C1 to junction with Canal R2)

First Stage

(1)	River improvement	Design discharge : 24 m3/s Type : trapezoidal earth-lining Bottom width : 9 m Length : 1,095 m Excavation : 14,200 m3 Embankment : 12,500 m3

		Bank protection : 70 m on both bank
(2)	Bridge for RVE-533 Road	Width : 12 m Length : 30 m
(3)	Drainage Sluice way	4 nos.
Second Stage		
(1)	River improvement	Design discharge : 50 m3/s Type : trapezoidal earth-lining Bottom width : 20 m Length : 1,095 m Excavation : 18,100 m3

Stretch E-3 (from junction with Canal R2 to junction with Canal N1)

First Stage		No river improvement
Second Stage		
(1)	River improvement	Design discharge : 28 m3/s Length : 70 m Twin type of concrete box culvert width : 3.9 m & height : 2.7 m Excavation : 2,200 m3 Concrete : 570 m3

Stretch E-4 and E-5 (from junction with Canal N1 to junction with Canal G2)

First Stage		No river improvement
Second Stage		
(1)	River improvement	Design discharge : 16 m3/s Length : 561 m Single type of concrete box culvert Width : 4.3 m & height : 2.7 m Excavation : 9,600 m3 Concrete: 2,700 m3

Stretch E-6 (from junction with Canal G2 to Diversion No.4)

First Stage		No river improvement
Second Stage		No river improvement

Stretch E-7 (from Diversion No.4 to Jct. with Canal G1)

First Stage		Included in Diversion No.4
Second Stage		Included in Diversion No.4

Stretch E-8 (from junction with Canal G1 to Diversion No.3)

First Stage — No river improvement

Second Stage

(1) River improvement (To construct additional concrete box culvert)
- Design discharge : 7 m3/s
- Existing culvert : 3.5 m3/s
- Additional culvert : 3.5 m3/s
- Length : 984 m
- Single type of concrete box culvert
- Width : 2.3 m & height : 1.6 m
- Excavation : 12,800 m3
- Concrete : 2,800 m3

Stretch E-9 (from Diversion No.3 to junction with Canal C3)

First Stage — No river improvement

Second Stage

Downstream half

(1) River improvement
- Design discharge : 12 m3/s
- Length : 366 m
- Single type of concrete box culvert
- Width : 4.3 m & height : 2.2 m
- Excavation : 8,500 m3
- Concrete : 1,650 m3

Upstream half

(1) River improvement
- Design discharge : 12 m3/s
- Length : 626 m
- Single type of concrete box culvert
- Width : 2.9 m & height : 2.2 m
- Excavation : 11,600 m3
- Concrete : 2,250 m3

Stretch E-10 (from junction with Canal C3 to Retarding basin I under GP-8 Road)

First Stage — No river improvement

Second Stage

(1) River improvement
- Design discharge : 7 m3/s
- Length : 32 m
- Single type of concrete box culvert
- Width : 2.0 m & height : 2.2 m
- Excavation : 600 m3
- Concrete : 125 m3

Stretch E-11 (from Retarding basin I to Jct. with Canal C5)

First Stage

(1) River improvement
- Design discharge : 7 m3/s
- Length : 485 m
- Single type of concrete box culvert
- Width : 2.2 m & height : 2.0 m

Excavation : 7,300 m3
Concrete : 1,470 m3

Second Stage

(1) River improvement (To construct additional concrete box culvert)

Design discharge : 14 m3/s
First stage : 7 m3/s
Additional culvert : 7 m3/s
Length : 485 m
Single type of concrete box culvert
Width : 2.2 m & height : 2.0 m
Excavation : 5,800 m3
Concrete : 1,470 m3

9.3.2 Canal C1

Existing Canal C1 is a small river and running in the low laying area between RVE-533 road and RVE-543 road. Trapezoidal earth-lining section with bottom widths of 11 m and 18 m is proposed for the 10-yr flood and 100-yr flood respectively in the lower reaches. Dike with a height of approximately 1.5 m is required in this section.

This canal is to be one of the most important canal because much flood water will be diverted from the Oued Ennkhilet through the Diversion No.3. No river improvement is required in the upper most stretch C1-4, because the design flood discharge is a minimal and the existing canal has a sufficient discharge capacity.

Principal features for each stretches of this river are as follows;

Canal C1

Stretch C1-1 (from junction with Oued Ennkhilet to junction with Canal C2)

First Stage

(1) River improvement

Design discharge : 22 m3/s
Type : trapezoidal earth-lining
Bottom width : 11 m
Length : 535 m
Excavation : 8,600 m3
Embankment : 8,700 m3
Bank protection : 30 m on both bank

(2) Drainage Sluice way

2 nos.

Second Stage

(1) River improvement

Design discharge : 35 m3/s
Type : trapezoidal earth-lining
Bottom width : 18 m
Length : 535 m
Excavation : 4,500 m3

Stretch C1-2 (from junction with Canal C2 to Diversion Route No.5)

First Stage

(1)	River improvement	Design discharge : 20 m3/s Type : trapezoidal earth-lining Bottom width : 10 m Length : 469 m Excavation : 6,300 m3 Embankment : 8,500 m3
(2)	Drainage Sluice way	2 nos.

Second Stage

(1)	River improvement	Design discharge : 35 m3/s Type : trapezoidal earth-lining Bottom width : 18 m Length : 469 m Excavation : 4,100 m3

Stretch C1-3 (from Diversion Route No.5 to junction with Diversion No.4)

First Stage

(1)	River improvement	Design discharge : 16 m3/s Type : trapezoidal earth-lining Bottom width : 4 m Length : 573 m Excavation : 6,600 m3 Embankment : 5,700 m3 Bank protection : 30 m on both bank
(2)	Drainage Sluice way	1 no

Second Stage

(1)	River improvement	Design discharge : 35 m3/s Type : trapezoidal earth-lining Bottom width : 11 m Length : 573 m Excavation : 6,400 m3

Stretch C1-4 (from junction with Diversion No.4 to Upstream)

First Stage	No river improvement
Second Stage	No river improvement

9.3.3 Canal R2

Canal R2 is running along RVE-533 road and no river improvement has been carried out. Since urbanization is progressing along this road, the proper river improvement will be required in near future.

Trapezoidal earth-lining section is adopted for all stretches for 10-yr flood and the rectangular concrete channel is proposed for 100-yr flood. Some small approach bridges

are required for the right bank.

Principal features for each stretches of this river are as follows;

Canal R2

Stretch R2-1 (from junction with Oued Ennkhilet to junction with Canal N2)

First Stage

(1) River improvement

Design discharge : 12 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m
Length : 220 m
Excavation : 600 m3
Bank protection : 30 m on both bank

Second Stage

(1) River improvement

Design discharge : 24 m3/s
Type : rectangular concrete wall
Bottom width : 6 m & height : 2.0 m
Length : 220 m
Excavation : 2,500 m3
Concrete : 660 m3

Stretch R2-2 Downstream (Downstream half between Jct. with Canal N2 and U/S end)

First Stage

(1) River improvement

Design discharge : 8 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m
Length : 370 m
Excavation : 1,000 m3
Bank protection : 80 m on both bank

(2) Small bridge

Type : Concrete box culvert
Width : 4.3 m & height : 2.3 m
Length : 8 m
4 sites

Second Stage

(1) River improvement

Design discharge : 16 m3/s
Type : rectangular concrete wall
Bottom width : 4.3 m & height : 2.0 m
Length : 338 m
Excavation : 3,200 m3
Concrete : 870 m3

Stretch R2-2 Upstream (Upstream half between junction. with Canal N2 and U/S end)

First Stage

(1) River improvement

Design discharge : 8 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m
Length : 328 m

Excavation : 1,000 m3
Bank protection : 10 m on both bank

(2) Small bridge to quarry — Type : Concrete box culvert
Width : 3.2 m & height : 1.8 m
Length : 12 m
1 site

Second Stage

(1) River improvement — Design discharge : 16 m3/s
Type : rectangular concrete wall
Bottom width : 3.2 m & height : 1.5 m
Length : 316 m
Excavation : 2,100 m3
Concrete : 600 m3

9.3.4 Canal G2

Retarding Basin A is proposed in the upper reaches of this canal. Flood water is expected to be controlled by this retarding basin and design discharges for the lower stretches are also decreased. Trapezoidal earth-lining section is proposed for both stages.

Housing development is going on in the middle reaches and some roads are crossing with this canal. Almost all these bridges are necessary to be replaced because the concrete pipe culvert installed in the bridges has no sufficient discharge capacity.

Principal features for each stretches of this river are as follows;

Canal G2

Stretch G2-1 Downstream (D/S between junction with Ennkhilet and junction with tributary)

First Stage

(1) River improvement — Design discharge : 7 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m & depth : 1.0m
Length : 559 m
Excavation : 1,600 m3
Bank protection : 20 m on both bank

(2) Small bridge — Twin type of Concrete box culvert
Width : 2.4 m & height : 1.7 m
Length : 8 m
1 site

Second Stage

(1) River improvement — Design discharge : 14 m3/s
Type : trapezoidal earth-lining

Bottom width : 2 m & depth : 1.4 m
Length : 559 m
Excavation : 850 m3

Stretch G2-1 Midstream (M/S between junction with Ennkhilet and junction with tributary)

First Stage

(1) River improvement

Design discharge : 7 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m & depth : 0.9m
Length : 499 m
Excavation : 1,100 m3
Bank protection : 40 m on both bank

(2) Small bridge

Twin type of concrete box culvert
Width : 2.2 m & height : 1.5 m
Length : 8 m
2 sites

Second Stage

(1) River improvement

Design discharge : 14 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m & depth : 1.2 m
Length : 499 m
Excavation : 400 m3

Stretch G2-1 Upstream (U/S between junction with Ennkhilet and junction with tributary)

First Stage

(1) River improvement

Design discharge : 7 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m & depth : 0.8m
Length : 197 m
Excavation : 330 m3

Second Stage

(1) River improvement

Design discharge : 14 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m & depth : 1.1 m
Length : 197 m
Excavation : 350 m3

Stretch G2-2 (from junction with tributary to upstream)

First Stage

No river improvement

Second Stage

(1) Small bridge

Twin type of Concrete box culvert
Width : 1.8 m & height : 1.3 m
Length : 8 m
2 site
Bank protection : 40 m on both bank

9.3.5 Canal G1

Ain Snoussi Dam is located in the upper reaches of this canal and much flood control effects are expected to the lower reaches. Trapezoidal earth-lining section is proposed for the first stage, and the rectangular concrete channel is adopted for the second stage considering the availability of land.

Housing development is also going on in the middle reaches and some roads are crossing with this canal. Almost all these bridges are necessary to be replaced because those have no sufficient discharge capacity.

Since existing river has a sufficient discharge capacity, no river improvement is required for the upper most river stretch G1-2 in the first stage. Principal features for each stretch of this river are as follows;

Canal G1

Stretch G1-1 Downstream (D/S half between junction Ennkhilet and junction with Canal G1')

First Stage

(1)	River improvement	Design discharge : 12 m3/s Type : trapezoidal earth-lining Bottom width : 2 m Length : 890 m Excavation : 1,800 m3 Bank protection : 30 m on both bank
(2)	Bridge	Type : Concrete box culvert Width : 4.0 m & height : 2.1 m Length : 17 m 1 site

Second Stage

(1)	River improvement	Design discharge : 24 m3/s Type : rectangular concrete wall Bottom width : 4.0 m & height : 1.8 m Length : 873 m Excavation : 7,300 m3 Concrete : 2,000 m3

Stretch G1-1 Upstream (U/S half between junction Ennkhilet and junction with Canal G1')

First Stage

(1)	River improvement	Design discharge : 12 m3/s Type : trapezoidal earth-lining Bottom width : 2 m

Length : 223 m
Excavation : 340 m3
Bank protection : 20 m on both bank

(2) Bridge

Type : Concrete box culvert
Width : 3.6 m & height : 2.1 m
Length : 8 m
1 site

Second Stage

(1) River improvement

Design discharge : 24 m3/s
Type : rectangular concrete wall
Bottom width : 3.6 m & height : 1.8 m
Length : 215 m
Excavation : 1,800 m3
Concrete : 470 m3

Stretch G1-2 (from junction with Canal G1' to GP-8)

First Stage

No river improvement

Second Stage

(1) River improvement

Design discharge : 12 m3/s
Type : rectangular concrete wall
Bottom width : 2.2 m & height : 1.8 m
Length : 480 m
Excavation : 4,900 m3
Concrete : 840 m3

(2) Bridge

Type : Concrete box culvert
Width : 2.2 m & height : 2.1 m
Length : 8 m
2 site

9.3.6 Canal G1'

Canal G1' is a short canal between GP-1 road and Canal G1. Housing development is proceeding in the upper hilly area and flood runoff will increase in the future. Since there only exists a small road side drain now, urgent implementation is required.

Trapezoidal earth-lining section is applied for first stage at this canal, and the rectangular concrete channel is proposed in the succeeding stage. Principal features of this canal are as follows;

Canal G1' (from junction with Canal G1 to GP-8)

First Stage

(1) River improvement

Design discharge : 10 m3/s
Type : trapezoidal earth-lining
Bottom width : 2 m
Length : 299 m

		Excavation : 1,400 m3 Bank protection : 20 m on both bank
(2)	Bridge	Type : Concrete box culvert Width : 3.2 m & height : 2.1 m Length : 8 m 1 site
Second Stage		
(1)	River improvement	Design discharge : 20 m3/s Type : rectangular concrete wall Bottom width : 3.2 m & height : 1.8 m Length : 299 m Excavation : 2,400 m3 Concrete : 610 m3

9.3.7 Canal C4

Canal C4 has been improved by MOEH with the concrete pipe of diameter 1.25 m. Flood discharge capacity of this pipe is enough to convey the outflow from proposed Retarding Basin G for the first stage. However an additional culvert is required for the further stage. River slope is very steep and some drops are to be introduced for this canal.

Principal features of this canal are as follows;

Canal C4 (from Retarding Basin I to Retarding Basin G)

First Stage		No river improvement
Second Stage		
(1)	River improvement (To construct additional concrete box culvert)	Design discharge : 5 m3/s Existing culvert : 2.6 m3/s Additional culvert : 2.4 m3/s Length : 555 m Single type of concrete box culvert Width : 1.2 m & height : 1.2 m Excavation : 4,600 m3 Concrete : 1,050 m3

9.3.8 Flood Diversion No. 3

This Flood Diversion No.3 is an important facility for flood control plan of the Oued Ennkhilet. ONAS's drainage canal, named as Choutrana canal, is running here in the lower half of this diversion. There is a small canal between the RVE-533 road to the Choutrana canal.

Trapezoidal earth-lining section is applied for this diversion channel. Widening and

deepening of the Choutrana canal with the bottom width of 34 m is required for 100-yr flood. This dimension is necessary not only for diverted flood water from the Oued Ennkhilet but also for the Choutrana basin itself. On the other hand, a small channel with a bottom width of 2 m is proposed for upper half stretch.

ONAS' sewage open canal and sewage pipe are crossing in the Choutrana canal. Some rehabilitation works are required at these crossing points. Road bridge for RVE-543 road and box culvert for RVE-533 are proposed respectively considering those required canal dimensions.

Principal features for each stretches of this diversion channel are as follows;

Flood Diversion No.3

Stretch Div.3 D/S (from Sebkhet Ariana to junction with tributary)

First Stage

(1)	River improvement	Design discharge : 22 m3/s Type : trapezoidal earth-lining Bottom width : 14 m Length : 1,861 m Excavation : 43.000 m3 Embankment : 15,500 m3 Bank protection : 100 m on both bank
(2)	Bridge for RVE-543 Road	Width : 12 m Length : 43 m
(3)	Rehabilitation of ONAS Sewage Canal	Length : 50 m
(4)	Rehabilitation of ONAS Sewage Pipe	Length : 50 m
(5)	Drainage Sluice way	4 nos.

Second Stage

(1)	River improvement	Design discharge : 50 m3/s Type : trapezoidal earth-lining Bottom width : 34 m Length : 1,861 m Excavation : 53,000 m3

Stretch Div.3 U/S (from junction with tributary to junction with Oued Ennkhilet)

First Stage

(1)	River improvement	Design discharge : 5 m3/s Type : trapezoidal earth-lining Bottom width : 2 m & depth : 1.3 m Length : 1,939 m Excavation : 8,600 m3 Embankment : 10,200 m3

		Bank protection : 70 m on both bank
(2)	Small bridge	Twin type of concrete box culvert Width : 3.0 m & height : 2.2 m Length : 8 m 3 sites
(3)	Bridge for RVE-533 Road	Type : Concrete box culvert Width : 2.5 m & height : 2.2 m Length : 25 m
(4)	Drainage Sluice way	2 nos.

Second Stage

(1)	River improvement	Design discharge : 12 m3/s Type : trapezoidal earth-lining Bottom width : 2 m & depth : 1.9 m Length : 1,939 m Excavation : 8,400 m3
(2)	Bridge for RVE-533 Road (Additional culvert)	Type : Concrete box culvert Width : 3.5 m & height : 2.2 m Length : 25 m

9.3.9 Flood Diversion No. 4

Flood Diversion No.4 is proposed to be connected with the Oued Ennkhilet and Canal C1 through the open space of the premise of secondary school. Box culvert is introduced for both stages. Same culvert is applied for crossing with the RVE-533 road.

Principal features of this diversion channel are as follows;

Flood Diversion No.4 (from junction with Canal C1 to junction with Oued Ennkhilet)

First Stage

(1)	River improvement	Design discharge : 16 m3/s Length : 288 m (incl. under RVE-533) Single type of concrete box culvert width : 3.4 m & height : 2.2m Excavation : 5,800 m3 Concrete : 1,130 m3

Second Stage

(1)	River improvement (To construct additional concrete box culvert)	Design discharge : 35 m3/s First stage : 16 m3/s Additional culvert : 19 m3/s Length : 288 m (incl. under RVE-533) Single type of concrete box culvert width : 3.8 m & height : 2.2m Excavation : 4,900 m3 Concrete : 1,200 m3

9.3.10 Retarding Basin A

Retarding Basin A is located at just upstream of GP-8 of Canal G2 as shown in Fig.9.4. No dike is required because elevated GP-8 road is acting as a man-made dike for this retarding basin. Concrete wall type outlet facility with a height 4.5 m is introduced.

Inflow peak discharge of 5.4 m3/s will be controlled to 0.2 m3/s for 10-yr flood. Flood control space is approximately 7,800 m3.

Principal features of this retarding basin are as follows;

Retarding Basin - A

First Stage		
(1)	Type	Concrete wall dam
(2)	Dimension	Dam crest elevation : EL.43.0 m
		Maximum storage volume : 7,800 m3
		Dam height : 4.5 m
		Dam crest length : 40 m
		Orifice size : 0.2 m x 0.2 m
(3)	Work Volume	Excavation volume : 1,100 m3
		Concrete volume : 260 m3
		Screen weight : 1.2 ton
(4)	Hydraulic Design	Peak discharge of inflow (10-yr) : 5.4 m3/s
		Peak discharge of outflow (10-yr) : 0.2 m3/s
		Maximum water level : EL.41.5 m
Second Stage		
(1)	Extension Work	Extension of Orifice
(2)	Dimension	Orifice size : 0.6 m x 0.6 m
(3)	Hydraulic Design	Peak discharge of inflow (100-yr) : 10.9 m3/s
		Peak discharge of outflow (100-yr) : 1.9 m3/s
		Maximum water level : EL.42.6 m

9.3.11 Retarding Basin G

Retarding Basin G is proposed to be constructed at just upstream of Canal C4 as shown in Fig.9.5. Judging from the topographical and hydraulic conditions, the excavated pond type is adopted for this site. Flood control space of 17,400 m3 is required for 10-yr flood and this will be expanded to 37,500 m3 for 100-yr flood in the second stage. Inflow peak discharge of 9.3 m3/s will be controlled to 1.5 m3/s for 10-yr flood, accordingly.

Excavation volumes of pond are estimated to be 25,600 m3 and 27,600 m3 for each stage. Outlet structure with an orifice of 0.55 m x 0.55 m is proposed for each stages.

Principal features of this retarding basin are as follows;

Retarding Basin - G

First Stage

(1)	Type	Pond type
(2)	Dimension	Pond area : 0.66 ha Maximum storage volume : 17,400 m3 Pond bed elevation : EL.16.7 m Average pond height : 5.3 m Orifice size : 0.55 m x 0.55 m
(3)	Work Volume	Excavation volume : 25,600 m3 Concrete volume : 40 m3 Screen weight : 1.4 ton
(4)	Hydraulic Design	Peak discharge of inflow (10-yr) : 9.3 m3/s Peak discharge of outflow (10-yr) : 1.5 m3/s Maximum water level : EL.20.7 m

Second Stage

(1)	Extension Work	Extension of pond and construction of new outlet structure with same dimension as in the first stage
(2)	Dimension	Pond area : 1.26 ha Maximum storage volume : 37,500 m3 Pond bed elevation : EL.16.7 m Average pond height : 5.2 m Orifice size : 0.55 m x 0.55 m
(3)	Work Volume	Excavation volume : 27,600 m3 Concrete volume : 40 m3 Screen weight : 1.4 ton
(4)	Hydraulic Design	Peak discharge of inflow (100-yr) : 18.9 m3/s Peak discharge of outflow (100-yr) : 2.8 m3/s Maximum water level : EL.20.7 m

9.3.12 Retarding Basin I

Retarding Basin I is proposed to be constructed at junction with GP-8 and RVE-533 roads as shown in Fig. 9.6. The excavated pond type is adopted for this site and flood control space of 22,500 m3 is required. Inflow peak discharge of 5.8 m3/s will be controlled to 1.2 m3/s for 10-yr flood. Maximum flood water level will reach to EL. 9.0 m and this water level is lower than the surrounding ground levels.

Excavation volumes of pond are estimated to be 42,700 m3. Outlet structure with an orifice of 0.6 m x 0.6 m is proposed for the first stages and this orifice will be expanded to 1.7 m x 1.7 m in the second stage.

Principal features of this retarding basin are as follows;

Retarding Basin - I

First Stage

(1)	Type	Pond type
(2)	Dimension	Pond area : 1.45 ha Maximum storage volume : 22,500 m3 Pond bed elevation : EL.7.1 m Average pond height : 3.3 m Orifice size : 0.6 m x 0.6 m

(3)	Work Volume	Excavation volume : 42,700 m3 Concrete volume : 30 m3 Screen weight : 0.8 ton
(4)	Hydraulic Design	Peak discharge of inflow (10-yr) : 5.8 m3/s Peak discharge of outflow (10-yr) : 1.2 m3/s Maximum water level : EL.9.0 m

Second Stage

(1)	Extension Work	Extension of orifice
(2)	Dimension	Orifice size : 1.7 m x 1.7 m
(3)	Hydraulic Design	Peak discharge of inflow (100-yr) : 11.6 m3/s Peak discharge of outflow (100-yr) : 6.6 m3/s Maximum water level : EL.9.0 m

9.3.13 Retarding Basin J1

Retarding Basin J1 is proposed to be constructed on Canal C3 by GP-8 road as shown in Fig.9.7. Judging from the topographical and hydraulic conditions, the excavated pond type is adopted for this site. Flood control space of 19,600 m3 is required for 10-yr flood and this will be expanded to 32,100 m3 for 100-yr flood in the second stage. Inflow peak discharge of 7.6 m3/s will be controlled to 0.5 m3/s for 10-yr flood.

Excavation volumes of pond are estimated to be 24,100 m3 and 15,200 m3 for each stage. Outlet structure with an orifice of 0.4 m x 0.4 m is proposed for the first stage and this orifice will be expanded to 1.4 m x 1.4 m in the second stage.

Principal features of this retarding basin are as follows;

Retarding Basin - J1

First Stage

(1)	Type	Pond type
(2)	Dimension	Pond area : 1.47 ha Maximum storage volume : 19,600 m3 Pond bed elevation : EL.7.2 m Average pond height : 2.8 m Orifice size : 0.4 m x 0.4 m
(3)	Work Volume	Excavation volume : 24,100 m3 Concrete volume : 80 m3 Screen weight : 0.7 ton
(4)	Hydraulic Design	Peak discharge of inflow (10-yr) : 7.6 m3/s Peak discharge of outflow (10-yr) : 0.5 m3/s Maximum water level : EL.8.7 m

Second Stage

(1)	Extension Work	Extension of Pond & orifice
(2)	Dimension	Pond area : 2.35 ha Maximum storage volume : 32,100 m3 Pond bed elevation : EL.7.2 m Average pond height : 2.8 m Orifice size : 1.4 m x 1.4 m
(3)	Work Volume	Excavation volume : 15,200 m3

(4) Hydraulic Design

Peak discharge of inflow (100-yr) : 15.5 m3/s
Peak discharge of outflow (100-yr) : 3.9 m3/s
Maximum water level : EL.8.7 m

CHAPTER 10 ESTIMATION OF POTENTIAL FLOOD DAMAGES

10.1 Introduction

The areas which are subject to flooding by the Oued Ennkhilet can be considered under two broad categories : those where the floods can be solely attributed to overflow from the Oued, and those where the floods are due partly to water flows from the Oued, but also to flows from other sources.

An evaluation has also been made of potential damages under 1-yr and 10-yr probable floods.

Figure 10.1 shows the delineation of these areas under a 100-yr probable flood. For the purposes of the evaluation they have been divided into different zones. Zones A and B, which will be flooded directly by the Oued Ennkhilet are estimated at 359 ha. The other areas, (Zones C, D, E and F), where flooding is partly due to the Oued Ennkhilet are estimated at 388 hectares. The total flooded areas are expected to remain the same under present and future conditions, although the land use will change within these areas.

The Delegations which are located in the flood prone areas directly attributable to flooding from the Oued Ennkhilet consist of Ariana Superieur (Zone A), and Raoued (Zone B). Other areas are located in Borj Louzir (Zones C and D), and parts of Soukra Chotrana (Zones E and F). Basic Socio-economic Data reflecting the different characteristics of these zones is presented below in the evaluation of the specific zones.

10.2 Methodology

10.2.1 Introduction

An assessment of the direct and indirect costs associated with flooding will depend on the extent, depth and expected duration of the floods. An analysis of flood damage is made on two base cases : Impact under present land use conditions, and impact under future land use conditions. Damage assessment has been made for 1-yr, 10-yr and 100-yr return periods.

Flood damage has been assessed in categories related to residential, industrial, commercial and, agricultural areas; the analysis also considers the effect of flooding on roads and transport movements. The methodology for each of these categories is

discussed below.

10.2.2 Damage and Losses in Residential Areas

(1) Introduction

Some residential areas affected, particularly in the immediate vicinity of the Oued include large areas of spontaneous housing. In Ariana Nord it has been estimated that as much as 65% of the housing in certain parts is spontaneous. According to the Revised Urban Plan for the Commune of Ariana, it was estimated that in 1993 more than 600 ha. were illegally occupied, leading to bad control of development of public areas, and the fragmentation of property. This has also resulted in increased flooding due to drainage problems, and pollution of agricultural areas.

It is clear that damage to spontaneous housing will need to be taken into account, since there appear to be no moves by the Authorities to resettle residents to officially designated areas. Indeed, in many cases, the Authorities have provided drainage and water connections to spontaneous illegal housing, thus accepting that this is a permanent situation. Land use estimates have been made of the potentially flooded areas; housing densities and the number of houses affected are based on site visits.

The main damage categories attributable to the flood, will be physical damage caused to buildings and to household effects, and potential loss of income to residents through disruption, which will result in their absence from work for a period of time.

(2) Damage to Buildings

(a) Methodological Approach

There are a number of approaches which can be adopted to estimate potential flood damage. Such hypothetical damage, particularly in residential areas, could be obtained through a comparison of land values for similar property in flooded and non-flooded areas. In normal circumstances, flooding should have an impact on property prices. However, in Tunis, but particularly in the Ariana area, exposure to flooding does not seem to be a contributory factor in determining land and house prices. The range of land prices quoted in Madina El Fadila/El Gazelle varies from DT25 to DT35 per m2, while the range is even higher in Ennkhilet - from DT10/m2 to DT 25/m2. Thus cases even exist where similar neighboring properties in the same area have a considerable price differential.

It is evident that factors other than potential flooding have a greater influence in determining prices. It is also frequently the case that spontaneous construction itself causes the flooding. It should be noted that in present circumstances, flooding is regarded by occupiers to be a temporary phenomenon, and therefore to be considered a nuisance, rather than a serious problem.

Another approach to estimation of flood damage - the contingent valuation approach ("assessment of the willingness to accept compensation for the inconveniences caused by flooding") is considered invalid, in view of the infrequency, and little damage actually experienced in recent years. The assessment of flood damage cannot in this case be based on actual experience.

Difficulties are likely to be encountered in arriving at unbiased and undistorted opinions about the "willingness to pay" of the different respondents. Actual market behavior relating to, for example, property values in flooded as against non-flooded areas has been distorted by the pressure on accommodation within most of the urban area, and it would be extremely difficult to assign realistic values to any hypothetical environmental improvements.

A separate approach to evaluation of the likely benefits of the projects is to use the hedonic method as applied to property prices, between flooded areas and similar homogeneous areas. In principle, the difference in values is taken as an indicator of the likely premium paid to avoid the inconveniences and damage caused by flooding. However, an investigation of the municipal rates shows that these reflect neither the true value of properties nor the environment in which they are located, but are set rather on an basis which does not reflect economic factors. Property values are therefore not considered to be a valid basis for estimating flood damage in the Ariana/Chotrana area.

The approach which is adopted here for the estimation of flood damage is based on assigning hypothetical values for repairing and rehabilitating buildings in relation to construction costs for different categories of buildings.

(b) Assumptions

Increasing urbanization is a phenomenon which is likely to carry on in the potentially floodable areas in the Ariana/Chotrana districts. Land use has been estimated for these areas under present and future conditions. The impact of flooding on buildings will be felt on the deterioration of foundations and rehabilitation required in repairing walls and plaster work and other physical damage. Since it is impossible to carry out surveys on all individual buildings likely to be flooded, some general criteria is used.

Estimation of typical construction costs is notoriously difficult in view of physical factors relative to specific sites. An analysis of data provided by SNIT (Study of Construction Costs of Buildings in Tunis - Etude des couts de production des logements dans le District de Tunis), indicates that foundation costs vary between 5% and 12% for SNIT buildings, and are generally around 8% in the private sector. The cost of interior decoration and glass used is between 5% to 6%. These costs are generally therefore between 10% and 18%. For the purposes of the analysis, it is assumed that in a 100-year flood, damage could amount to 10% of construction costs.

Construction costs naturally vary considerably depending upon the nature of terrain and type of construction and finish. Housing in the Ariana area can be generally divided into three categories as shown below (Costs have been estimated through discussion with the relevant Departments of MOEH, District of Tunis, as well as the Agence Foncier de l'Habitation).

*Popular/social housing (including spontaneous housing)	:DT150/m2 to DT200/m2
*Medium standard housing	:DT250/m2 to DT300/m2
*High Class/Villas	:DT350/m2

Flood damage is assessed at 10% of these costs.

Housing Density is based on site visits and data from other studies, in particular the Master Drainage Plan of ONAS, the 1984 Population Census, and Specific Reports prepared by the Ariana Governorate and the District of Tunis. In the Chotrana area housing plots vary from 50 m2 to 4 ha For spontaneous and popular housing, average typical constructed areas of 60 m2 are assumed, for medium standard housing coefficients of 100m2 and for high class housing 150 m2.

(3) Losses of Household Articles

The value of typical items of household articles in a middle class house, is estimated at around DT3,500. This includes refrigerators, cookers, furniture, carpets, mattresses, clothes and food items. Experience in other countries indicates that flooding of up to 1 meter results in damage of around 10% to household articles. This climbs significantly to nearly 70% at a height of more than 3 meters.

It is unlikely in view of the nature of the terrain that flood depth in Ariana will exceed 1 meter. It is therefore proposed to use 10% of the value of goods as indicative of the

likely flood damage (i.e. DT350 per house).

(4) Losses of Income to Residents

It is assumed that disruption caused by flooding will result in loss of income to residents and households. The number of workers per household will vary according to the active population and the level of unemployment in different areas. Ariana is a mainly commercial and services area with an important Industrial Estate located at Charguia, (but out of the flooded areas). The breakdown of employment in the District was estimated as follows;

Ariana : Breakdown of Employment (%)

Sector	1984	1989
Agriculture	17.9	17.2
Industry	37.1	35.8
Services	45.0	47.0

Source : Commune of Ariana, Revision of the Urban Development Plan, Feb. 1991.

Statistics on active population and employment in the Ariana Governorate indicate that generally employment was around 1.6 workers per household. However, this figure is likely to be misleading, since it does not take into account the informal sector. Accordingly, it is assumed that there will be 2 workers in each household.

Projections of wages have been made till the year 2020 based on increasing incomes in line with expected growth of GDP (6% p.a. till the year 2000, 5.5% between 2000 and 2010 and 5% between 2010 and 2020). On this basis, estimates for skilled labor are DT16 per day at present and DT67 per day in 2020, and for unskilled labor DT5 and DT22 respectively.

10.2.3 Losses to Industry and Commercial Enterprises

In a 100-year flood a considerable number of commercial and industrial enterprises on the RVE 533 will be affected. Losses can be measured in this sector in terms of loss of income for workers, actual damage to the physical assets of a company and disruption to factories resulting in higher costs for the delivery of raw materials and transport of finished products. In order to account for periods of starting up after flood, additional days of inconvenience will be felt beyond the period of flooding.

It is assumed that damage to industrial buildings will be less than to residential buildings,

in view of their more basic construction and simpler decoration. Since most of the industry is of a light or commercial nature, actual physical damage will not be significant, and damage is assumed at 5% of construction cost, estimated at DT300/m2 i.e. DT15/m2. In order to estimate the number of workers , data is taken from the Industrial Survey of the Charguia Estate as being typical The average employment per factory unit was 33 (see Table 10.1). The loss of income for workers for the duration of the flooding is based on the estimated wages, as calculated above.

10.2.4 Losses to Agriculture

There has been considerable loss of agricultural land to housing and this can be expected to continue as urban areas expand. In the meantime, flooding will also cause losses to agricultural crops. Major crops grown include vegetables, irrigated cereals, animal foodstuffs and root crops. There is also some arboriculture, olive tees and citrus. Table 10.2 shows estimated areas cultivated and productivity in the plain of Soukra/Chotrana.

Productivity of the land varies enormously as do prices of crops. For olives it is proposed to use a figure of 10 tons per ha (Assuming a density of 200 trees per ha, and an average productivity of 50 kg per tree) which at current prices (DT0.160/kg), puts a value of the crop at around DT1,600 per ha.

With regard to vegetables, a wide range of crops are grown in the area. Productivity varies from 3.8 tons per ha for cereals to 35 tons per ha for root crops (the latter is based on a number of crops per year). Winter crops have a productivity of 9 tons per ha and it is proposed to use this as a basis for calculating damage loss. Assuming a medium price level of DT0.200/kg, losses are estimated at DT1,800 per ha per crop.

In the Ariana area most of the olive trees are cultivated on higher levels which will not be affected by the flooding. It is therefore assumed that the majority of the crops in the flooded areas will be vegetables. For the evaluation, it is assumed that 75% of areas will be devoted to vegetable and the rest to arboriculture. On this basis the typical loss per hectare of agricultural crops is estimated at DT1,750.

10.2.5 Losses to Transport

(1) Road Damage

It is assumed that in both present land use conditions and expected future land use, roads flooded will need rehabilitation. Construction costs for a new two way road are

estimated at around DT240,000 (excluding taxes). Rehabilitation costs are estimated at 50% of the construction cost, and are assumed at DT120,000 per km for primary roads and DT80,000 per km for secondary roads, based on a general estimate provided by the Department of Bridges and Roads. The construction costs for basic agricultural roads (pistes) are estimated at DT25,000 per km.

The major road affected will be the RVE 533. Secondary roads will also be affected, particularly in Borj Louzir and Chotrana. Future plans mentioned in the Urban Development Plan include the extension of the X 20 across Soukra and Chotrana. There are also number of agricultural roads in the area.

(2) Traffic Delays and Value of Time

For the purposes of the evaluation, it is assumed that the roads will be cut off for the duration of the floods under a 100-yr probable flood. This will entail delays and diversions to other roads, and will result in loss of income. Damages will be less under 1-yr and 10-yr flood conditions due to the lower duration and depth of flooding.

The number of passengers affected is based on the vehicle occupancy rates from the 1989 Survey of traffic in Tunis, carried out by the Ministry of Transport; traffic projections are based on GDP growth rates.

The value of time of passengers is calculated on forecasts of wages to the year 2020 (see Paragraph 10.2.2). In transport studies generally, the loss of leisure time is calculated at 20% of salary levels, and that of business time at 33% of hourly income. Due to lack of sufficient data in the traffic surveys on purpose of journeys it is proposed to apply an average factor to all journeys. The value of time is therefore taken at 25% of earnings.

At current rates the appropriate value is estimated to be DT0.5 per hour for skilled labor and DT0.16 per hour for unskilled labor at present. These are assumed to increase in line with expected GDP growth and to be DT2.1 per hour and DT0.7 per hour respectively in the year 2020.

It is further assumed that passengers in private cars and taxis will be in the skilled labor bracket and all others (using buses, trucks and passengers on two wheels) will be unskilled.