No. 23

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 I SUMMARY REPORT

March 1994

Nippon Koei Co., Ltd., Tokyo

JICA THE STUDY ON FLOOD PROTECTION PROGRAM FOR GREATER TUNIS AND SOUSSE FINAL REPORT Volume I SUMMARY REPORT March 1994 Nippon Koei Co.,

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LIST OF VOLUMES

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.

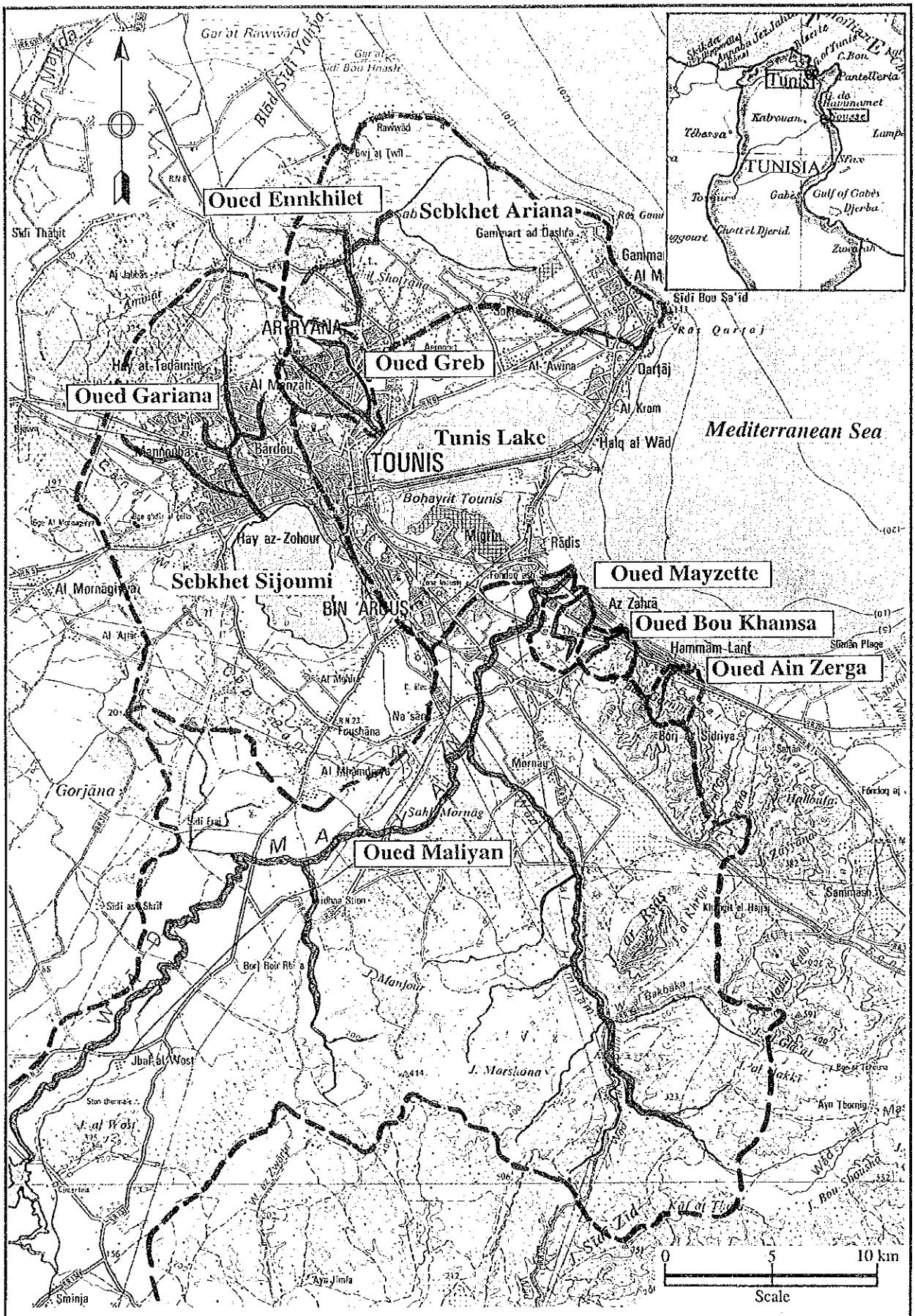
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

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.

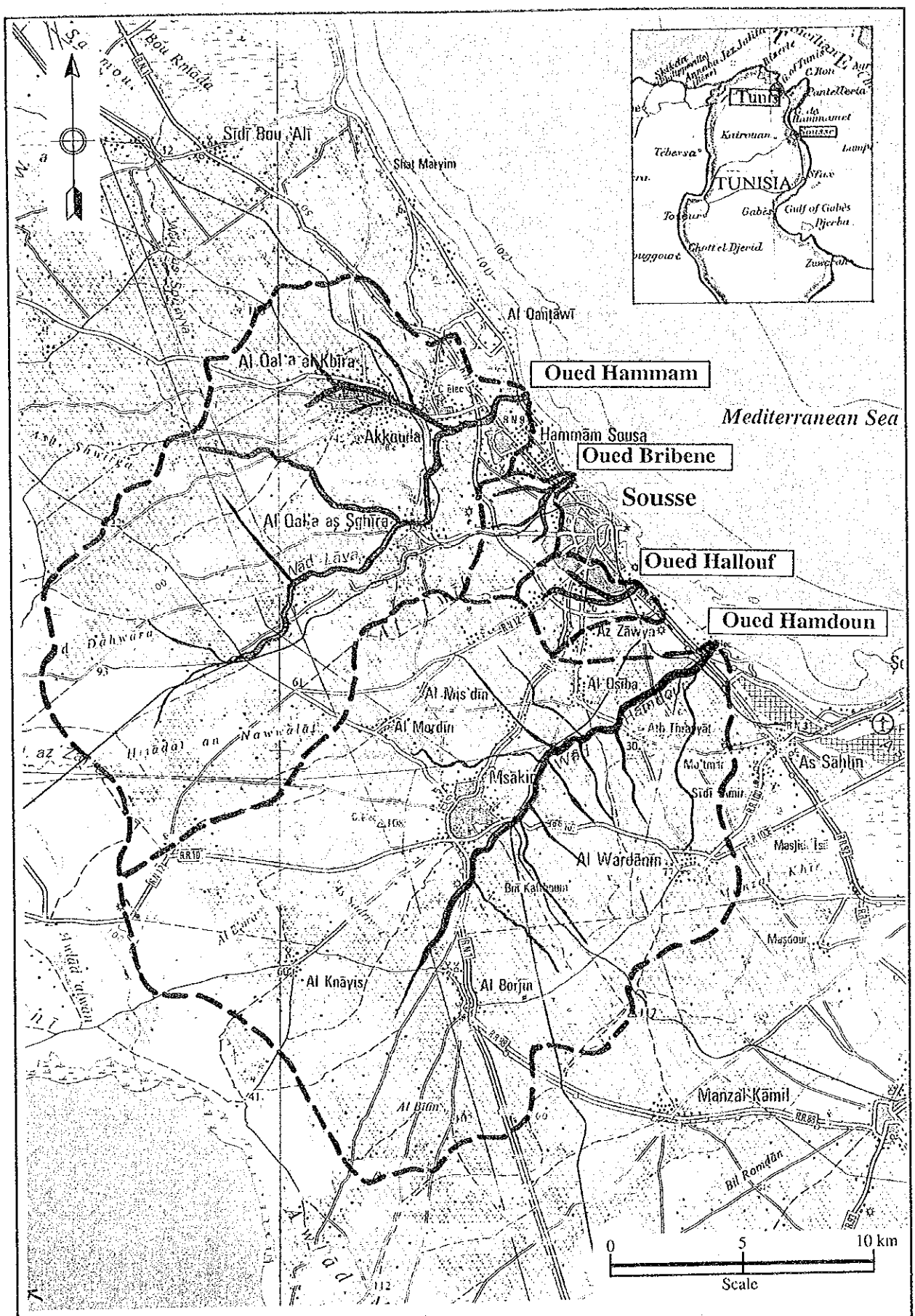
March 15, 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

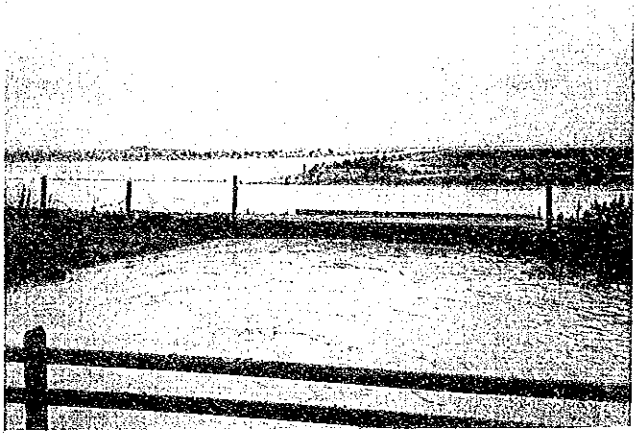


LOCATION MAP OF STUDY AREA IN GREATER TUNIS

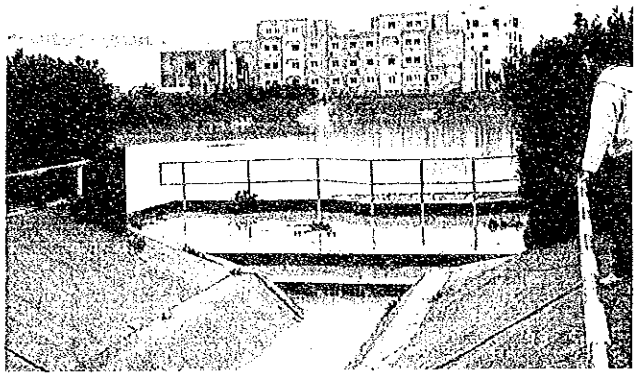


LOCATION MAP OF STUDY AREA IN GREATER SOUSSE

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

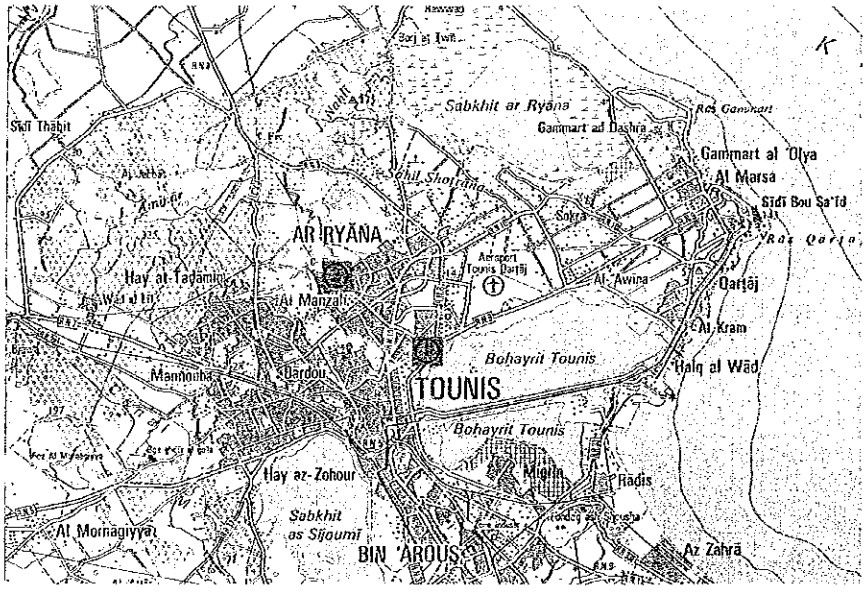


① Oued Greb, Downstream View from L.N.S. Road

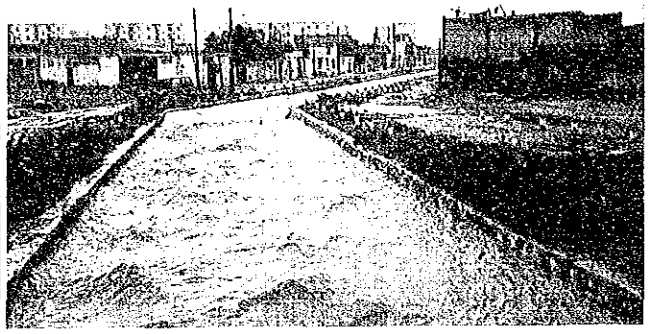


② Outlet of Retarding Pond "ERO-3B"

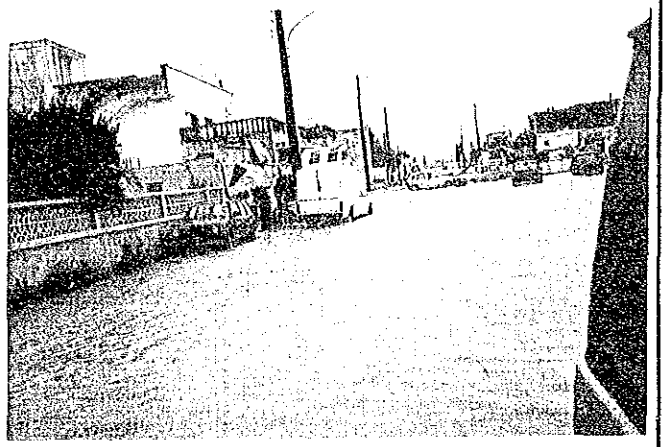
Those photos show the flooding situation of central part of Tunis on May 5/6, 1993 when the rainfall depth during the period reached to 97.5 mm. It was recorded at the newly installed Gauging Station at ECOLE NATIONALE D'INGENIEURS DE TUNIS during 22:00 of May 5 to 17:00 of May 6,'93.



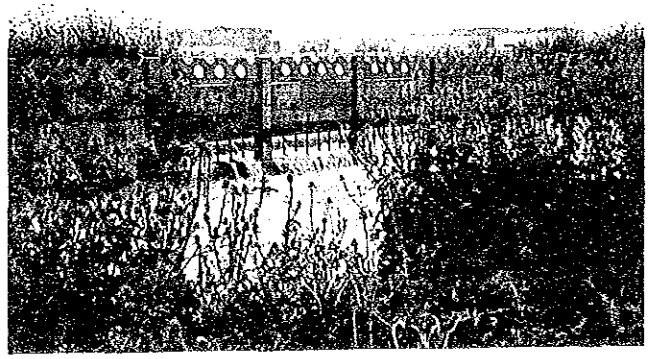
Location Map



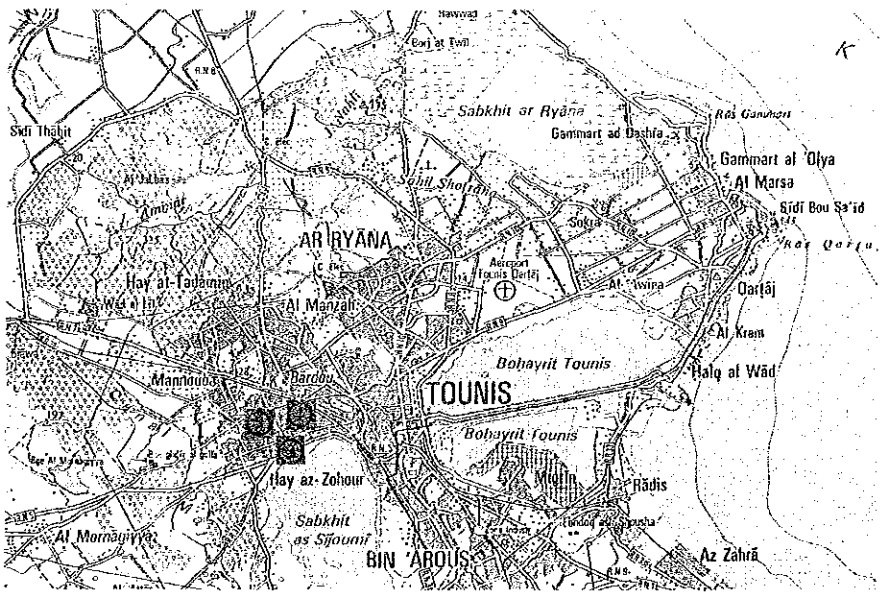
③ Oued Gariana, Upstream View from the road



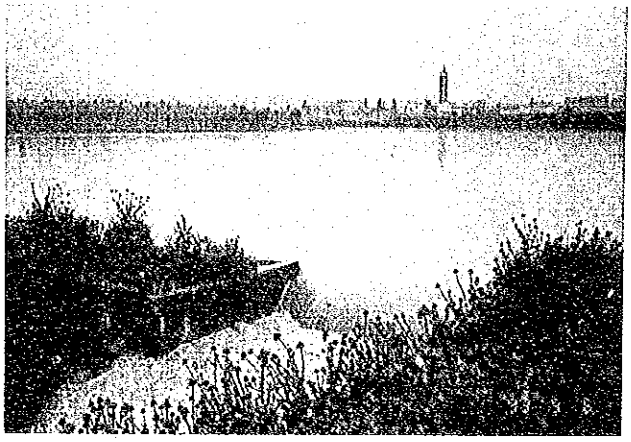
④ Inundated Road near EBA-1



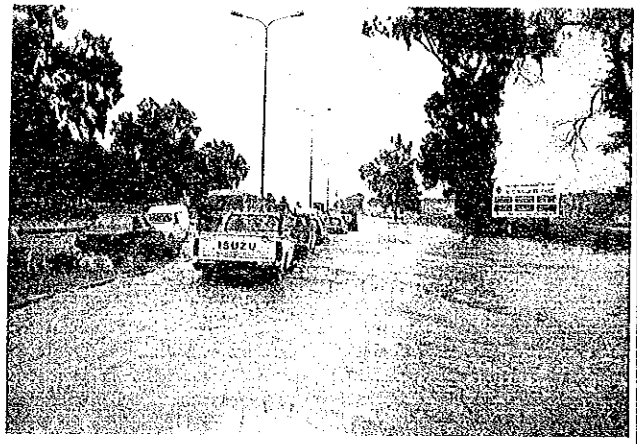
⑤ Spillout from Retarding Pond "EBA-1"



Location Map

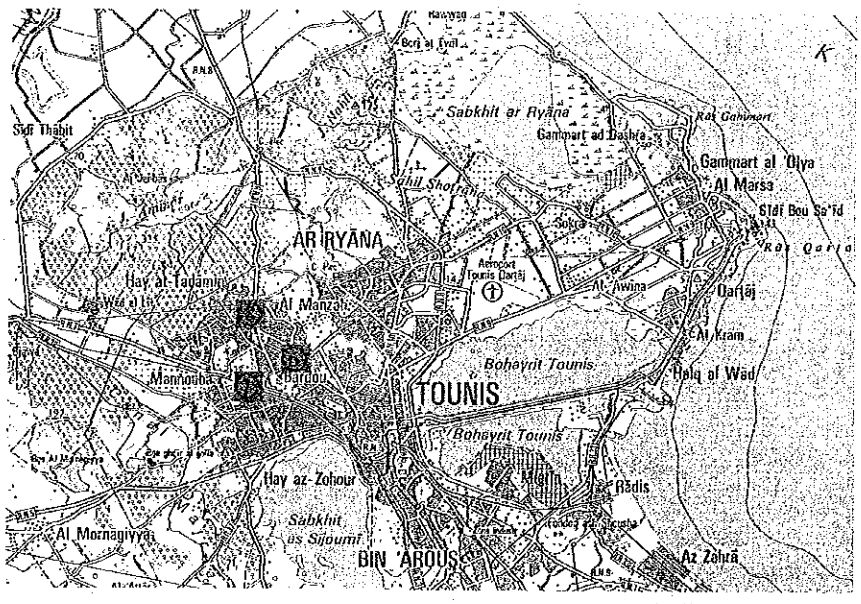


⑥ Spillout from Outlet of Retarding Pond "EBA-3"

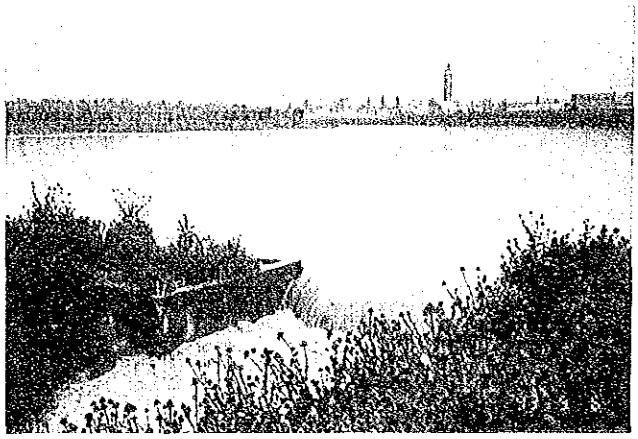


⑦ Inundated Road near Ettadhamen

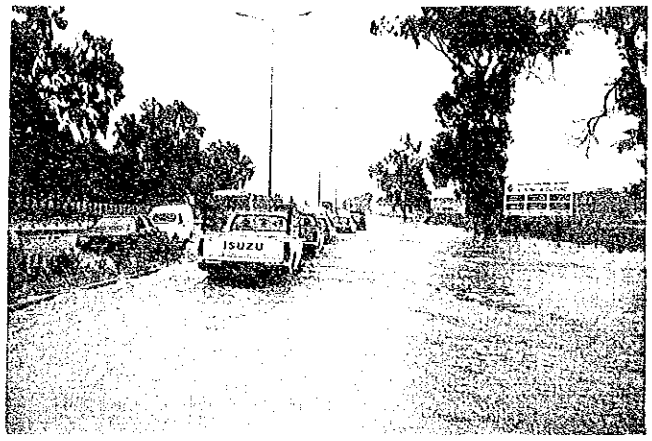
⑧ Flood Running on the Road, South of "EBA-4"



Location Map



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



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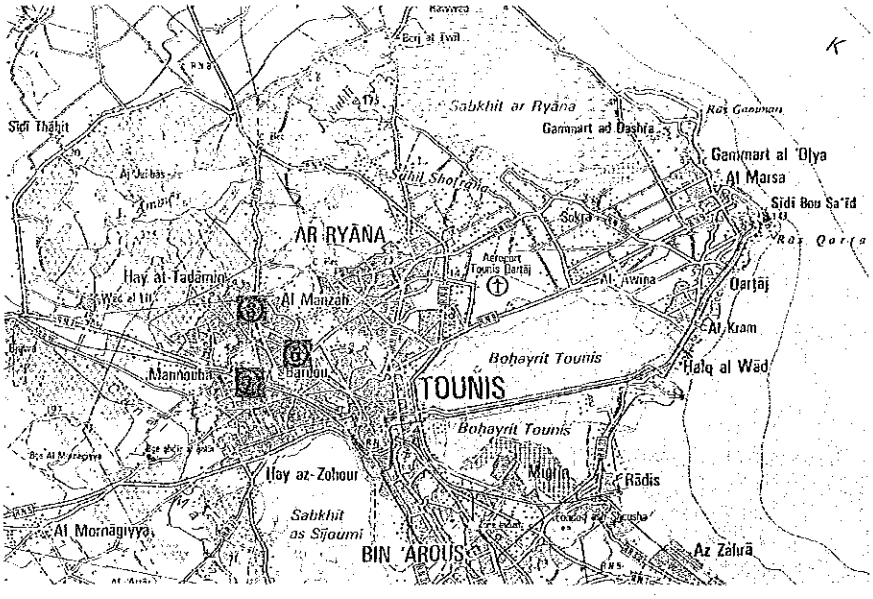
⑧ Flood Running on the Road, South of "EBA-4"



Location Map

SUMMARY

1. 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").

2. Master Plan

Alternative flood control plans as shown in Figs.-2 to -8 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. Since there is no prospective retarding basin site for Oued Mayzette, Oued Bou Khamsa, Oued Blibene and Oued Hallouf, river improvement plan only is studied for formulating the Master Plan for these rivers.

Name of river basin	Description of flood control plan selected
Greater Tunis Area	
- Oued Ennkhilet and Sebkhet Ariana:	River improvement with Ain Snoussi Dam and Retarding Basin A (ENK-1) / EIRR=12%
- Oued Greb:	River improvement with existing and additional retarding basins, and rehabilitation and expanding of existing dams and retarding basins (GB-3) / EIRR=8%
- Oued Gariana and Sebkhet Sijoumi:	River improvement with existing additional retarding basins, including expansion of existing retarding basins (GR-2) / EIRR=4%
- Oued Maliyan:	River improvement with existing dam, and Hamma dam (ML-2) / EIRR=12%
- Oued Mayzette:	River improvement only / EIRR=10%

- Oued Bou Khamsa:	River improvement only / EIRR=7%
- Oued Ain Zerga:	River improvement and Retarding Basin (AZ-2) / EIRR=10%

Greater Sousse Area

- Oued Hammam:	River improvement only (HM-1) / EIRR=18%
- Oued Blibene:	River improvement only / EIRR=5%
- Oued Hallouf:	River improvement only / EIRR=13%
- Oued Hamdoun:	River improvement only (HD-1) / EIRR=5%

3. Selection of projects for feasibility study

Through the study on alternative plan, the most effective flood control measure was selected for each river. It is recommendable the first priority project would be the "Oued Maliyan" case for the Greater Tunis area and the "Oued Hammam" case for the Greater Sousse area. However, through the discussion and consultation among staff concerned of JICA Tokyo, the JICA Study Team, and MOEH, the "Oued Ennkhilet and Sebkhet Ariana" case was eventually selected to be taken up for the succeeding Feasibility Study in the Greater Tunis area considering its high economic return and severe flood problem in the subject area. As for the Greater Sousse area, the Oued Hammam was selected as the project for Feasibility Study as recommended by the JICA Study Team.

4. Feasibility Study

4.1 Comparative study of alternative plans for flood protection measures

(1) Oued Ennkhilet

To formulate the flood protection measures for the Oued Ennkhilet, comparative study on alternative plans was made on the basis of the 10-year probable flood and then the 100-year probable flood was taken into consideration for the feasibility study on the best plan selected through the comparative study. Among all the alternative plans, the combination plan of Diversion Canals No.3 and No.4 and Retarding Basins A, G, I and J1 is selected as a most economical case. 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 as shown in Figs.-29 and -30 is considered as the most reasonable plan. Principal features of the plan are shown in Table-3.

(2) Sebkhet Ariana

Main reason of flood inundation problem to the surrounding area of the Sebkhet Ariana is clogging by sand drift at the outlet to the Mediterranean Sea. The most simple and practical

measure to keep this outlet open would be to carry out a periodical dredging or excavation. The flood routine calculation was carried out based on the cross sectional survey for the Sebkhet Ariana, and the rise of water level during 100-yr probable flood was calculated to be in the order of El.70 cm. So, it appears that the inundation to the surrounding area is avoidable by the periodical dredging or excavation.

(3) 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. To formulate flood control plan, the river course consisting of the Oueds Hammam, Laia and Kebir was divided into nine (9) river stretches. Then, the flood control alternative plans were formulated and 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 plan, and the Alternative 3 that is shown in Figs.-33 and -34 was selected as the most recommendable plan. River improvement of 4,450 m in total and construction of the four (4) new bridges are proposed in this plan. Principal features of the plan are shown in Table-4.

4.2 Flood Damage

(1) Oued Ennkhilet

The major element of losses will be damage to buildings that represent 62% of all damages under present conditions, and 68% in the future. Road damages are estimated at 21% and 16% respectively. Total flood damages caused by the Oued Ennkhilet in flood prone areas under 100-yr, 10-yr and 1-yr flood conditions are estimated as follows;

(Unit: 1,000 TD)

Flood Probability	Present Land Use	Future Land Use
100-yr	6,266	33,776
10-yr	2,830	15,597
1-yr	1,054	5,344

(2) Oued Hammam

Under a 100-yr flood situation and in present land use conditions, nearly half (48%) of the losses arise from the transport sector, and 26% from the damage to residential buildings. Under future land use conditions, damage to residential buildings is the largest category (37%), while the losses from the transport sector account for 31% of flood damages. Total flood damages under 100-yr, 10-yr and 1-yr flood conditions are estimated as follows;

(Unit: 1,000 TD)

Flood Probability	Present Land Use	Future Land Use
100-yr	6,805	15,306
10-yr	2,636	6,244
1-yr	431	952

4.3 Project Cost

(1) Oued Ennkhilet

Flood control plans in the Oued Ennkhilet basin and surrounding basins have been formulated by the Tunisian government basically for the 10-yr flood, and some stretches have already been improved on this basis. Then flood control plan against the 10-yr flood is also adopted in this study for the first stage development considering the coincidence with the existing plan through the discussion and consultation among staff concerned. In addition to this, 100-yr flood that is often applied for the basic flood control plan at the major cities in foreign countries, is adopted for the future second stage development. The project financial costs for both stages were worked out as follows with its price level of January 1994.

Project Financial Cost of the Oued Ennkhilet Scheme

(unit : 1,000 DT)

Cost Items	1st Stage	2nd Stage
1. Direct construction cost	6,502	7,467
2. Land acquisition and compensation costs	3,738	0
3. Government's administration expenses	325	373
4. Engineering services expenses	975	1,120
5. Price contingency	1,712	-
6. Physical contingency	1,841	-
Total	15,094	8,960*

* : The contingency cost is not estimated since implementation schedule of the 2nd stage can not be fixed yet.

(2) Oued Hammam

The project financial cost for the Oued Hammam scheme was worked out as follows.

Project Financial Cost of the Oued Hammam Scheme

(unit : 1,000 DT)

Cost Items	1st Stage	2nd Stage
1. Direct construction cost	6,323	656
2. Land acquisition and compensation costs	362	0
3. Government's administration expenses	316	33
4. Engineering services expenses	948	98
5. Price contingency	1,228	-
6. Physical contingency	1,235	-
Total	10,413	787*

* : The contingency cost is not estimated since implementation schedule of the 2nd stage can not be fixed yet.

4.4 Economic Evaluation

(1) Oued Ennkhilet

The implementation schedule of the second stage development for 100-yr flood control plan can not be fixed yet, so that the economic evaluation is carried out only for the first stage development for 10-yr flood control plan. Annual average benefits for 10-yr probable flood are estimated to be DT1,447,000 in the present land use condition and to be DT7,721,000 in the future land use condition. And, economic cost of the Oued Ennkhilet flood control project for the 10-yr probable flood is estimated to be DT12,475,000. Economic internal rate of return (EIRR) is introduced as an indicator of the economic evaluation and following assumptions are applied.

i) Project life is fixed for 50 years.

ii) Five (5) years from 1994 to 1998 are required for the implementation of project including pre-construction activities such as financial arrangement, detailed design, and tender and contract.

iii) Economic benefit is increased linearly from just after the completion of the first stage development to the year of 2020, and is constant after the year of 2020.

iv) 2.0 % of the direct construction cost is required for operation and maintenance cost.

On the basis of these assumptions, economic evaluation was executed and EIRR of 24.6 % was obtained for the Oued Ennkhilet flood control plan. In addition to this, sensitivity analysis was also carried out and the results are follows;

Case 1	Cost increase of 20 % ----------	EIRR=21.4 %
Case 2	Cost decrease of 20 % ----------	EIRR=29.1 %
Case 3	Benefit increase of 20 % ----------	EIRR=28.4 %
Case 4	Benefit decrease of 20 % ----------	EIRR=20.6 %
Case 5	Cost increase of 20 % and benefit decrease of 20 % -------	EIRR=18.0 %

Judging from the results of these evaluations, implementation of the flood control plan for the Oued Ennkhilet is considered economically feasible. EIRR in the Feasibility Study became higher than that of the Master Plan by the following reasons;

i) Construction cost was decreased by adopting the river diversion plan to the other river basin.

ii) It was clear that the flood water from the Oued Ennkhilet causes flood damage not only in the Oued Ennkhilet basin but also in the neighboring river basin. These flood damages could be counted as the benefit of the project.

(2) Oued Hammam

On the basis of the same assumption as described above, economic evaluation was executed. Annual average benefits for 10-yr probable flood are estimated to be DT1,015,000 in the present land use condition and to be DT2,328,000 in the future land use condition. And, economic cost of the Oued Hammam flood control project for the 10-yr probable flood is estimated to be DT8,368,000. EIRR of 17.4 % was obtained for the Oued Hammam flood control plan. In addition to this, sensitivity analysis was also carried out and the results are follows;

Case 1	Cost increase of 20 % ----------	EIRR=14.8 %
Case 2	Cost decrease of 20 % ----------	EIRR=21.4 %
Case 3	Benefit increase of 20 % ----------	EIRR=20.9 %
Case 4	Benefit decrease of 20 % ----------	EIRR=14.0 %
Case 5	Cost increase of 20 % and benefit decrease of 20 % -------	EIRR=11.9 %

Judging from the results of these evaluations, implementation of the flood control plan for the Oued Hammam is considered economically feasible.

6. Conclusions and Recommendations

As a result of the study, it was confirmed that the flood protection plans proposed for both rivers 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 rivers.

THE STUDY
ON
FLOOD PROTECTION PROGRAM
FOR
GREATER TUNIS AND SOUSSE

SUMMARY REPORT

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1. 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. 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.

2. 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 and shown in Figs.-2 to -8. Since there is no prospective retarding basin site for Oued Mayzette, Oued Bou Khamsa, Oued Blibene and Oued Hallouf, river improvement plan only is studied for formulating the Master Plan for these rivers.

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 Area	
- 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.

3. 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 as shown in Fig.-13. 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 as shown in Fig.-31. Then, the flood control alternative plan was formulated as follows by selecting the river stretch to be improved (Ref.to Fig.-32).

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.

4. 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.

5. Summary of Study Results on Each Sector

1) Socio-economy

(1) Oued Ennkhilet

The Oued Ennkhilet is located in the Delegation of North Ariana, which contains about one third of the total population of the Governorate. It is also a major urban expansion zone for Tunis, with constructed areas increasing rapidly in recent years at an annual growth rate of 6.4%. A major problem in the area is that of anarchic construction and spontaneous housing. Population in 2020 is expected to be in the order of 358,000.

Economic activities are largely centered on the commercial/services sector. There is also some industrial development in the flood prone areas, and the major industrial estate of Charguia is located nearby. In 1989, services accounted for 47% of employment, followed by industry with 35.8%. Agriculture is in serious decline in the area, largely due to loss of areas to urbanization and increasing salinity of soils; it is expected to virtually disappear from the flood prone areas by the year 2020.

Two main roads are located in the zone, the GP-8 and the RVE-533, both of which carry heavy traffic, and will be affected by serious flooding.

(2) Oued Hammam

The population of the towns located on the Oued Hammam is estimated at 102,000 (25% of the population of the Governorate of Sousse), and is expected to exceed 250,000 by the year 2020. The main economic activities in the flood prone areas are concerned with tourism and industry. Agriculture in the area is in decline, and this can be expected to continue as a result of rapid urbanization. Spontaneous housing is a major problem, in the area of Kalaa Kebira.

Flooding will cause disruption to traffic, particularly on the tourist road which links Sousse with El Kantaoui and Hergla.

2) Geology and Topography

(1) Oued Ennkhilet

The topography of Oued Ennkhilet 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. The alluvial plain consists of sand layer covered with clayey soil layer varying its thickness from a few tens centimeters to a few meters. Since it is judged from the field reconnaissance that there is no problem in the foundation bed against the culvert box, the geotechnical investigation were made focusing on the foundation of the dams for the retarding basins and the embankment materials for the dams and levees.

From the reconnaissance result, two boring sites for the dam foundation, three sites for dam embankment material and three sites for levee embankment material were finally selected. At each boring site, three (3) core borings were sank with the in-situ permeability test and the standard penetration test. As a result, it was revealed that the geology of the investigated sites consists of the clayey soil layers of talus deposit and/or residual soil and the marl occasionally intercalated with thin layers of limestone. The in-situ permeability test showed the permeability coefficients are much lower than 10^{-5} cm/sec in all test sections. The thickness of soil layers varies from several meters to about 10 meters and the standard penetration test on them showed N-values much more than 30. It is judged from these result that the subsurface layers at the investigated sites have a sufficient bearing capacity and water-tightness for the foundation of a fill type dam. The geotechnical conditions at the other dam sites, which was not investigated in this time, are estimated to be quite similar to those at the investigated sites from the outcrops and topographic status. Accordingly the subsurface layers in these sites are estimated to have the sufficient bearing capacity and water-tightness.

At six (6) embankment material sites, the disturbed samples were taken. The samples taken were tested on their index properties and permeability. According to the laboratory test, all samples of the dam embankment material are classified into "CL" by the Unified Classification System of ASTM, having natural moisture contents 3 - 12 %. These are lower than their respective optimum moisture contents. Their permeability coefficients are much lower than 10^{-6} cm/sec. Consequently these materials are judged to be available for a homogeneous earth fill dam embankment though moistening treatment shall be required. One (1) of three (3) levee embankment samples is classified into "SP" having the natural moisture content 9 % higher than its optimum moisture content and the other two (2) samples into "CH" having their all natural moisture contents 4 - 10 % higher than their respective optimum moisture contents. The permeability coefficients of "CH" material are much lower than 10^{-5} cm/sec and that of "SP" is 7×10^{-4} cm/sec. Consequently the soil materials around the proposed levee except the sand in the downstream end stretch are judged to be available for the levee embankment, though they are not superior and some drying treatment may be required. The sand is judged to be very erodible, then the clay lining will be required when it is used for levee embankment.

(2) Oued Hammam Basin

The topography of the study area is a flat alluvial plane developed between the Quaternary fluvial low hills undulated very gently. The comparatively high hills are developed on the right bank area near the river-mouth. The geology of the study area consists of the alluvial deposits of alternation of sand and clay layers of 10 - 15 m in total, and the fluvial deposits of the similar alternation of sand and clay layers below and on the both side hills. In the higher hills near the river-mouth, some soft rock outcrops of the marl are found.

Since only the levee embankment has been planned as flood protection measures, the geotechnical investigation was made focusing on the levee embankment material. According to the field reconnaissance, four (4) sampling sites, one in the fluvial hill on the right bank area and three in the alluvial plain on/besides the river course were determined.

The disturbed samples were taken from the four (4) sites. The samples taken were tested on their index properties and permeability. According to the test result, the samples of alluvial deposits are classified into "CL" or "SM" of the Unified Classification System of ASTM, having the natural moisture contents 7 - 12 %. These are higher than their respective optimum moisture content. The fluvial deposit is classified into "SP" of fine particles having the natural moisture content 6 % , that is lower than its optimum moisture content. The permeability coefficients of the alluvial material are much lower than 10^{-5} cm/sec and that of the fluvial material is 5 x 10^{-3} cm/sec. From these test result, the alluvial deposits is judged to be advantageous for the levee embankment material though it will require some drying treatment, and the fluvial deposits in the shallow portion is very erodible and it will require the clay lining and land compensation to use that.

Accompanying to the levee construction, new bridges should be required at the Touristic road, old GP-1 road and/or the site near Akouda. To study the foundation conditions for the new bridges, the previous boring and sounding results carried out at the new bridge site or near to them were collected from ONAS and MOEH and reviewed. According to them, it is revealed that the alluvial deposits are developed to 10 - 15 m depth from the present ground surface having the cone resistance varying from 3 to 40 kg/cm2 or the elastic moduli varying from 10 to 60 kg/cm2. These values correspond to N-values of 5 - 10, which are judged to be insufficient to attain the bearing capacity for a bridge. Below this alluvial deposits layer, the fluvial deposits layer is developed. The elastic moduli of this layer is not less than 130 kg/cm2 which correspond to the N-value of about 30 and only one N-value of 43 of this layer was recorded at the depth of about 16.5 m in the boring at the new bridge site on the Touristic road. Accordingly a pile foundation to be founded on the fluvial deposits is recommended. The pile driving length is recommended to be 15 m deep from the present ground surface.

3) Meteorology and Hydrology

(1) Data collection

Meteorological and hydrological data, information and related study reports in both the Greater Tunis and Sousse areas were collected in the field study period and hydrological data were reviewed especially for the flood runoff analysis.

(2) Climate

The project area of the Oued Ennkhilet and the Sebkhet Ariana lies between 36°0' and 37°0' of north latitude, and 9°30' and 10°20' of east longitude. The average monthly temperature ranges from 11.6°C in January to 27.6°C in August at Tunis-Carthage, and from 8.7°C in January to 27.0°C in July at Siliana. The average monthly relative humidity varies from 61.3% in July to 81.3% in January at Tunis-Carthage, and from 45.0% in July to 79.1% in December at Siliana. The monthly sunshine duration ranges from 138.1 hours in January to 332.7 hours in July at Tunis-Carthage and from 130.0 hours in December to 323.4 hours in July at Siliana. The average annual evapotranspiration is 1,196 mm. It has a high potential of monthly evapotranspiration in July and low potential in December and January. The mean annual rainfall is about 380 to 540 mm. The average annual maximum daily rainfall varies from 29 mm to 108 mm. The recorded maximum daily rainfall is 252.5 mm in Oct. 1969 at station of SID ADAPT.

The project area of the Oued Hammam lies between 35°35' and 35°55' of north latitude, and 10°20' and 10°40' of east longitude. The average monthly temperature ranges from 12.1°C in January to 27.9°C in August at Monastir. The average monthly relative humidity varies from 63.4% in July to 72.4% in January at Monastir. The monthly sunshine duration ranges from 158.1 hours in December to 342.6 hours in July at Monastir. The average annual evapotranspiration is 984 mm. It has a high potential of monthly evapotranspiration in July and low potential in January. The mean annual rainfall is about 330 to 340 mm. The average annual maximum daily rainfall varies from 23 mm to 164 mm.

(3) Establishment of Gauging Stations

The location and condition of existing rainfall and water-level gauging stations are reviewed to select the sites of new hydrological gauging station. Four (4) rainfall gauging stations in Greater Tunis and one (1) station in Sousse area and four (4) water-level gauging stations in Greater Tunis and one (1) station in Sousse area are installed. At these gauging stations, hydrological data are being recorded now. Recorded data of these rainfall and water-level gauging stations were collected and checked.

(4) Runoff Analysis in M/P Study

Following three runoff calculation models are selected for the runoff analysis in M/P study, in consideration of the basin characteristics and scale, data availability, flood control facilities in the existing condition or the alternative plan, etc.

- Rational method : applied for small river basins without existing or plan of regulation ponds or reservoirs which require the hydrograph analysis.

- Unit hydrograph method with rational formula's peak discharge : applied for smaller and medium river basins with existing or plan of regulation ponds or reservoirs which require the hydrograph analysis.

- Storage function method : applied for basins with existing or plan of regulation ponds or reservoirs which require the hydrograph analysis, and where hydrological data to develop and calibrate the model are obtainable.

(5) Review of Runoff Analysis in F/S

Basically, the same method applied for the M/P stage was considered in the runoff analysis of Oued Ennkhilet and Sebkhet Ariana basin, and Oued Hammam basin to F/S stage. The rational method was utilized for the determination of basic flood runoff in consideration of the basin scale and availability of hydrological data. The unit hydrograph method with rational formula's peak discharge was also used to develop runoff hydrographs for storage design and evaluation of existing flood control facilities and flood damages. The classification of runoff coefficient was reviewed in accordance with the detail future land use plan. The river system models were reviewed and modified 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.

4) Land Use Plan

(1) Oued Ennkhilet

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 and expansion of urbanization in the agricultural zones and flood inundated zones. Many habitants have suffered damages from flood inundation by constructing their houses inside inundated zones and agricultural zones in a form of illegal way. In this aspect, the delimitation of the study area was determined by a catchment area basis against flood inundation. The study aims to clarify the

present and future land use plan with a target year of 2000 in a short term and 2020 in a long term.

Ariana Community is composed of Sebkhet Ariana and abundant agricultural zones that involve Chutrana, Soukra and Raoued. Present land use plan in Ariana Community is presented in Fig.-9. The Sebkhet Ariana is located in the upper part of the study area, covering an area of approximately 36.5 km2. As this sebkhet lacks communication with the Mediterranean Sea, it causes flood inundation around the sebkhet during a rainy season. Ariana Center and all the agglomerations of El Menzah and Superior Ariana constitute most important urbanized area with high density in the Greater Tunis area. The expansions take the formation of urbanization with various residential types in the Ariana Community. Concerning the Choutrana area, it occupies about 17.6 km2. This area is composed of agricultural area and spontaneous housing areas. The zone of Soukra extends from the GP-8 and along the RV-533 until reaching the Sebkhet Ariana in the North. The majority of this zone consists of agricultural fields. In addition, a big occupation of spontaneous settlements accounting for 6.0 km2 in a total area of Soukra is observed. In the zone of Raoued, 10.1 km2 of the area accounts for agricultural fields and 9.0 km2 of the area is open space in the total area of 30.2 km2. The zone is already occupied by the spontaneous housing areas in the agricultural fields along the RVE 546.

Residential zone in La Marsa Community covers about 6.4 km2 in an total area of 25.2 km2. The characteristic of residential zone is predominance of isolated housing. This phenomenon has led inefficient land use in the form of low density and waste of space. In addition, the spontaneous housing area represents 21% of the residential sector. Commercial zone is mainly located in the central town of La Marsa. Concerning the recreational zone, it covers an area of approximately 0.5 km2 including sports/ entertainment facilities and touristic places. Agricultural zone incorporates three sub-divisions in the plain of Soukra, Gammarth and Sidi Daoud. The area between the RVE-550 and the GP-9 has reserved for vegetable agriculture.

The flood inundation zone in this Community creates great constraints to urbanization. This is because the ground water flows close to the ground level and drainage facilities is insufficient. This phenomenon is witnessed conspicuously along the Oued Ennkhilet and in flat agricultural zones of Ariana North and Soukra.

In consideration of the existing constraints, the future land use plan should be carried out. Future land use map is illustrated in Fig.-10, which was prepared referring to the land use plan by the MOEH.

(2) Oued Hammam

The towns of the study area incorporate Hammam Sousse, Akouda, Kalaa Kebira and Kalaa Sghira within the Governorate of Sousse. The geographical situation near the Metropolitan Sousse has encouraged urban development of these towns. Under the present land use of this region, several phenomena are observed in these towns such as predominance of spontaneous settlements and expansion of urbanization in the agricultural zones and flood inundated zones (Ref.:Fig.-11). In this aspect, the delimitation of the study area was determined by a catchment area basis against flood inundation. The study aims to clarify the present and future land use plan with a target year of 2000 in a short term and 2020 in a long term.

Four towns in the study area are located approximately 10 km away in the North and Northwest of Metropolitan Sousse. Motivated by the geographical situation near the Metropolitan Sousse, the region has transformed from an agricultural village to an urban agglomeration for a few decades. Also, this urban expansion has evolved in a formation of residential development from an old town center. Nevertheless, all of this region is under the catchment area of Hammam Sousse. Concerning the transportation system, the GP 1 in the East and Auto route in the West of this region provides linkage to main urban centers.

The residential zones in Hammam Sousse is characterized as segregation in the East, West and in-between area of the GP-1 by upper-class and modest residents. In case of Akouda, the zone is expanding along the GP-1 By-pass and in the West. Kalaa Kebira is surrounded by two oueds. This constraint affects urban expansion that concerns mainly housing development. The residential development in Kalaa Sghira has taken place all direction of the town. Nevertheless, one of the phenomenon in common in these towns is spontaneous settlements in the surrounding urban zones and agricultural zones, where are prone to flood inundation.

Agricultural zone is distributed for irrigated cultivation and dry cultivation. The agricultural sector produces mainly olive fruits , grenadine and vegetables. The boom of industry activities was the origin of the urban growth of the region. However, this development was occurred at the expenses of the agricultural sector. Also, high land price and lack of space in the old towns encouraged the appearance of spontaneous settlements in surrounding urban areas and agricultural zones.

The oued crosses urbanized area in the town and particularly, the lower areas are prone to flood inundation. The inundation is observed by spontaneous settlements because these built-up areas obstruct the natural flow of the oueds. In addition, the infrastructure facilities against flood inundation are insufficient state in these towns.

In consideration of the existing constraints, the future land use plan should be carried. The presentation of this proposed land use plan was approached to regional concept considering rapid-changing urbanization in the context of conurbation in the Regional Sousse as illustrated in and Fig.-12.

5) Urban Drainage

(1) Oued Ennkhilet

Urban drainage systems in the study area consist of storm water drainage system and sewerage system. Reviewing related data and information 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. 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 ONAS. MOEH is also implementing the storm water drainage projects in the study area. Review of Master Plan and the Feasibility Study on priority projects which cover whole the Greater Tunis area are now under finalization by ONAS, however, the study result has not been released yet. Major findings through the field reconnaissance and review of data and information collected, are as follows:

(i) 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 road by MOEH.

(ii) 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 the southern shore of Sebkhet Ariana. Treated water 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.

(iii) 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.

(iv) During May 1993, it was observed several roads and flat agricultural lands spreading at the shore line of 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.

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 in the frame of feasibility study.

(2) Oued Hammam

Urban drainage systems in the study area also consist of storm water drainage system and sewerage system. Reviewing data and information on storm water drainage system and sewerage system in study area, and also through field reconnaissance and interview, it has been revealed that the inundation of the low-lying area along the river course is the critical since before. It was found that the studies and succeeding implementations of storm water drainage and sewerage systems in the Greater Sousse area had mainly been made to date in several steps by National Sanitation Agency (ONAS). The Oued Hammam basin is locating at the northern end of the entire system.

To grasp the relation between water supply and urban drainage system, data concerning water supply were also collected from Water Authority (SONEDE). Water supply to urban and rural areas in the country is autonomously operated and managed by SONEDE since before. Stage-wise development of water supply system has been carried out to date, and now SONEDE is implementing the Eighth Plan which covers five years starting 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.

Major findings through the field reconnaissance and review of data, are as follows:

(i) In Greater Sousse area, there exist two sewer treatment plants now, Sousse South Plant (WWTP South) and Souse North Plant (WWTP North). The latter locating at the right bank near Touristic road is overloaded, and untreated sewer water is being spilled out to the Mediterranean Sea at the river mouth of Oued Hammam. Moreover, at many places it was observed waste water is discharged into oueds, and it emits bad odor to the surrounding

areas. The quantity of this sewer water is not known yet, but it would be not so significant from the viewpoint of flooding.

(ii) 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. The staff concerned of ONAS Sousse explained the JICA Study Team that the Oued Maouar basin is the most problem area, causing inundation of the area due to poor drainage system.

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

In the urbanized area of the Oued Hammam 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.

6) Environment

(1) Objectives

Environmental assessment was considered as an integral part of both the master plan study and feasibility study of priority projects. The environmental assessment determined the existing environmental problems of the study area as they related to the problem of flooding, and determined the positive and negative impacts of the proposed structural flood control alternatives and measures. Environmental mitigation and monitoring measures are then recommended in the form of non-structural measures, which if implemented along with the structural measures would result in adequate flood control with minimal negative environmental impacts.

(2) Methodology

During the Phases 1 and 2 of the study, an Initial Environmental Examination (IEE) was carried out for each of the river basins in Greater Tunis and Greater Sousse. This involved data collection in the form of reports, pamphlets, drawings, maps and interview surveys. Existing

institutional set-up and laws and regulations concerning the environment were determined. Extensive field surveys and investigations were carried out in order to:

- determine the cause and magnitude of flooding problems in the study area and their relationship with environmental aspects.
- 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 the rivers to supplement field observations and other available water quality data.
- obtain information of sites where structural flood control measures are already existing, being planned or proposed in the present study to determine and evaluate impacts.

The IEE done in the master plan study by first determining the existing environmental conditions in each river basin. Next an environmental baseline evaluation was done. This step involved an identification of the important environmental elements, an evaluation of their present condition, and an evaluation of their predicted future condition without the project. Finally, an assessment of future environmental disruptions and benefits was made for each project flood control alternative plan considered in each river basin. All results of the IEE are summarized in an environmental compatibility and decision matrix which indicates the environmental impacts for the with and without project case in each river basin. One of the criteria used for selection of the priority projects in the feasibility study stage is the project with minimum negative environmental impacts.

The Environmental Impact Assessment (EIA) in Phase 3 for the priority project selected was again done with a more detailed study of the problems of the concerned river basin. Again, projects impacts were determined for the with project and without project alternatives for each proposed flood control structural measure in the river basin. Environmental mitigation and monitoring measures are recommended which need to be implemented along with the project structural measures for adequate flood control with minimal negative environmental impacts.

(3) Results

Existing environmental conditions vary from one river basin to another. However some general problems are seen to be present in almost all the river basins in Greater Tunis and Greater Sousse, although to varying degrees. These include:

- Existence of spontaneous housing settlements.
- Eutrophication of riverbed with dense vegetation growth.
- Disposal of garbage, industrial waste water and domestic waste water without treatment directly into the rivers or sebkhets.
- Illegal constructions and culverts blocking and impeding flow in river, thereby causing floods.
- Conversion of agricultural lands for urban use in the absence of a clear land use plan and policy.
- Absence of or non-provision of adequate drainage as well as sanitation facilities.

The IEE indicated that without the project structural measures for flood protection, flood damage would continue to cause considerable economic disruption and social hardship to a high proportion of the population, particularly spontaneous housing settlements living in each basin. Eutrophication of rivers would continue, further impeding normal river flow and thereby increasing the flood prone area. Loss of agricultural crops would continue in the flooded agricultural area. Soil erosion and riverbed erosion problems would persist. Road damage and traffic delays could result in high damage costs. Risk of spread of waterborne diseases after flooding would be high as garbage, industrial waste water and domestic sewage are disposed into many of the study area rivers.

The flood protection structural measures considered for each river basin in the master plan include a combination of : river improvement works, new retention basin, rehabilitation of existing retention basin or dam, new diversion channel or tunnel, and new flood control dam. The IEE determined that the proposed flood protection structural measures under each alternative plan for each river basin largely lead to positive environmental impacts. The construction of new flood control measures or upgrading and rehabilitation of old structures itself does not result in negative impacts such as resettlement of population. However, in the case of the Soukra-Choultrana plain of Ariana in the Greater Tunis area, the extensive proliferation of spontaneous housing in a low lying area itself is largely the cause of flooding. Man made causes of flooding like spontaneous housing in flood prone area, construction of illegal poor culverts and disposal of industrial waste water, domestic sewage and garbage into the rivers, needs to be tackled by appropriate non-structural measures like defining and enforcing necessary regulations and policies.

During Phase 1, data concerning the ecosystem and wintering bird population of Sebkhet Ariana, Sebkhet Sijoumi and Tunis Lake was not available. This was determined to be important as some of the alternatives proposed in the master plan proposed land reclamation from the sebkhet in the concerned river basin. This aspect was therefore studied more in detail in the feasibility study stage.

The IEE thus determined that the alternative plans proposed for each river basin was acceptable from the environmental point of view. The EIA of the priority projects was done by presentation of more detailed information of the existing environmental conditions in each basin to supplement information already presented in the master plan study. For Oued Ennkhilet and Sebkhet Ariana area, this information was regarding the following:

- Physical environment: geography and site location, slope, ground water location and difficulties in drainage.
- Ecological environment: terrestrial flora and fauna in Sebkhet Ariana and other wetlands nearby.
- Human use and living environment: urbanization, agriculture, and problems created by construction of and/or lack of social amenities and municipal facilities.

For Oued Hammam in Sousse area, this covered:

- Physical environment: general physiography, erosion problems, and eutrophication.
- Human use and living environment: rapid urban growth and concurrence of city-countryside, inadequate sanitation network and treatment facilities and lack of drainage network, industrial pollution and garbage disposal problems, and encroachment of river beds.

Flood damage assessment for Oued Ennkhilet basin indicated that without the project, under both present and future land use conditions, significant damage to housing and residential property, and income losses resulting from traffic delays constitute major part of the flood damage (90 %). In this damage assessment, the Soukra-Choultrana plain is not included. Flooding problem is significant in this area and damage to the vast agricultural area is significant without the project. Other problems like risk of water-borne diseases after floods are also very high in this area and in the northern part of Ariana near Sebkhet Ariana due to inadequate sanitation and drainage facilities there. The land reclamation proposal of Sebkhet Ariana put forward in the master plan study was discarded. Extensive data collected on the ecosystem of Sebkhet Ariana and the flora and fauna, particularly wintering birds population indicated the wintering birds to be of significant local and national value. Thus, Sebkhet Ariana is to be preserved in its natural state. Very positive impacts of other structural measures considered are perceived. The multi-purpose retention ponds considered in open spaces of the urban areas will provide a temporary storage during flooding, while under normal circumstances they would be used for recreational purposes. The diversion channel and river improvement works would contribute to reducing the eutrophication of the riverbed and also enhance the riverine landscape and aesthetics. For enhancement of riverine landscape, various methods would be used which would include improvement of river revetments, clearing of river reserve, provision of pedestrian ways and resting areas, conservation of natural vegetation and riverine improvement in conjunction with the development of nearby commercial and residential areas. Adequate construction methods during the project construction stage would control the problem of temporary erosion and siltation. Other negative impacts of the proposed structural measures are not perceived.

Thus, for Oued Ennkhilet and Sebkhet Ariana area, the project structural measures are determined to be environmentally sound. However environmental mitigation and monitoring measures are recommended for consideration along with the proposed structural measures. These concern rational land use, water pollution prevention, monitoring of flora and fauna of Sebkhet Ariana, watershed management activities, ground water pollution risk monitoring, flood warning and evacuation plan and environmental education and public awareness program.

The middle reach of Oued Hammam at the confluence with Oued Kebir does not have sufficient flow capacity and flooding occurs here frequently. The potential flood inundation area is extensive and is increasing year by year. Without the flood protection structural measures, the

risk to flood damage would be very high. Considerable economic disruption and losses could occur. In addition to direct losses by damage to property and roads, indirect losses by traffic delays would be high. Risk of spread of water-borne diseases would also be high after flooding.

The proposed structural measures for flood protection of Oued Hammam basin is only river improvement works. Enhancement of riverine landscape and aesthetics would be a very positive benefit in addition to decrease in river eutrophication and erosion. However, environmental mitigation and monitoring measures are recommended in addition to the proposed structural measures. These concern promoting rational land use, prevention of water pollution, watershed management, flood warning system and environmental education and public awareness program.

7) River and Flood

(1) Oued Ennkhilet

The Oued Ennkhilet locates at the West of the Sebkhet Ariana basin as shown in Fig.-13. 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.

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.

To formulate the future river improvement plan, estimation of the existing river capacity is necessary. The river capacity is estimated by applying the flood runoff distribution as shown in Fig -14. Their results are illustrated in Figs.-15 and -16. 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.

Flood inundation areas are assumed based on the above hydraulic analysis, topographical conditions and field reconnaissance. Fig.-17 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.

River improvement work has been proceeding from the upstream reaches by the MOEH to solve the flood inundation problems in the Oued Ennkhilet basin. Location and typical sections are shown in Fig.-18. First and second phases were executed during the years 1990 to 1992 and third phase is on-going now. Concrete pipes and rectangular culvert are adopted for these improved sections. 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.

MOEH had prepared a river improvement plan for the Oued Ennkhilet on March 1991 and is now implementing the project with the minor modification. Rectangular shaped concrete canal is proposed for the almost all stretches except downstream end. Location and typical sections are shown in Fig. -18. 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.

(2) Oued Hammam

The Oued Hammam basin is located at the northwestern and western region of the Greater Sousse with a catchment area of 222 km2. The feather-shaped Oued Hammam basin is bounded by the Chabet el Menndra hills in the northwest and indistinct hills between the Oued Hamdoun in the southeast as shown in Fig.-19.

The Oued Laia, a main tributary of the Oued Hammam, is originated in Hennchie Chinchou area and travels some 30 km from southwest to northeast direction. Very flat plain is spreading in the upper areas and river courses are not identified clearly. The Oued Hammam is collecting the flood water from the tributaries on the left bank and finally discharges into the Mediterranean Sea. River slopes of the main stream are approximately 1/400 in the upper reach, 1/550 in the middle reach and 1/750 in the lower reach respectively. There are rather deep valleys with a height of 10 to 20 m in the upstream from Kalaa Srira. Almost all stretches are under the natural conditions except lower reaches from GP-1 road where confining dikes have been constructed.

The flood runoff discharges are studied based on the divided sub-basins and river system models with due consideration of the present and future land use conditions. Those are shown in Fig.-20. The peak discharges from the Oueds M'darrej, Seghir and Kebir are conceived to

be increased up to approximately 1.4 times in future due to a rapid urbanization. On the other hand, the peak discharges from the Oued Laia basin will not increase so much because the changing of the land use in this area is assumed negligibly small.

To formulate the future river improvement plan, estimation of the existing river capacity is necessary. Flow capacity of the existing Oued Hammam is estimated by using uniform and non-uniform flow calculation based on the above flood runoff distribution. Their results are illustrated in Figs.-21 and -22. It is obvious that the lower end of the Oued Hammam where there is the confining dike has a sufficient discharge capacity to convey the flood runoff of 100-yr flood under the future land use conditions. The Oued Laia also has a sufficient discharge capacity against 10-yr flood. On the other hand, other stretches have only the flow capacity equivalent to 1- to 5-yr flood. This means some river improvement works are urgently required.

The intensive interview surveys were conducted in order to identify the flooding areas in the Oued Hammam basin for the 1969 flood mainly. The interview survey results were checked up with the topographical maps and flood marks. Finally the boundary of flooded area by 1969 flood is delineated as shown in Fig.-23. The inundated area is estimated to be 3.5 km2 for 1969 flood.

Flood inundation areas for each return period are assumed based on the above 1969 flood information, hydraulic analysis and topographical conditions. Fig -24 shows the assumed flood prone areas for 2-yr, 10-yr and 100-yr floods under the future land use condition. The figure shows big flood prone area is spread in the lower reach. The potential inundation area is extensive and it is increasing year by year. It is desirable to carry out some flood control works as soon as possible.

River improvement works with the confining dikes have been carried out by the Ministry of Tourism under the guidance of MOEH from river mouth to GP-1 road except Touristic road site. Its total length is about 1,860 m. River bottom has been metalled by excessively large-sized rocks to cover exposed polluted stagnating water in river channel between the river mouth and the Touristic road. That length is approximately 350 m and a bottom width is 56 m. Upstream of this improved section has been left under natural condition in which flooding might occur easily.

MOEH prepared a flood control plan for the Oued Hammam in 1990. Flood control structures against 100-yr flood are recommended. Location and typical sections of these facilities are shown in Fig.-25. Three small dams i.e., Laia Dam, M'Darrej Dam and Guemgame Dam located on each tributary are studied by the MOEH for flood control purposes. These dams were reviewed during the Master Plan stage and discarded for the further study because these dams were judged to be uneconomical.

8) Comparative Study on Alternative Plans

(1) Oued Ennkhilet

The flow capacity of the Oued Ennkhilet is not enough to discharge the flood runoff of 10-year probability, but the river improvement works for the existing river facilities, particularly for the existing culvert along the RVE-533 road, are not easy. To avoid rehabilitation work of the existing culvert, it is necessary to construct not only a new diversion channel but also several retarding basins. The comparative study is carried out based on such river facilities for the 10-yr probable flood. And then the 100-yr flood is taken into consideration for the feasibility study on the best plan selected through the comparative study.

The sites of the diversion channel and retarding basin are sought on the 1/5000 scale topographic map and through the site reconnaissance. Then, 15 sites (A to N2) for the candidate of retarding basin and the routes of four (4) diversion channels (No.2 to No.5) are picked up as shown in Fig.-16. The topographic survey was carried out for seven (7) hill side retarding basin sites (A to G) to prepare storage curve.

The screening is conducted for the candidates of retarding basin to select effective one. The river improvement cost in case with retarding basin is estimated and then cost balance is calculated comparing with the cost without a retarding basin. These are summarized in Table -1. The Retarding Basins -A, G, I, J1, L and M are judged that it is necessary to be studied in the alternative plan.

The flood control alternative plan for the Oued Ennkhilet is formulated based on the following three (3) kinds of basic plans, using four (4) diversion channels and seven (7) retarding basins including the existing Ain Snoussi Dam.

i)	River Improvement Only Plan	: 1 alternative plan
ii)	River Improvement + Diversion Channel Plan	: 7 alternative plans
iii)	River Improvement + Diversion Channel + Retarding Basin Plan	: 9 alternative plans

These alternative plans are illustrated in Figs.-26 to -28. The flood runoff distribution is calculated for each alternative plan and respective construction cost is estimated. These costs are summarized in Table -2.

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. This

plan is considered as the most reasonable plan. Location of river improvement works for first (10-yr flood) and second (100-yr flood) stages are presented in Figs.-29 and -30 respectively.

(2) Oued Hammam

In the Master Plan Study, the river improvement plan without retarding basin was finally selected through a comparative study since construction of the retarding basin is not so effective for flood control in the lower reaches of the Oued Hammam basin. The river improvement only plan for 10-yr flood was studied for comparative study in the feasibility study stage. 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, flood damage along some river stretch is not so serious. To formulate flood control plan, the river course consisting of the Oueds Hammam, Laia and Kebir is divided into nine (9) river stretches from H-1 to K-5 (Refer to Fig.-31). Then, the flood control alternative plan is formulated as follows by selecting the river stretch to be improved. These plans are schematically illustrated in Fig.-32.

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 are compared each other by economic internal rate of return (EIRR) as one of the economic index for a public undertaking. According to the cash and benefit flow based on the assumed construction schedule, the EIRR is calculated for each alternative plans and the Alternative 3 is selected as the most recommendable plan. The rehabilitation of upper-most stretches of the Oued kebir (stretches K-4 & K-5) is not so economical by itself, however, it is necessary to improve these stretches because there are many bridges to be protected.

Location of river improvement works for first and second stages are presented in Figs.-33 and -34. The remained river stretches (H-3, K-2 and K-3) not to be improved in this plan are forming a natural retarding basin, then it will not cause social problem or adverse effect to the upstream basin.

9) Selected Flood Control Plan

(1) Oued Ennkhilet

Through the comparative studies, 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.

In addition to this, following criteria and conditions are introduced for designing the river facilities and the retarding basins.

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 -29, -30 -35 and -36 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.-37 to -40. Principal features are summarized in Table -3.