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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

FINAL REPORT

Volume II MAIN REPORT

March 1994

Nippon Koei Co., Ltd., Tokyo

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PREFACE

In response to a request from the Government of the Republic of Tunisia, the Government of Japan decided to conduct a master plan and a feasibility study on Flood Protection Program for Greater Tunis and Sousse and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Tunisia a study team headed by Mr.Hideki Sato, Nippon Koei Co., Ltd., two times between February 1993 and February 1994.

The team held discussions with the officials concerned of the Government of the Republic of Tunisia, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

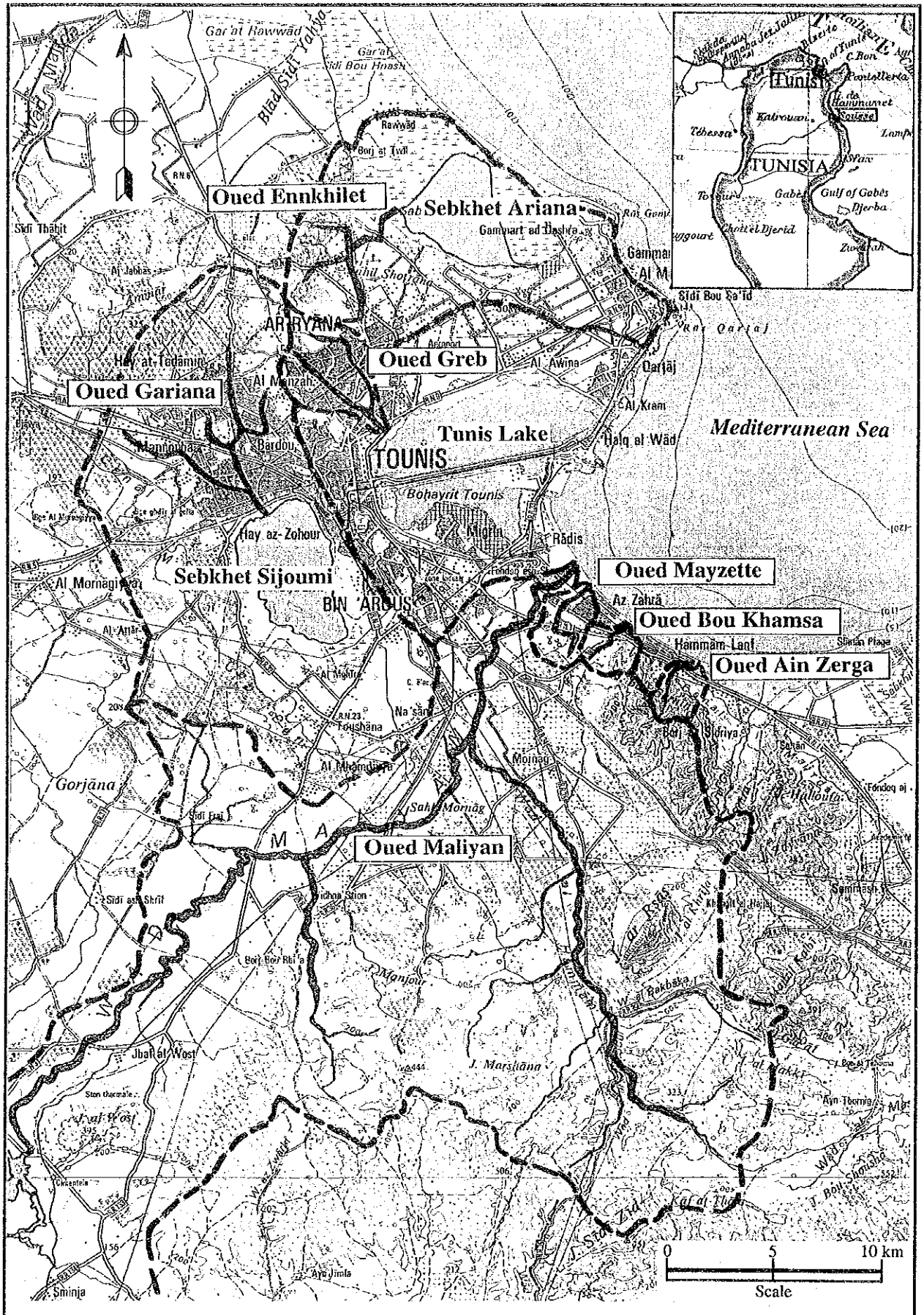
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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

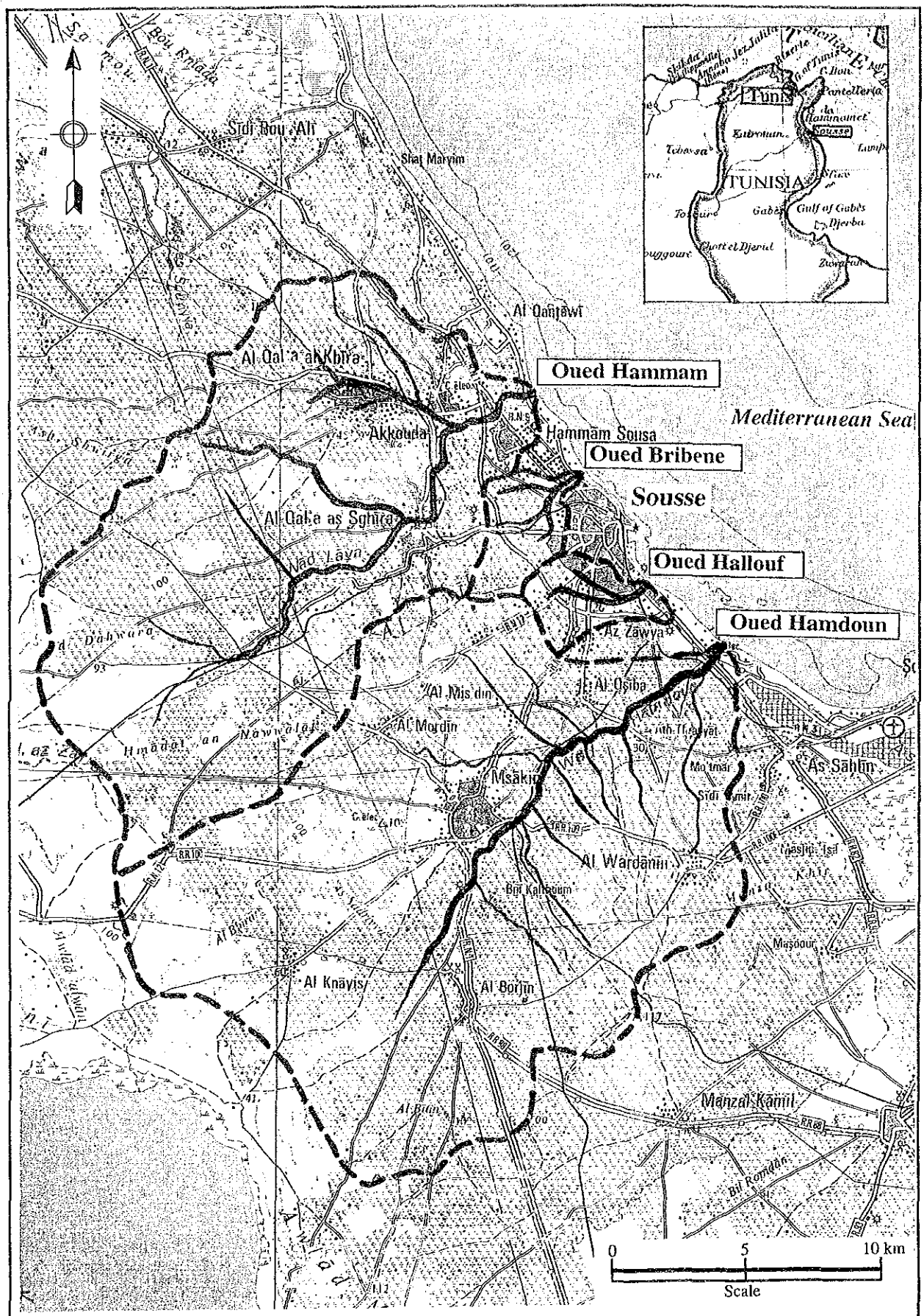
March 15, 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

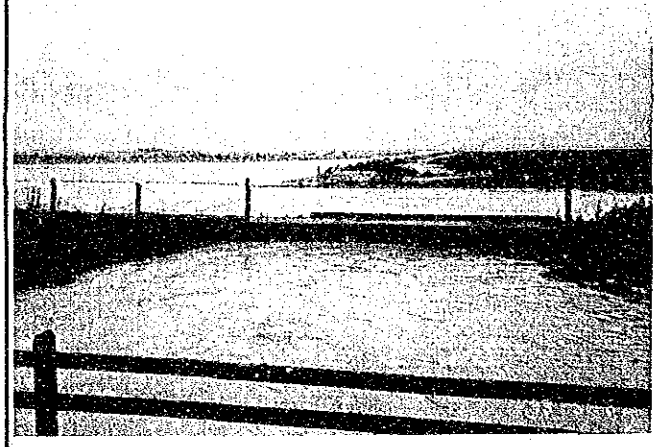


LOCATION MAP OF STUDY AREA IN GREATER TUNIS

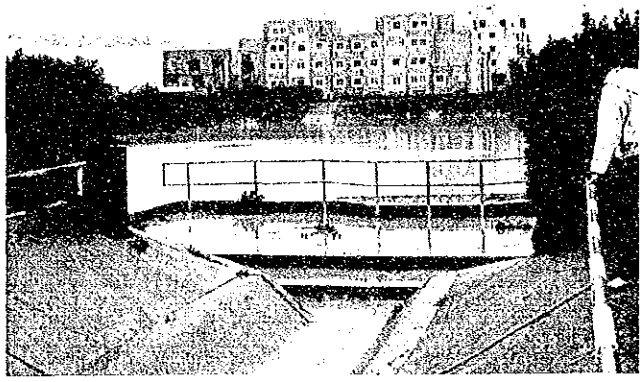


LOCATION MAP OF STUDY AREA IN GREATER SOUSSE

The Study on Flood Protection Program for Greater Tunis and Sousse in the Republic of Tunisia

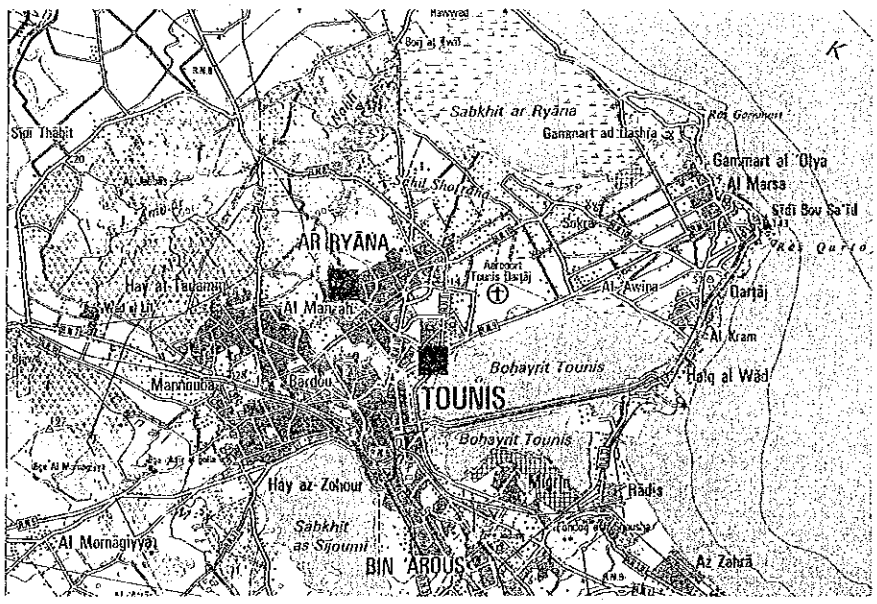


① Oued Greb, Downstream View from L.N.S. Road



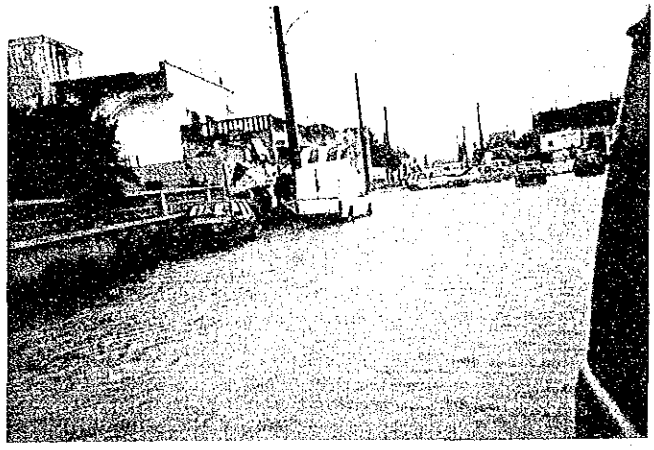
② Outlet of Retarding Pond "ERO-3B"

Those photos show the flooding situation of central part of Tunis on May 5/6, 1993 when the rainfall depth during the period reached to 97.5 mm. It was recorded at the newly installed Gauging Station at ECOLE NATIONALE D'INGENIEURS DE TUNIS during 22:00 of May 5 to 17:00 of May 6,'93.

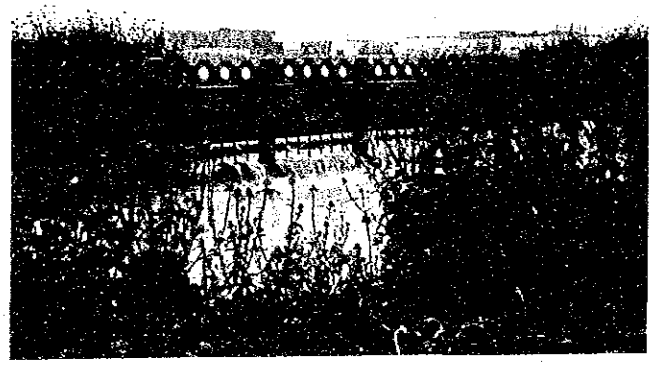


Location Map

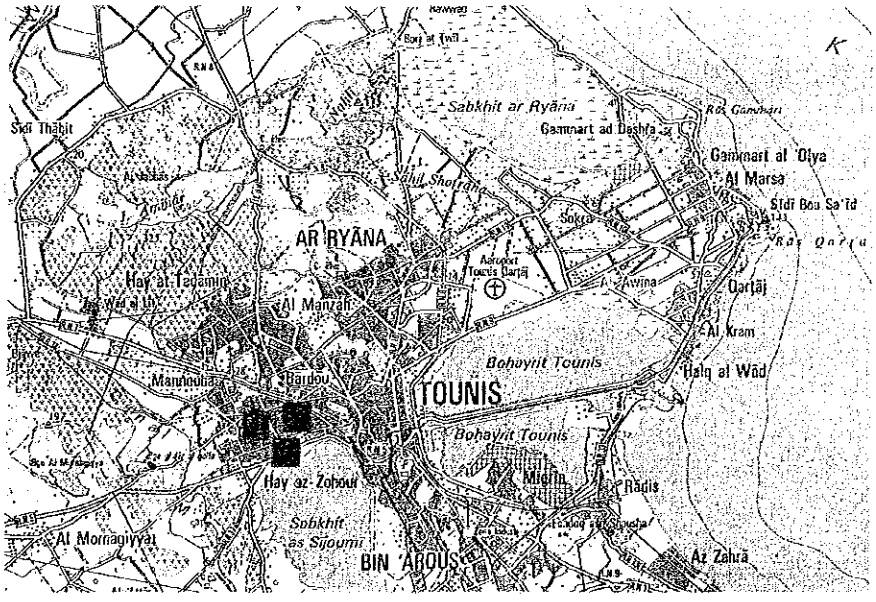
③ Oued Gariana, Upstream View from the road



④ Inundated Road near EBA-1



⑤ Spillout from Retarding Pond "EBA-1"

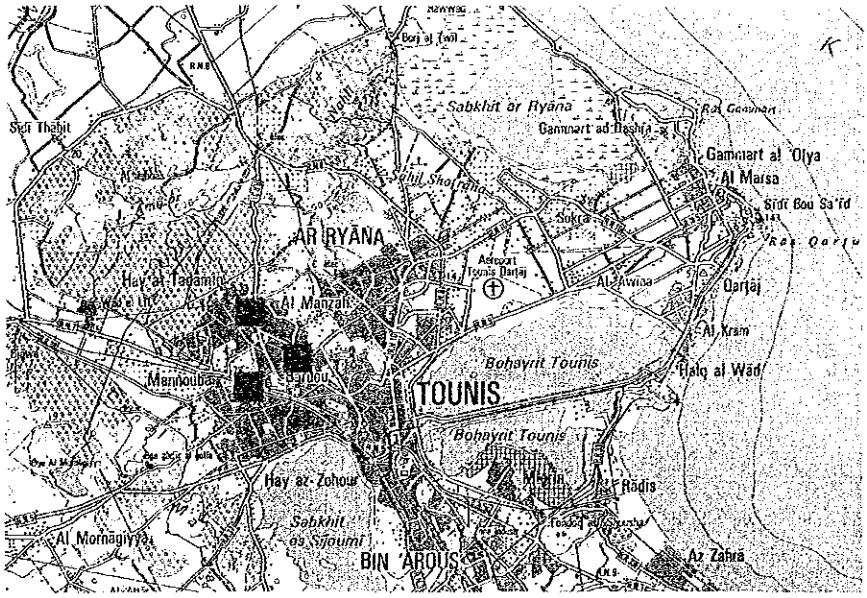


Location Map

⑥ Spillout from Outlet of Retarding Pond "EBA-3"

⑦ Inundated Road near Ettadhamen

⑧ Flood Running on the Road, South of "EBA-4"



Location Map

SUMMARY

General

This Final Report titled "THE STUDY ON FLOOD PROTECTION PROGRAM FOR GREATER TUNIS AND SOUSSE" summarizes the results of study made by the JICA Study Team during the course of Phases 1, 2 and 3 both in the field in Tunisia (late-February- mid-May 1993, and end-September 1993 - beg-February 1994) and in Tokyo (mid-May - mid-August 1993, and mid-February - March 1994). The major purposes of the study are to formulate a master plan and to carry out a feasibility study on selected priority projects for flood protection both in Greater Tunis and Greater Sousse area. Priority projects proposed in this report have been selected from technical and economical viewpoints, after having explanation to and discussion with the Ministry of Equipment and Housing (hereinafter referred to as "MOEH").

1) Overall work schedule

The study has been made in the following three (3) phases:

Phase 1 : Basic Investigation (mid-February - mid-May 1993)
Phase 2 : Formulation of Master Plan for Flood Protection (mid-May - mid-August 1993)
Phase 3 : Feasibility Study on Priority Projects (mid-September 1993 - March 1994)

Work flow chart of the study is attached in Fig.-1 of Summary Report. Works done during Phases 1, 2 and 3 are summarized below.

Phase 1

- Data collection and review of the available data
- Field reconnaissance
- Field investigation
- Preparation of Progress Report

Phase 2

- Analysis of collected data
- Study on basic framework of plan

- Evaluation of existing plans/facilities
- Study on alternative plans
- Initial Environmental Examination (IEE)
- Estimate of cost and benefit
- Selection of optimum plan
- Formulation of master plan
- Institutional study
- Selection of priority projects
- Preparation of Interim Report

Phase 3

- Explanation of Interim Report
- Supplemental field investigation
- Feasibility design
- Study on operation and maintenance
- Estimate of cost and benefit
- Environmental Impact Assessment (EIA)
- Project evaluation
- Preparation of implementation program
- Preparation of Draft Final Report/Final Report

2) Submission of reports

a) Inception Report

The JICA Study Team submitted the Inception Report to MOEH on February 26, 1993. A meeting was held on the same day to explain the contents of the report, and also to discuss how to proceed the works in line with the scope of works determined. The JICA Study Team and MOEH basically agreed on contents of the report. Minutes of the Meeting, after its review by both parties, was signed on March 1, 1993 by Mr.Kharrat Mahmoud, director of Urban Hydraulic Division of MOEH, and Mr.H.Sato, team leader of the JICA Study Team. The Advisory Committee members, chairman Mr.R.Ikushima and its member Mr.M.Nakayasu, and JICA's coordinator Mr.T.Murakami, witnessed the signing.

b) **Progress Report**

The Progress Report which summarizes the works done during Phase 1 as of April 27, 1993 was prepared and submitted to MOEH on May 3, 1993. At the meeting held on May 3, 1993, the JICA Study Team explained the contents of the report and also discussed with MOEH how to complete the works remained such as topographic survey of oueds, installation of water level recorders and rain gauges, and collection of additional data and information.

c) **Interim Report**

The Interim Report which summarizes the works done during Phases 1 and 2 as of August 19, 1993 was prepared and submitted to MOEH on September 29, 1993. The study results described in the Interim Report were explained by the JICA Study Team at the site during end-September to beg-October 1993 to MOEH in detail. The JICA Study Team and MOEH showed different opinions on the top priority project in the Greater Tunis area, the former recommended the "Oued Maliyan" case, and the latter proposed the "Oued Ennkhilet and Sebkhet Ariana" case. JICA Tokyo finally accepted MOEH's proposal in due consideration of its requirement.

d) **Draft Final Report**

The Draft Final Report was prepared at the site by beg-February 194, and submitted to MOEH on February 5, 1994. The contents of the report was fully explained to MOEH by the JICA Study Team prior to the submission of report. MOEH understood the study results and showed his satisfaction on it. Reviewing the report, MOEH showed his comments on some items, and these comments were carefully reviewed and examined by the JICA Study Team. Finalization of the report was made in due consideration of the studies made to date and also MOEH's comments.

Overall Work Progress in Phases 1 and 2

1) Data collection

Scope of Work (S/W) Mission who visited the site on October 1992 collected relevant data and information from the government authorities concerned with the help of MOEH, and all those data and information were transferred to the JICA Study Team. At the beginning of Phase 1, the JICA Study Team made a quick review of those data and information, and found that more data and information are necessary to formulate a

master plan. Collection of additional data and information was mainly done by members of the JICA Study Team in collaboration with MOEH's counterparts during the period of February through April 1993. Government agencies visited are Ministry of Agriculture (MOA), National Sanitation Agency (ONAS), Water Authority (SONEDE), Governorate of Tunis, Institute of National Statistique, and so forth. In addition, the JICA Study Team also visited some local consultants who participated in the development projects in Tunis and Sousse, which have close relations with the Study.

2) Review of data collected

Data and information collected consist of reports, pamphlets, statistical year books, drawings, aerophotos and topographic maps. The JICA Study Team carefully reviewed them and grasped the level of studies made by Tunisian Government to date. As a result, it was revealed that some data and information collected previously are to be updated. Based on this, schedule of field reconnaissance and field investigation was prepared by each member of the JICA Study Team.

3) Field reconnaissance

Initial field reconnaissance was made immediately after the first JICA Study Team members arrived at the site on February 23, 1993. It aimed to understand the actual situation of the project area both in Greater Tunis and Sousse prior to the explanation of Inception Report. The JICA Study Team confirmed there exist no major problems in carrying out the works in line with the scope of work determined.

In early March 1993, most of members of the JICA Study Team arrived at the site and commenced the full-scale field reconnaissance in each sector together with MOEH's counterpart personnel. Major difficulty the JICA Study Team met during initial stage of the field reconnaissance was a lack of enough information on topography at the site. The JICA Study Team was obliged to carry out the field reconnaissance with limited number of topographic maps collected before. However, the JICA Study Team mostly finished the field reconnaissance by the end of April 1993.

4) Field investigation

Reviewing the data and information collected, and also the results of field reconnaissance, the plan of field investigation was prepared in consultation with MOEH. The JICA Study Team explained and discussed with MOEH's counterpart personnel in

advance the methodology of investigation and analysis to be applied for the Study. Field investigation was made for the following four (4) items.

- Hydrological investigation
- Geological/geotechnical investigation
- Topographic survey
- Environmental survey

(i) Hydrological investigation

Hydrological investigation consists of i) analysis of collected data, ii) installation of measuring equipment such as automatic water level recorder, staff gauge, rain gauge, and check of existing stations, and iii) transfer of technology regarding measurement and analytical method of hydrological data to MOEH's counterpart personnel. Hydro-meteorological data such as temperature, humidity, sunshine hour, monthly rainfall, etc. were collected from Meteorological Agency and MOA. Daily rainfall records are available at 57 stations in the study area of Greater Tunis and its surrounding area, and 15 stations in Greater Sousse, which cover the records during past eight (8) years. On the other hand, measurement records of water level at respective oueds are quite limited. Out of seven (7) oueds in Tunis area, and four (4) oueds in Sousse area, measurement of water level is only made for the Oued Maliyan and the Oued Hammam.

Field reconnaissance was made to determine the locations of water level gauges (5 nos) and rain gauges (6 nos) to be installed newly. The JICA Study Team contacted with MOEH and MOA to discuss the suitable locations of these gauges in view of existing gauges in the study area. It was finally determined to install water level gauges at Ariana Lake (1 no), Sijoumi Lake (1 no), Oued Maliyan basin (2 nos), and Oued Hamdoun basin (1 no). Rain gauges are at Oued Ennkhilet basin (1 no), Oued Gariana basin (1 no), Oued Maliyan basin (2 nos), Oued Hammam basin (1 no), and Oued Hamdoun basin (1 no). Installation of rain gauges had been completed by early-May 1993. Installation of water level gauges had also been completed by the end of August 1993. MOEH was responsible for the installation work of such gauges.

(ii) Geological/geotechnical investigation

To judge the geological conditions of the river course and dam site where some flood control measures are to be considered, geological investigation such as core boring, permeability test, compressive strength test, and embankment material test were planned. Through field reconnaissance and review of existing data and information, the location of core boring and sampling of embankment materials was determined by the JICA Study Team. The field investigation works were sublet to a local contractor by the JICA Study

Team. The contractor commenced the field work from April 15, 1993, and completed all the works including analysis and preparation of report by May 8, 1993. Existing geological data and information were also reviewed and analyzed.

(iii) Topographic survey

Topographic survey planned are river profile and cross section survey for seven (7) oueds in Greater Tunis area and four (4) oueds in Greater Sousse area. Through the review of the existing topographic map and field reconnaissance, survey plan was prepared by the JICA Study Team in consultation with MOEH. According to this survey plan, MOEH sublet the works to the following four (4) local surveying companies:

Name of contractor	Name of oued/survey distance
- Boudabous Abderrazak	Oued Maliyan (61 km)
- Salem Abid	Oued Ennkhilet (16 km)/Oued Greb (13 km)
- Hedi Chabbouh	Oued Gariana (23 km)/Oued Mayzette (5.6 km)/ Oued Bou Khamsa (3.9 km)/Oued Ain Zerga (2.4 km)
- Hassen Brahem	Oued Hammam (14.5 km)/Oued Blibene (5.2 km)/ Oued Hallouf (4.5 km)/Oued Hamdoun (17.5 km)

The field works were commenced from early April 1993 by each local surveying company, and all the works were completed by early May 1993. The JICA Study Team carefully reviewed the survey results, and the output such as river profile and river cross section for all oueds was fully availed for the succeeding study in Phase 2.

(iv) Environmental survey

Environmental survey for both socio-economic and natural environment in the study area was carried out to grasp the impact of the project to be implemented. Field reconnaissance was conducted in order to:

- determine the causes and magnitude of flooding problems in the study area and to see how they relate to environmental aspect,
- examine and assess the environmental aspects of the study area in terms of their importance and present condition,
- conduct water sampling at selective locations in oueds to supplement field observations and other available water quality data, and
- obtain information of sites where structural flood control measures exist and are being planned or proposed by the present study to determine and evaluate impacts.

With relation to the quality of surface water, the JICA Study Team determined to carry out the water quality test at several points at oueds both in Greater Tunis and Sousse areas. The JICA Study Team requested National Institute of Engineer, Sfax (ENIS) to make sampling and testing of water. Sampling was made at Greater Sousse area (9 points) on April 21, 1993, and at Greater Tunis area (10 points) on April 24, 1993, respectively. Analysis of water sampled were completed by early May 1993.

5) Findings

(1) Problems in view of flood control/urban drainage

Through field reconnaissance, review and analyses of data and information collected, and interview with staff concerned of related government agencies and local consultants, it was revealed there exist some problems in view of flood control and urban drainage. These are;

a) Government agencies relating to flood control and urban drainage are MOEH, ONAS, and MOA, however the territory of each government agency is not clearly defined. For example, improvement of Oued Ennkhilet has been planned by both MOEH and ONAS. Similar cases have been observed especially in oueds in urban area.

b) It has been observed flood control facilities such as dike and retention pond have been constructed sporadically in the study area, and each facility seems not to function well. Good example is dikes newly constructed at the downstream end of Oued Hammam just between the highway and the river mouth. Both banks upstream of the highway are remained as it is without being connected to these new dikes.

c) Design condition or design standard applied for flood control and urban drainage in the past studies are not consistent.

d) Records relating to flood damages are scarce. Several data obtained from Ministry of Interior, and MOA only show general description on floods occurred in the past, but not on precise duration, damages, and so forth.

e) There are a lot of gauging stations in the study area, and those data are handled and stored in both MOA and the Meteorological Agency. Data management is not being done well, and it is rather difficult to obtain the data required from these agencies in time.

f) It is observed almost all oueds in the study area are not controlled or maintained well. Local people dispose garbage into oued, and polluted industrial water and untreated sewer water are flowing into oueds here and there, and it emits bad odor. In some oueds it is observed many olive trees are planted in the river course.

g) There are three (3) lakes in Greater Tunis, Sebkhet Ariana, Sebkhet Sijoumi, and Tunis Lake. It was found that Sebkhet Ariana is under control of MOEH, Sebkhet Sijoumi is of MOA, and Tunis Lake is of semi-private body. Those lakes are closely related to flood control and urban drainage of oueds pouring into the lake, however, the development philosophy that such government agencies and/or semi-private body have, is not clear yet.

(2) Conceivable alternative flood control plans

The JICA Study Team commenced the Phase 2 work immediately after they arrived at Tokyo on mid-May 1993. Based on the available data and information collected and analyzed, the JICA Study Team concentrated on the study on alternative plans of flood control measures for each river basin, and on formulation of master plan which are the principal part of Phase 2 work. Most of the oueds are running in urban areas in Greater Tunis and Sousse, and some flood control measures had already been constructed by MOEH, MOA, and ONAS to date. However, these facilities are not enough to protect the valuable areas from flooding. The JICA Study Team examined the flood control plans for each oued in view of technical, social, economical and environmental aspects. As the data and information concerning floods occurred in Tunisia to date are scarce, it was obliged to make some assumptions in the study referring to the data and information available and also the experiences of the JICA Study Team members in other countries where similar natural and social environments are considered.

It is conceivable that alternative flood control plans to be applied for oueds in the study area would be i) river improvement, ii) retarding basin, iii) dam, and iv) diversion channel, or a combination of them. Detailed information on existing and planned flood control facilities and storm water drainage system under the control of MOA and ONAS are essential to study and formulate such alternative flood control plans. However, the information collected so far are not enough for the study. Then the Study Team was obliged to formulate such alternative flood control plans taking some assumptions into consideration judging from the past experiences in the similar projects. General concept of the alternative flood control plans is explained in Chapter 8 of Part I "MASTER PLAN STUDY". Number of alternative plans conceived at each river basin is summarized below:

Name of river basin	Nos. of alternative plans
Greater Tunis Area	
- Oued Ennkhilet and Sebkhet Ariana	4
- Oued Greb	3
- Oued Gariana and Sebkhet Sijoumi	4
- Oued Maliyan	5
- Oued Mayzette	1*
- Oued Bou Khamsa	1*
- Oued Ain Zerga	4
Greater Sousse Area	
- Oued Hammam	7
- Oued Blibene	1*
- Oued Hallouf	1*
- Oued Hamdoun	4

Note: Figure with (*) means the case that no alternative plan is conceived, an river improvement plan only is studied.

(3) Flood control plan selected at each river basin

Alternative flood control plans conceived above were carefully examined from technical and economical viewpoints on the basis of study results obtained through review and analysis of data and information collected. The followings are the brief description of flood control plan selected by the JICA Study Team for each river basin.

Name of river basin	Description of flood control plan selected
Greater Tunis Are	
- Oued Ennkhilet and Sebkhet Ariana:	ENK-1: River improvement with Ain Snoussi Dam and Retarding Basin A.
- Oued Greb:	GB-3: River improvement with existing and additional retarding basins, and rehabilitation and expanding of existing dams and retarding basins.
- Oued Gariana and Sebkhet Sijoumi:	GR-2: River improvement with existing additional retarding basins, including expansion of existing retarding basins.
- Oued Maliyan:	ML-2: River improvement with existing dam, and Hamma dam.
- Oued Mayzette:	River improvement only.
- Oued Bou Khamsa:	River improvement only.
- Oued Ain Zerga:	AZ-2: River improvement and Retarding Basin A.
Greater Sousse Area	
- Oued Hammam:	HM-1: River improvement only.

- Oued Blibene: River improvement only.
- Oued Hallouf: River improvement only.
- Oued Hamdoun: HD-1: River improvement only.

(4) Selection of projects for feasibility study

Through the study on alternative plan, the most effective flood control measure was selected for each oued based on mainly technical and economical points of view. For the Greater Tunis area, it is recommendable the first priority project would be the "Oued Maliyan" case, consisting of river improvement including flood control dam at Oued Hamma, a tributary of Oued Maliyan, and the second would be the "Oued Ennkhilet" case. For the Greater Sousse area, the "Oued Hammam" case has been determined as the top priority project that mainly consists of river improvement of lower reaches, and the second priority is "Oued Hallouf" case.

As was described herein before, the "Oued Ennkhilet and Sebkhet Ariana" case was eventually selected to be taken up for the succeeding Feasibility Study in the Greater Tunis area through the discussion and consultation among staff concerned of JICA Tokyo, the JICA Study Team and MOEH. As for the Greater Sousse area, the Oued Hammam was selected as the project for Feasibility Study as recommended by the JICA Study Team.

Overall Work Progress in Phase 3

1) Collection and review of data

Reviewing the data collected during the Phase 1 stage, the JICA Study Team continuously collected additional information and data relevant to the further study in collaboration with MOEH's counterparts. Principal data collected are those related to environment, urban planning and construction cost estimate. Data collected were carefully reviewed and availed in the feasibility study in this phase.

2) Field reconnaissance

The JICA Study Team made the field reconnaissance of the oueds proposed for further feasibility study, that is, Oued Ennkhilet and Sebkhet Ariana in Greater Tunis area, and Oued Hammam in Greater Sousse area, together with an Advisory Committee member, immediately after they arrived at Tunis on beg-October 1993. In parallel with the desk work to formulate the alternative flood protection plans for each oued, the field

reconnaissance by the JICA Study Team followed from time to time to confirm the actual situation at the site. MOEH newly provided the JICA Study Team the topographic map in scale of 1/5000, which was recently issued by Office de la Topographie et de la Cartographie (OTC). Those topographic maps were fully availed for the field reconnaissance of this time.

3) Field investigation

Field investigation was mainly planned for the Oued Ennkhilet and Oued Hammam. Items investigated are the following three:

- Geotechnical investigation,
- Topographic survey, and
- Environmental survey.

(i) During Phase 1, the basic geotechnical information was obtained through the field investigation and the review of relevant data. Additional geotechnical investigation to be made during this phase was checked by the expert of the JICA Study Team, and the kind of investigation and the sites were determined in consideration of the conceivable various kinds of flood protection measures such as dam, retarding basin, diversion channel and dike. Field works and laboratory test for the samples exploited were carried out by a local contractor during October and November 1993. The results obtained through the investigation works were examined and reflected to the further study of the flood protection measures of each oued.

(ii) Topographic survey was planned for both the Oued Ennkhilet/Sebkhet Ariana, and the Oued Hammam to supplement the survey data obtained by the previous survey. Plain table survey for the structure sites such as bridge and retarding basin, and the cross section survey of the Sebkhet Ariana were newly made. The works were sublet to local surveying companies by MOEH, and the field works were supervised by the survey experts of the JICA Study Team during late-October to December 1993. River profile and cross section survey of the oueds and the plain table survey were completed as scheduled, however the cross section survey of the Sebkhet Ariana was delayed due to bad access to the site.

(iii) Environmental survey for the oueds and the sebkhet was intensively made by the expert of the JICA Study Team from the viewpoint of positive and negative effects by the project implementation. As it is considered the protection of the Sebkhet Ariana is very

important, the eco-system of the sebkhet was carefully reviewed and examined referring to the information and data collected this time.

4) Comparative study of alternative plans for flood protection measures

Oued Ennkhilet

To formulate the alternative plans of flood protection measures for the Oued Ennkhilet, the following three concepts were basically contemplated:

(i) Flood is discharged through the existing channel without expecting any decrease of peak flow to be provided by retarding basin. Existing channel, especially most of existing concrete box culvert be rehabilitated due to insufficient flow capacity.
(ii) Flood is discharged through the existing channel and a newly planned diversion canal. In this case, no retarding basin is considered and also the rehabilitation of existing concrete box culvert is minimized.
(iii) Both retarding basin and diversion canal are to be considered so that existing concrete box culvert will function without any rehabilitation work.

Judging from the flood runoff analysis made this time, it was revealed that the flow capacity of the existing concrete box culvert is only 3m3/s, and is not enough to pass the flood flow smoothly, even if some peak cut is considered by applying the retarding basins to the maximum extent. Comparative study on alternative plans was made on the basis of the 10-year probable flood, as it is a MOEH's design standard applied for the existing concrete box culverts on the Oued Ennkhilet. And then the 100-year probable flood was taken into consideration for the feasibility study on the best plan selected through the comparative study. Some minor tributaries or tributaries where only some spots are required to be improved are discarded in the feasibility study.

Following this basic concept, the selection of sites for retarding basins and diversion canals was studied using the topographic maps and also by the field reconnaissance. As a result, sixteen retarding basin sites and five diversion canal routes were selected. Two kinds of retarding basin are planned, one is a dam type to be located at the junction of sloped hilly area and the flat plain, and the other is a pond type to be located at the flat plain area, where agricultural land is extending. Out of five diversion canals, one canal (No.3) is a transbasin diversion canal with which flood flow will be diverted to the neighboring Chautrana Basin. In this case, the upstream part of the canal will newly be opened but the downstream part will be the existing ONAS's canal. One of the alternative plan, Diversion Canal No.1 to be connected with the Retarding Basin J2, was

discarded on the way of the study due to the difficulty of developing this retarding basin because of the recent housing development at the site. Eventually fifteen retarding basin sites were considered in the further comparative study. Numbers of combination of those retarding basins and diversion canals are numerous, then the economic advantage of each retarding basin was firstly examined comparing the construction cost including land acquisition cost of the retarding basin, and the construction cost balance of the downstream river channel improvement with and without the said retarding basin. As a result, nine retarding basin sites were discarded due to unfavorable economic disadvantage. Retarding Basins named I, L, and M seem to be not so attractive from the economic viewpoint, but it is judged that the further study is required in combination of other retarding basins and/or diversion canals.

Comparative study on alternative plans was eventually made on seven retarding basin sites (including existing Ain Snoussi Dam) and five diversion canals. Among the all, the case "Alt.Div.3" is the most prospective in case of independent plan, and the case "Alt.Div.3,4 & 5" which is a combination of three diversion canals, are the best. Judging from this comparative study, it is considered the development of Diversion Canal No.3 is indispensable for the flood protection program of the Oued Ennkhilet.

Sebkhet Ariana

Study on drainage plan for the surrounding area of Sebkhet Ariana was not included in the feasibility study of this time. However, the discharge from the small oueds which flow into the sebkhet was taken into consideration in the simulation study of Sebkhet Ariana. Cross section survey of the sebkhet was carried out by a local surveying company to check the storage volume of it. As a result, the storage volume of the sebkhet was almost the same to that estimated in Master Plan stage, then it was calculated the rise of water level during flood would be in the order of El.70 cm. The outlet to the Mediterranean Sea is often clogged by sand drift. The most simple and practicable measure to keep this outlet open would be to carry out a periodical dredging or excavation. It will take a time to realize other counter-measures such as jetty construction, sand flushing system and so forth, as there exist insufficient data and information to make such study in detail.

Oued Hammam

The river improvement plan only was studied for comparative study in the feasibility study stage, as the retarding basin is not so effective for flood control in the lower

reaches of the Oued Hammam basin. Some minor tributaries or tributaries where only some spots are required to be improved are discarded in the feasibility study.

Based on the estimated 10-yr and 100-yr flood damages, it was found that flood damages along some river stretch are not so significant. To formulate flood control plan, the river course consisting of the Oueds Hammam, Laia and Kebir was divided into nine (9) river stretches from H-1 to K-5. Then, the flood control alternative plan was formulated as follows by selecting the river stretch to be improved.

Alternative 1: This is a plan of river improvement work for all the river stretches from H-1 to K-5. This plan includes construction of proper river channel for the stretches K-2 & K-3 and swamp area of the H-3.

Alternative 2: This is a plan of river improvement work for river stretches H-1, H-2, H-3 excepting swamp area, H-4, K-1 and K-4 & K-5. In this plan, the construction of proper river channel for the stretches K-2 & K-3 and swamp area of the H-3 is not included.

Alternative 3: This is a plan of river improvement work for river stretches H-1, H-2, H-3 excepting swamp area, H-4, K-1 and K-4 & K-5. In the stretch H-4, river improvement work is carried out only for the short stretch near the confluence with the Oued Kebir.

These flood control alternative plans were compared each other from technical and economical viewpoints. According to cost and benefit flow based on the assumed construction schedule, the EIRR was calculated for each alternative plans and the Alternative 3 was selected as the most recommendable plan.

Undertakings by MOEH

MOEH acted as a counterpart agency to the JICA Study Team and also as a coordinating body in relation with other governmental and non-governmental organizations concerned for the smooth implementation of the study. In response to the request of the JICA Study Team, MOEH's counterpart personnel did their best from time to time to obtain necessary data and information from various sources, and also attended the field reconnaissance and field investigation made by the JICA Study Team during the period of late-February to mid-May 1993, and late-September 1993 to January 1994.

MOEH provided at its own expense the JICA Study Team with the following:

a) available data and information related to the Study.
b) topographic maps in scale of 1/200000, 1/50000, 1/25000, and 1/5000 which covers almost all of the study area.

c) Aerophotos in scale of 1/80000 which cover all of the study area.
d) counterpart personnel consisting of five (5) engineers on full-time basis, and eight (8) engineers on part-time basis.
e) office spaces with necessary equipment and furniture in Tunis.
f) assistance of custom clearance of equipment brought from Japan.
g) identification cards.

Conclusions and Recommendations

1) Through the comparative studies on conceivable alternative plans of flood protection for the Oued Ennkhilet and the Oued Hammam, the following are finally selected as recommendable ones from technical and economical viewpoints.

Oued Ennkhilet

The case of "Combination of Diversion Channels No.3 and No.4, and Retarding basins A, G, I and J1". The project financial costs and economic internal rate of return (EIRR) are;

- The project financial cost for the first and second stages are estimated at;

First stage	: DT15,094,000.-
Second stage	: DT 8,960,000.-
Total	: DT24,054,000.-

- EIRR for the implementation of first stage work is calculated at 24.6 %.

Oued Hammam

The case of "River improvement works only between the Touristic road and Bypass road of GP-1 on the Oued Hammam, on the lower reach of the Oued Kebir and the upper-most stretches of the Oued Kebir." The project financial costs and EIRR are;

- The project financial cost for the first and second stages are estimated at;

First stage	: DT10,413,000.-
Second stage	: DT 787,000.-
Total	: DT11,200,000.-

- EIRR for the implementation of first stage work is calculated at 17.4 %.

2) As a result of the study, it was confirmed that the flood protection plans proposed are technically sound and economically feasible. Then it is strongly recommended MOEH to take immediately necessary actions for further steps such as securing finance, land acquisition of proposed retarding basins and river stretches, and so forth. It is

recommendable the first stage to be implemented in near future in view of urgency of such flood protection measures for these oueds.

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 I

MASTER PLAN STUDY

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Part I

MASTER PLAN STUDY

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CHAPTER 1 SOCIO-ECONOMIC CONDITIONS OF THE STUDY AREA

1.1 Introduction

The basic socio-economic framework for the Study is described in this Chapter. The purpose of this section is to provide:

- Demographic aspects
- A review of flood damage in the past within the study areas
- A methodological approach to flood evaluation in the present socio-economic context

1.2 Evaluation of Economic Trends

(1) Past Trends

An evaluation has been made of recent developments of the Tunisian economy, based on data collected from the National Institute of Statistics and the Ministry of Planning, including the Eighth National Development Plan (1992-1996), and the latest Statistical Year Book 1992, and the National Budget 1993.

The development of the economy in recent years is summarized in Table 1.1.

The average rate of growth of the economy between the years 1987 and 1991 was estimated at 3.7% p.a. in spite of a bad year in 1988. The economy picked up considerably in 1990/1991 due largely to an increase in the agricultural sector, which grew by 27%, and sustained economic growth in export industries.

Nevertheless, the dependence of the economy on tourist earnings is evident from the figures, as seen by the consequences of the Gulf War, which led to a considerable drop in income and a negative impact on the balance of payments.

No estimates are available on the Regional Gross Domestic Product for Greater Tunis and Sousse. It is unlikely that even informal estimates from the Commissariat Generale du Developpement Regional will be available soon for either town. In 1990/91, per capita household expenditure for the country was estimated at DT 716. Tunis, with major industrial and commercial development had an average per capita income of DT 1,007, while that in Sousse was estimated at DT 806. However, these figures are well below the per capita GNP figure that was estimated by the World Bank at $1,440.

(2) Projections

Prospects for the future development of the economy under the Eighth Development Plan have been examined. In comparison with the Seventh Plan, the economy is expected to grow rapidly, averaging a growth rate of 6% p.a. as compared with 4.2% in the Seventh Plan, due to higher investment. Per capita income is expected to increase at twice the rate experienced in the Seventh Plan - 4.1% p.a. as compared with 2.1%.

The future development of the economy under the Eighth Development Plan is summarized in Table 1.2.

Projections for the growth of the economy in the near future are optimistic, as Table 1.3 shows in comparing the objectives of the VII and VIII Plans.

Growth in 1992 has already exceeded the objectives of the VIII Plan, when GDP grew by 6.5% compared with an expected 3.8%. This was due to a number of reasons including increased production in the agricultural sector, growth in the tourist sector (14.2%), increased price of petroleum etc.

The average growth rate for the VIII Plan (1992/1996) is expected to be 6.0%, with manufacturing industry playing a major role with an annual growth rate of 8.67%, followed by tourism which is expected to grow at 6.7% p.a. These rates will be reflected in rapid growth in the regional economies in Tunis and Sousse, where these sectors are important to the local economies. Employment creation in Tunis for this period is estimated at 21,000, and 40,000 for Ariana.

The implementation of the projects and programs proposed in the Plan will result in employment creation in Tunis for this period is estimated at 21,000, and 40,000 for Ariana.

With regard to developments in the long term, it is assumed that high rates cannot be maintained, and for forecasting purposes it is proposed to use growth rates of 6.0% p.a. till the year 2000, 5.5% between 2000 and 2010 and 5% p.a. beyond 2010.

1.3 Population Trends and Projections

1.3.1 Introduction

An analysis is presented below of the past trends and projections at the national and regional levels. More specific data has been prepared recently on population projections in certain districts and these are considered in estimating the future benefits of the projects (see Chapter 9.2 and 9.3).

1.3.2 Past Trends

(1) District of Tunis

The analysis of population trends has been based on the last full Census of 1984, and the "mini census" of 1989, (National Population and Employment Survey, 1989).

In general, two trends are to be noted at the national level, in analyzing population growth in the past.

(a) A decreasing trend in the growth rate, which has reduced from an average of 2.7% in the 1970s to 2.3% in the decade of the 1980s. It was estimated at an annual average of 1.95% between 1986 and 1991, and is forecast to be between 1.7% and 1.8% during the Eighth Plan. Beyond the year 2000, the rate is expected to be between 0.8% and 1.2%. On these hypotheses, the present population of Tunisia of 8.2 million will reach between 9.6 and 9.8 million in 2001, and between 11.7 and 13.1 million by the year 2026.

(b) A general trend towards urbanization has seen the urban population in Tunisia increase from 40% of total population in 1966 to 60% in 1989.

However, where Tunis is concerned, there has been a trend of population movements from Tunis towards the outlying suburbs due mainly to saturation of the center (as reflected in the high densities). For example, among 1984 and 1989 it was estimated that Tunis Governorate lost 69,900 persons, while Ariana and Ben Arous gained 53,400 and 32,200 persons respectively.

(2) Governorate of Sousse

According to the latest estimates, the population for the Governorate is 403,000 inhabitants. The average annual growth rate among 1984 and 1991 was estimated at 3.24%, with urban population representing an average of 75.5% of total population.

The estimation of the populations by delegation indicates that the towns likely to be affected by flooding have high rates of urbanization, ranging from 77% for M'Saken to 100% for Hammam Sousse, with a population between them of around 150,000.

1.3.3 Population Projections

(1) National Level

With regard to increases in population for the long term the Ministry of Planning has assumed two hypotheses:

I. Population increase is determined by the continuation of the trend in decreasing fertility (from 3.45 at present, to 2.61 in 2001 and 2.05 in 2026);

II. The fertility rate drops more rapidly to reach 2.05 in the year 2001.

These represent rates of growth of 1.8% and 1.7% during the VIII Plan. Over the longer term (2000-2025), the growth rates are even lower, at 1.2% and 0.8%. The Ministry of Planning proposes two hypotheses which result in population projections of 11.7 million and 13.1 million in the year 2026.

(2) District of Tunis

Future projections have been made till the year 1996 for the three Governorates, by the District of Tunis, as basis for the elaboration of the VIII Plan, as shown in Table 1.4. From the table, it can be seen that the growth rate for Tunis is well below that for the other two Governorates - 1.8% compared to 4.5% for Ariana and 4.0% for Ben Arous. This reflects negative growth rates for a number of central districts, and more rapid increases for outlying areas. Tunis is thus expected to reduce its share from 52% in 1984 to 46% in 1996, mainly at the expense of Ariana which will increase its share from 26% to 32%.

Growth rates beyond 1996 are expected to be lower (averaging 1.52%), and it is expected that population will reach 2.3 million in the year 2011.

(3) Governorate of Sousse

The latest population estimates for the Governorate of Sousse are 418,000 inhabitants. Growth rates are estimated at 3.2%, with an urbanization rate of 75.5%.

The estimation of the populations by delegation is shown in the Table 1.5 for the year 1992.

Population forecasts for the region of the Centre-East in the VIII Development Plan are as follows:

Year 1991	: 1,724,000
Year 1996	: 1,889,000
Year 2011	: 2,367,000

This represents a rate of growth of 1.84% among 1991 and 1996, and 1.52% p.a. between 1996 and 2011.

Future growth rates for Sousse, according to official forecasts, vary between 2.8% and 3.45% p.a. However, ONAS has predicted a lower rate for the long term, 2.33% p.a. and this is used in making projections.

1.4 Socio Economic Characteristics of the District of Tunis

Data on basic socio-economic indicators has been collected at the regional and local level from the District of Tunis, and the Governorates of Ariana, Tunis and Ben Arous. An analysis has also been made of Regional Master Development Plans, and Urban Master Plans for a large number of Communes in the Region.

For most of the indicators, the latest data available is for 1989. Their relative importance can be seen from Table 1.6.

The following are the main conclusions to be drawn from these statistics:

* The District of Tunis has the largest concentration of people in the country, with approximately 20% of the population located in the three Governorates. Higher than average population growth rates in the future will increase the percentage of population located in the District.

* Tunis Governorate appears to have reached saturation; however, a trend towards increasing urbanization can be expected in the other two Governorates, resulting in planned and illegal residential areas.

* All three Governorates are important industrial centers, in particular, Ben Arous that has industrial areas at Rades, Meghrine, Ben Arous and Bir Kassa, with 685 enterprises and 600 hectares of industrial areas. In addition, both the Tunis District and Ariana has considerable industrial development, with one third of the population of Ariana employed in the sector.

* The services sector is the largest. The city is an important conference and tourist center. There are over 100 hotels with 13,000 beds, representing 12% of the Country's tourist infrastructure. The sector employs 10,000 people within the district. On average over the past few years, tourists have spent 1.1 million nights in Tunis center and 0.5 million nights in the tourist areas of North Tunis.

* Construction in Ariana has increased at a rapid rate rising from 70,200 buildings in 1984 to 94,900 in 1989, a growth rate of 6.2% per annum. Much of this construction is spontaneous and illegal housing. It has been estimated that in Ariana, spontaneous housing provides shelter for one third of the population and covers around 50% of space. This has strong implications for the evacuation of flood waters, insofar as these

constructions impede the natural flow of rain and used water. This phenomenon is evident in the large number of stagnant pools in the area.

* While a large percentage of houses is connected to utilities, the phenomenon of illegal ("spontaneous") housing construction has resulted in ad hoc and badly planned provision of services, as well as causing severe drainage problems and the impounding of used and rain water. In Ariana in particular, areas occupied by illegal housing are equal to those with legal housing (1,900 ha). In Tunis spontaneous housing covers and estimated 1,000 ha., while in Ben Arous it is estimated at around 3,500 ha (see Chapter 4).

* Literacy rates are higher in all three Governorates compared to the national average.

1.5 Socio-Economic Characteristics of the Governorate of Sousse

Basic socio-economic data for the Governorate of Sousse is shown in Table 1.7.

The structure of the regional economy, as reflected in the occupation of the employed population (see Table 1.8), indicates that industry is the major employer (28%) followed by tourism (21.3%). Sousse has a major industrial area at Sidi Abdel Hamid located alongside the Oued Hamdoun. There are estimated 460 factories in the area, of which 114 are polluting industries. The major share of manufacturing is taken up by textiles.

As a result of increasing urbanization and growth of the services sector, agriculture has shown a considerable decline - it represented 35.6% in 1966, but has now dropped to 16.7%. Arboriculture is a major activity covering 45,000 ha, of which 64% is planted in olives, representing 1,675 million trees.

Undoubtedly, tourism is the major sector with the most rapid growth prospects. The Governorate accounts for nearly 25% of total hotel and beds in the country with development concentrated along the coast.

The major activities in the different delegations within the catchment areas of the oueds are shown in the Table 1.9.

The unemployment rate of the different delegations varies. Of the delegations within the catchment areas of the oueds, Kalaa Seghira shows the lowest rate (1984 figures) with 4.3%, followed by Hammam Sousse (9.9%), Kalaa Kebira and Sousse Riadh (11.5%), Sousse Jawhara (13.2%), Akouda (13.7%), Sousse Medina (15%), and M'Saken (19.2%).

1.6 Assessment of Flood Damage

1.6.1 Introduction

Major floods in Tunisia in recent years have occurred in 1969, 1973, 1982, 1986 and 1989 ("Assessment of the Major floods observed in Tunisia over the past 20 years" KALLEL/BENZERTI, Jan. 1990"). The Report indicates that for the most part, the southern areas of the country have been the worst affected.

Overall damage can be considerable as illustrated by the floods of 1969, when 300,000 people were affected throughout the country, with 500 deaths, and 70,000 houses destroyed; damage to the economy was estimated at 12% of the GNP. In addition, flash floods have occurred which while causing flooding of a temporary nature, have resulted in considerable damage. The type of damage experienced have concerned destruction and damage to buildings (foundations, walls and roofs), isolation of communities through the destruction of roads, traffic delays etc.

Several actions have been taken in recent years to avert or diminish flood damage and these have shown some success, in considerable reducing the damage and loss caused in housing, infrastructure, agriculture and other material. This particularly applies to the Oued Maliyan, where the barrages of El Kebir and Bir M'Cherga have had some effect. However, the Oued El Hamma tributary of the Maliyan, is still not controlled, and it is expected that the barrage at El Kebir will be silted up by the year 2005.

1.6.2 Previous Estimates of Flood Damage

(1) Introduction

No official estimates have been made of the damage caused by the floods. Moreover, evaluations of these floods have concerned mainly estimations of flow and general descriptions of flooding rather than detailed estimates of damages. Only in the case of major disasters in the South have any calculations of damage been made. Little data is available on the extent, duration and depth of flooding in the Tunis and Sousse areas.

(2) District of Tunis

Introduction

The last serious floods affecting the Tunis were those of 1969 and 1973. No detailed assessments are available for these floods. Damage and inconvenience caused by the floods of 1982 and 1989 were minor in comparison, due largely to the construction of dams on the Oued Maliyan, and retention basins on the Oued Gariana.

The Flood of 1982

A cursory study was made of the flood along the Oued Maliyan in 1982 by the Ministry of Agriculture. However, no estimates were made of the extent, duration or damage caused, but only approximate areas and direction of flow were indicated.

The Flood of 1987

Following heavy rains in March 1987, when it was estimated that flood water lay around for a month in El Boustene, Borj Louzir and Choutrana, a report in "La Presse" quoted estimates of 250,000 Dinars to evacuate the stagnant water, in addition to 23,000 Dinars for rehabilitation, 14,000 Dinars for improving the egress channels for water between the sebkha and the sea, and 50,000 Dinars for recruiting doctors to treat patients affected by diseases arising from unhygienic conditions.

The Flood of April 1989

A report was undertaken following the heavy rains of April 11, 1989, which lasted for three hours (15h to 18h) and caused the capital to come to a stand still, as well as causing human and material damages. The commission consisted of the District of Tunis, Protection Civil, Ministry of Agriculture and National Defense identified specific roads where flooding problems were the greatest (Refer to the Report Programmme de Protection du District de Tunis contre les Inondations).

According to this report, the Tunis District is particularly subject to risk in the areas at the foothills of the hills such as Jebel Nahli, Kerch El Ghabain in the North, Jebel Ammar in the West, and the hills of Ain Krima and Jebel Boukourine in the South. The area around Kerch El Ghaba is considered to be a priority area.

No data is available on the damage sustained, but evidently, the short term effect on traffic in terms of delays was considerable, As the report indicates, major as well as minor roads were affected by the flooding, in particular, sections of GPI, which handles around 20,000 vehicles per day.

Flood Assessment 1988

A Study on the Soukra Choutrana Plain carried out by the District of Tunis in 1988 indicated that there was stagnant water of between 20 cm and 50 cm in some areas resulting in crop damage. Evidently there is damage to the foundations of the spontaneous housing built in the area, as well as health risks. However, no precise estimates of damage are available.

(3) Sousse

In the Sousse area concerned by the present Study, the following towns were identified as prone to almost total flooding: Sousse, Hammam Sousse, Akouda, Kalaa Kebira, Sousse Riadh, and M'Saken. At that time it was estimated that over 22% of Sousse Governorate were susceptible to flooding (532 km^2).

However, even these evaluations need to be taken with caution in view of the considerable works carried out since then (retention dams, re calibration of drains and outlets, clearance of channels etc.)

1.6.3 Methodology for Assessment

(1) Introduction

As noted above, no specific damage assessments of floods in the past have been made in the Tunis and Sousse areas, and there is therefore no firm data base on which to estimate likely future damages. It should also be noted that, following the floods of recent years, action has been taken on a number of fronts, (e.g. the construction of retaining basins and dams, improvements in the maintenance of oueds, dredging etc.) , which will ensure that damage will not be experienced to the same level as in the past.

To overcome this lack of data a number of alternative approaches have been considered for assessing the flood impact.

(2) property and Land Values

In normal circumstances, flooding should have an impact on property prices and land values. However, this is patently not the case in the Study area, where, demand exceeds supply on the one hand, and speculation is rife leading to high prices, whether the land is prone to flooding or not. The range of land prices within potentially flood-prone areas and other areas is wide. Cases exist where neighboring properties in the same area have a considerable price differential.

Other factors, in particular access to roads and the provision of other infrastructure play a major role in determining prices. In fact, it is often the case that the construction of illegal housing itself is the cause of local flooding. It would be impossible to isolate the effect of local flooding on prices and land values. It should be noted that in present circumstances, flooding is regarded by occupiers to be a temporary phenomenon, in the expectation that, despite illegal occupation, they will eventually be connected to the various networks, including the evacuation of used and rain water.

(3) Contingent Valuation

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. Moreover, difficulties are likely to be encountered in arriving at unbiased and undistorted opinions about the "willingness to pay" of the different respondents. As noted above, 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.

(4) Hedonic Pricing

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. 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 that they are located, but are set rather on an basis which does not reflect economic factors.

(5) The Proposed Approach

Because of the lack of damage assessment data, it is proposed at this stage to use a number of assumptions concerning damages. The approach adopted consists of a broad evaluation of the following aspects in the flooded areas:

i) Impact on local population
ii) Potential damage to buildings, industry and equipment
iii) Transport and traffic inconveniences including delays, increased vehicle operation costs and road damage
iv) Damage to agriculture

A detailed methodology is given in Section 9.3.

CHAPTER 2 GEOLOGY AND TOPOGRAPHY

2.1 General

In order to clarify the geological/topographical conditions and to select the core boring spots for the dam foundation and sampling spots for the embankment material, each river basin in the study area was reconnoitered referring to the existing regional geological maps. According to the reconnaissance, three (3) core boring spots were selected and drilled at the Guemgame dam site which locates on a tributary of the Oued Hammam. This dam site has been contemplated by MOA. Sampling for the laboratory test as embankment material was made at eight (8) spots including the Guemgame dam site.

The location of the spots of core boring and sampling is shown on Figs.2.1 and 2.2.

2.2 Geology and Topography

2.2.1 Greater Tunis

1) General geology

In the north-western part of study area of Greater Tunis, moderately sloped hills with the maximum height of about 300 m above the sea level are developed. In the south and south-eastern part, mountains with the height ranging from 400 m to 800 m are developed. On the east side foot of the hills, the Sebkhet Ariana is situated, and the Tunis Lake is situated on the south-eastern side foot and they are connected to the sea. The Sebkhet Sijoumi is situated on the south foot and has no outlet to the sea. In the north-eastern side along the coast of the Tunis bay including the areas around the above sebkhet and lake, the low plain is developed with the maximum height of about several meters except the local hilly area from Carthage to Gammart. In the central area along the Oued Maliyan, the comparatively high plain is developed from north-east to the south-west, undulating gently and increasing the altitude from about 15 m to about 60 m at about 10 km downstream of the Bir M'Cherga Dam. The south-western end of the study area is bounded by the Bir M'Cherga Dam, and the undulation degree increases and some steeply sloped hills are developed in the area from the dam to 10 km downstream.

The geology of hills in the north-western part consists of marl, sandstone, clay-stone, their weathered soils and talus deposits aged from the Cretaceous to the Neocene. The mountains in the south and south-eastern part consists of marl, sandstone, clay-stone, limestone and

their weathered soils and talus aged from the Triassic to the Neocene. The coastal plain consists of the alluvial deposits of clay and sand, and dunes are developed locally along the seashore. The central plain consists of the alluvial deposits of clay, silt and sand along the Oued Maliyan and its tributaries and the fluvial deposits of clay, silt and sand on the both banks. The hills in the south-western boundary consist of the Cretaceous marl, limestone and sandstone.

2) Geological condition by river basin

- Oued Ennkhilet, Oued Greb and Oued Gariana

The Oued Ennkhilet, Oued Greb and Oued Gariana originate from the hills north to the urban area of Tunis. The geology of those oueds' upstream parts is quite similar consisting of the talus deposits of clay, silt and sand originated from the marl, sandstone and clay-stone. The downstream parts consist of the coastal alluvial deposits.

- Oued Maliyan

The geology along the Oued Maliyan consists of the following three parts. About 10 km stretch of the upstream end of the study area consists of the Cretaceous marl, limestone and sandstone. The successive 20 km downstream stretch consists of the fluvial deposits of clay, silt and sand. The alluvial deposits is developed in the vicinity of the river course with a width of about 1 km. The downstream end stretch of about 10 km consists of the alluvial deposits. An isolated hill is situated along the right bank (north side) about 1 km apart from the river channel. This hill consists of the Neocene alternations of sandstone and clay-stone.

The Oued Hamma, one of the big tributaries, branches at about 10 km upstream from the river mouth. The geology along this river in the downstream half consists of the fluvial deposits similarly to that of the Oued Maliyan. The upstream half about 10 km above the confluence flows among the mountainous area. The river flows also on the fluvial plain but the fluvial deposits contain the gravel and coarse sand. The geology of both sides mountains is the marl and limestone aged from the Triassic to the Neocene.

- Oued Magzette and Oued Bou Khamsa

The geology of both the Oued Magzette and Bou Khamsa consists of the coastal alluvial deposits.

- Oued Ain Zerga

The Oued Ain Zerga flows on the talus deposits among the mountainous area. The talus deposits consist of the sand and gravel with some red clay. Geology of both side mountains is the same marl, limestone and sandstone as in the upstream area of the Oued Hamma.

2.2.2 Greater Sousse

1) General geology

The study area of Greater Sousse is situated on the gently undulated hills of about 80 m high above the sea level at the maximum. The rivers flow down dissecting the depressed area.

The geology of the area consists mainly of the Quaternary fluvial deposits of clay and sand. Among them, the Pliocene sandstone and marl are distributed sporadically. Along the river course of the Oued Hammam, Oued Hamdoun and their main tributaries, the alluvial deposits of clay and fine sand are developed.

2) Geological condition by river basin

- Oued Hammam

The geology of Oued Hammam basin is the Quaternary fluvial deposits of clay and fine sand and the Tertiary marl and sandstone is distributed at the left bank near the river mouth and the west and south of Kalaa Kebira.

- Oued Blibene

The Oued Blibene flows down the comparatively steep hill in the northern part of Sousse urban area. The geology is mainly the Quaternary fluvial deposits of clay and sand. Around the hill top, the semi-angular gravel of sandstone are found. These are estimated to be the residual soil of the Neocene sandstone.

- Oued Hallouf

The Oued Hallouf mainly flows in the low and flat area in the southern periphery of the urban part. The geology consists of the alluvial deposits of fine sand in the downstream part and clay in the upstream part.

- Oued Hamdoun

The geology of Oued Hamdoun consists mainly of the Quaternary fluvial deposits of clay and fine sand. In the middle reach, the alluvial deposits of fine sand are developed wider than that in the Oued Hammam.

2.3 Investigation Result

2.3.1 Field Investigation

1) Core boring with standard penetration test and field permeability test

For the most prospective retarding basin, the Guemgame dam which is contemplated by MOA was selected from the topographic condition and the land use situation. Three (3) core borings were drilled there. Two (2) borings were sunk to 15 m deep on the river bed and the left bank, and one (1) boring was sunk to 20 m deep on the right bank. In each bore hole, the standard penetration was made at 1 m depth interval and the field permeability test was made at 5 m depth interval.

The stratification is composed of alternation of the yellowish brown silty fine sand and the yellowish/reddish brown clay. The thickness of sand ranges from 1 m to 3 m and that of clay ranges from 20 cm to 2 m. The strata are estimated to be developed almost horizontally from the outcrops.

The N-values ranges from 21 to more than 50 and most of them are more than 30. Accordingly the bearing capacity against the homogeneous type dam up to about 30 to 40 m is judged to be sufficient.

The field permeability ranges from 1×10^{-5} to 2×10^{-5} cm/sec and most of them are lower than 10^{-5} cm/sec. Accordingly the imperviousness for the retarding basin foundation is judged to be sufficient because it is considered the reserving period is within several days.

The boring logs are shown on Fig.2.3 including the results of standard penetration test and the field permeability test.

2) Sampling

In the Greater Tunis, sampling for the embankment material test was made at the following three (3) spots.

- Left bank of retarding basin B of Oued Ain Zerga (T-1)
- Right bank of crossing of Oued Maliyan and GP-1 road (T-2)
- Left bank of retarding basin A of Oued Maliyan (T-3)

In the Greater Sousse, the sampling was made at the following five (5) spots.

- Upstream right bank of Guemgame dam site (S-1)
- Upstream left bank of M'Darrej dam site (S-2)
- Upstream left bank of Laira dam site (S-3)
- Left bank of retarding basin A of Oued Hamdoun (S-4)
- Left bank of retarding basin B of Oued Hamdoun (S-5)

The sample was taken from ground surface to 3 m deep except the top soil at each spot. The logs of sampling holes are shown on Fig.2.3.

2.3.2 Laboratory Test Result

The summary of laboratory test result for embankment test is shown in Table 2.1. According to the result, the materials distributed around the proposed embankment sites except M'Darrej dam site are classified to CL by the Unified Soil Classification by ASTM and judged to be available for the dam and/or levee embankment material, though the permeability coefficients of the materials in the Greater Sousse area are judged to be high comparing with their gradation and Atterberg's limits. Those high values are estimated to be caused by the test errors.

The material of S-2 is classified to SP-ML by the same classification standard and is judged to be unsuitable for the dam/levee embankment. However the available earth fill material is estimated to be gotten nearby from the reconnaissance result.

2.4 Geological and Geotechnical Conditions of Existing/Proposed Dam Sites

2.4.1 Greater Tunis

1) Foundation

- Oued Ennkhilet

On one tributary of the Oued Ennkhilet, a flood retarding basin named Ain Snoussi exists. The small earth fill dam of about 5 m high is founded on the compact talus deposits of clayey

soil layer. The embankment material is estimated to have been borrowed from the same layer as the foundation.

One retarding basin is being studied on another tributary. The geological and geotechnical condition is quite similar to the Ain Snoussi dam.

The location of the existing dam and a candidate of the proposed dam is shown on Fig.7.3.

- Oued Greb

On the Oued Greb and its main tributary Oued Roriche, eight flood retarding basins named as below exist.

Barrage Greb, Ennasr Basin, EGU-4, EGU-7,
Barrage Roriche, ERO-3, ERO-3B, and ERO-5

Among them, Barrage Greb, Ennasir Basin and Barrage Roriche are equipped with small earth fill dams and the others are excavated basins. Three (3) dams are founded on the talus deposits of compact clayey soil layers and the embankment materials are estimated to have been borrowed from the same layers as the foundation.

A flood retarding basin with a dam was studied at the downstream of Barrage Greb. The geological and geotechnical conditions of the site for this candidate of the proposed dam is quite similar to the existing ones.

The location of the existing dams and a candidate of the proposed dam is shown on Fig.7.10.

- Oued Gariana

On the Oued Gariana, eight (8) flood retarding basins exist and the five (5) additional basins are planned by ONAS. The geological and geotechnical conditions of the sites of the existing and planned flood retarding basins are quite similar to those of the Oued Ennkhilet and Oued Greb.

The location of the existing and planned basins is shown on Fig.7.17.

- Oued Maliyan

In the Study area of the Oued Maliyan , the existing flood control works are only dike

downstream from the confluence with the Oued Hamma. The geology of this area is the alluvial deposits of clay dominant soil which is not so inferior for the levee embankment material and the foundation. However the dike collapsed some places. The cause of dike embankment collapse is estimated because of the erosion by the river flow.

For this river, one flood retarding basin was studied on the main stream and a multipurpose dam named Hamma dam was planned on the middle reach of the Oued Hamma.

The geology of the site for the candidate of a flood retarding basin is the Quaternary fluvial deposits of clay dominant soil layers. These are considerably compact and have a sufficient bearing capacity and imperviousness as the foundation of a dam up to about 10 m high.

The geology of the Hamma dam site also is the fluvial deposits. However the fluvial deposits include the gravely and sandy layers in the shallow portion above the consolidated thick clayey layer and the geology of surrounding mountains are the marl, limestone and sandstone. This site is investigated by the core borings and test pitting. From the investigation result, the clayey layer is judged to have sufficient bearing capacity and imperviousness against a earth fill dam of about 40 m high.

The location of the Hamma dam and the candidate of the proposed dam is shown on Fig.7.24.

- Oued Magzette and Oued Bou Khasma

On both of the Oued Magzette and Oued Bou Khamsa, there is no prospective flood retarding basin site.

- Oued Ain Zerga

On the Oued Ain Zerga, two (2) flood retarding basins are being studied. The location of those is shown on Fig.7.45.

The geology of two (2) sites are the talus deposits of clay, silt, sand and gravel. The geology of the surrounding mountains is the marl, limestone and sandstone. These talus deposits are estimated to have sufficient bearing capacity against a dam foundation but questionable in the imperviousness.

2) Embankment material and concrete aggregates

The dams of retarding basin in the Oueds Ennkhilet, Greb, Gariana, Maliyan and Ain Zerga shall not require the rock materials because they will be not higher than 10 m, although for the Oueds Ennkhilet and Ain Zerga, the sandstone, marl and/or limestone which are distributed within 1 km are available.

For the Hamma multipurpose dam also, the sandstone, marl and/or limestone which are distributed within 1 km are available. These material can be used for rip rap, filter/drain and concrete aggregates.

The earth embankment material for each dam and levee can be borrowed easily nearby. However sand and gravel materials except the Oued Ain Zerga and the Hamma multipurpose dam shall be imported from the borrow area other than each catchment area.

2.4.2 Greater Sousse

1) Foundation

- Oued Hammam

There exists no dam on the Oued Hammam. Three dams named Guemgame, M'Darrej and Laia was planned for the flood retarding basin by MOA. Adding to these, two retarding basins named temporarily Retarding Basins A and B were studied. The location of those retarding basins is shown on Fig.7.52.

The geological conditions of these five dam sites are quite similar consisting of the Quaternary fluvial deposits of compact clay and dense fine sand with some silt. The marl outcrops locally on the left bank about 1 km upstream of the Guemgame dam site and on considerably wide area of the right bank of the Laira dam site.

The compact clay layer is estimated to have the sufficient bearing capacity and imperviousness as the foundation of an earth fill dam of about 10 m high. The dense fine sand layer is estimated to have the sufficient bearing capacity and its imperviousness is estimated to cause no serious trouble by the temporary water storage.

- Oued Hamdoun

Two retarding basins also named Retarding Basins A and B temporary were studied. The geological conditions of those candidates for the proposed dam are quite similar to those in the Oued Hammam consisting of the Quaternary fluvial deposits of compact clay and dense

fine sand with some silt though the uppermost loose alluvial deposits are estimated to be thicker than them. The location of those is shown on Fig.7.71.

2) Embankment material and concrete aggregates

No prospective quarry site is found in the study area though there are some outcrops of marl which are judged to be unsuitable for the concrete aggregates. Accordingly the materials for rip rap, filter/drain and concrete aggregates shall be imported from the outside of the project area.

The clayey soil distributed near the proposed dam sites is judged to be available for embankment materials of the earth fill dam. The fine sand alone, however, is judged to be unsuitable for the embankment materials though it can be used if it is mixed with the clayey soil.

2.5 Erosion and Sedimentation

There are intercalated fine sand layers of homogeneous grain size in the study area especially in Greater Sousse area. Their average grain size is about 0.1 mm. These material is very erosive and easily silted when the flow velocity becomes slow. Therefore the countermeasures against sedimentation is indispensable for the retarding basin.

CHAPTER 3 METEOROLOGY AND HYDROLOGY

3.1 Hydrological Investigation

3.1.1 Data Collected

Meteorological and hydrological data in both the Greater Tunis and Sousse area were collected. The recorded hydrological data such as rainfall, water level and discharge, have been stored in data base system in Directorate General of Water Resources (D.G.R.E.) of Ministry of Agriculture.

(1) Climatological data

Climatological monthly data such as air temperature, relative humidity, evaporation, sunshine duration and rainfall at two stations (Tunis-Carthage and Siliana) in the Greater Tunis area and two stations (Sousse and Monastir) in the Sousse area are available in a yearbook published by "INSTITUT NATIONAL DE LA METEOROLOGIE". The recent five years' data from Sept. 1986 to Dec. 1991 were collected.

(2) Rainfall record

Daily rainfall data of the whole Tunisia are compiled in a yearbook of rainfall "ANNUAIRE PLUVIOMETRIQUE DE TUNISIE" by D.G.R.E. This yearbook is available since Sept. 1968 and the daily rainfall data in other year are compiled by monthly basis. The Yearbook 1986/87 is a newest one and contains a daily rainfall data at 56 stations in Greater Tunis and 16 stations in Sousse area. The recent 25 years' (from Sept.1967 to Aug. 1991) daily rainfall data at above 72 stations were collected. The rainfall hyetograph data were also collected at few stations for limited period.

(3) Rainfall intensity

Intensity-Duration-Frequency (IDF) analysis was done by "Institut National De La Meteorologie". These results were adopted for the ONAS's planning. The IDF study reports on Tunis-Carthage and Monastir were collected.

(4) Runoff record

Daily mean discharge data in the Tunisia are compiled in a yearbook of Hydrology "ANNUAIRE HYDROLOGIQUE DE TUNISIE" by D.G.R.E. The yearbook 1987/88 is a newest one and contains a daily mean discharge data at 3 stations in Oued Maliyan basin. All available yearbooks (1974/75 to 1987/88) were checked and 14 years' daily mean discharge data was collected. The water levels and discharge hydrograph data were also collected at few stations for limited period.

(5) Tide level

Some study reports on tide level were collected but the actual tide records were not available. Recently, the tide level observation was commenced by individual organization in Tunis, because there are no existing tide level record stations. Directorate of Port and Airport under the MOEH have a plan to install a tide level recorder at 8 ports in Tunisia including Tunis port and Sousse port.

3.1.2 Review of Data Collected

This Sub-section describes general explanations about the review of data collected. Details and findings on Greater Tunis and Sousse are mentioned in Sections 3.2 and 3.3.

(1) Climate

Climatological monthly data at two stations, Tunis-Carthage and Siliana in the Greater Tunis area and two stations Sousse and Monastir in the Sousse area are available. Locations of these stations are shown in Fig. 3.1. The monthly data for recent five years (Sept. 1986 - Dec. 1991) in these stations was reviewed.

(2) Rainfall

The recent 25 years' daily rainfall data were collected at 56 stations in Greater Tunis and 16 stations in Greater Sousse area and these are listed in Table 3.1. The available periods of data are summarized in Fig. 3.2 and the location of the stations are shown on Fig. 3.3. Annual maximum daily rainfall in collected 25 years' data at each station were checked and in available 23 years' data (1968/69 to 90/91) at each station was arranged and summarized in Table 3.2.

(3) IDF curve

The study on IDF curve at the stations Tunis-Carthage and Monastir was made by "Institut National De La Meteorologie". These studies are based on rainfall record in 21 years (1970 to 1990) at the station Tunis-Carthage and in 10 years (1981 to 1990) at the station Monastir. Annual exceedence series of duration from 6 minutes to 6 hours were used for frequency analysis and two types formula were adopted for IDF curve. Results of these studies were summarized in Table 3.3 and graphically shown on Fig. 3.4, respectively. These study results are useful and reliable for rainfall and runoff analysis.

(4) Tide level

The tidal movement varies from about 0.8 m at northern coast to 2.0 m at southern coast in Tunisia. In the gulf of Tunis, the tidal movement is very small and ranges from +0.30 to +0.40 mNGT in the high tide and -0.12 mNGT in the low tide. Information about the tide level in northern coast of Tunisia is summarized below;

BIZERTE
- Observed max. : +0.57 (mNGT)
- Observed min. : -0.63 (mNGT)

GULF TUNIS
- High tide : +0.30 to +0.40 (mNGT)
- Low tide : -0.12 (mNGT)

SOUSSE
- Observed max. : +0.58 (mNGT)
- High tide : +0.45 (mNGT)
- Low tide : -0.05 to -0.10 (mNGT)

According to the information of the OTC, the elevation datum of 0.0 mNGT was defined with equal to the mean sea level.

3.1.3 Design Rainfall

(1) Hydrologic design scale

Following basic conditions were applied for the design rainfall.

- Design scale for master plan : 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 rainfall hyetograph

Design rainfall hyetograph is utilized to obtain design discharge hydrographs. The following two types of design hyetograph were applied;

- The alternating block method was applied for smaller and medium river basins that time of concentration is less than 12 hours. Design hyetograph is developed as center density distribution from an IDF curve with time interval is equal to the time of concentration.

- The actual observed hyetograph was applied for bigger river basins that time of concentration is more than 12 hours. Rainfall hyetographs in May 1973 and Sept. 1986 are available, and these data were used for typical design hyetograph patterns.

3.1.4 Runoff Calculation

(1) Selection of runoff calculation model

Following three runoff calculation models were selected in consideration of the basin characteristics and scale, data availability, facilities in the alternative plan and so on.

- Rational method : applied for small river basins without existing or plan of regulation ponds or dams that is needed to consider the hydrograph analysis.

- Triangular unit hydrograph method with rational formula's peak discharge : applied for smaller and medium river basins with existing or plan of regulation ponds or dams that is needed to consider the hydrograph analysis.

- Storage function method : applied for basins with existing or plan of regulation ponds or dams that is needed to consider the hydrograph analysis, and hydrological data to develop and calibrate the models are obtainable.

(2) Runoff calculation model

Runoff calculation model of each river basin were chosen as listed below;

Oued Ennkhilet (17 km2) : Triangular Unit Hydrograph + Rational Formula
Oued Greb (19 km2) : Triangular Unit Hydrograph + Rational Formula

Oued Gariana (87 km2)	: Triangular Unit Hydrograph + Rational Formula
Oued Maliyan (1,996 km2)	: Storage Function Method
Oued Magzette (7.0 km2)	: Rational Method
Oued Bou Khamsa (6.2 km2)	: Triangular Unit Hydrograph + Rational Formula
Oued Ain Zerga (4.2 km2)	: Triangular Unit Hydrograph + Rational Formula
Oued Hammam (222 km2)	: Triangular Unit Hydrograph + Rational Formula
Oued Blibene (15 km2)	: Rational Method
Oued Hallouf (12 km2)	: Rational Method
Oued Hamdoun (313 km2)	: Triangular Unit Hydrograph + Rational Formula

(3) Basic conditions of rational formula

- Runoff coefficient (f) : The definition of a runoff coefficient of the rational method is that it is the ratio of the peak rate of direct runoff to the average rainfall in a storm. According to the ONAS's study report, the following runoff coefficient is adopted for runoff analysis in Sousse area.

Land Use Description	Runoff Coefficient
Agricultural Land	0.2
Traditional District	0.8
Urban Center	0.7
Working-class District	0.7
Middle-class Residential Area	0.5
High-class Residential Area	0.4
Industrial Area	0.6

Following runoff coefficients for various land use types were determined taking account of ONAS's report, standard of Japan and USA, available topographic map and present and future land use map.

	Present Land Use Condition	Future Land Use Condition
Urban center, Commercial, Industrial and Residential areas :	0.6	0.8
Agricultural lands, Open spaces :	0.2	0.2
Water surface :	1.0	1.0