REPUBLIC OF TUNISIA
MINSTRY OF AGRICALTURE
DIRECTORATE GENERAL FOR DAMS AND MAJOR HYDRAULIC WORKS

PREPARATORY SURVEY ON INTEGRATED BASIN MANAGEMENT AND FLOOD CONTROL PROJECT FOR MEJERDA RIVER IN REPUBLIC OF TUNISIA: DEVELOPMENT OF FLOOD PREVENTION MEASURES FINAL REPORT (SUMMARY)

MARCH 2013

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

YACHIYO ENGINEERING CO., LTD.

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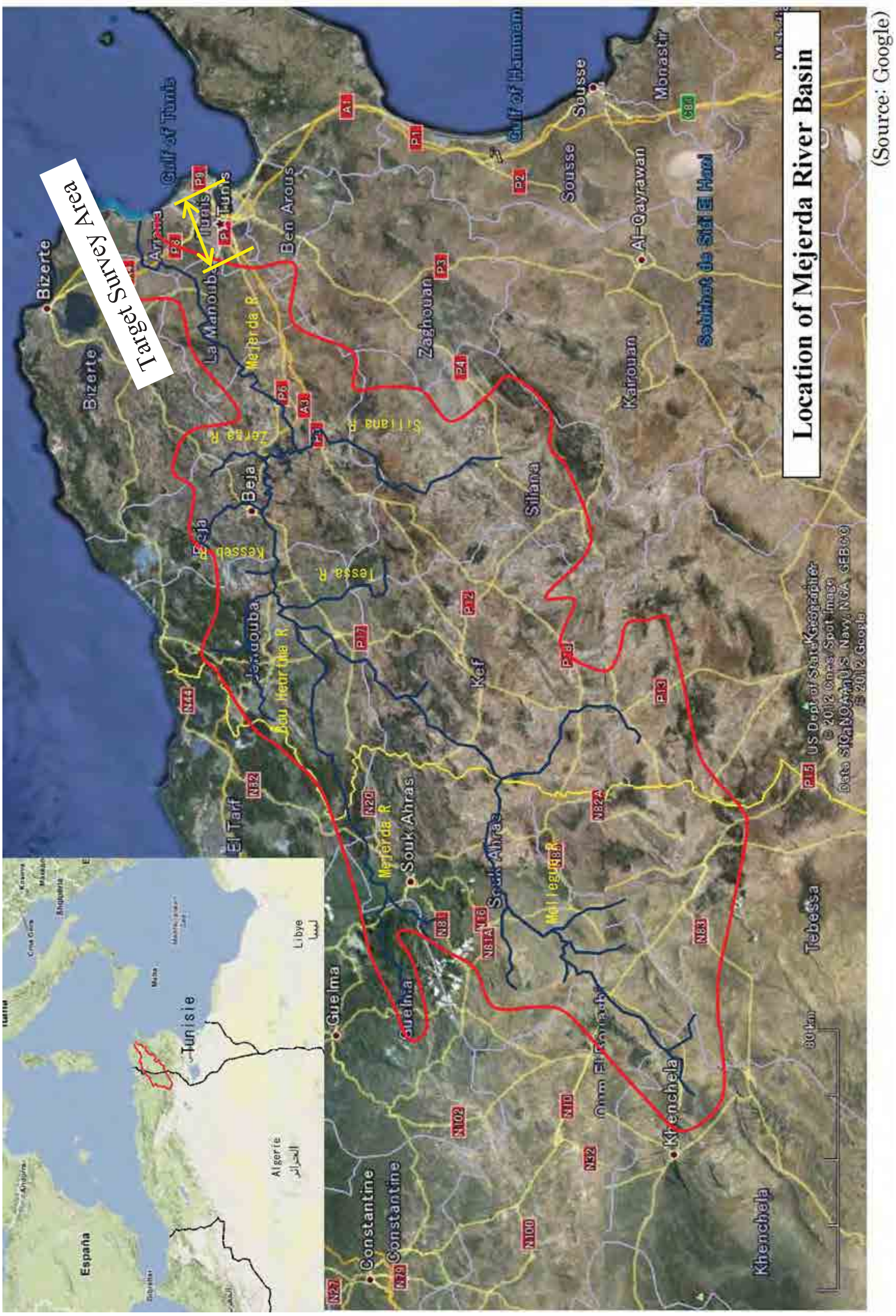
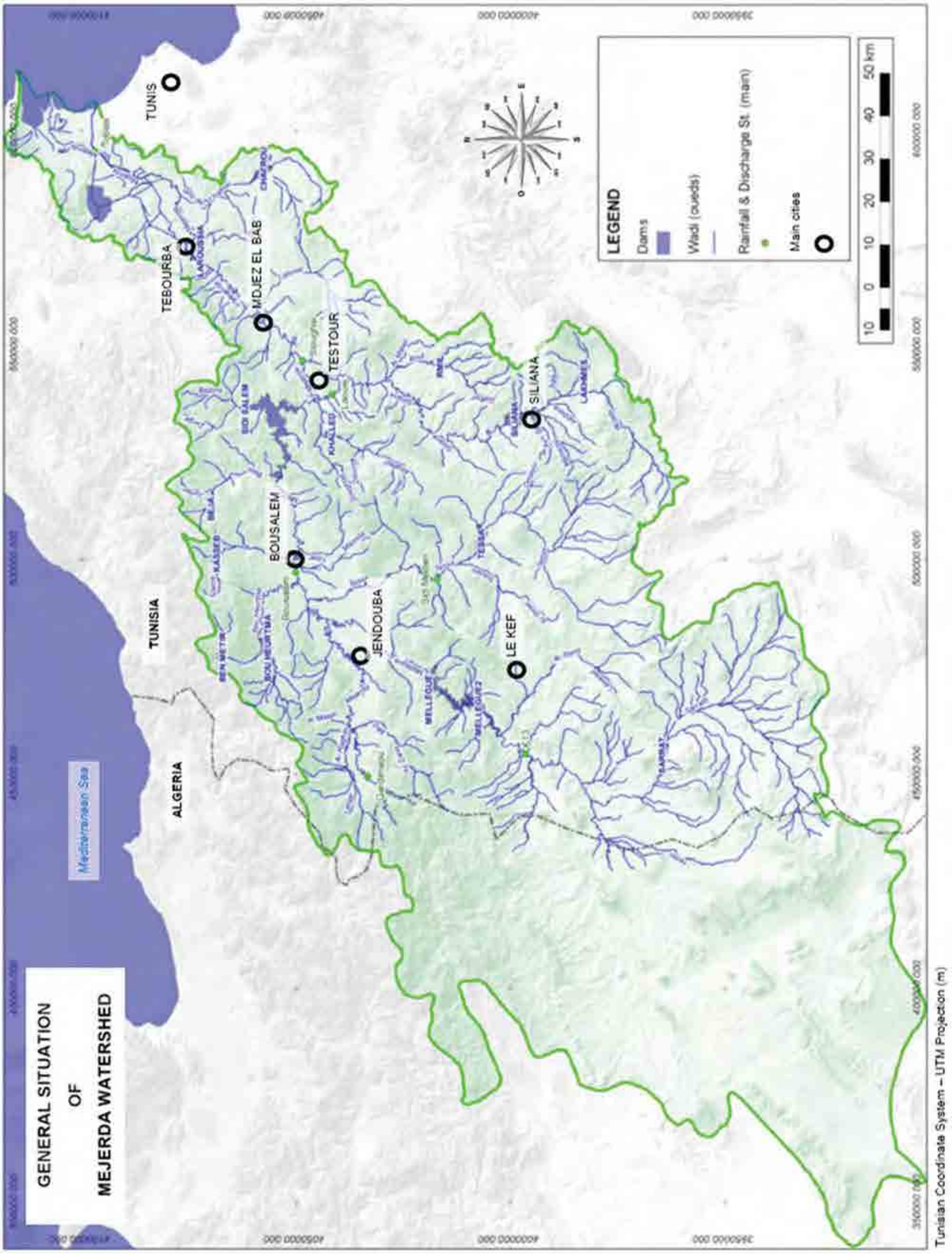
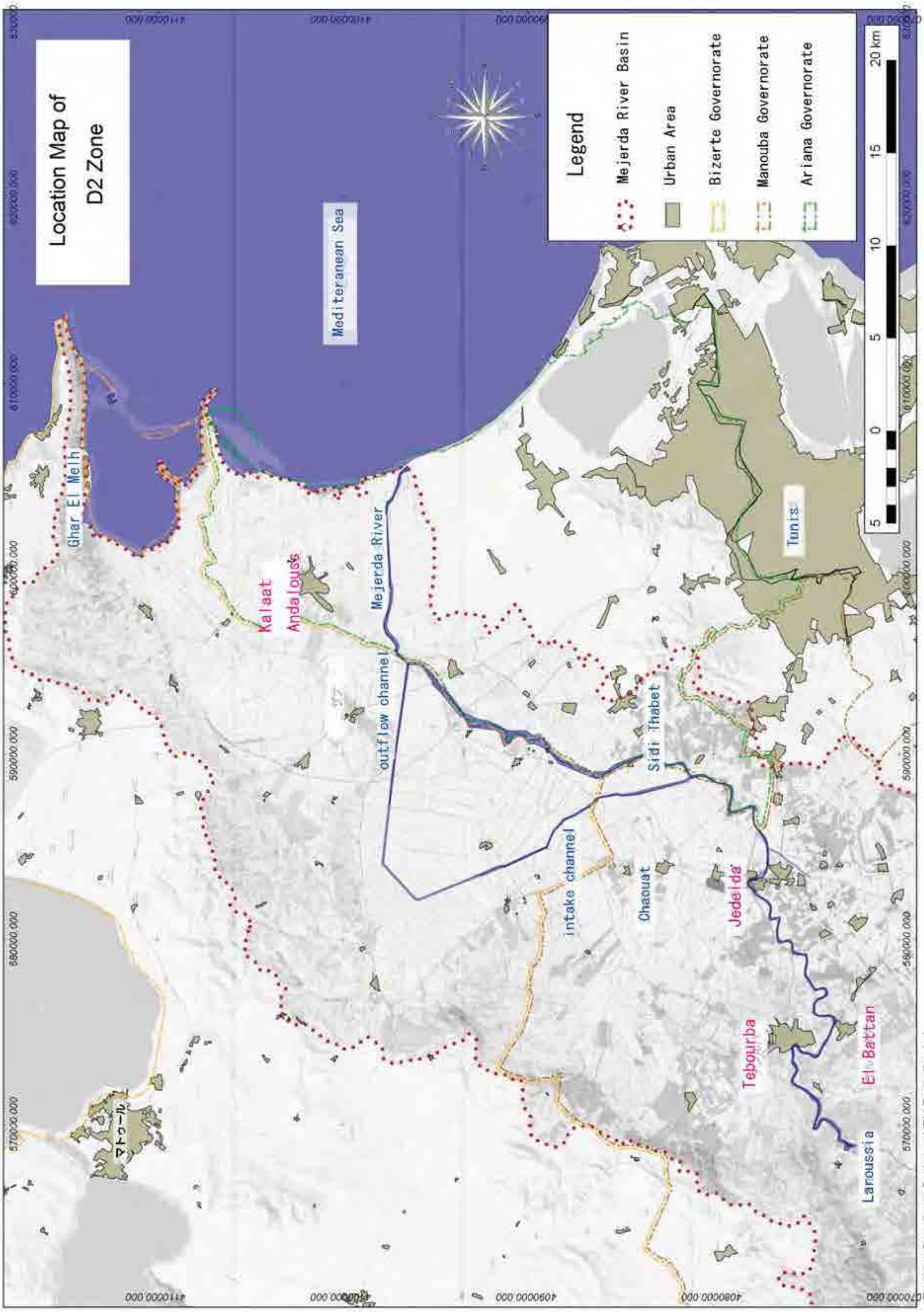


Drainage basin and survey area location map



Drainage basin overview diagram



D2 zone overview diagram


Cebalat
Sidi Thabet
Oued Ellil
Jedeida
Tebourba
30
29
28
27
24-26
21-23
20
19
18
17
16
14-15
12-13
09-11
08
04-07
P8
P7
X4
X3
X20
C50
C32
C64

Photo location map

01.Ministry of Agriculture and Water Resources Kick-off Meeting (2012.08)

02. Sidi Salem Dam (2012.08)

03. Al Heri Agricultural Water Intake Facilities (Water from the Medjerda River (2012.08))

04. Field survey with counterparts (2012.08)

05. El Batan Bridge (2012.08)

06. El Batan Bridge (2012.08)

	
07. El Batan Bridge pier situation (2012.08)	08. Jeideida No. GP7 Bridge Upstream Right Bank Embankment Situation (2012.08)
	
09. Old Jeideida Bridge (2012.08)	10. Old Jeideida Bridge – Bridge pier situation (2012.08)

11. Jeideida New/Old Bridge right bank sedimentation situation (2012.08)

12. Confluence point of the Mejeruda River and the Chafrou River (2012.08)

13. Chafrou River confluence point upstream river channel situation (2012.08)

14. Former Jeideida Railroad Bridge (2012.08)

15. New Jeideida Railroad Bridge (2012.08)

16.Looking in the anti-flood basin water direction from the Medjerda River intake point (2012.08)

17. Looking at the south side drainage from the C50 road bridge (2012.08)

18. El Maputo anti-flood basin drainage (2012.08)

19. El Maputo anti-flood basin (2012.08)

20. Gate adjustment in drainage at the boundaries of the Zone 1 and Zone 2 anti-flood basins (2012.08)

21. Drainage directly upstream of the Medjerda River confluence point (2012.08)

22. Gutter inflow point to Medjerda River drainage (2012.08)

23. Inflow point to Medjerda River drainage (2012.08)

24. Tobias canal gates – immediately upstream of the bridge (2012.08)

25. Tobias canal gates (Mejerda River downstream) (2012.08)

26. Water conduit from the Tobias weir (2012.08)

27. Delta bridge downstream flow (2012.09)

28. Delta bridge right bank downstream embankment flow situation (2012.09)

29. Mejeruda River Wetlands near the river mouth (2012.08)

30. Mejeruda River Estuary portion (2012.08)

31. Ministry of Agriculture Directorate General of Water Resources - Hearing (2012.08)

32. Ariana Governorate Hearing (2012.09)

33. Meeting with JICA (2012.09)

34. Planning meeting with parties related to the Ministry of Agriculture (2012.09)

The Republic of Tunisia
Preparatory Survey on Integrated Basin Management and Flood Control Project for Mejerda River: Development of Flood Prevention Measures

Table of Contents

Abbreviation and Terms

Abbreviation

Abbreviation	French	English
ANGED (MEn)	Agence Nationale de Gestion des Déchets	National Agency for Waste Management
ANPE (MEn)	Agence Nationale de Protection de l'Environnement	National Agency for the Protection of the Environment
BIRH (MA)	Bureau Inventaires et Recherches Hydrauliques	Office of Hydraulic Inventories and Research
BPEH	Bureau de Planification et des Equilibres Hydrauliques	Bureau of Water Planning and Hydraulic Equilibriums
CNE	Comité National de l'Eau	National Water Commission
CRDA (MA)	Commissariats Régionaux au Développement Agricole	Regional Offices of Agriculture Development
CTV (MA)	Cellule Territoriale de Vulgarisation	Territorial Extension Unit
DGACTA (MA)	Direction Générale de l'Aménagement et de la Conservation des Terres Agricoles	Directorate General of Planning, Management and Conservation of Agricultural Lands
DGBGTH (MA)	Direction Générale des Barrages et des Grands Travaux Hydrauliques	Directorate General for Dams and Major Hydraulic Works
DGCES (MA)	Direction Générale de la Conservation des eaux et du sol	Directorate General of Water Conservation and Soil
DGEQV (MEn)	Direction Générale de l'Environnement et de la Qualité de la Vie	Directorate General of Environment and Quality of Life
DGF (MA)	Direction Générale des Forêts	Directorate General of Forests
DGGREE (MA)	Direction Générale du Génie Rural et de l'Exploitation des Eaux	Directorate General of Rural Engineering and Water Exploitation
DGPA (MA)	Direction Générale de la Pêche et de l'Aquaculture	Directorate General of Fishing and Aquaculture
DGRE (MA)	Direction Générale des Ressources en Eau	Directorate General of Water Resources
DHER (MA)	Direction de l'Hydraulique et de l'Equipement Rural	Directorate of Hydraulics and Rural Equipment
DSE (MA)	Direction du Développement Socio–Economique	Socio–Economic Development Department
DSP	Direction du Sylvopastoralisme	Sylvopastoralism Department
DVPPA	Division pour la Vulgarisation et la Promotion de la Production Agricole	Division for Extension and the Promotion of Agricultural Production
ERI	Eco–Ressources International	Eco–Ressources International
ESIER	Ecole Supérieure des Ingénieurs de l'Equipement Rural	Rural Equipment Engineering School
INAT (MA)	Institut National Agronomique de Tunisie	National Institute of Agronomy of Tunisia
INM (MT)	Institut National de la Météorologie	National Institute of Meteorology
INS (MDCI)	Institut National de la Statistique	National Institute of Statistics

Abbreviation	French	English
IRESA (MA)	Institut National de la Recherche Agronomique de Tunisie	National Institute of Agronomical Research of Tunisia
MA	Ministère de l'Agriculture	Ministry of Agriculture
MDEAF	Ministère des Domaines de l'Etat et des Affairres Foncières	Ministry of State Domains and Land Affairs
MEn	Ministère de l'Environnement	Ministry of Environment
MEq	Ministère de l'Equipement	Ministry of Equipment
MF	Ministère des Finances	Ministry of Finance
MDCI	Ministère du Développement et de la Coopération Internationale	Ministry of Development and International Cooperation
MICI	Ministère de l'Investissement et de la Coopération Internationale	Ministry of Investment and International Cooperation
MT	Ministère des Transport	Ministry of Transport
ONAS (ME)	Office National de l'Assainissement	National Sewerage Board
ONPC	Office National de la Protection Civile	National Protection Civil Office
OTC (ME)	Office de la Topographie et du Cadastre	Topography and Cadastral Office
SECADENORD	Société d'Exploitation du Canal et des Adductions des Eaux du Nord	North Water Canal, Adductions and System Management Company
SNCFT	Société Nationale des Chemins de Fer Tunisiens	Tunisian Railways
SONEDE (MA)	Société Nationale d'Exploitation et de Distribution des Eaux	National Water Distribution Utility
ULAP	Union Locale des Agriculteurs et des Pêcheurs	Local Union of Farmers and Fishers

2– Other organizations		
Abbreviation	**French**	**English**
AAO	Association Amis des Oiseaux	Friends of the Birds Association
AfDB	Banque africaine de développement (BAfD)	African Development Bank
AFD	Agence Française de Développement	French Development Agency
ANRH (Algeria)	Agence Nationale des Ressources Hydrauliques	National Agency of Water Resources
BEI	Banque Européenne d'Investissement	European Investment Bank
EU	Union Européenne	European Union
GETU	Géotechnique Tunisie	Tunisia Geo-technology
GIZ	Agence Allemande de Coopération Internationale	German Agency for International Cooperation
IBRD	Banque internationale pour la reconstruction et le développement	International Bank for Reconstruction and Development
JBIC	Banque Japonaise de Coopération Internationale	Japan Bank for International Cooperation

2– Other organizations		
Abbreviation	**French**	**English**
JICA	Agence Japonaise de Coopération Internationale	Japan International Cooperation Agency
NEPAD	Nouveau Partenariat pour le Développement de l'Afrique	The New Partnership for Africa's Development
UNDP	Programme des Nations Unies pour le Développement	United Nations Development Program
FAO	Organisation pour l'alimentation et l'agriculture	Food and Agriculture Organization
UNESCO	Organisation des Nations Unies pour l'Education, la Science et la Culture	United Nations Educational, Scientific and Cultural Organization
WB	La Banque Mondiale	The World Bank

3– Other		
Abbreviation	**French**	**English**
APS	Avant Projet Sommaire	Basic Design
BM	Bassin de la Mejerda	Mejerda River Basin
EIA	Etude d'Impact sur l'Environnement	Environmental Impact Assessment
EIRR	Taux Interne de Rentabilité Economique	Economic Internal Rate of Return
F/S	Etude de Faisabilité	Feasibility Study
FFWS	Système de prévision des inondations et d'alerte	Flood Forecasting and Warning System
FFWRS	Système de prévision des inondations, d'alerte et de réponse	Flood Forecasting, Warning And Response System
GEOSS	Système mondial des systèmes d'observation de la Terre	Global Earth Observation System of Systems
GIC	Groupement d'Intérêt Collectif	Collective Interest Group
GIS	Système d'Information Géographique	Geographic Information System
GDP	Produit intérieur brut (PIB)	Gross Domestic Product
GFAS	Système d'alerte des inondations mondial	Global Flood Alert System
GPRS	General Packet Radio Service	General Packet Radio Service
GSM	Groupe Spécial Mobile	Global System for Mobile Communications
HWL	Niveau des Plus Hautes Eaux	High Water Level
IEE	Examen Initial sur l'Environnement	Initial Environmental Examination
IFAS	Système intégré d'analyse des inondations	Integrated Flood Analysis System
ITS	Services des Technologies de l'Information	Information Technologies Services
IWRM	Gestion Intégrée des Ressources en Eau	Integrated Water Resources Management
JORT	Journal Officiel de la République Tunisienne	Official Journal of the Republic of Tunisia
MDGs	Objectifs du Millénaire pour le Développement	Millennium Development Goals
M/P	Plan Directeur	Master Plan

3– Other		
Abbreviation	**French**	**English**
NGO	Organisation Non Gouvernementale	Non–governmental Organization
NWL	Retenue Normale	Normal Water Level
O&M	Exploitation et Maintenance	Operation and Maintenance
OMB	Bassin de la Mejerda	Mejerda River Basin
ORSEC	Organisation de la Réponse de SÉcurité Civile	Civil Security Response Organization
PHD	Domaine Public Hydraulique	Public Hydraulic Domain
SMAG	Salaire Minimum Agricole Garanti	Guaranteed Minimum Agriculture Wage
SMIG	Salaire Minimum Interprofessionnel Garanti	Guaranteed Minimum Wage
SMS	Short Message Service	Short Message Service
STEG	Société tunisienne de l'électricité et du gaz	Tunisian Society of Electricity and Gas
SYCOHTRAC	SYstèm de COllecte des mesures Hydrologiques en Temps Rèel et Annonce des Crues des oueds tunisiens	Real-time Hydrological Information Collecting Measurement and Flood Announcement System in Wadis
TICAD	Conférence Internationale de Tokyo pour le Développement de l'Afrique	Tokyo International Conference on African Development
TND	Dinars tunisiens	Tunisian Dinar
TOR	Termes de Référence	Terms of Reference
ZICO	Zone Importante pour la Conservation des Oiseaux	Important Bird Area

Terms

Terms	**Description**
Garaet	Low swamp
Gouvernorat (in French), Governorate (in English)	Unit of local government under the government of Tunisia
Sebkha *or* sebkhat	Area which becomes swamp except for during the dry season

Alphabetic Names of Tunisian Areas

Alphabet	Arabic	Alphabet	Arabic
Ain Ghelal	عين غلال	Kairouan	قيروان
Ariana	اريانة	Kalaat El Andalous	قلعة الاندلس
Bach Hamba	باش حامبة	Kasseb	كساب
Barbara	بربارة	Lakhmes	لخميس
Bejaoua	بيجاوة	Laroussia	لاروسيا
Ben Metir	بن مطير	Manouba	منوبة
Besbassia	بسباسية	Mejerda	مجردة
Bizerte	بنزرت	Mejez El Bab	مجاز الباب
Borj Ettoumi	برج التومي	Mellegue	ملاق
Bou Heurtma	بو هرطمة	Mellila	مليلة
Bou Salem	بوسالم	Mongi Slim	المنجي سليم
Cap Bon	الوطن القبلي	Ouenza	وانزة
Chafrou	شافرو	Rmil	رميل
Chaouat	شعواط	Sahel	ساحل
Chorfech	شرفش	Sejnane	سجنين
Djebel Chakir	جبل شاكر	Sfax	صفاقس
El Battan	البطان	Sidi Bahroun	سيدي بحرون
El Henna	الحنا	Sidi El Barrack	سيدي البراق
El Herri	الحري	Sidi Othman	سيدي عثمان
El Mabtouh	المبطوح	Sidi Salem	خزان سيدي سالم
Ellil	الليل	Sidi Smail	سيدي اسماعيل
Garaet El Mabtouh	قرعة المبطوح	Sidi Thabet	سيدي ثابت
Ghar el Melh Lake	بحيرة غور الملح	Siliana	سيليانة
Ghardimaou	غار دماء	Slouguia	سلوقية
Ghezala Dam	غزالة	Souani	السواني
Henchir Tobias	هنشير طوبياس	Sousse	سوسة
Hir Tobias	هير طوبياس	Tebourba	طبربة
Ichkeul	اشكل	Utique	اوتيك
Jedeida(Jedaida)	الجديدة	Zerga	زرقة
Joumine	جومين	Zouitina	زويتنة

Exchange rate (Investigation common subjects, FY2012 Yen Loan Project, November 6th, 2012):

1.0 TND (Tunisian dinar) = JPY 49.0

1.0 US$ = JPY 79.0

Chapter 1. General

1.1 Purpose of the survey

Based on the Preparatory Survey and the Climate Change Impact Analysis separately conducted by JICA, we will conduct a feasibility survey for the Integrated Basin Management and Flood Control Project for Mejerda River in order to facilitate implementation of the Project.

1.2 Basic Framework of the Survey

1.2.1 Study Area

The study area for this survey is the lowest basin of the Mejerda River, Zone D2.

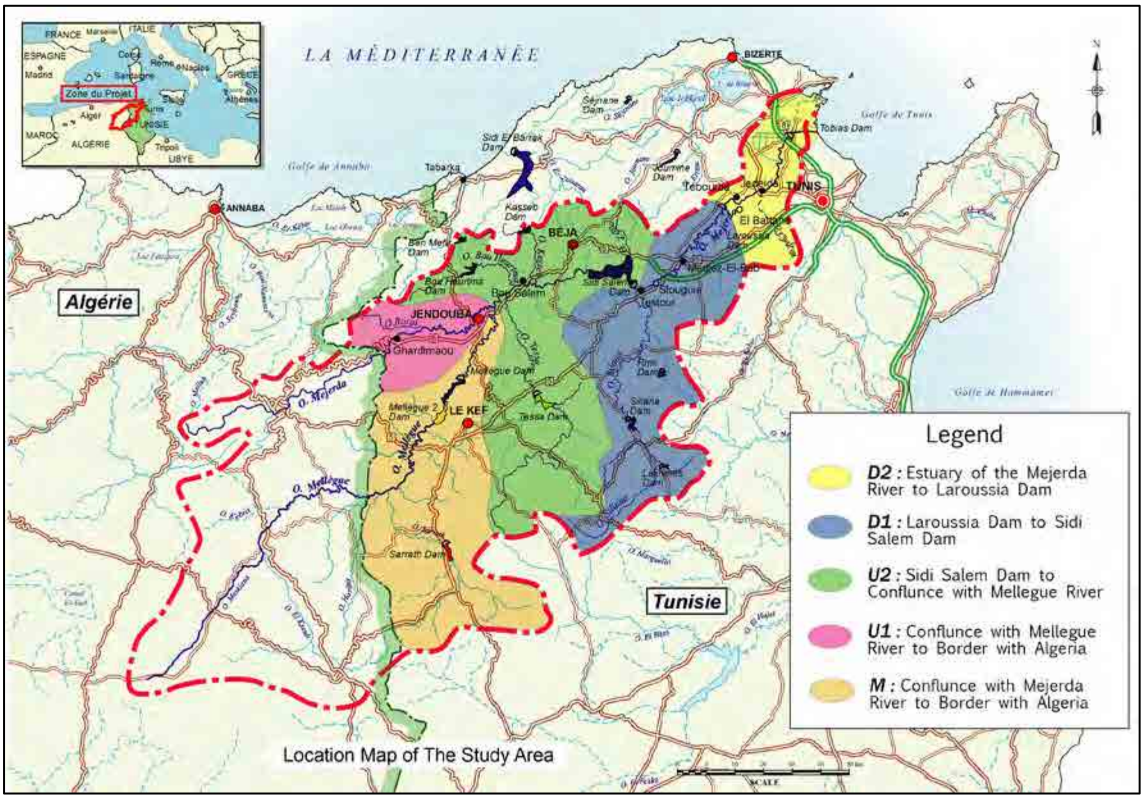


Figure 1-1: Basin divisions

1.2.2 Summary of Actions, Outputs and Goals

Table 1-1: Actions, Outputs and Goals

Overall goal	To eliminate flood damage in the lower Mejerda River basin by implementing the Project. To reduce barriers to economic development by improving social stability in the study area and help to both improve the socioeconomic situation and eliminate poverty in Tunisia.
Project purpose	To design a project plan and make technical preparation for implementation of the project
Outputs	1) Proposals for appropriate scale, content, and methods for implementing the Project 2) Confirmation of the necessity and effects of the Project
Actions	The following actions will be taken in order to conduct the feasibility survey: 1) Review the relevance and background of the Project 2) Understand the current situation and project content through additional data collection and field study 3) Prepare an environmental impact assessment report, including mitigation of environmental social impacts and a monitoring plan 4) Assist in creating a resident relocation plan 5) Devise flood control measures which account for climate changes 6) Devise consulting service details for the Project 7) Formulate an implementation schedule for the Project 8) Confirm implementation and maintenance schemes for the Project 9) Review the Project EIRR and propose operational effect indicators 10) Collect additional information and data 11) Provide assistance necessary to open a stakeholder's meeting

1.2.3 Consultant Group Organization and Work Schedule

Table 1-2: Study team organization and work schedule

Items			2012 July	2012 August	2012 September	2012 October	2012 November	2012 December	2013 January	2013 February	2013 March
[Assignment]		Name									
<Japanes Experts >											
1	Team Leader/ Channel Planning	Junji Yokokura	30	19	2 15		4 11				
2	Hydrology	Tadafumi Sato	30	19			4 11				
3	Geography, Geology and Geotechnique	Hisashi Oura	30	19							
4	Hydraulic Analysis	Masahiro Kitano	2	19							
5	Basin Management/ Flood Control Planning	Toru Takahashi	2		15						
6	Bridge Design	Hitoshi Ito		27	9						
7	River Structure Design 1	Tamotsu Shingu		30	13						
8	River Structure Design 2	Masakazu Yatoge		27	13		4 11				
9	Assistance for Bridge Design/Cost Estimate	Hiroshi Nakata		27	14						
10	Economic & Financial Analys/Organization	Hidetoshi Kanamura	2		11						
11	Flood Conrol Economy 1	Kinuyo Fukuda		23	15						
12	Flood Conrol Economy 2	Yoshio Yabe		10 19							
13	Environment/ Social Consideration 1	Nobuyuki Iijima		27	15						
14	Environment/ Social Consideration 2	Yui Matsuo	2		15						
15	Project Coordination/Flood Control Planning	Ru Ying	2		15						
16	Project Coordination	Akira Someya	30	19							
<Employed in Japan>											
	Interpreter 1	Gentaro Suzuki	30		15						
	Interpreter 2	Norihiko Iguchi					4 11				
<Employed in Tunisia>											
	Interpreter 2										
	Interpreter 3										
	Employees (3 members)									Field Study	
[Work Places and timing of report presentation]											
	Works in Japan 1			IC/R							
	Field study						DF/R(1st)				
	Works in Japan 2										
	DFR interim report								DF/R(2nd)		
	Works in Japan 3										F/R
	DFR explanation										
	Works in Japan 4										
			7	8	9	10	11	12	1	2	3

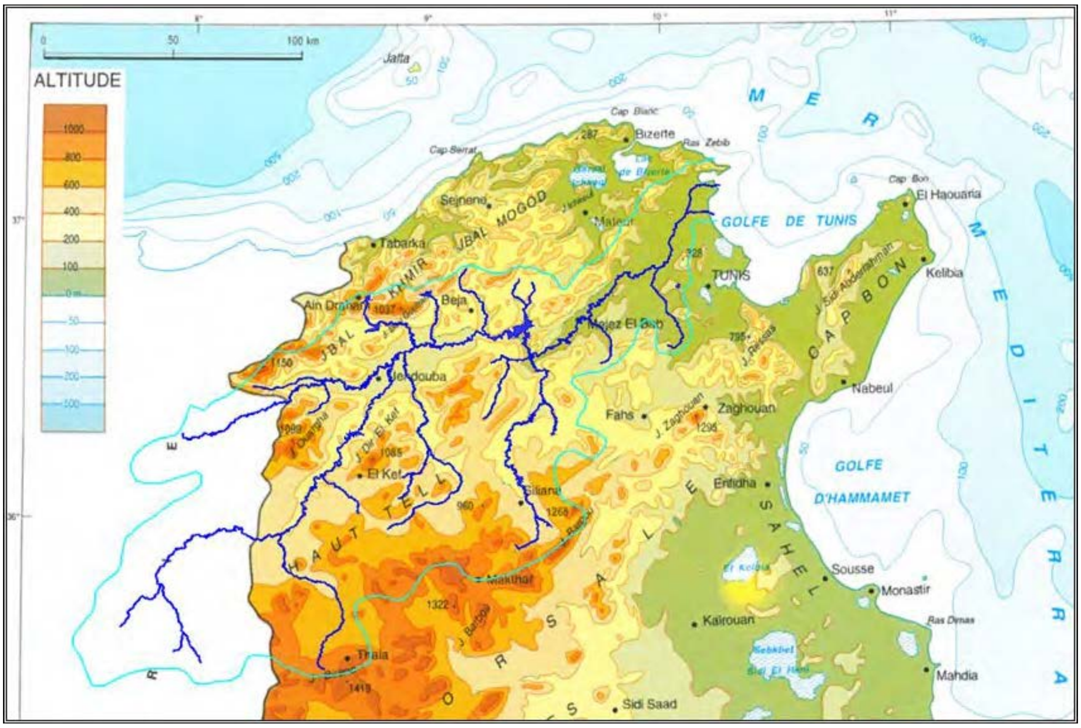
Chapter 2. An Overview of the Basin and Flood Damage

2.1 Overview of the Basin

2.1.1 Topography, Geology, and Soil

(1) Topography

The Mejerda is an international river that originates in the northeastern section of the Atlas Mountains and flows from northeastern Algeria down to northern Tunisia before finally settling in the Gulf of Tunis. The river's flow channel is 460 kilometers, and its basin covers 23,700Km^2. Of this, 312 kilometers of the channel length and 15,830Km^2 of the area lie on Tunisian soil, making it Tunisia's longest river. An expanse of arable land lies within the basin, with the river serving as a major water supply for both agriculture and cities, including Tunis. The regional topography for the Tunisian side of the Mejerda river basin is shown in the illustration below.



Source: Data from the National Institute of Meteorology

Figure 2-1: Topography of the Mejerda River Basin (Tunisia)

(2) Geology and Soil

1) The geological features of the Mejerda River Basin are a distribution of sedimentary rock including limestone, dolomite, tuffite, sandstone, shale, and evaporite in mountains and hills formed during the Triassic period Mesozoic era, the Cretacious period, the Paleocene epoch Cenozoic era, the Eocene epoch, the Oligocene epoch, the Miocene epoch, and the Pilocene epoch, as well as sand, clay, and other sedimentary layers in the lowlands formed during the Pleistocene epoch and Holocene epoch of the Quaternary period.
2) The soil analysis performed in the preparatory study showed that the ground of the Mejerda River's Zone D2 was formed of silty clay, sandy clay, muddy clay, and sand. The area downstream of the Jedeida railroad bridge

mostly consists of the three varieties of aforementioned clays, with the rare thin layer of sand between. Upstream of the Jedeida bridge, sand layers are estimated to be thicker.

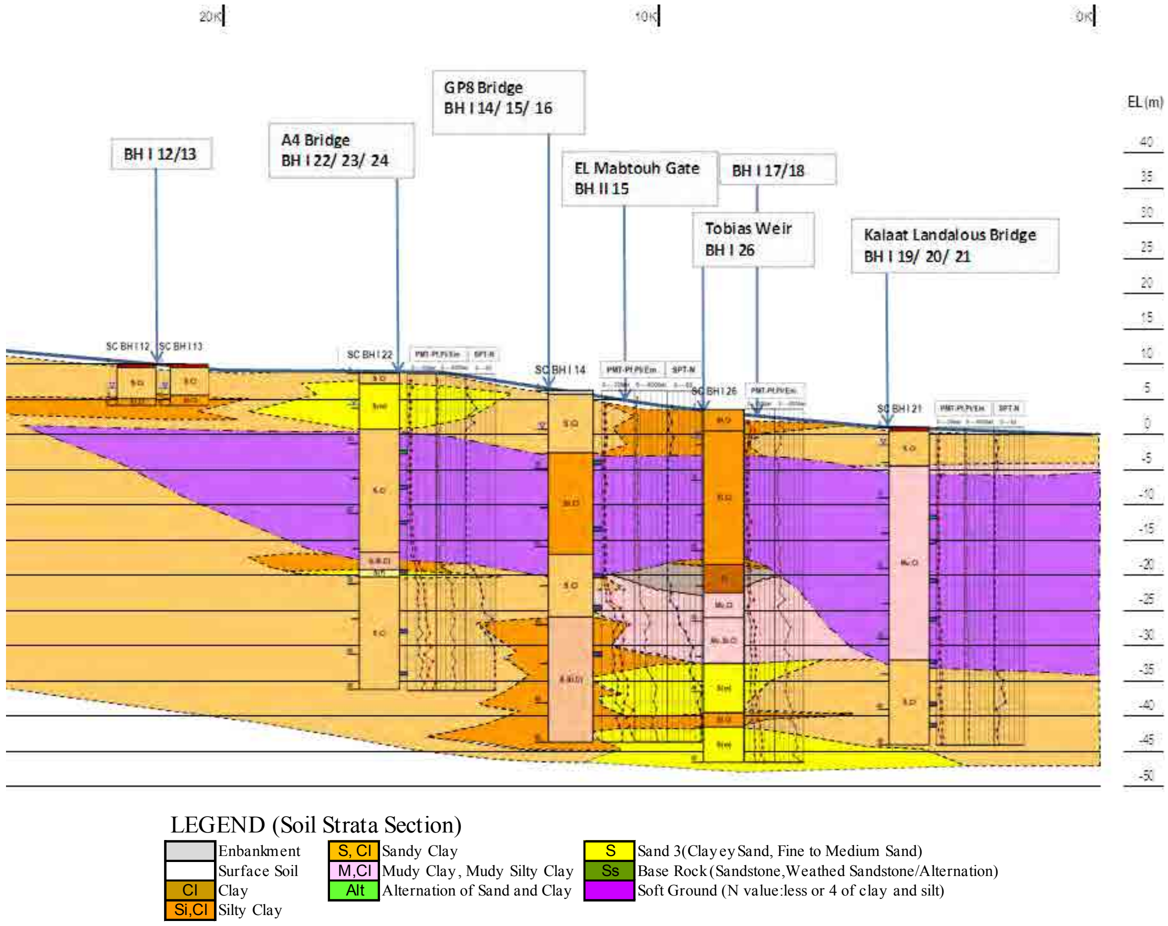


Figure 2-2: Vertical cross-section of downstream main Mejerda River riverside area (showing soft layer)

2.1.2 Weather and Hydrology

(1) Weather

Tunisia sits on the northern African coast of the Mediterranean Sea. The majority of southern Tunisia, which is home to the Sahara desert, is compromised of arid desert and steppe climates, while northern Tunisia has a Mediterranean climate.

The northern part of Tunisia, including the survey area, features a climate that is hot and dry in the summer and warm and moist in the winter. Temperature, evapotranspiration, and daylight hours all peak between July and August, with humidity and precipitation lowest at this time.

The annual average temperature of the survey area is generally between 17 and 20˚C. The monthly average in July and August is between 27 and 29˚C, with the highest temperatures of those months averaging between 33 and 34˚C.

(2) Precipitation

The degree of variation in rainfall between seasons and regions in Tunisia is very high. The annual average rainfall of the mountainous area of Kumil in the northwestern edge of the country reaches 1,500 mm. This decreases further south, with the annual average of Tunisia's southern tip measuring in at under 100 mm. As shown in the illustration (map) below, the Mejerda basin exhibits a large regional bias in terms of precipitation. As shown in the figure (graph) below, the monthly average precipitation increases greatly between October and April in the north of the survey area on the left bank of the Mejerda basin, with a particularly prominent peak noticeable between December and January. Meanwhile, month-to-month variations in average precipitation are not as prominent in the southern section on the right bank of the Mejerda basin as in the north over the course of the year. The average annual precipitation of the survey area is generally between 400 and 500 mm.

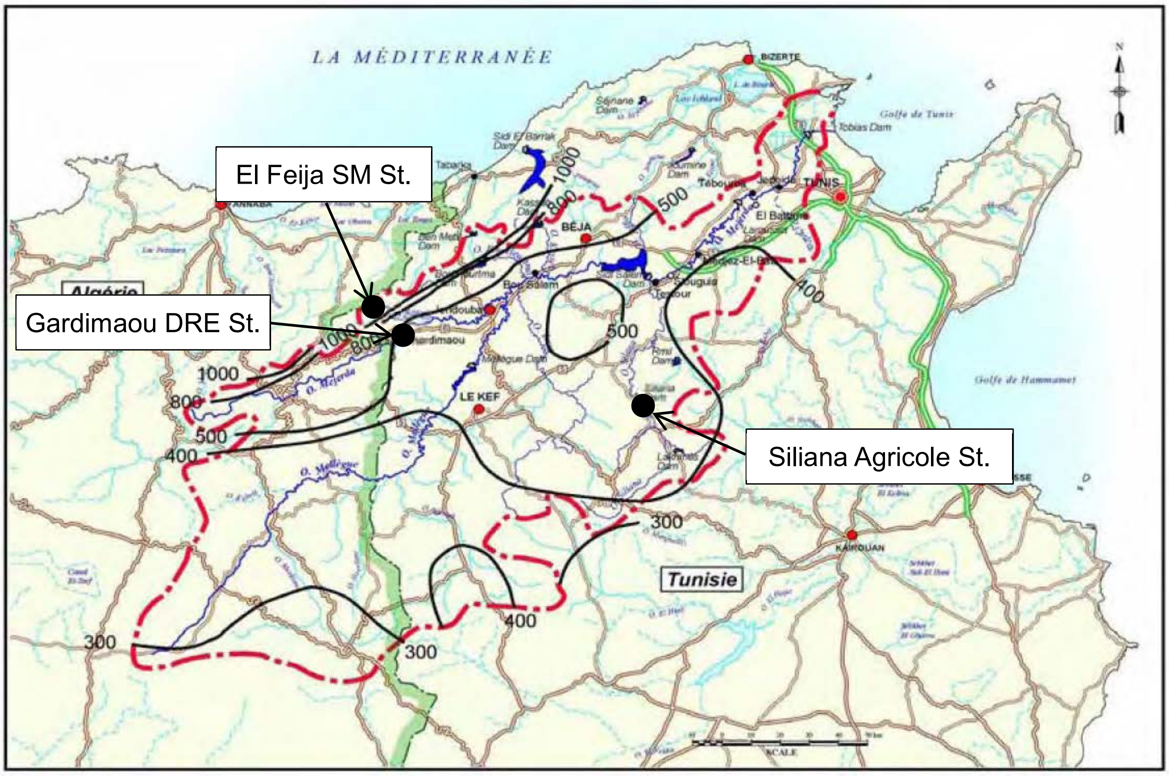


Figure 2-3: Isopluvial map in the Mejerda basin (average annual precipitation)

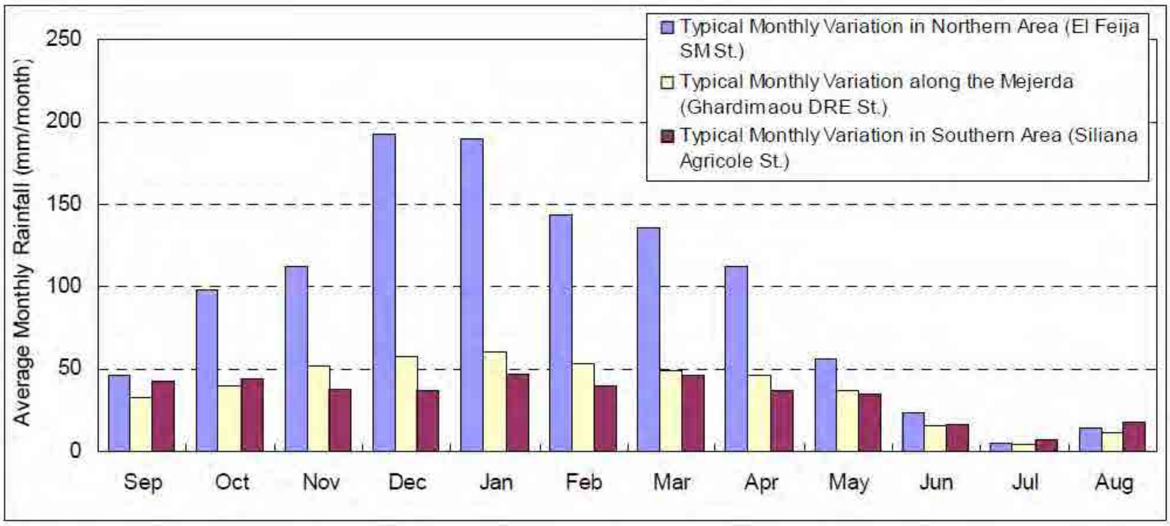


Figure 2-4: Regional differences in average monthly precipitation

2.1.3 Flood controls and irrigation facilities

There are currently nine active dams in the Mejerda basin, with six more either in planning or under construction. An overview of the location of each is shown below. Additionally, Laroussia Dam is an intake facility that serves to convey water to the Cap Bon Canal. The Tobias Barrage also functions as an intake facility.

Table 2-1: Characteristics of Mejerda basin dams

Dam	Catchment area (Km^2)	Maximum reservoir capacity (millions m^3)
Sidi Salem	18,191	959.5
Mellegue 2*	10,100	334.0
Bou Heurtma	390	164.0
Mellegue	10,309	147.5
Siliana	1,040	125.1
Tessa*	1,420	125.0
Kasseb	101	92.6
Ben Metir	103	73.4
Sarrath*	1,850	48.5
Beja*	72	46.0
Khalled*	303	37.0
Chafrou*	217	14.0
Lakhmes	127	8.4
Rmil	232	6.0

Note: * = Under construction or in design/planning

Figure 2-5: Locations of Mejerda basin dams in Tunisia

2.1.4 Socioeconomics

(1) Population and population density

According to the 2004 national census, the population and population density of Tunisia and the Mejerda basin are as follows.

National population	9,910,872 (approx. 9.91 million)
National population density	61.1 persons/Km^2
National population growth rate	1.10%
National urban population ratio	64.8%
Population of the Mejerda basin	Approx. 1,330,000 (13.4% of total population)
Population density of the Mejerda basin	84.0 persons/Km^2

Source: 2004 National Census

(2) Economy

1) Agriculture

The Mejerda basin plays an important role in domestic agricultural production, with agriculture serving as the basin's economic base. A summary of this is as follows.

Area of the Mejerda basin	15,830 Km^2 (9.8% of total national area)
Area of basin upland field (non-irrigated)	10,392Km^2 (65.6% of total basin area)
Area of basin farmland (irrigated)	1,489 Km^2 (9.4% of total basin area)
Agricultural produce and livestock Wheat production	1,627,000 tons (51% of total national production)
Barley production	465,000 tons (34% of total national production)
Beef production	45.4% of total national production
Goat meat production	45.2% of total national production
Poultry production	51.9% of total national production
Basin cork production	75.7% of total national production

Source: National Bureau of Statistics

2) Manufacturing and Service

The current state of manufacturing and service companies in the governorates of Manouba and Ariana are organized in the following table. Being located in the outskirts the capital and country's best harbor in Tunis, export-oriented companies account for half of all enterprises in both governorates. Protecting these companies from flood damage is in the best interest of the national economy.

	Manouba	Ariana
Total companies	186	240
Export-oriented companies	92	111
Breakdown of companies	Textiles, clothing and leather, food processing (dairy, apples, pears), and electric machinery with a focus on auto parts	Textiles, clothing and leather, agro-processing, electronics, pharmaceuticals, computers and telecommunication

Source: Tunisia Foreign Investment Promotion Agency

2.2 Overview of Zone D2

2.2.1 River channel

Zone D2, the Mejerda's lowest basin, is an approximately 65-km section that runs from Laroussia Dam to the river mouth. In the upstream section of Zone D2 between Laroussia Dam and Jedeida, the river flows through an embedded channel among a belt of gently sloping hills. Excavations downstream of Laroussia Dam are more than 10 meters deep, with the depth gradually decreasing on its way to Jedeida. The central section between Jedeida and Tobias flows through alluvial plains. The Chafrou River merges with the right bank of the Mejerda in this section. At present, there is also a section with dikes of about two meters, but it is an essentially compound river channel comprised of a low flow channel (water route) and a flood channel.

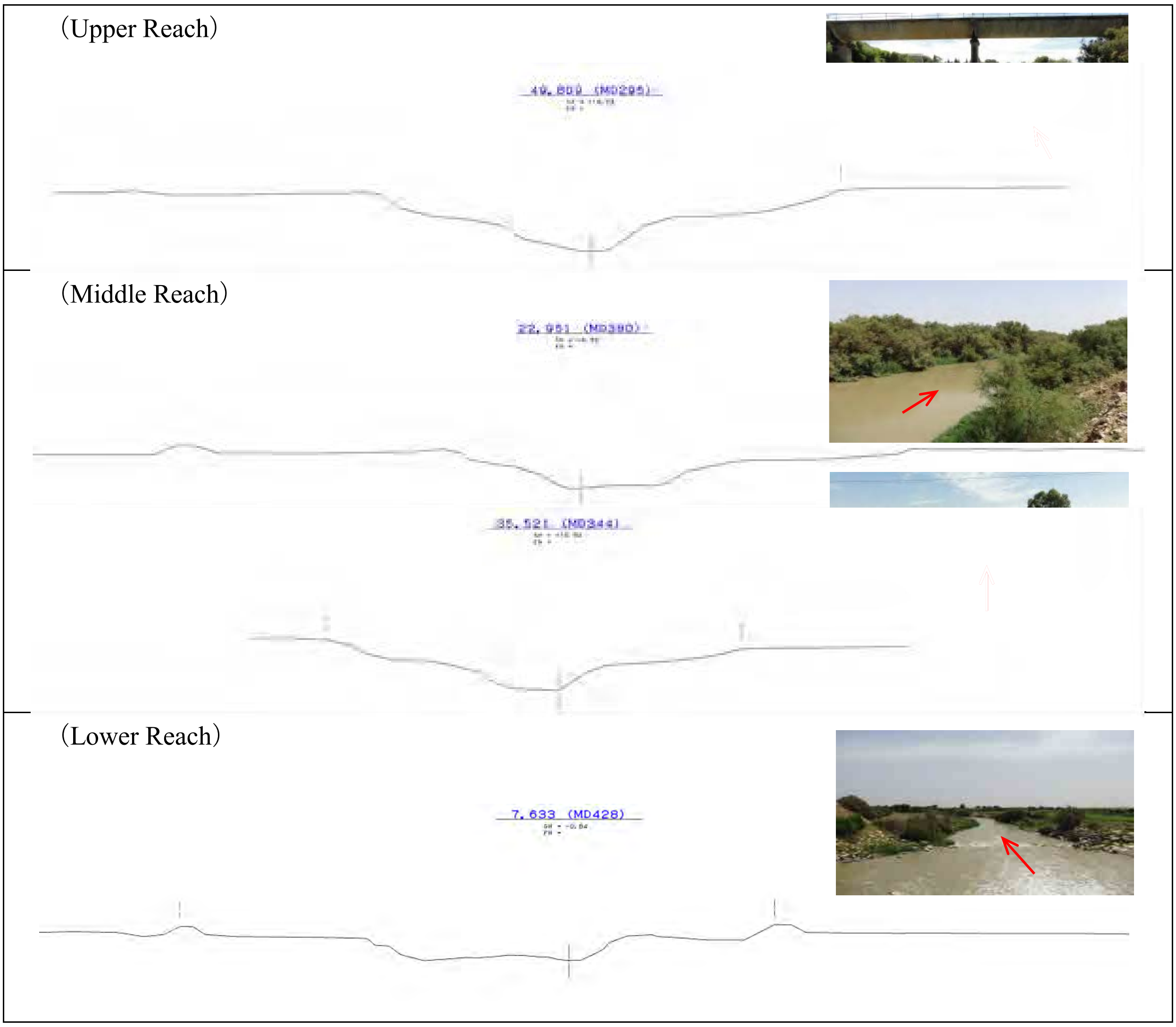


Figure 2-6: Typical cross sections of river channel

2.2.2 Facilities on the river channel

(1) Dams

There are two dams, Laroussia Dam and Tobias Barrage.

(2) Bridges

Currently, ther are 29 bridges in Zone D2. As a result of the upcoming river channel improvement, 15 bridges are expected to require renovation, and new bridge construction is 3. Note that the K. Landaous Bridge located at the lowest reaches of the river will also require alterations as the river channel is improved. However, it is expected to be included among another road project and therefore, falls outside the jurisdiction of this project.

(3) Existing sluicing outlets on the main river

The existing sluicing outlets along the main river are shown inbelow table. Sluicing gates expected to require modification as a result of the upcoming river channel improvement are 9 out of 18 existing gate. Note that the intake sluicing gate at Tobias Barrage that is located furthest downstream is a larger facility and will be used as-is.

Table 2-2: Sluicing gates requiring alterations due to upcoming river channel improvements

No.	Name	Accumulative distance(km)	On-site confirmation	Alterations required	Internal water area (km^2)	Cross section, application and land use of existing facilities
1	P71 Left	52.2	×	-	1.44	
2	P84 Left	48.8	×	-	3.95	
3	P110 Left	42.9	Yes	×	0.85	
3-1	P110 Left-2	L 41.7	Yes	Yes		500Φ/drainage/cities, etc.
4	P84 Right	R 48.8	Yes	Yes	3.47	Approx. 800Φ assumed / drainage / farmland
5	P105 Right	R 44.4	Yes	Yes	2.58	-
6	P110 Right	42.9	×	-	1.85	
7	P116 Right	R 41.7	Yes	Yes	0.20	Approx. 800Φ assumed / drainage / cities, etc.
8	P119 Right	38.6	Yes	×	0.42	
9	P132 Right	36.5	×	-	26.26	
10	P146 Right	R 33.7	Yes	Yes	6.72	2Box-3.2mBx1.2mH/drainage/farmland
11	P160 Right	R 30.8	Yes	Yes	18.42	U-1.04m×0.8mH (Drainage)/farmland
11-a	P160 Right	R 30.2	Yes	Yes		U-1.0m×1.0mH (drainage assumed)/farmland
12	P169 Right	R 28.4	Yes	Yes	7.01	2Box-2.2mB×1.2mH / drainage
13	PoMejCher Right	23.7	Yes	×	19.71	
14	PA4Mejam Left	L 16.7	Yes	Yes	0.70	Approx. 800Φ assumed / drainage / farmland
15	PA4Mejav Left	L 15.7	Yes	×	0.80	
16	PoMejProt Right	12.9	Yes	×	7.65	
17	PoMejTobias Right	10.7	Yes	×	0.40	
18	PTobias Left	10.6	Yes	x	0.63	Present facilities to be used as-is / intake / farmland

Notes:

- L and R in front of the distance mark in the distance column of the above table indicate either left bank or right bank. Source of internal water area: JICA Study Team
- ○ on the on-site confirmation column represents facilities confirmed during the field study, and x represents facilities that remain unconfirmed.
- — on the alterations required column represents facilities that were not able to be confirmed on location and thus, the

necessity of alterations to them cannot be determined as of yet. × represents facilities that have been confirmed on location but do not require alterations (besides removal) because they are currently not in service. The facilities represented by ○ are those that are currently in use and require structural alterations.

2.3 Flood damage situation

Floods that have occurred in the Mejerda basin since 1900 and the peak flow rates at major observation stations are as follows.

Table 2-3: Past floods in Mejerda basin

Flood	Peak Discharge(m^3/s)						
	Mellegue(K13)	Ghardimaou	Jendouba	Bou Salem	Slouguia	Mejez Elbab	Jedeida
Feb 1907	-	-	1,610	-	-	-	-
Feb 1928	-	-	-	1,220	-	-	-
Mar 1929	-	-	-	1,760	-	-	-
Dec 1932	-	-	-	2,060	-	2,250	-
Jan 1940	-	-	-	1,780	-	-	-
Oct 1947	-	-	-	1,700	-	1,280	-
Nov 1948	-	-	-	851	-	891	-
Jan 1952	-	-	-	904	-	981	-
Mar 1959	-	-	-	1,140	-	1,490	-
Sep 1969	4,480	-	-	1,485	-	1,440	-
Mar 1973	-	2,370	2,420	3,180	-	-	-
1976	-	1,013	970	-	-	-	-
1981	Sidi Salem Dam Completed						
Dec 1984	600	570	750	900	-	-	-
Jul 1989	-	-	-	-	470	-	-
May 2000	4,480	736	327	977	-	-	-
Jan 2003	2,600	1,090	1,070	1,020	744	730	-
Jan 2004	2,480	1,470	1,024	889	-	-	-
Jan 2005	-	838	616	529	-	224	-
Apr 2009	-	-	-	-	365	262	-
Feb 2012	-	-	-	-	-	-	324

The table below provides an overview of the major floods mentioned above.

Table 2-4: Overview of major floods

No.	Flood name	Overview of flood and damage caused
1	Flood of March 1973	A major flood in the Mejerda that was large in scale and caused damage throughout the whole of the river basin. The Sidi Salem dam did not yet exist at this time. The Mejerda also had two passages at the river mouth (the old river channel and the Tobias diversion channel). Characteristic of this flood was its large, climactic peak rainfall, inflow, and discharge. The rainfall and high water levels did not continue for long during this flood. It lasted less than a week in length.
2	Flood of May 2000	This flood caused serious flooding in the Mellègue basin and the upstream section of the Mejerda basin. Characteristic of this flood was the following: - A climactic inflow of heavy flooding into the Mellègue River (K13) from the Algerian side - Localized heavy downpours on the upstream section of the Mejerda basin The Sidi Salem dam had already been constructed by this time. Its flood control functions saved the downstream section of the Mejerda from flood damage.
3	Flood of January 2003	A flood that caused extensive, widespread damage between January and February 2003. Characteristic of this flood was the following: - Multiple large peak inflows at the Gardimaou observation station on the main Mejerda River as well as at the K13 observation station on the Mellègue River. - Multiple large peak rainfalls The inflow of the flood of January 2003 exhibited multiple large peaks. Unlike the flood of May 2005, it brought about long-term flooding downstream and upstream of the Sidi Salem dam and along the whole of the Mejerda. In particular, downstream areas suffered from flooding for over a month. 60% of all households were damaged and six individuals turned up dead.
4	Flood of January 2004	Multiple medium-scale floods occurred. Discharge of the Sidi Salem dam was required to maintain normal levels. This discharge caused a flood that would inflict damage downstream. Characteristic of this flood was the following: - Multiple medium-scale peak discharges were observed at Gardimaou observation station - Multiple peak rainfalls
5	Flood of 2005	
6	Flood of April 2009	Discharge of the Sidi Salem dam and dike break led to a flood that caused flood damage in irrigated farmland and at irrigated facilities. Characteristic of this flood was the following: - Covered mountain flood at Gardimaou observation station and Ragay observation station. - Localized heavy downpours in the Manouba and Ariana governorates on the downstream section of the Mejerda basin.
7	Flood of 2012	This flood caused large-scale flood damage in the vicinity of Jedeida. Characteristic of this flood was the following: - Covered mountain flood at the Jedeida observation station. The flooded area of the Mejerda was 2,216 ha, while flooded agricultural areas of Jedeida came to 700 ha.

Chapter 3. Current State of Flood Control Measures

3.1 Flood Control Policy and Organization Structure

3.1.1 Policy

The Tunisian government devised a 12th Five-Year Socio-Economic Development Plan (2010-2014) to follow its 11th Five-Year Socio-Economic Development Plan (2007-2011). According to the Ministry of Development and International Cooperation, the 12th five-year plan is under review following the Jasmine Revolution of January 2011 (as of December 2012). However, the government has made it clear that there will be no policy changes regarding this Project in Tunisia, even in the wake of the overthrow of the Ben Ali administration. The Islamist Ennahada party became the leading party of the Tunisian constituent assembly by capturing 90 of 217 seats in the election held on October 23, 2011. Principal members of the party then released a statement on October 27 that confirmed that there was hardly any change among government officials and that the objectives of existing policies would be carried over.

3.1.2 Legal Framework

All legislation related to water resources management and established under French colonial rule (1881-1956) was updated in 1975 as "Water Code" to define the authority of all operators and users in the water resources sector and conserve water resources and distribute them fairly. The Water Code has been further updated since 1975. Some of its articles were revised and new articles on socioeconomic development were added, shifting water demand and important environmental issues for the conservation of natural resources. The Water Code was most recently updated in 2010. Below are descriptions of each of the nine chapters that make up the Water Code:

Chapter	Description	Chapter	Description	Chapter	Description
1	Public Waters	4	Duties	7	Contamination and Flooding
2	Public Water Conservation, Policy	5	Authorized Use of Public Waters	8	Irrigation Associations
3	Water Rights	6	User Duties	9	Justice and Penal Regulations

The organization structure for flood and other disaster management was based largely on the following laws and decrees. These laws and decrees set forth procedures for devising plans, procuring materials and equipment, securing personnel and other structural organization, as well as implementing activities to mitigate damage from fires, earthquakes, storms and terrorism in addition to floods.

a) Law No. 39-1991 on disaster management, disaster measures and rescue organization (8 June 1991)
b) Decree No. 942-1993 on National and Regional Disaster Management Planning and Disaster Committees (26 April 1993) and Decree No. 2723-2004 on amendments to Decree No. 942-1993 (21 December 2004)

3.1.3 Administrative Framework

The Ministry of Agriculture has jurisdiction over flood control measures in rural areas and agricultural lands, while the Ministry of Equipment presides over those of urban areas. Administrative boundaries of urban and rural areas have been clearly established.

3.1.4 Administrative Agencies

(1) Ministry of Agriculture

Below is the Ministry of Agriculture organization chart:

1) Central Ministry of Agriculture Agencies

The General Directorate of Dams and Large Hydraulic Works (DGBGTH) and the General Directorate of Water Resources (DGRE) at the Ministry Headquarters fulfill important roles related to flooding.

(a) General Directorate of Dams and Large Hydraulic Works (DGBGTH)

DGBGTH has jurisdiction over dams and large-scale hydraulic facilities.

DGBGTH serves as the direct implementing authority during the implementation of this Project. DGBGTH worked with an annual budget of TND 84 million in 2008, 101 million in 2009 and 102.5 million in 2010, an increase of 22% over two years.

There are 819 workers (as of interviews in October 2011) organized as shown on the table and figure below. The budget and personnel appear to be sufficient to implement and manage this Project.

(b) General Directorate of Water Resources (DGRE)

This agency establishes, manages and collects data for a water resources monitoring network. It has jurisdiction over early flood warning systems.

Below is the DGRE organization chart:

2) Regional District Departments of Agricultural Development (CRDA)

In line with government policy on decentralization, the Ministry of Agriculture has commissioned the CRDAs in each of the 24 governorates with all activities related to agriculture in those regions. The nature of those activities ranges from agricultural production and natural resources to vegetation and forest areas and economic aspects.

CRDAs oversee agricultural activities in their governorate and administer agriculture in technical, political, legal and financial terms. They also manage river channels. There are 24 CRDAs in Tunisia, with the following three being directly involved in this Survey:

1) CRDA Ariana
2) CRDA Bizerte
3) CRDA Manouba

(2) Ministry of Equipment

As for flooding, the Ministry of Equipment is conducting countermeasures such as 1) Studying urban flood control projects, devising plans, monitoring construction, 2) Maintenance inspections of structures for urban flood control measures.

As of September 2011, a total of 162 projects are being implemented in 150 municipalities at a total cost of TND 220 million.

In addition to bridges and other river-crossing structures, the Ministry of Equipment also manages and presides over dirt quarries and disposal areas and is intimately involved in the implementation of this Project.

(3) National Water Committee (CNE)

The Water Code grants a level of authority regarding Tunisia's water resources to CNE. CNE serves as an advisory organization that investigates and assesses all aspects of water management, including dam management during times of flooding, and water use planning.

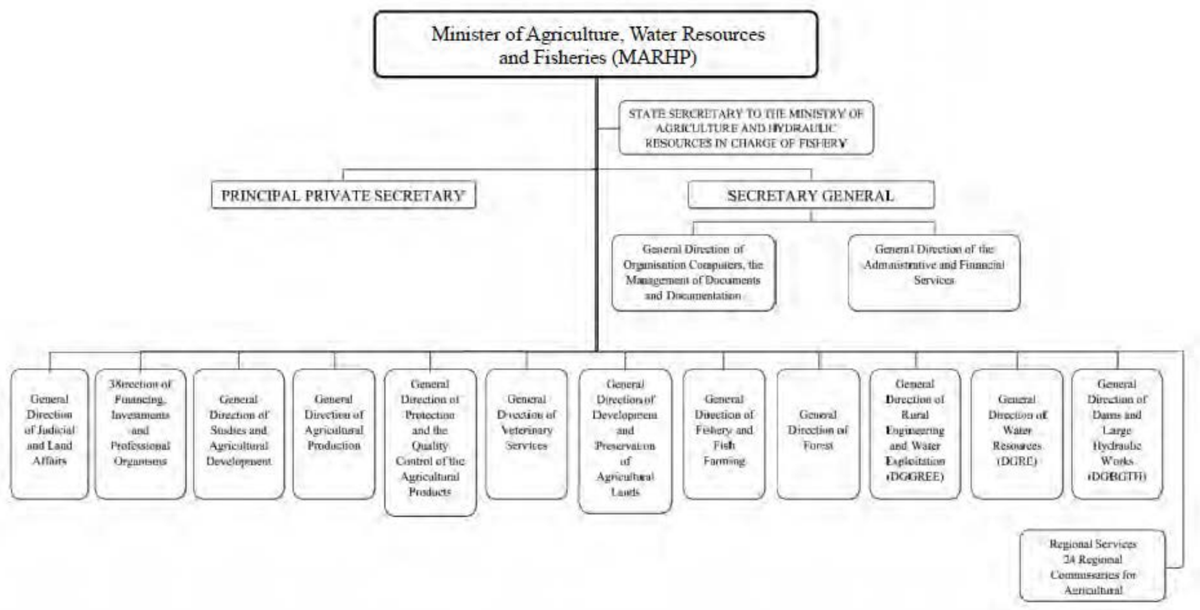


Figure 3-1: Ministry of Agriculture Organization Chart

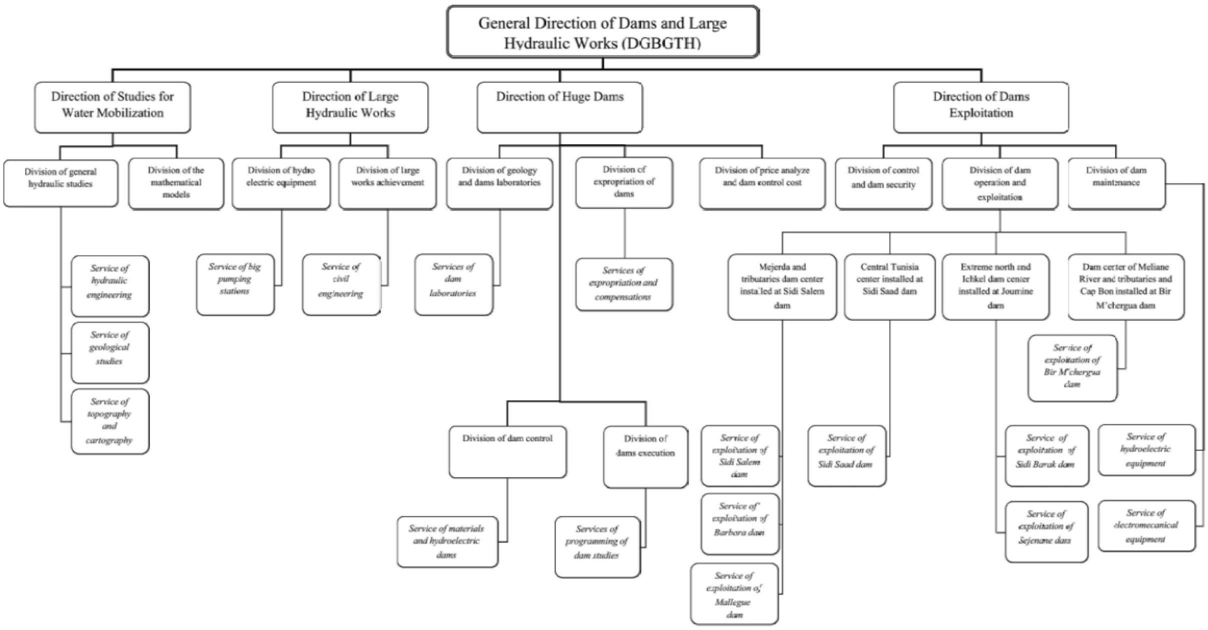


Figure **3-2:** General Directorate of Dams and Large Hydraulic Works (DGBGTH) Organization

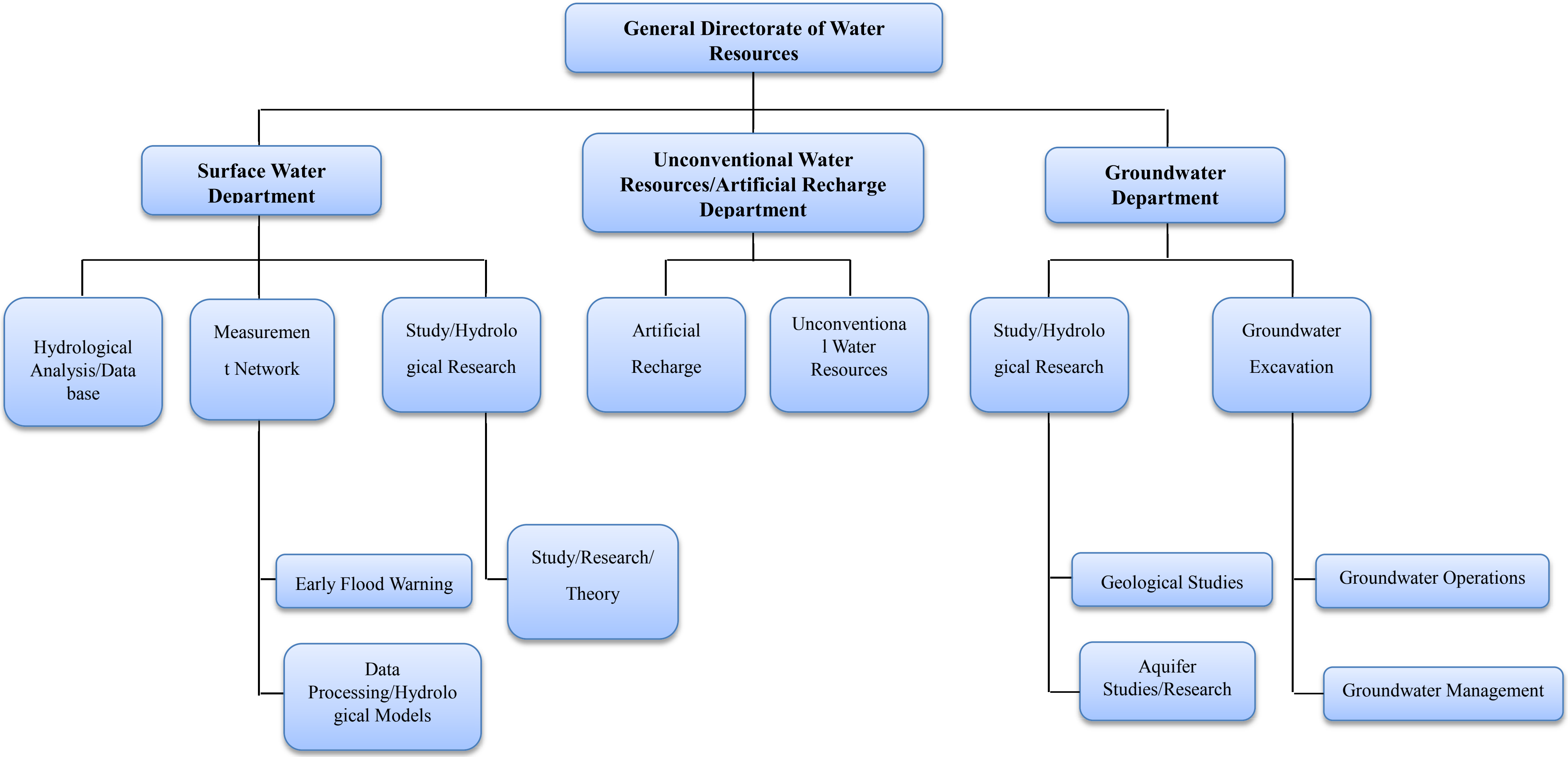


Figure 3-3: General Directorate of Water Resources (DGRE) Organization Chart

(4) National Institute of Meteorology (INM)

The INM manages a weather observation network that includes a central weather station, agricultural weather stations, rain gauges, marine observation stations and aviation weather observation stations.

3.2 Summary of Past Flood Control Projects

3.2.1 River Projects

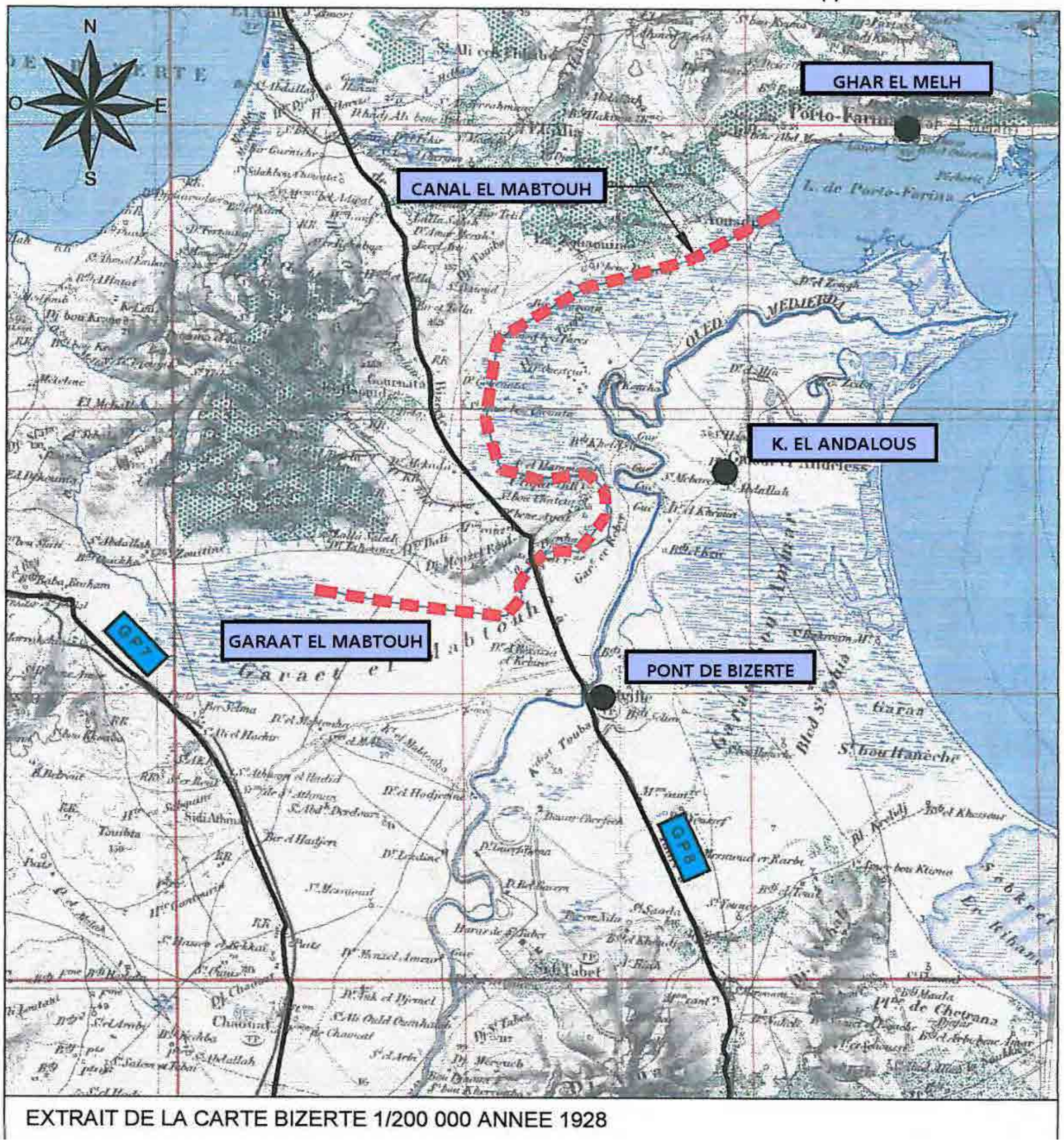
Below is a summary of river projects that were part of flood control measures on the Mejerda River. It is a compilation based on past documents.

Table 3-2: Summary of Past River Projects

Name of the Project	Year Commenced	Purpose & Description of the Project
1.Drainage Channel Construction Project	1909	Drainage for lowland areas in El Mabtouh Plain 1) Construction of Trapezoidal Channel (L=30km) 2) Channel Construction along the MejerdaRiver (L=0.95km)
2.Lowland Areas Development Plan in Mejerda River	1952	Lower to water level and improvement of the flow capacity 1)Short-cut of curved reach and removal of bridge at Protville 2)Short-cut of curved reach at Menzel Reached 3)Improvement of older structures at Jedaid and El Battan 4)Construction of dykes 5)Construction of diversion channel
3. Irrigation and Drainage Project in Galaat Andalous – Ras Djebel	1994	1) Improvement of Tobias Barrage (Movable Barrage) 2) Pipe irrigation by pumps (irrigated area: 11,675 ha)

Source : Project D'irrigation et de Drainage Galaat Andlous-Ras Djebel Rapport Final (MA,1992.6)

The first project on the table above sought to drain the El Mabtouh wetlands, and in 1909, the Public Works Department built a 30-kilometer trapezoidal channel with channel bottom width of four meters, slope gradient of 1/1 and longitudinal gradient of 0.15m/km (1/6666). A 950-meter channel was also built along the left bank of the Mejerda River. The broken red line on the map below shows the drainage route from the El Mabtouh wetlands to Ghar El Melh lagoon (Porto Farina).



Source: Collection B Bouvet

Figure 3-5: Drainage Channel Route

Following the flood of December 1931, the Mejerda River Lowlands Area Development Plan, the second project on the table above, was implemented to lower the design high water level, improve down flow capacity and reduce the frequency of flooding.

Since this was a large-scale project, it was implemented in several segments to align it with each year's budget and allow for observations of the results of each year's work so that the work done the following year could reflect the observations. The first work done on the curved reach in Protville began in 1952.

Tobias Barrage was built to ensure intake levels for irrigated areas, and it was improved and made into a movable barrage in the 1990s as part of the third project on the table above. Tobias Movable Barrage plays an extremely vital role in controlling the flow of the lower Mejerda River. The diversion channel (current river channel) was completed in the 1950s and the movable barrage in the 1990s. The movable barrage improvement altered the course of the Mejerda River into the path it follows today. The old course has been converted into an irrigation channel.

3.2.2 Dam Projects

Structural flood control measures in the Mejerda River Basin consist of dams in addition to channels and dikes. Dam projects on the Mejerda River mainly develop water to be used for agriculture, drinking and power generation, but dams such as the Mellegue and Sidi Salem also serve to control flooding. Below are eight dams capable of controlling flooding in the Mejerda Basin:

Table 3-3: Summary of Dam Projects (Flood Control)

Dam	River	Year	C. Area (km2)	Normal Water Level(m)		Surcharge WL & Flood Control Volume			
				El (m)	Volume (Mm3)	El (m)	Volume (Mm3)	Flood Volume (Mm3)	ERD (mm)
Sidi Salem	Mejerda	1981	18,191	115.0	674.0	119.5	959.5	285.5	15.7
Mellegue	Mellegue	1954	10,309	260.0	44.4	269.0	147.5	103.1	10.0
Bou Heurtma	Bou Heurtma	1976	390	221.0	117.5	226.0	164.0	46.5	119.2
Silliana	Silliana	1987	1,040	388.5	70.0	395.5	125.1	55.1	53.0
Kasseb	Kasseb	1968	101	292.0	81.9	294.4	92.6	10.7	105.9
Ben Metir	Bou Heurtma	1954	103	435.1	57.2	440.0	73.4	16.2	157.3
Lakhmes	Silliana	1966	127	517.0	7.2	521.1	8.4	1.2	9.4
Rmil	Rmil	2002	232	285.0	4.0	288.0	6.0	2.0	8.6
Total (8 Dams)								520.3	

Note: ERD (Equivalent Rainfall Depth,mm) = Flood Control Volume/Catchment Area

The eight dams offer a total flood control volume of 520 million m^3. The Sidi Salem and Mellegue Dams combine for 388 million m^3, 75% of the total volume.

3.2.3 Hydrological Information Gathering System and Flood Prediction

(1) Hydrological Information Gathering System

DGRE improved its system for gathering rainfall, total flow and other hydrological information about the Mejerda River in 2007 with technical and financial aid from the French Development Agency (AFD). It is worth noting that DGBGTH gathers and manages information about dams (rainfall, inflow, outflow, reservoir levels, etc.) separately.

The DGRE hydrological information gathering system is called SYCOHTRAC (SYstèm de COllecte des mesures Hydrologiques en Temps Rèel et Annonce des Crues des oueds tunisiens) and is made up of 75 observation stations located on the rivers of Tunisia. The Mejerda River Basin has 57 of those observation stations. Observation data is updated every day at 7:00 a.m., and it is possible to observe and gather data at 15-minute intervals during floods. There are 39 rain gauges and 37 water level observation stations, but only 30 rain gauges and 22 water level observation stations are operating as of September 2012.

(2) Flood Prediction

Flood prediction system capabilities do not include the ability to predict rainfall. The flood prediction system predicts water levels by considering propagation times to downriver areas based on the results of past water level and flow analysis from principal gauges. Below are propagation times from Sidi Salem Dam:

Table 3-4: Flood Propagation Times (From Sidi Salem Dam)

Reference Points	Slouguia	Mejes El Bab	El Battan	Jedeida	GP 8 Road	Tobias Barrage
Disatance from SS Dam(Km)	22	38	97	106	132	135
Min. Propagation Time (hrs)	4	8	23	23	31	32
Max. Propagation Time (hrs)	6	11	29	33	44	42

Source : DGRE

(3) System Problems and Solutions

The table below summarizes an interview with the Surface Water Department of DGRE, the agency responsible for the telemeter system and early flood warnings, about the current status of problems with said systems and solutions to those problems:

Table 3-5: SYCOHTRAC System and Maintenance Problems and Solutions

System or Maintenance Problem	DGRE Solution (as of 9/2012)
1. CZMS, the company that procured and installed hydrological equipment, and DGR entered an equipment maintenance contract, but the contract relationship failed to deliver the expected results. The contract was terminated in November 2011.	Terminated the contract in November 2011. DGRE is directly managing maintenance and equipment installation.
2. Something needs to be done about system theft and destructive behavior.	The structure housing observation facilities were improved and a lock added, and solar panels were stored inside. Equipment was purchased from OTT Germany and updated in 20 locations. This solution cannot be expected to wipe out theft, but theft has decreased.
3. The dam management system and SYCOHTRAC are not compatible with each other.	a. DGRE installed observation equipment at each dam, but it is not compatible with systems related to dams and was not operating well. The plan is to investigate whether equipment can be concentrated at Sidi Salem Dam and incorporated into the DGRE system. b. It was determined that data communication system problems caused the data incompatibility. The plan is to change from a GSM system to a GPRS system. c. The GPRS system can transfer data over the Internet, enabling it to exchange and provide information to relevant authorities in addition to CRDA. d. Tunisiana is the only company that has this system, and the contract with this company will be renewed.
4. Flood information is not being relayed outside of the Ministry of Agriculture.	Flood information is provided to CRDA only via an exclusive online access system. The system uses special monitoring software, and the information is not provided to other agencies. There is also a dedicated telephone line to communicate this information. The above is governed by the contract with Tunisiana.
5. It is not possible to obtain hydrological information from the Algerian side.	The two countries deliberated over this in 2011. They agreed to exchange information, but a political change followed and negotiations have not gotten off the ground.

Source: Interview with Surface Water Department of DGRE

3.2.4 Current Status of Emergency Flood Response

(1) Current Status of Emergency Disaster Response

According to the National Civil Protection Office (NCPO), flood damage accounts for 90% of disasters in Tunisia with fires, heavy snow, droughts and other disasters accounting for less than 10%.

According to Law No. 39-1991 on Disaster Management and Organization, Disaster Management Commissions are to be formed when disasters are expected to strike, with the Minister of the Interior serving as the chair of the national commission and governors serving as chairs of governorate commissions.

The government’s disaster management authority, the NCPO in the Ministry of the Interior, will serve as the standing office of the commissions and will coordinate between disaster organizations on central and regional levels. Governorates concerned with evacuation from flooding on the Mejerda River are Ariana in the lower region and Manouba and Bizerte, in which part of the retarding basin is located, in the upper region.Below are descriptions of disaster organizations on national and regional levels.

1) National Disaster Commission

According to Decrees No. 942-1993 and No. 2723-2004, the National Disaster Commission is the highest disaster management authority, and the Minister of the Interior serves as its chair. This commission is comprised of the chair and 26 representatives selected from related ministries. It is worth noting that these representatives are selected in response to the type of disaster.

2) Regional Disaster Commissions

Regional Disaster Commissions are set up in each governorate during disasters, and governors of each governorate serve as their chairs. These commissions are comprised of the chair and 17 representatives selected from the regional organizations of related ministries. These representatives are selected in response to the type of disaster.

3) Civil Protection Offices

Civil Protection Offices exist at the national (NCPO), governorate (Regional Civil Protection Office in Governorate) and even delegation (Delegational Civil Protection Center) levels. They cooperate with security forces, police and military forces and are in charge of evacuation and flood protection activities.

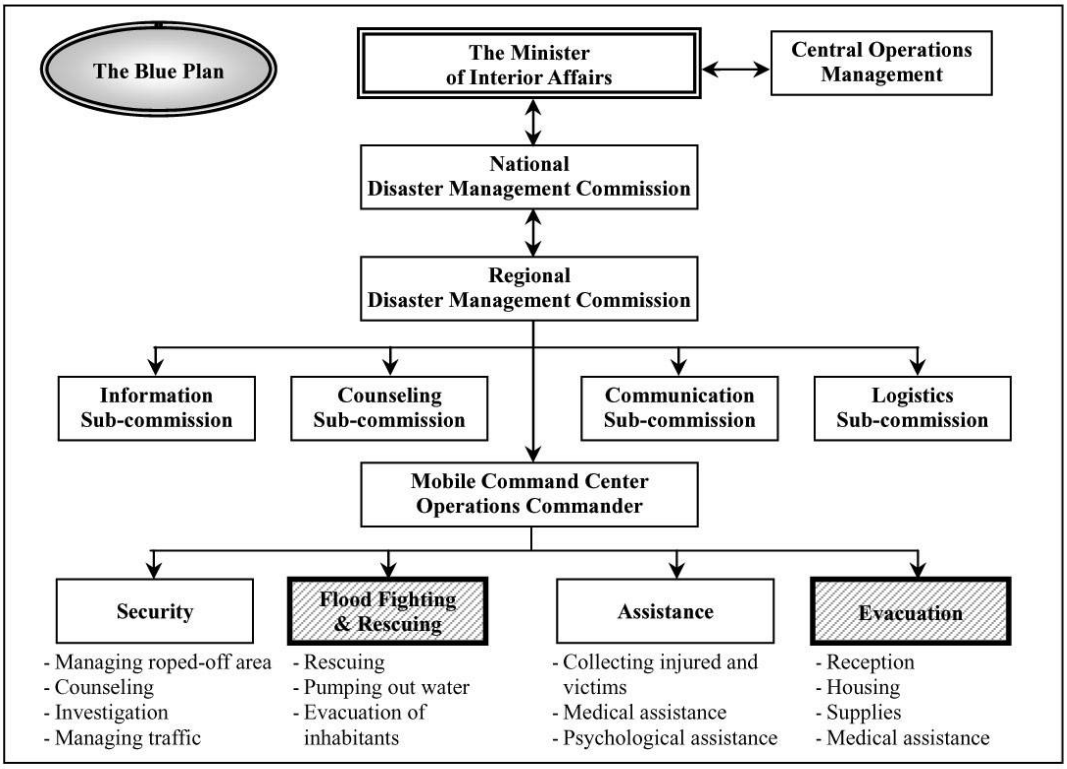
4) Citizen Volunteers, International Red Cross

Citizen volunteers assist in flood protection activities during disasters. According to Commission Regulation No. 2428-1999 on regulations for citizen volunteer participation in disaster management activities (1 November 1999), citizens 20 years of age or older who have passed citizen volunteer screening may register as citizen volunteers, and RCPOs will summon them during disasters.

(2) Disaster Management Plans

Regional Disaster Commissions work together with RCPOs in governorates to devise Disaster Management Plans based on Law No. 39-1991 and Decree No. 942-1993. National Disaster Commissions review the plans of each region, and governors approve them. Each governorate's distinct evacuation and flood protection plan includes ORSEC regional disaster management plans.

Governorate plans are devised based on guidelines that enable implementation systems and procedures employed when disasters strike to be standardized, but they are established in such a way that the specific needs of each governorate are met.



Source: NCPO & Mater Plan

Figure 3-6: Disaster Management Organization and Disaster Information Communication System (Blue Plan)

Blue Plans are the parts of disaster management plans that deal with floods. Blue Plans are organized as shown in the figure above.

(3) Issuing Flood Warnings

The Minister of the Interior is to issue flood warnings based on warnings and water level information provided by DGRE in the Ministry of Agriculture. A two-staged system has been set with Alert Levels and Overflow Levels as shown on the table below.

Table 3-6: Water Gauge Warning Levels

No.	Station Name	Relative CRDA	Alert Level(cm)	Overflow Level(cm)
1	Pt Bizerte	Ariana	600	750
2	Tobias	Ariana	590	694
3	Bj Toume	Monouba	400	500
4	Jedeida	Monouba	750	820
5	Larousia	Monouba	190	-

Note : Alert and overflow levels do not correspond to the ground elevation network system.
Source : DGRE

(4) Evacuation and Evacuation Centers During Floods

Local residents evacuate to designated evacuation centers when they receive an evacuation advisory. Residents evacuate in community and family units. Civil Protection Offices and military forces work together to implement evacuations.

(5) Issues with Flood Evacuation, Flood Warnings and Communication

The table below shows issues with flood evacuation, flood warnings and communication:

Table 3-7: Issues with Flood Evacuation, Flood Warnings and Communication

Type	Issues, Problems
Evacuation, flood prevention, rescue operations	1) Some residents do not evacuate in order to prevent theft in their absence. 2) Many heads of households with livestock ignore evacuation advisories and stay behind to care for their animals 3) There are not enough materials and equipment for rescue operations. Particularly lacking are pumps for discharging water and rescue boats. 4) Long-term evacuation brings on physiological and psychological damage. 5) Preparation and persuading residents with evacuation advisories takes time.
Issuing and relaying flood warnings	1) Information about flood inundation from the Ministry of Agriculture moves too slowly. In some cases, the information does not arrive until right before the inundation. 2) Relaying evacuation information requires patrolling and visits to each household, which takes time. 3) Ninety mostly vulnerable people were once left behind in an Ariana delegation where evacuation advisories never arrived. 4) Evacuating at night is difficult because there are many power outages.

Source: Interviews with the NPCO and Manouba Governorate

3.2.5 River Channel Maintenance

CRDAs are responsible for Mejerda River channel maintenance in the administrative districts in which they have jurisdiction.

River channels were excavated and rampant vegetation in river channels removed in Manouba Governorate after the flood of 2003. From May 2004 to November 2004, the Manouba CRDA removed deciduous tamarisk shrubs proliferating along the five kilometers of river channel they excavated from a new road bridge in Jedeida to Sidi Thabet at the border with Ariana. Unfortunately, the roots left behind grew back into shrubs two to four meters high less than two years later because tamarisk are hearty and exuberant and can grow in various types of soil. Military forces used a bulldozer equipped with a ripper to remove tamarisk roots in Jedeida within a 500-meter area upstream of the road bridge. Young tamarisk roots were dug out of the ground in that case, so they were not able to grow or proliferate as fast as they had before. A 2.5-kilometer stretch of the Chafrou River channel from its confluence with the Mejerda River was also excavated in 2004.

3.2.6 El Mabtouh Retarding Basin Functions and Land Use Regulations

The El Mabtouh Retarding Basin is a low-lying area that has been used for salt production since ancient times. It is the entry point for runoff from the mountains located in the northern and western parts of the area and currently serves as a temporary holding area for overflow from the left bank of the Mejerda River; it is a retarding basin. A diversion channel from the retarding basin joins the Mejerda River upstream of Tobias Barrage. Gate facilities are set up at the confluence to prevent discharge and backflow on the diversion channel side, but they are broken and currently out of order.

The retarding basin is split into three zones with inundation and discharge sequences determined for each.

3.3 Donor Water Resources Management Activities

3.3.1 Donor Activities

(1) Flood Control

Most flood control efforts to this point have actually been funded by Tunisia itself. The African Development Bank (ADB), the World Bank and JICA are international donors who have funded past flood control projects. Below are descriptions of those efforts:

1) The African Development Bank

The ADB is currently implementing the North and West Tunis Flood Protection Study (FS). The construction period is 13 months from May 16, 2012 through June 15, 2013. The Urban Hydrology Department of the Ministry of Equipment is serving as the Tunisian government authority of this Study. The ADB report will be used to determine the relevance of project implementation and entities from which to procure funding. As shown on the map below, the northern part of which overlaps with the target area of this Study. This Study calls for improvement of the river channel upstream of the Kalaat Andalous Bridge, but there will be no overlap in the project implementation stage because the Ministry of Agriculture will implement that part, coordinating with the Ministry of Equipment.

Figure 3-7: North and West Tunis Flood Protection Study Area

2) JICA

Japan has continuously cooperated toward the development of Tunisia in the form of ODA loans, grant aid, and technical cooperation. Below is JICA's experience with flood control measures from that cooperation:

1. Inundation Protection Plan	Ministry of Equipment	1997 LA	JPY 3.13 billion	ODA Loan
2. Greater Tunis Flood Control Project	Ministry of Equipment	2007 LA	JPY 6.808 billion	ODA Loan
3. Development Study on the Integrated Basin Management and Flood Control Project in the Mejerda River	Ministry of Agriculture	2006-2008		Technical Cooperation (Development Study)

3) The World Bank

The World Bank provided reconstruction assistance after the flood in the city of Sfax in 1982. The World Bank contributed USD 25 million of USD 48 million project funds. The project consisted of repairing dikes, improving drainage channels and helping restore neighboring municipalities.

(2) Water Use

From as early as the 1950s, foreign donors have assisted Tunisia in implementing many projects dealing with water use. These projects involved dam construction, irrigation improvement, drinkable water supply and water and wastewater facilities. International organizations, community development finance institutions, regional cooperation groups and many other agencies provided assistance. Bilateral aid also occurred. Below are prominent donors:

1) World Bank
2) German Agency for International Cooperation (GIZ)
3) French Development Agency (AFD)
4) African Development Bank (ADB)
5) European Fund (European Bank (SEI), Neighborhood Investment Facility (NIF))
6) Arab Fund for Economic and Social Development (FADES)
7) JICA
8) Other: Abu Dhabi Fund, Kuwait Fund for Arab Economic Development

According to OECD data, 20,000 hectares of Tunisian soil turn to desert every year. Countering desertification is a major policy issue in Tunisia, and many projects are being implemented.

3.3.2 Connection between This Project and Japanese Policy on Aid for Tunisia

According to policy on aid for Tunisia released by the Japanese Ministry of Foreign Affairs (MOFA), as one of the priority areas to be addressed on a extremely high priority, support for the development and management of water resources are listed.

The vote in the TICAD Yokohama Declaration held in 2008 at Yokohama was related to issues of environment and climate change in particular, it emphasized the importance of water and recognized need to encourage the sustainable use of water resources. This Study is intended to function as part of the feasibility study of the ODA loan project seeking to control, at minimum, flood damage in the Mejerda River Basin, and it conforms to Japanese aid policy.

3.4 Development Plans for Mejerda River Zone D2

Two privately funded development projects, Tunis Bay Finance Harbour and Tunis Telecom City, have been planned for the coastal region around the mouth of the Mejerda River. Both development projects will be implemented in Zone D2, the target area of the Mejerda River Flood Control Plan. The locations for these projects are shown in the figure above. This plan is expected to reduce flood damage for those projects.

3.5 Project Necessity and Positioning

3.5.1 Project Necessity

This Project aims to mitigate flood damage in Zone D2, the lower Mejerda River Basin, and area that has suffered serious flood damage. Structurally, the Project will improve the river, establish a retarding basin through flow diversion and improve bridges that traverse the river and other river infrastructure; non-structurally, it will update the hydrological observation system at the Ministry of Agriculture (SYCOHTRAC), improve the operability of diversion management systems at dams, enhance flood response capacity at the Ministry of Agriculture and improve community disaster management. All things considered, this Project will contribute to the economic and industrial development of the Republic of Tunisia, and it is highly necessary.

3.5.2 Project Positioning

(1) History

Based on the request of the Government of Tunisia, JICA implemented the Development Study on the Integrated Basin Management and Flood Control Project in the Mejerda River (hereinafter referred to as “Development Study”) from 2006 to 2008 and devised a master plan for integrated basin water management. Afterward, a feasibility study on the actualization of integrated basin management and the flood control project on the Mejerda River was implemented from September 2012 through March 2013 in Zone D2, the lowest part of the basin in which the economic effects would be the strongest according to the master plan, via the Preparatory Study on Integrated Basin Management and Flood Control Project in the Mejerda River and this Study.

(2) Disaster Management and Flood Control Policy in Tunisia and the Mejerda River Basin

Mitigating flood damage was a crucial element of the 11th five-year plan (2007-2011). Flood control measures were also a crucial element in the 12th five-year plan (2010-2014); the plan demands more effort toward basin management, dam preservation, urban flood protection, erosion control measures, fertile soil preservation and productivity improvement.

(3) Connection Between This Project and Japanese Policy on Aid for Tunisia

This Study is intended to function as part of the feasibility study of the ODA loan project seeking to control, at minimum, flood damage in the Mejerda River Basin, and it conforms to both Japanese aid policy and the Yokohama Declaration.

(4) Overview of Related Projects

The Urban Hydrology Department of the Ministry of Equipment is implementing the North and West Tunis Flood Protection Study from May 16, 2012 through June 15, 2013 on the strength of grant aid from the African Development Bank. The scopes of the ministry's study and this Study overlap in the Mejerda River Basin downstream of Tobias Barrage, but coordination between the Ministry of Agriculture and the Ministry of Equipment will prevent overlapping in the project implementation stage.

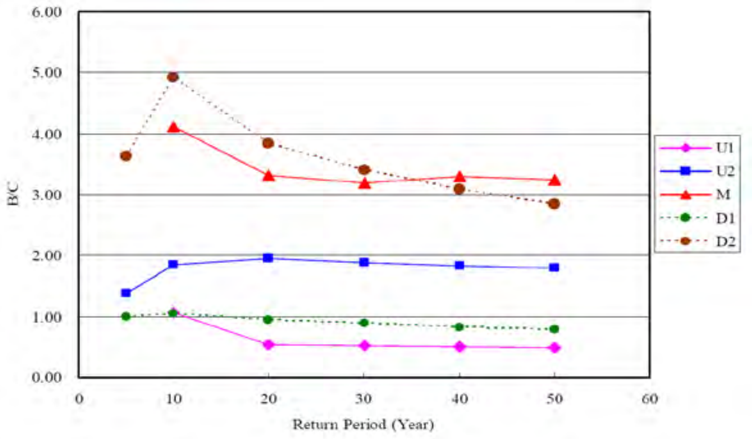
Chapter 4. River Improvement Plan

4.1 Basic Conditions for River Improvement Plan

4.1.1 Flood Safety Levels

The target safety level for flood controls will follow the Master Plan, taking the safety level with the highest benefit-cost ratio.

The figure below gives the relation between benefit-cost ratio and flood safety levels for each section. From the following study results, the target flood safety level for Section D2 is a 10th-year flood.

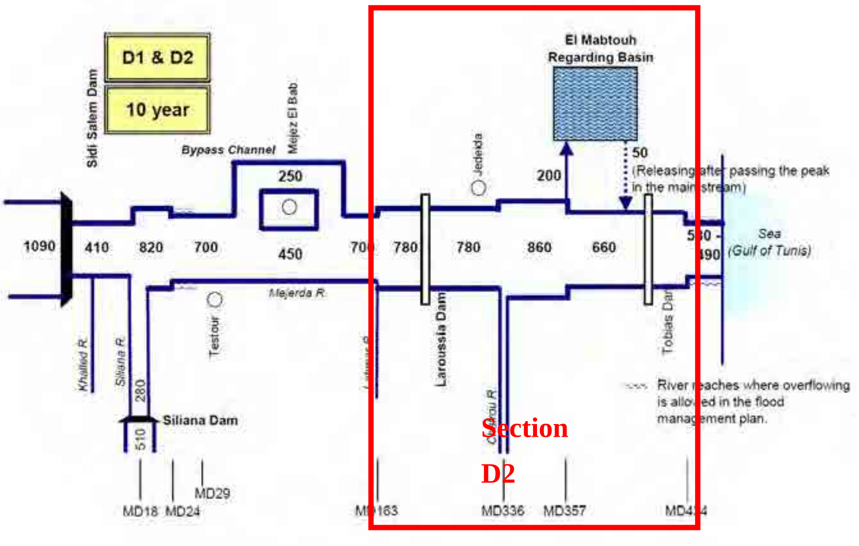


Source: Master Plan Study

Figure 4-1: Main site hydrograph

4.1.2 Structural measures

The 10th-year probability in the design flood discharge distribution in the Master Plan is outlined below. For Section D2, this means structural measures based on a combination of river channel improvements and a retarding basin. Structural measures for this study are also a combination of river channel improvements and retarding basins.



Source: Master Plan Study

Figure 4-2: Design discharge distribution in Master Plan

4.2 Base Discharge

Discharge calculations have been addressed separately in the Mejerda River Basin Climate Change Impact Assessment in Tunisia (hereinafter the MRCCIA). This study will use the discharge calculations studied in the MRCCIA to determine base discharge and design flood discharge.

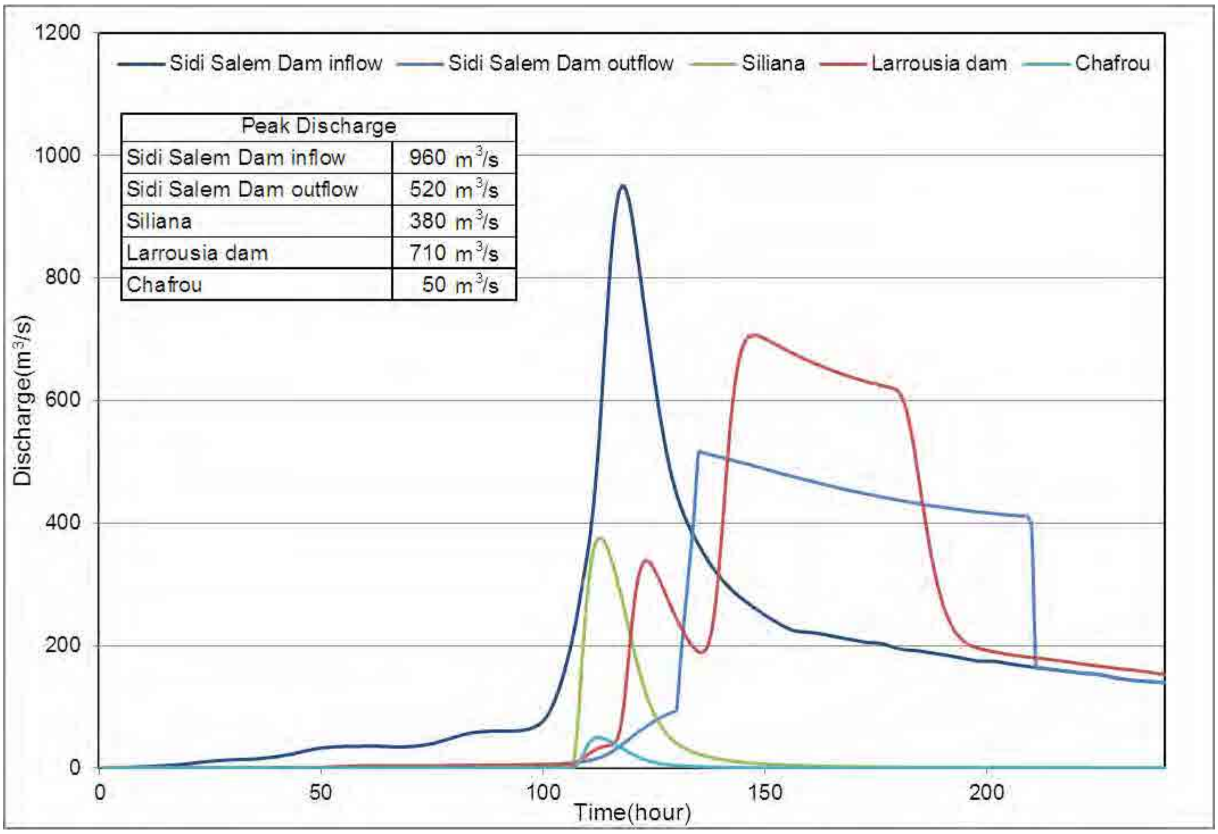
The hydrograph and base discharge distribution for the major sites as obtained in the MRCCIA is given below. Peak discharge for the Laroussia Dam site is 710 m3 per second, but we have set base discharge in Section D2, the target section of this study, to 800 m3 per second to account for residual basin runoff downstream of Laroussia Dam (including Chafrou River runoff).

In addition, water discharge amount at Sidi Salem Dam is calculated by assuming the operation below;

・Flood Control Start Level: 116.0m

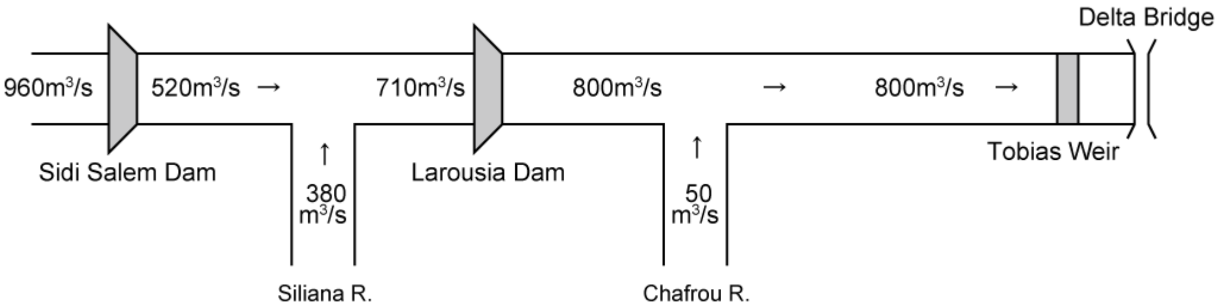
・The gate will be opened at 0.9m/h and fully opened after 6 hours.

・When water level is low, the gate will fully be opened steady basis until 115.0m, full capacity.



Source: JICA Survey Team

Figure 4-3: Main site hydrograph



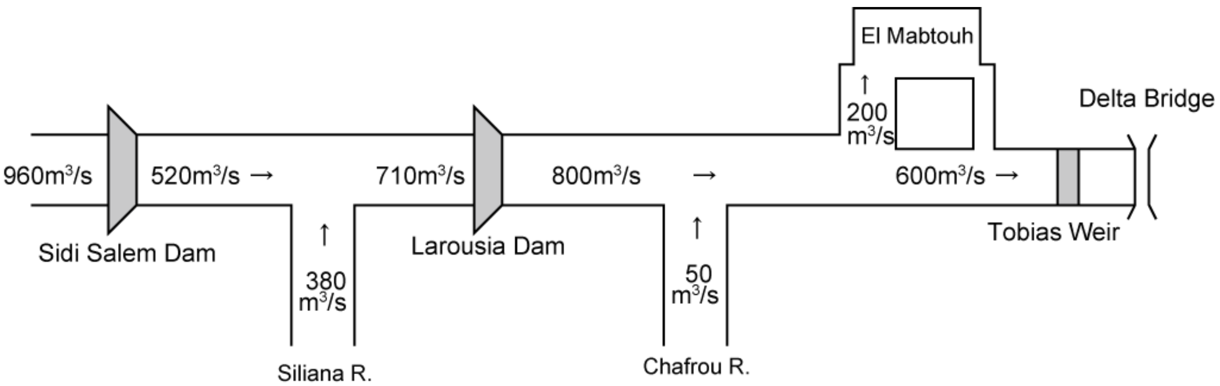
Source: JICA Survey Team

Figure 4-4: Base Discharge Distribution Chart

4.3 Design Flood Discharge

Design discharge is a combination of river improvements and the El Mabtouh basin based on the Master Plan.

Given the capacity of the El Mabtouh wetlands, the amount distributed into the El Mabtouh basin was set to 200 m^3 per second according to the Master Plan. Below is a distribution hydrograph for design flood discharge.



Source: JICA Survey Team

Figure 4-5: Design Flood Discharge Distribution Hydrograph

4.4 Channel Characteristics

4.4.1 Channel Cross Sections and Longitudinal Sections

This is a study of Zone D2, the section from the Laroussia Dam to the downstream end of the Mejerda River. The survey data used to understand channel characteristics for this study are found in the table below.

Table 4-1: Channel Survey Data

	Section	Measurement Year	Source	Length	Cross Sections
1	Mejerda River (from Laroussia Dam to lower Mejerda River basin)	2007	Master Plan	64.974 km	199

Source: JICA Survey Team

4.4.2 Understanding the Runoff Analysis

We will understand the current flow capacity of the study section. The conditions for hydrological calculation used to determine flow capacity are given in the table below.

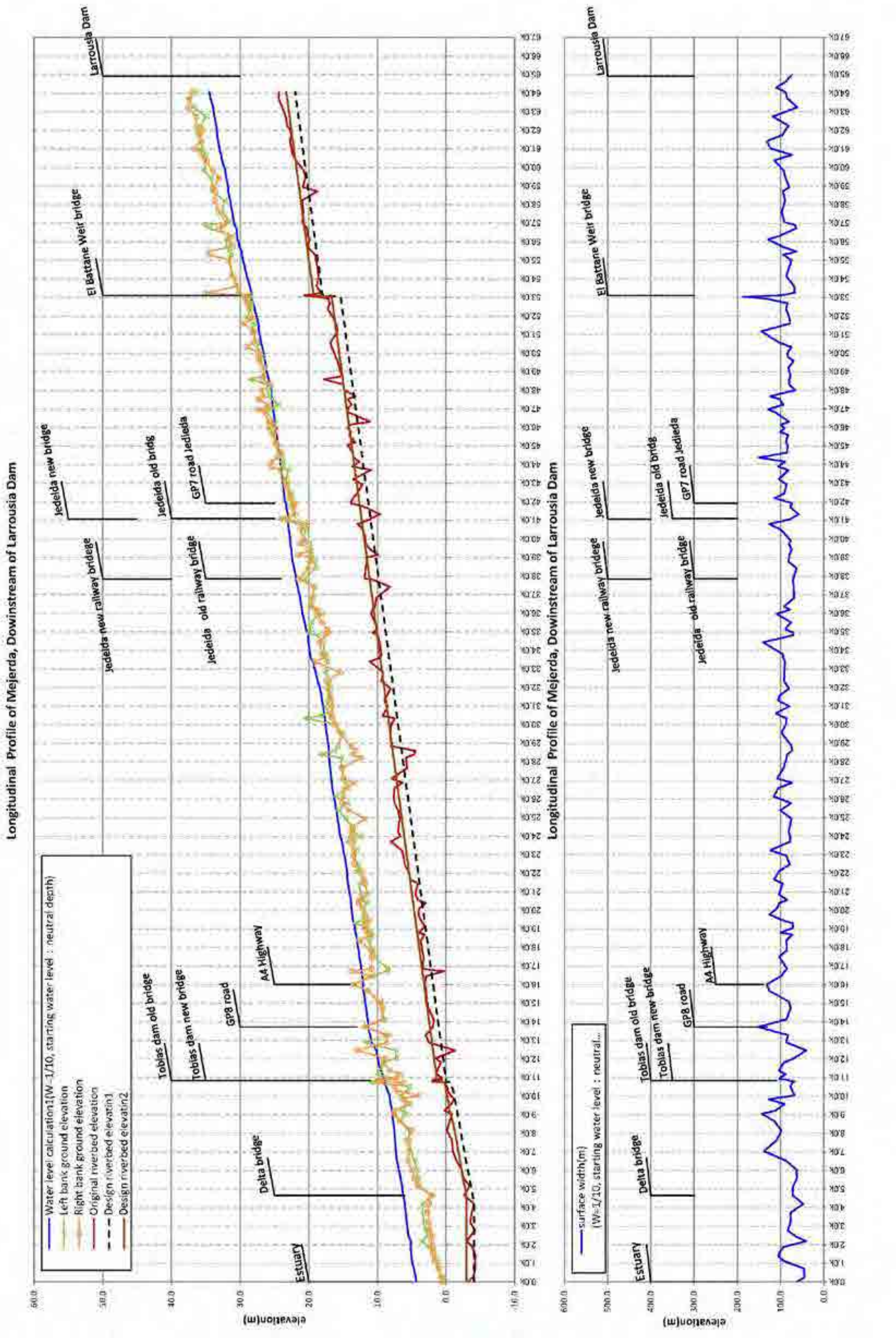
Table 4-2: Conditions for Hydrological Calculations

No	Item	Condition
1	Calculation Method	Non-uniform flow
2	Section	Mejerda River (Downstream end to Laroussia Dam, 64.974 km)
3	Channel	Channel in current state (as of 2007)
4	Flow	W = 6 cases of 20-120% for 10th-year (800 m^3/sec.)
5	Roughness Coefficient	0.04
6	Starting Water Level	0.77 m
7	Structures	11 bridge piles

Table 4-3: Structure Specifications

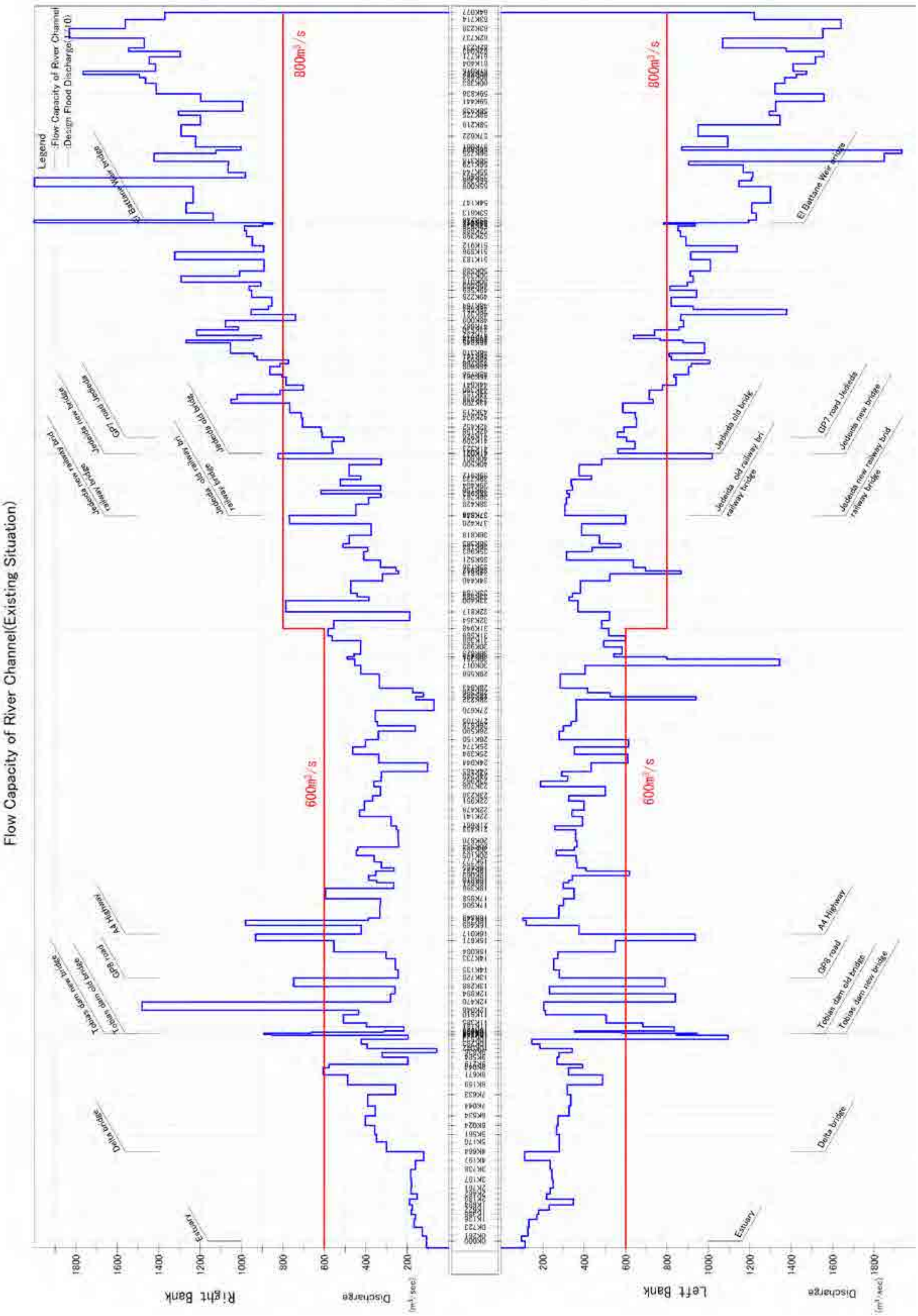
No	Structure Name	Distance from Mouth	Pier Width	Piers
1	El Battane Weir bridge	53.111	2.24	17
2	GP7 road Jedieda	41.926	1.2	4
3	Jedeida old bridge	41.091	6	3
4	Jedeida new bridge	41.071	1	2
5	A4 Highway	16.017	2	5
6	GP8 road	13.728	0.6	10
7	Tobias dam old bridge	10.836	0.5	4
8	Tobias dam new bridge	10.828	0.8	2
9	Delta bridge	4.664	0.37	3
10	Jedeida old railway bridge	37.848	2.278	1
11	Jedeida new railway bridge	37.834	1.013	2

Source: JICA Survey Team



Source: JICA Survey Team

Figure 4-6: Current Longitudinal Sections



Source: JICA Survey Team

Figure 4-7: Water Level Calculations from Current Longitudinal Sections and Cross Sections

4.5 Channel planning

4.5.1 River Improvements for Mejerda River

We compared proposals for banking and excavating the design channel. The basic approaches for both proposals are as given below.

・**Case 1: Banking**

We considered an embankment with a 1:2 gradient and crown width of four meters in order to account for an allowance height of one meter for banking the current cross section.

・**Case 2: Excavating**

Aims were made to keep the channel embedded to the extent possible, including allowance height. Allowance height was one meter, gradient was 1:2 and riverbed gradient was 1/2,600, based on the current deepest riverbed point. In order to leave the water route, a lower limit of two to five meters above the design riverbed was set for excavation.

The lower limit for excavation was set at 2.0 meters from the design riverbed in the lower basin and at 5.0+ meters from the design riverbed in the upper basin with a straight line connecting the two serving as the excavation lower limit line since the channel in the upper basin is deeper and has considerable flow capacity compared to that in the lower basin. The gradient of this excavation lower limit line is roughly 1/2,000.

・**Case 3: Banking and Excavating**

Based on the excavating plan, this proposal would perform banking with the allowance height of one meter to reduce the amount of excavation.

Case 1 produces water levels 1.5 to 3.3 meters (average: 2.4 meters) higher than Case 2. In terms of land required, Case 3 is preferable. Cases 1 and 3 would require either removing or relocating the old Jedeida Bridge, and historical structure.

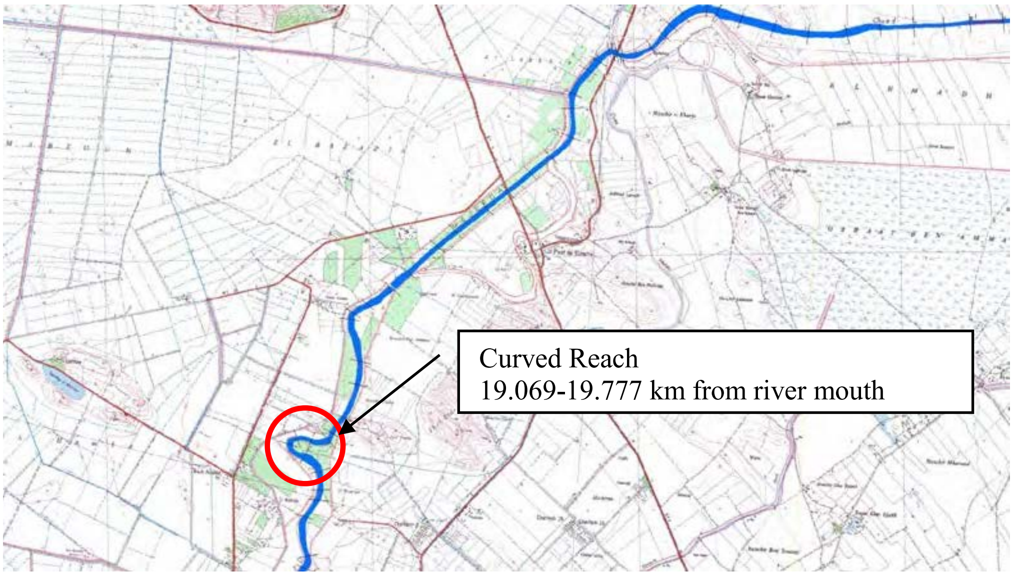
Item	Case 1: Banking	Case 2: Excavating	Case 3: Banking and Excavating
Land Required	Large	Large	Small
Impact on historical structures	Old Jedeida bridge must be removed or relocated	None	Old Jedeida bridge must be removed or relocated
Impact on internal waters	Large	Almost none	Some
Fitness for larger floods brought on by climate change	Low	High	Mid

Upon consulting with the Tunisia side based on the above results, they confirmed that we would adopt Case 2 and excavate due to the impact on historical structures and internal waters.

4.5.2 Cutoff for Curved Reach

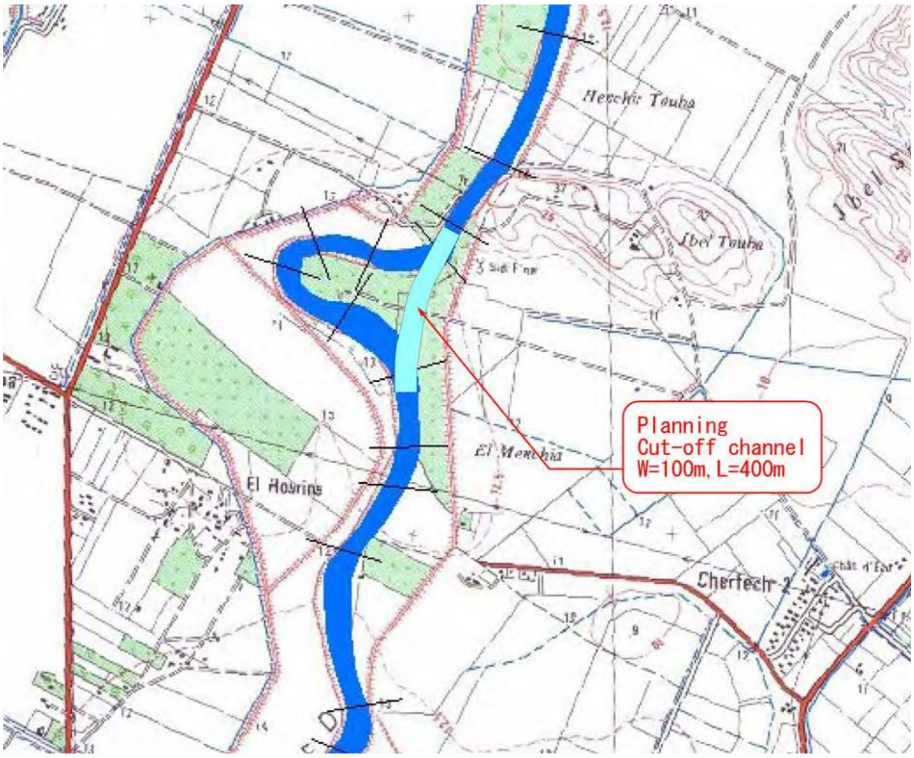
We have proposed a cutoff for the curved reach shown in the figure below using general improvement methods. This cutoff is meant to stabilize the channel and reduce upstream channel water levels.

The Tunisia side wanted to improve the river without making a cutoff, voicing concerns that it would increase land acquisition costs, cause unexpected bank erosion and other unwanted environmental impacts. Thus, this study will not make a cutoff at the curved reach.



Source: JICA Survey Team

Figure 4-8: Location of Curved Reach



Source: JICA Survey Team

Figure 4-9: Proposed cutoff channel

4.5.3 Chafrou River

Tributaries will be used as backwater dikes based on the Master Plan.

As the runoff analysis methods are the same for the main river and tributaries in this study, we will perform the hydrological calculations with the following two boundary conditions, setting both water levels as the comprehensive high water levels.

・Boundary condition 1

Tributary flow: design flood discharge of 50 m^3 per second

Main river water level: 16.9 meters during tributary flood discharge

・Boundary condition 2

Tributary flow: 1 m^3 per second flow during main river design flood discharge

Main river water level: Main River design high water level: 19.8 meters

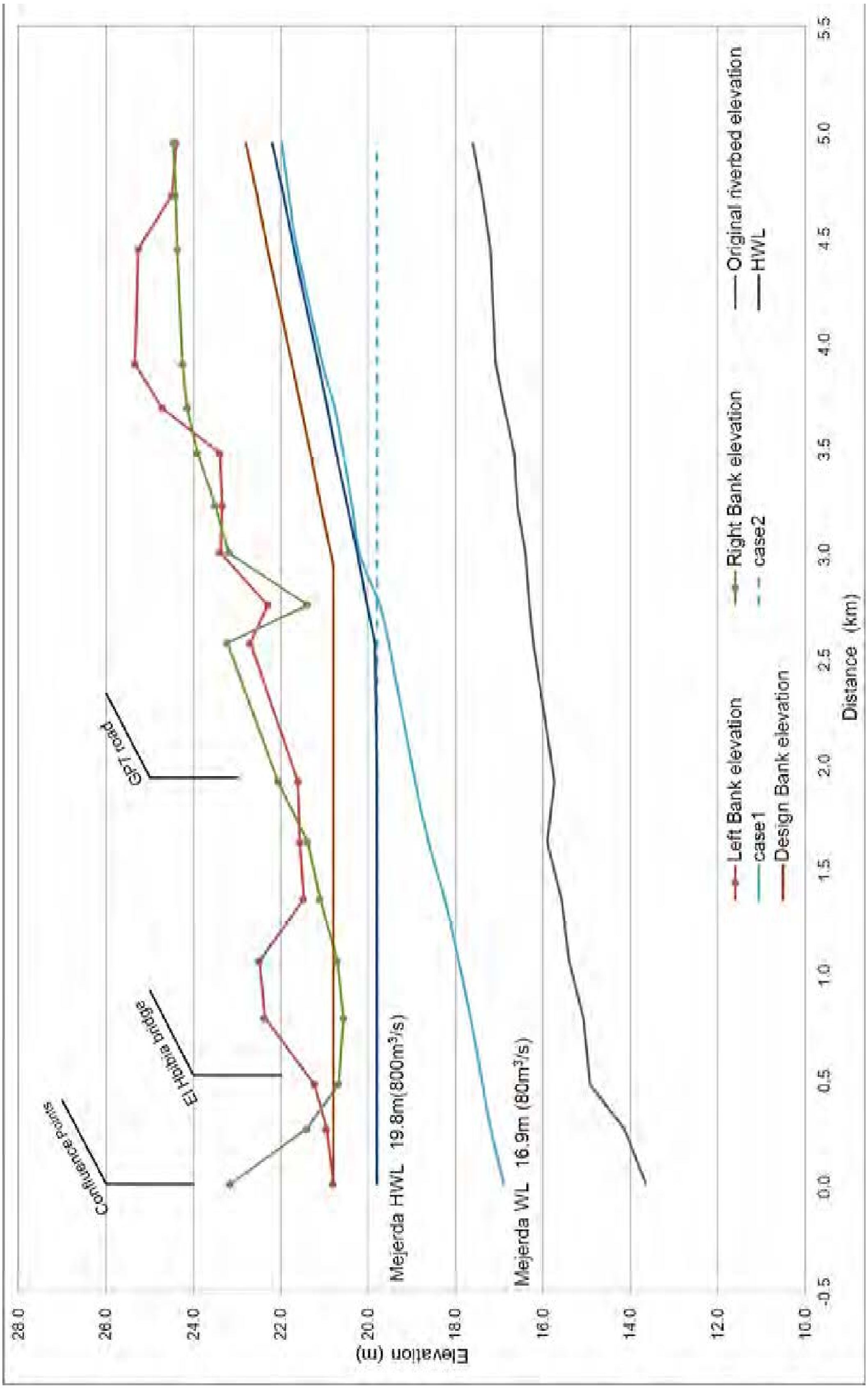
Conditions for hydrological calculations are given in the table below:

Table 4-4: Conditions for Hydrological Calculations

No	Item	Condition
1	Calculation Method	Non-uniform flow
2	Section	Chafrou River (from confluence with Mejerda River to 4.944 km)
3	Channel	Channel in current state (as of 2011)
4	Flow	W = 10th-year discharge (50 m^3/sec.) and 1 m^3/sec.
5	Roughness Coefficient	0.04
6	Starting Water Level	Condition 2: Mejerda River high water level: 19.8 m Condition 1: Mejerda River water level with Chafrou River at peak: 16.9 m

The non-uniform flow calculations and set designs for the back dike are given on the following page. The right bank of the Chafrou River must be raised slightly.

The Chafrou River is the only major tributary in Section D2, but it contains sluice gates and/or sluiceways in nine places. These sluice gates and sluiceways will be improved.



Source: JICA Survey Team

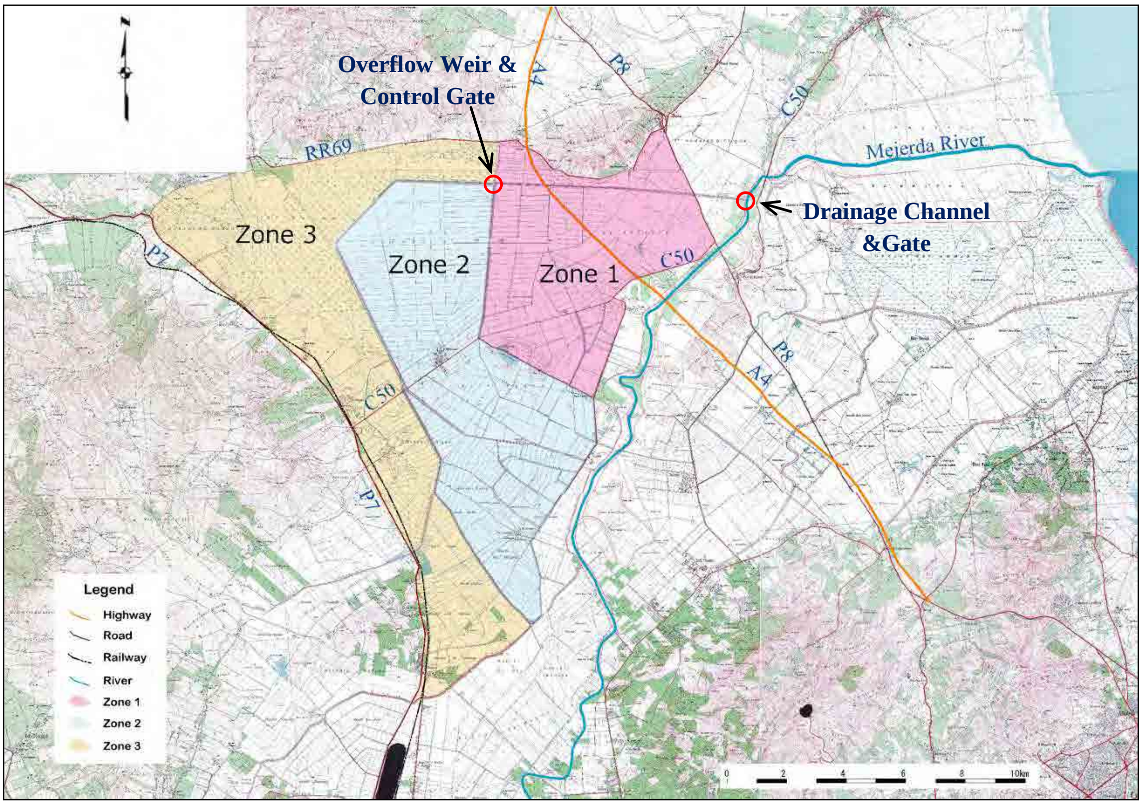
Figure 4-10: Non-uniform flow calculations for Chafrou River and back dike settings

4.6 El Mabtouh Retarding Basin Plan

The El Mabtouh wetlands are the proposed site for a retarding basin in the Master Plan. This area offers topographic advantages for a retarding basin: it is lower than the surrounding area, with hills stretching from the north to northwest.

In terms of its function as a retarding basin, the existing El Mabtouh wetlands are divided into three zones as given below. The usage rules for each zone are given below.

・Flooding order: Zone 3 → Zone 2 → Zone 1
・Drainage order: Zone 1 → Zone 2 → Zone 3



Source: JICA Survey Team

Figure 4-11: Existing zones in El Mabtouh plains

As for zone divisions and operational rules for the El Mabtouh wetlands retarding basin, we kept with the current way in accordance with Tunisia side requests.

We plan to make effective use of the current channel route to have water branch out from the Mejerda River at the 32.35-kilometer point and discharge into the Mejerda River at the 11.81-kilometer point.

Following the Master Plan, water will discharge into the retarding basin at 200 m^3 per second. Water at that point in the Mejerda River will be slowed from its rate of 800 m^3 per second down to 600 using a side weir for the diversion facilities.

We will repair the existing channel to the retarding basin after diversion, but plan to reconstruct a new inflow channel from the diversion point to the same existing channel.

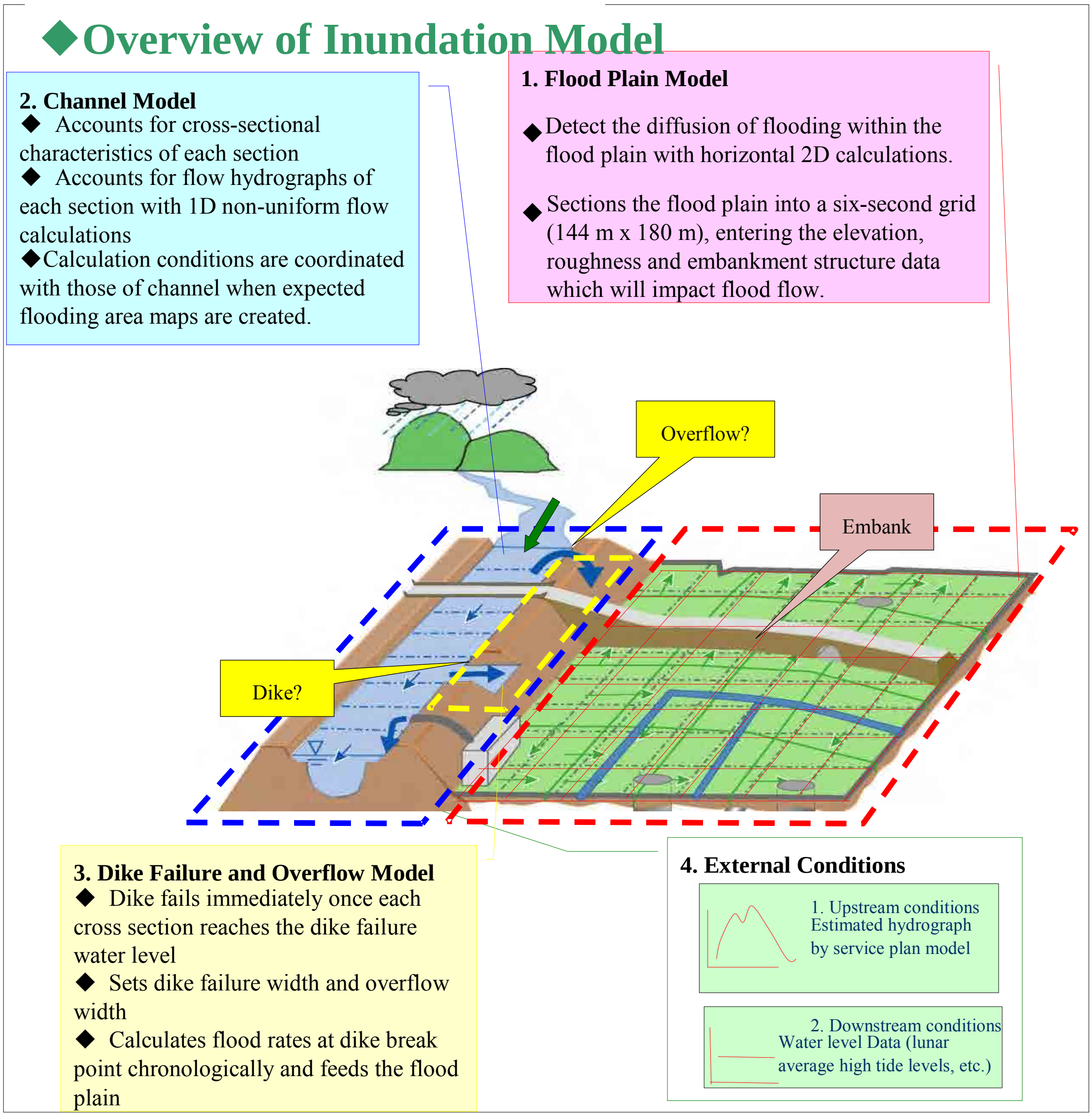
Considering the ground elevation, riverbed height of the existing channel and design high water level, we took the overflow depth at design flow of the fixed inlet overflow weir to be 1.0 meter. In this condition, the width of the overflow weir will be equal to or greater than 150m.

4.7 Inundation Analysis

4.7.1 Inundation Model

Generally, one of the three models “1D Unsteady Flow Model”, “Pond Model” or “Horizontal 2D Unsteady Flow Model” is used for inundation analysis.

Given the gentle gradient of the flood plain and need to account for internal waters, we will use a horizontal two-dimensional unsteady flow model in this study.



Source: JICA Survey Team

Figure 4-12: Overview of Horizontal Two-Dimensional Unsteady Flow Model

4.7.2 Creating the Inundation Model

(1) Creating Topographic Data

1) Revising topographic data

We modeled topographic data for the flood plain using a two-dimensional model. The topographic data used to create the flood plain model is given in the table below.

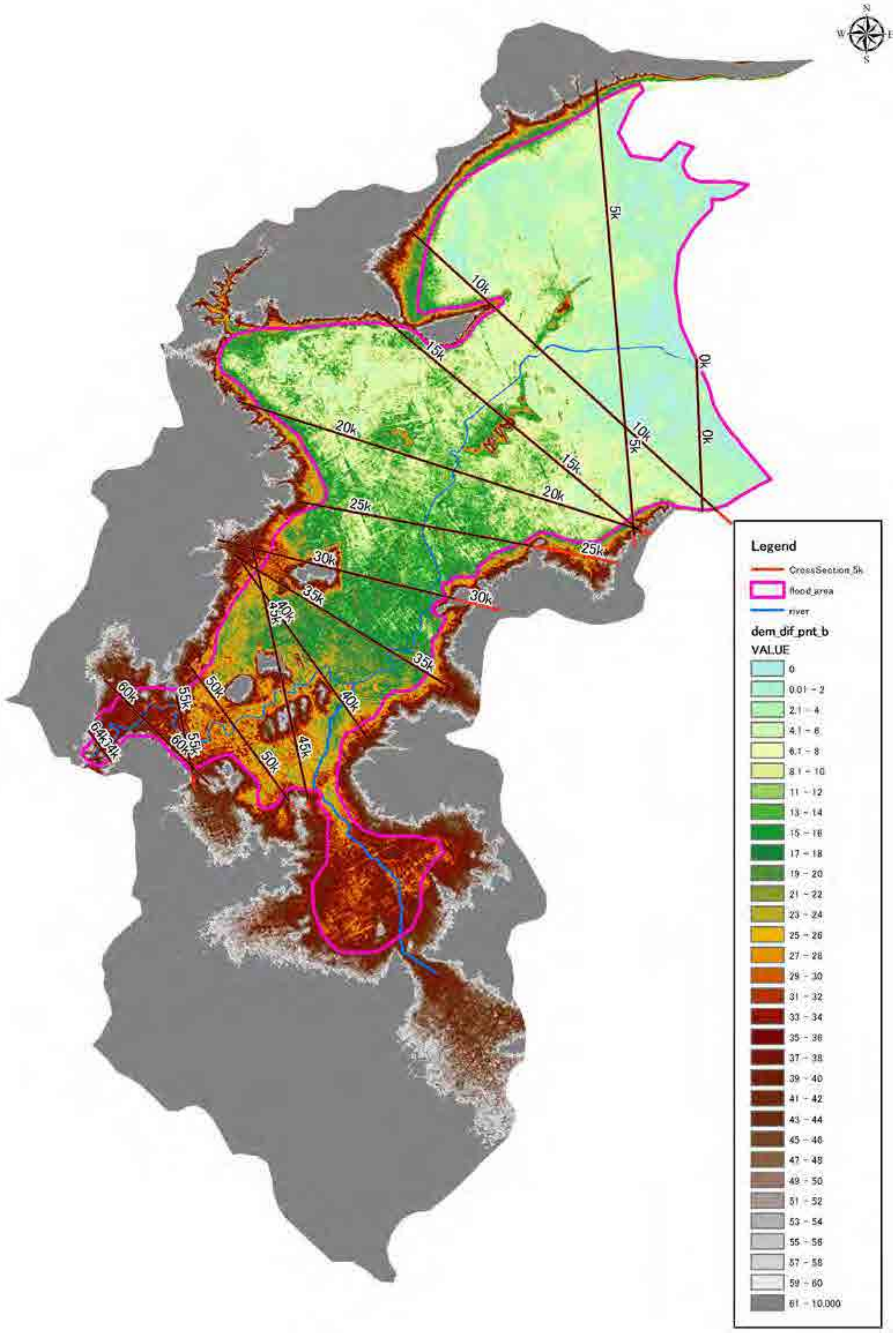
We revised topographic data based off three-dimensional full global data (Aster Gdem with 30-meter mesh). We calculated ground height differentials using endpoint elevations extracted from a 1:25,000 scale topographic map and riverbank endpoints extracted from cross sections of the Mejerda River.

Table 4-5: Topographic Data

	Data Type	Data	Pixel Interval	Creating Agency	Use
1	Full 3D global data (Aster Gdem)	Mesh	1 second (approx. 30 m)	METI/NASA	Terrain model creation
2	1 topographic map, 1:25,000 scale	2,544 endpoints	See figure	MARHP (Ministry of Agriculture, Water Resources and Fisheries), 2007	Terrain model revision
3	400-meter sections of Mejerda River from Laroussia Dam to lower Mejerda River	345 endpoints	See figure	M/P	Terrain model revision

2) Setting the Expected Inundation Area

The expected inundation area will be set based on the topographic data created. As shown in the figure below, we have created a cross section of the flood plain and set an expected inundation area based on the current dike height.



Source: JICA Survey Team

Figure 4-13: Flood plain cross section creation points

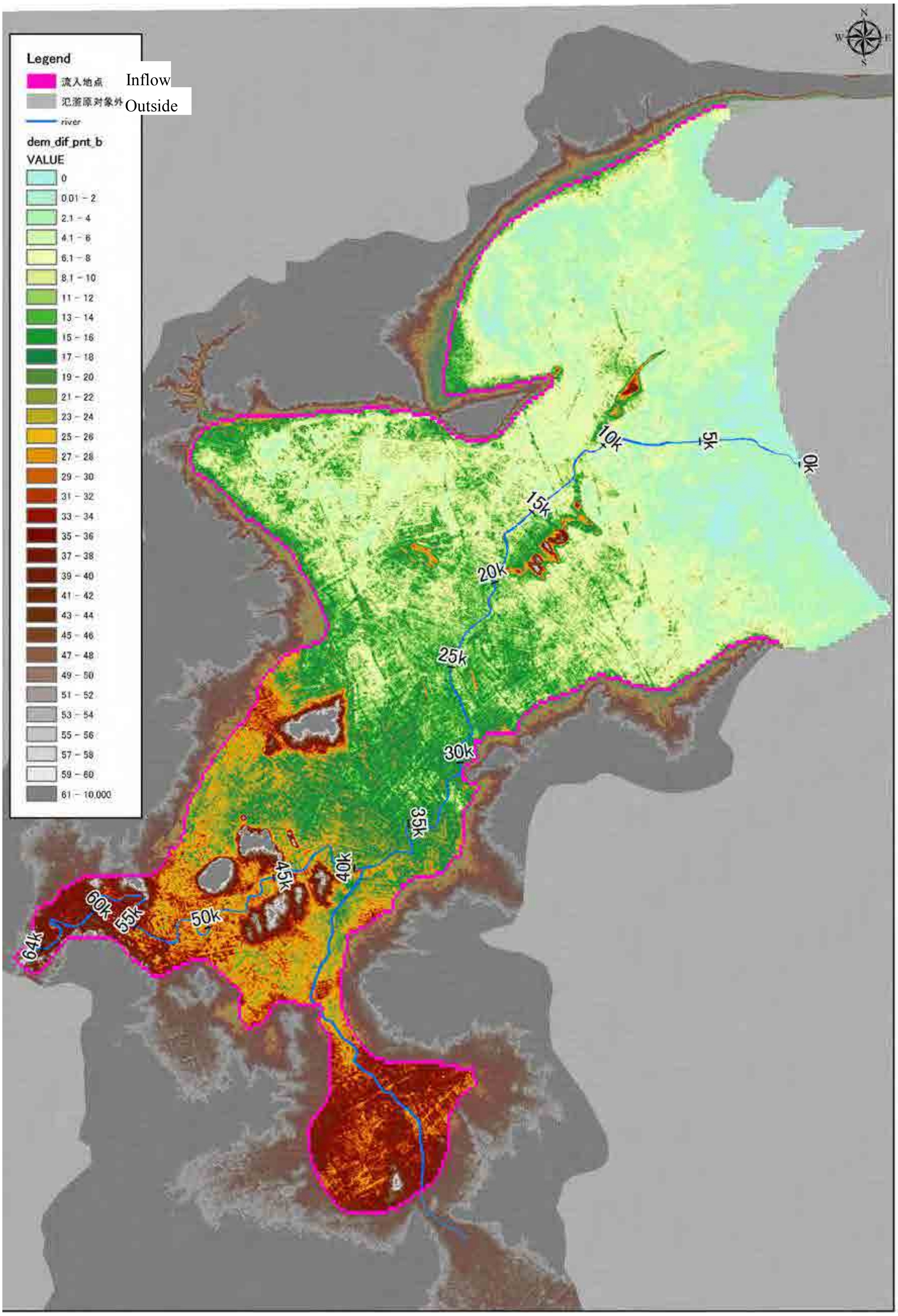
3) Creating grid ground height

As the Aster Gdem ground height data to be used is made on a one-second grid (24- by 30-meter), we went with a six-second (144- by 180-meter) configuration for the modeling grid.

Below is a ground height mesh grid which averages revised full three-dimensional global data (Aster Gdem, 30-meter mesh) into a 150-meter mesh.

Table 4-6: Mesh grid creation specifications

	Item	Description	
1	Original topographic data	Full 3D global data (Aster Gdem)	Size: 1 second (24 x 30 m)
2	Calculation grid	150 m mesh	Size: 6 seconds (144 x 80 m)
3	Grid squares	Total: 325 x 425 = 138,125 Flood plain: 27,858	
4	Coordinate system	Geodetic survey system: French Clarke 1880 (ClarkelGN) Projection: UTM Zone 32	



Source: JICA Survey Team

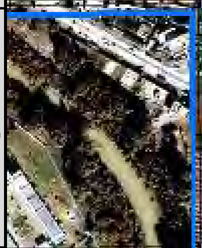
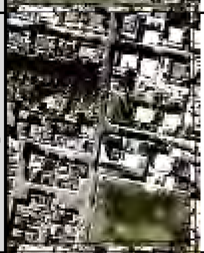
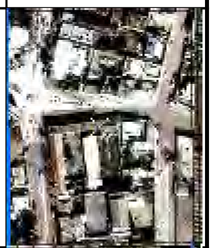
Figure 4-14: Average grid ground height

(2) Flood plain roughness

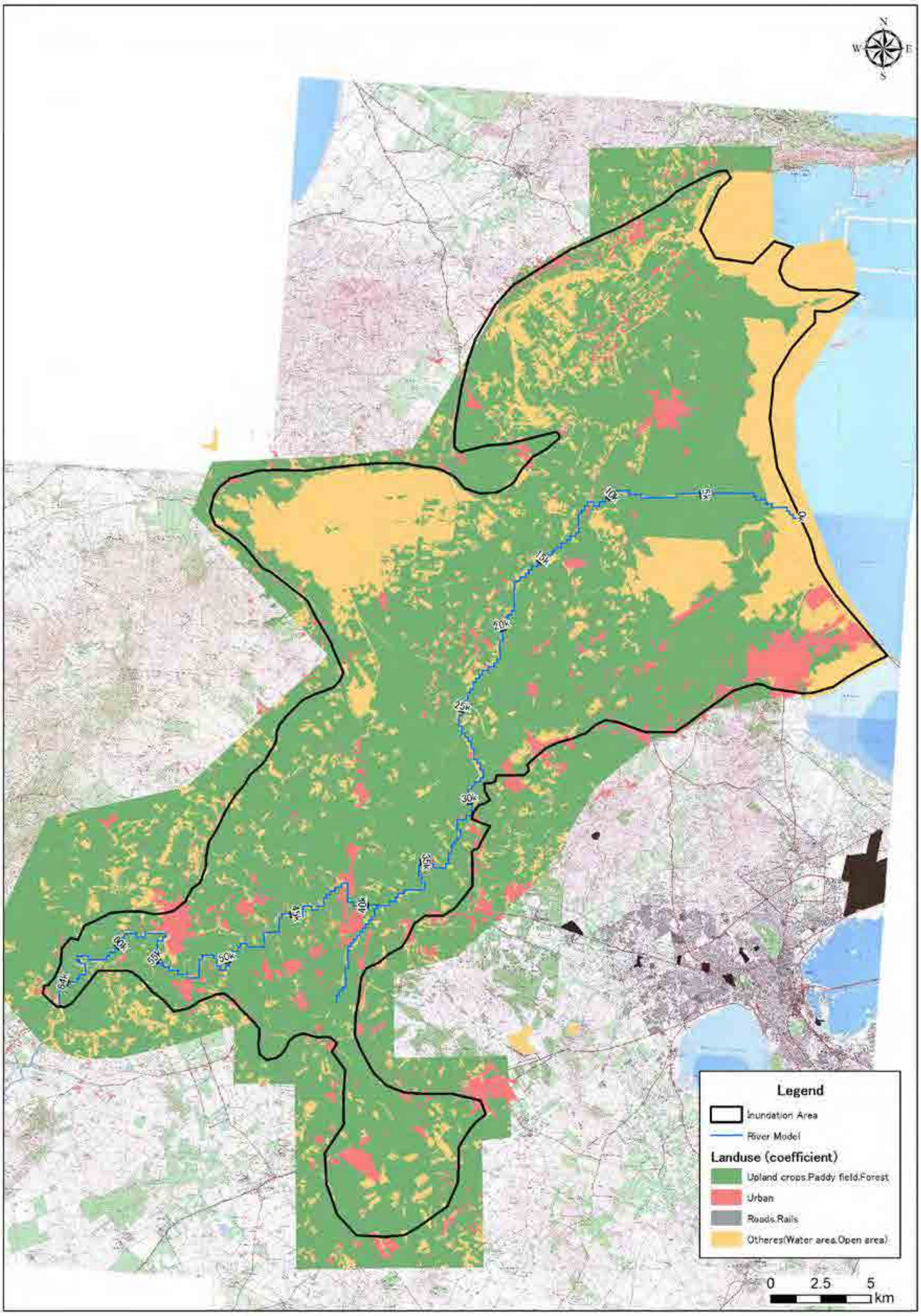
We solved for the roughness coefficient for the flood plain by taking the weighted average of area by land usage for the base roughness coefficient of non-buildings. We will also use the composite equivalence roughness coefficient given below, derived from a building density based on building occupancy rates.

In setting the roughness coefficient, we reclassified the land use map shown below into four classes. For building occupancy rates, we set the grid share by eye based on satellite imagery.

Table 4-7: Legend for setting building occupancy rates

10%			60%		
20%			70%		
30%			80%		
40%			90%		
50%					

Source: JICA Survey Team



Source: JICA Survey Team

Figure 4-15: Land use partition map (roughness coefficient settings)

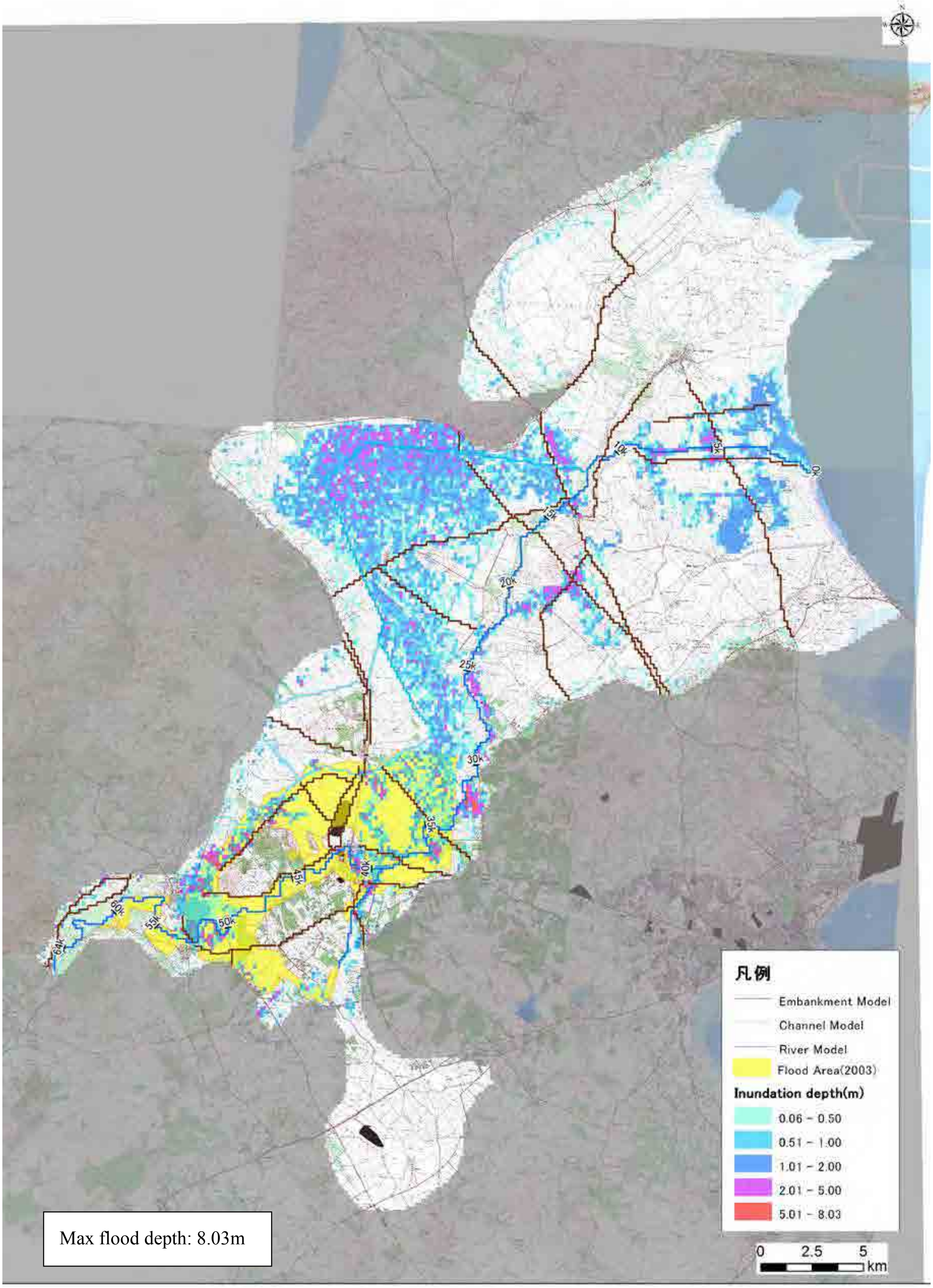
4.7.3 Reproducing flooding from 2003

Using the created inundation model, we made calculations to reproduce flooding from 2003, the largest flooding year in recent years.

A map overlaying actual flooding and inundation analysis results is given on the next page. Only results from around El Bataan to around Jedeida have been sorted for actual flooding data. A look at the calculations shows that the flow route of inundation overlaps with actual flooding. We were able to reproduce the current state of the middle course and lower sections not sorted which currently discharge into the El Mabtouh wetlands along the channel and accumulate in the retarding basin. We thus chose to use this model for the inundation model. The conditions for inundation analysis calculations are given in the table below.

Item		Condition	Notes
External Conditions	Design Scale	2003 results	
	Flow Hydrograph	Taken from Slouguia observatory	
	Rainfall Waveform	2003 flood	
	Rainfall	Taken from 3 observatories downstream of Laroussia Dam	
Channel Model	Calculation Method	One-dimensional non-uniform flow	
	Scope	Lower Mejerda River to Larrousia Dam, 64.974 km	
	Calculation Pitch	Roughly 300-500 m	
	Section to be Used	2007 measurement cross section Current channel	
	Downstream Water Level	T.P.0.77m (fixed)	
	Roughness Coefficient	0.040	
Inundation Model	Flooding Format	Diffused	
	Calculation Method	Two-dimensional non-uniform flow	
	Ground Height	Created from full 3D global data	
	Roughness Coefficient	Farmland: 0.060, Roads: 0.047, Other: 0.050	
	Building Occupancy Rate	Created from aerial photography	

<table>
<tr><td rowspan="5"></td><td colspan="2">Inundation Conditions</td><td>Determined with one-dimensional non-uniform flow
Inundation coefficient: set accounting for side overflow from official sources
Inundation height: current dike height or design dike height
Inundation sections: all</td><td></td></tr>
<tr><td colspan="2">Dike Failure Conditions</td><td>None set</td><td></td></tr>
<tr><td rowspan="3">Effective Rainfall</td><td>f1</td><td>Paddy fields: 0, Mountains: 0.15, Fields: 0.25, Towns: 0.6-0.9</td><td rowspan="3"></td></tr>
<tr><td>Rsa</td><td>Paddy fields: 50, Mountains: 300, Fields: 150, Towns: 55</td></tr>
<tr><td>fsa</td><td>Paddy fields: 1, Mountains: 0.6, Fields: 1, Towns: 1</td></tr>
</table>



Source: JICA Survey Team

Figure 4-16: Calculated reproduction of 2003 flooding

4.7.4 Comparison of Internal Water Inundation of Banking and Excavating Proposal Sections

Due to its insufficient flow capacity, channel excavation, widening, banking or other means are necessary to ensure the needed sectional area for the Mejerda River. As all sections of the Mejerda River are embedded, banking could incite internal water damage.

Therefore, we verified validity of the channel plan by comparing flooding conditions of cross sections from the banking proposal (Case 1 above) and embanking proposal (Case 2 above).

Conditions for inundation analysis calculations are given in the table below.

Table 4-8: Calculation Conditions

Item		Condition	Notes
External Conditions	Design Scale	5 times 10th-year discharge	
	Flow Hydrograph	None	
	Rainfall Waveform	Centralized	
	Rainfall	5 times 10th-year discharge: 526.1 mm/48hrs.	W=1/10 105.2 mm/48hrs.
Channel Conditions	Scope	Lower Mejerda River to Larrousia Dam, 64.974 km	
	Calculation Pitch	Roughly 300-500 m	
	Section to be Used	2007 measurement cross section Case 1: Banking proposal section, Case 2: Excavating proposal section	
	Downstream Water Level	T.P.0.77m (fixed)	
	Roughness Coefficient	0.040	
Flood Plain Conditions	Flooding Format	Diffused	
	Calculation Method	Two-dimensional non-uniform flow	
	Flood Plain Model	1. Ground height: Avg. ground height from aforementioned 150 m grid 2. Roughness Coefficient: Crop fields and wastelands – uniformly 0.06 3. Building occupancy rate: 40-80%, cities only	
	Channels	Not considered	
	Inundation Conditions	Considered return from flood plains for embedded channels, ignoring inundation from channel	
	Effective Rainfall	f1: Crop fields, 0.15 Rsa: 0	Flood plain assumed to be damp

Comparisons results are given on the next page. The colored portions in the comparison results are the range in which banking would incite internal water damage. Water depth is given by color. The results verify that installing a two-meter bank with the banking proposal would incite internal water damage. Therefore, it has once again become clear that the expense to account for internal water would be greater with the banking proposal than it would be with the excavation proposal.

4.7.5 Inundation Analysis Results by Probability Scale

We ran inundation analyses by rainfall probability for both the current channel and design channel.

The conditions for inundation analysis calculations are as given below.

Table 4-9: Calculation Conditions

Item		Condition	Notes
External Conditions	Design Scale	Current channel: 1/5 1/10 1/20 1/50 1/100 Design channel: 1/10 1/20 1/50 1/100	
	Flow Hydrograph	Flow by probability scale at Laroussia Dam	
	Rainfall Waveform	Centralized	
	Rainfall	From 3 observatories downstream of Laroussia Dam, by probability scale	
Channel Model	Calculation Method	One-dimensional non-uniform flow	
	Scope	Lower Mejerda River to Larrousia Dam, 64.974 km	
	Calculation Pitch	Roughly 300-500 m	
	Section to be Used	2007 measurement cross section Current channel and design channel	
	Downstream Water Level	T.P.0.77m (fixed)	
	Roughness Coefficient	0.040	
Inundation Model	Flooding Format	Diffused	
	Calculation Method	Two-dimensional non-uniform flow	
	Ground Height	Created from 360˚ 3D global data	
	Roughness Coefficient	Farmland: 0.060, Roads: 0.047, Other: 0.050	
	Building Occupancy Rate	Created from aerial photography	
	Inundation Conditions	Determined with one-dimensional non-uniform flow	

			Inundation coefficient: set accounting for side overflow from official sources Inundation height: current dike height and design dike height Inundation sections: all	
	Dike Failure Conditions		None set	
	Effective Rainfall	**f1**	Paddy fields: 0, Mountains: 0.15, Fields: 0.25, Towns: 0.6-0.9	
		Rsa	Paddy fields: 50, Mountains: 300, Fields: 150, Towns: 55	
		fsa	Paddy fields: 1, Mountains: 0.6, Fields: 1, Towns: 1	

Based on the flood analysis result, it is needless to say that flooding due to external water by 1/10 years which is the design size at design river channel was not occurred and flooding until 1/20 years was not occurred under the assumption of no washout even if the water level is risen up to dike levee crown. Also, flooding area is limited by diversion to retarding basin at 1/50 and 1/100 years. Meantime, immersion depth is increased at unimproved section in downstream but flooding area remained virtually unchanged.

Chapter 5. Facility Design and Non-Structural Measures

5.1 Channel Improvement and River Structures

5.1.1. Overview of Channel Improvement and River Structures

The Mejerda River improvement area under this Project covers 60.4 kilometers from the Kalaat Landaous Bridge 4.6 kilometers upstream of the river mouth to the Laroussia Dam. In addition, the El Mabtouh Retarding Basin and the Chafrou River, which is greatly affected by backflow from the Mejerda River, will be improved and sluice gates rebuilt as part of improvements to Mejerda River. Below is an overview of plans to improve channels and river structures:

Overview of Channel Improvement and River Structures

Item	Description
Mejerda River Channel Improvement	Laroussia Dam to Retarding Basin Diversion Weir (Q=800 m^3/s): 32.6 km Diversion Weir to Retarding Basin to Kalaat Landaous Bridge (Q=600 m^3/s): 27.8 km
Mejerda River Sluiceway Improvement	Nine places along the banks of the Mejerda River
Chafrou River Channel Improvement	Backwater area from Mejerda River confluence to about 2 km upstream
El Mabtouh Retarding Basin Improvement	One diversion weir to retarding basin, 23.0 km of diversion channel, one overflow weir, one control gate, one side ditch gate, 7.5 km of drainage channel, one drainage gate

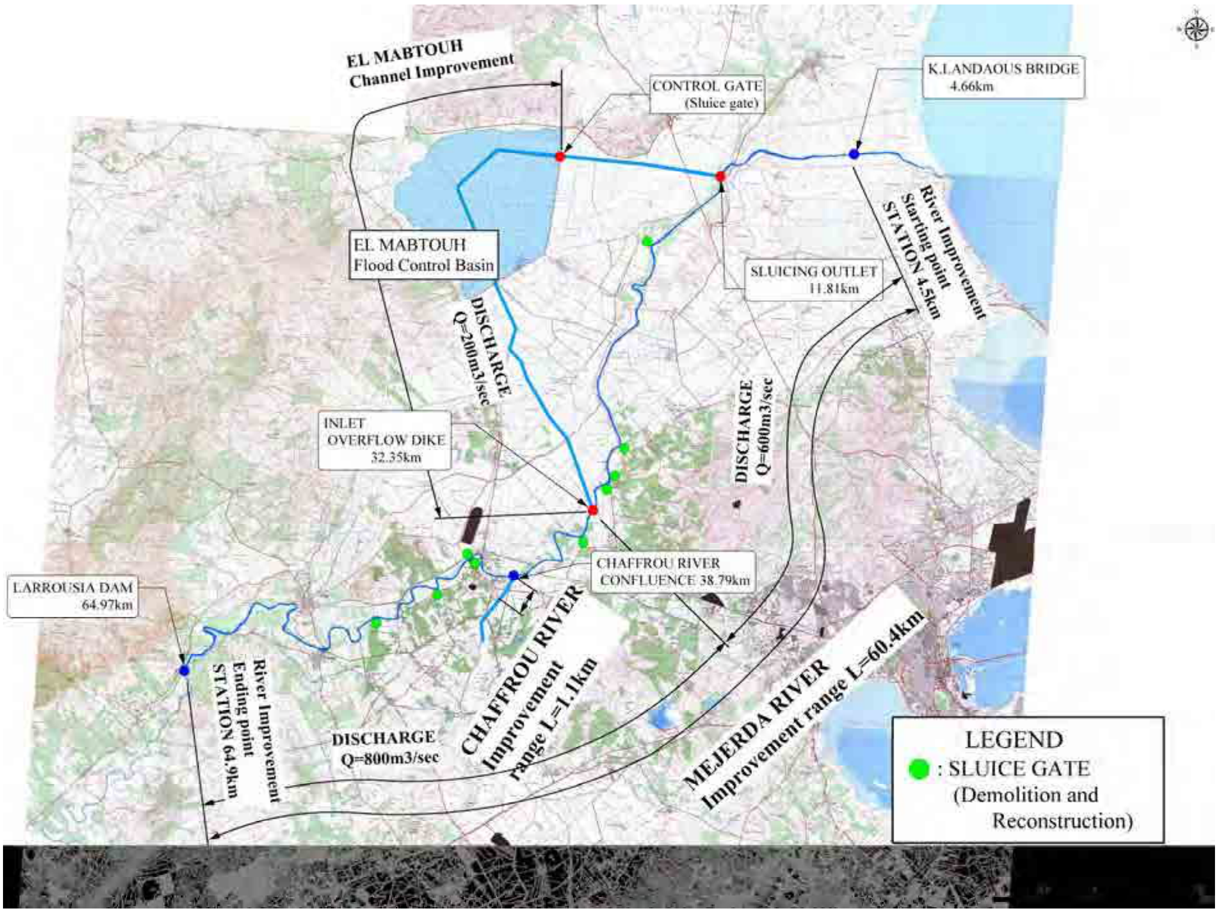


Figure 5.1-1: Improvement Area Map

5.1.2. Channel Cross Section Specifications

Below are specifications for design cross sections of the channels of the Mejerda and Chafrou Rivers. The specifications for the Chafrou, a tributary to the Mejerda, are the same as those for the Mejerda because the Chafrou is affected by backflow from the Mejerda.

1) Crown width: 4.0 m
2) Freeboard: 1.0 m
3) Slope gradient: 20% (1:2)
4) Berm: A three-meter berm is built into banks higher than five meters.

5.1.3. Protective Dike/Groundsill Work

(1) Protective Dike Work

Flow velocity after the channel improvement done under this Project generally stays between one and two meters per second, and revegetation following construction should provide resistance to erosion. And, protective dikes will not be built, with the exception of following zones, because this Project generally calls for channels excavated and because new cross sections can provide a width of 20 to 30 meters:

1) in crowded residential areas at risk due to erosion on the outer banks of curved reaches of the river channel.
2) upstream and downstream of highways, railways and other critical river-crossing structures (bridges, etc.).
3) upstream and downstream of confluences with tributaries, major drainage and diversion structures.

Below are proposals for two models for protective dikes in this Study with focus on procuring materials from the target region:

(i) Concrete Frame/Mortar Masonry

This model will be used in a 10-meter range upstream and downstream of major bridges and on curved reaches on whose outer banks sit crowded residential areas such as Jedeida.

(ii) Gabion/Riprap

This model will be placed around structures or on the edges of concrete protective dikes to prevent local scouring on the edges of concrete or earthen dikes.

(2) Groundsill Work

The river improvement does not call for sweeping changes to the current grade of the riverbed. For this reason, groundsill work to stabilize the riverbed will not be done. However, groundsill work will be done via gabion wire mesh because inconsistent water currents could very likely cause scouring at confluences with tributaries and major channels, at the inlet of the diversion channel from the El Mabtouh Retarding Basin, at outlets and around bridge abutments and piers.

5.1.4. Sluiceways

Existing sluiceways will need to be removed and rebuilt because of channel expansion. New sluiceways will also need to be built in sections with dikes.

Nine sluiceways will be rebuilt as determined by field surveys.

5.2 Retarding Basin

5.2.1. Overview of Retarding Basin Plans

The El Mabtouh Wetlands will be used as a retarding basin. Water will be diverted from the river at 200 m^3 per second and stored temporarily at El Mabtouh.

Taking into consideration the customs of the plan area, water will be stored first in Zone 3 and then in Zone 2. Hydraulic analysis shows that Zones 2 and 3 have adequate water storage capacity; water will not be stored in Zone 1.

5.2.2. Fixed Overflow Weir

The fixed overflow weir for diverting water from the Mejerda River will allow a flow rate of 200 m^3 per second and overflow depth of one meter and be 160 meters wide at the crown.

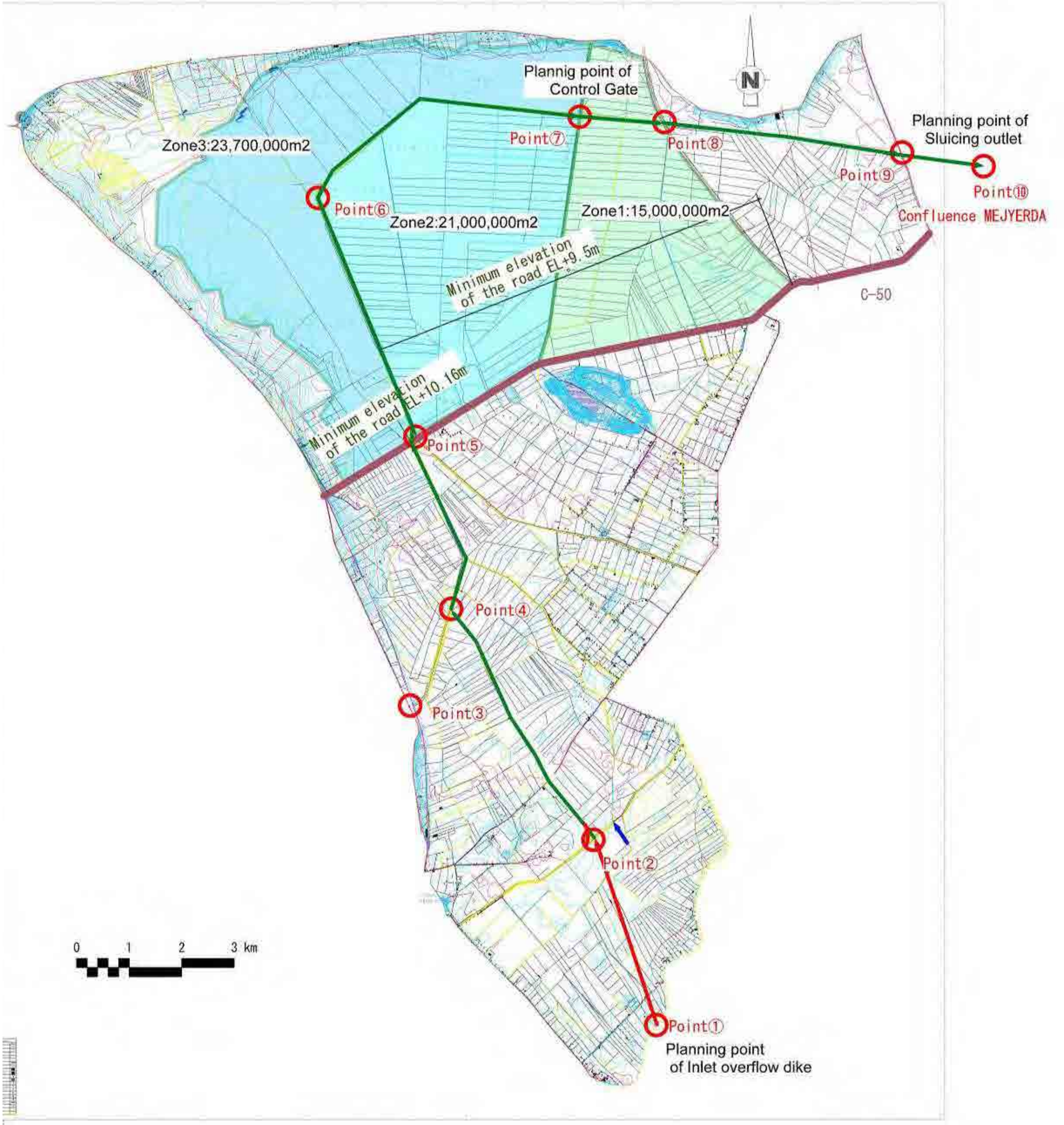


Figure 5.2-1: El Mabtouh Flood Control Basin Schematic Drawing

5.2.3. Diversion Channel/Drainage Channel

(1) Longitudinal Section Design

Table 5.2-1 and Figure 5.2-2 show the longitudinal design of the diversion channel and drainage channel.

Table 5.2-1: Longitudinal Design of Diversion Channel and Drainage Channel

Survey Cross-section No.	Point No.	Distance (km)	Supplementary distance (km)	Grand elevation (m)	Plan Batter	Bed EL of Intake Outlet channel (m)	Note
-	Point①			17.0	1/2000	14.89	Mejerda 32.354km(MD353)
		3.73					
1	Point②		3.73	13.5			
-	(Point③)			11.6			
		5.32					
22	Point④		9.05	10.4			
		3.53					
36	Point⑤		12.58	8.4			
		4.53					
54	Point⑥		17.11	7.6		6.34	
		6.08					Diverion Channel
78	Point⑦		23.19	7.1	≒1/7000		
		1.77					Drainage Channel
85	Point⑧		24.96	7.2		5.21	Expressway cross point
		3.99					
101	Point⑨		28.95	7.1	≒1/4000		
		1.58					
-	Point⑩		30.53	-		3.82	Mejerda 11.810km(MD411)

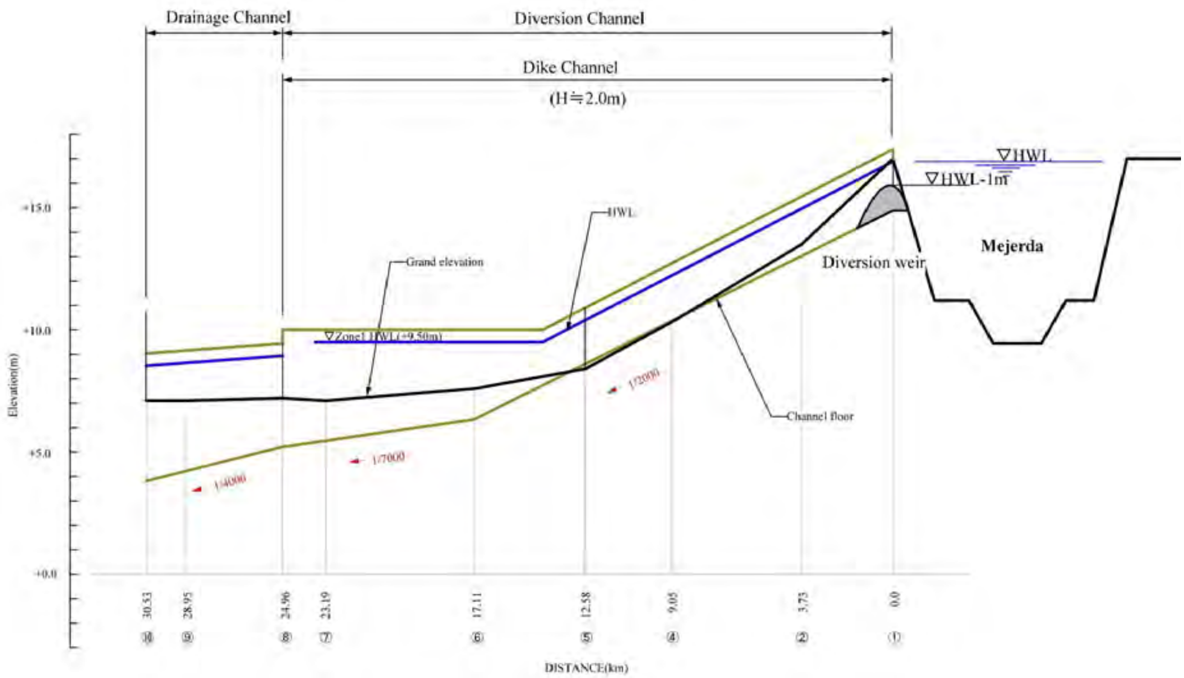


Figure 5.2-2: Longitudinal Section of Diversion Channel and Drainage Channel

(2) Basic Designs

(1) Section between Points (1) and (6)

1) This channel will have a slope of 1/2000 in line with the geographical slope and existing longitudinal slope of the channel, a depth of two meters and a width of 100 meters.

2) The section between Points (1) and (2) will be newly built. The existing channel between Points (2) and (6) will be widened.

(2) Section between Points (6) and (7)

1) A dike will be built at one side at the downstream of Point (6). An overflow dike (crest elevation NGT +9.0 m) will be newly built in the area upstream of Point (7) to enable storage water overflowed into Zone 2 when filled with water to capacity. Typical cross-section is shown on Figure 5.2.8.

2) Flow rate adjusting facilities will be built at the Point (7) with sluice gate to adjust the flow rate. Specifically, double 2mB x 2mH sluice gates will be used by regulating gate divergence to adjust the flow rate.

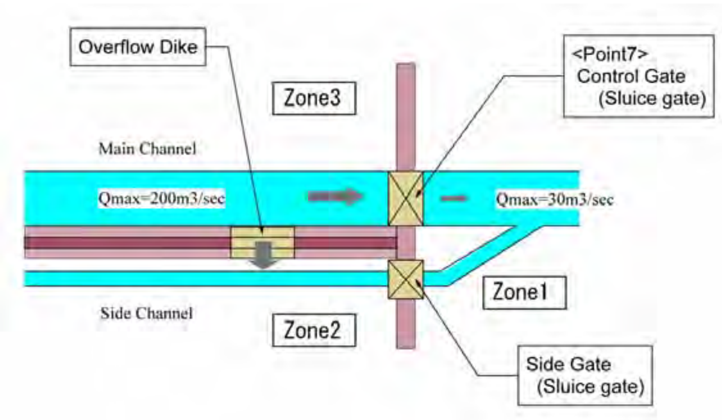


Figure 5.2-3: Explanatory Drawing of Facility Layout near Point (7)

3) A side channel gate will be installed so that the inside water channel of Zone 2 joins main drainage channel at the downstream of Point (7).

(3) Section between Points (7) and (10)

1) The channel shall not be improved to keep discharge equivalent to the downflow capacity of the existing channel (about 30 m^3 per second).

2) Currently, there is a gate-type sluice gate at the confluence with the main river. However, since it is broken, it will be removed and a new gate will be built.

5.2.4. Auxiliary Structures in Channel

(1) Overflow Weir

1) An overflow weir will be built in the area just upstream of flow rate adjusting facility, Point (7). The overflow weir height will be NGT +9.5m and the overflow rate 30 m^3/s. (cf. Figures 5.2-11 and 5.2-12 typical structural drawings)

(2) Flow Rate Control Gate of Discharge Channel

1) At Point (7), a flow control gate will be installed on the Zone 3 side and a side channel gate will be installed on the Zone 2 side. A sluice gate type of facility will be adopted for flow control.
2) At Zone 3 side, diversion flow will be controlled by double 2mB x 2mH sluice gates with adjustment of gate divergence, and the discharge will be done up to allowable diversion flow rate of 30 m^3 per second. Typical structural drawings are shown on Figure 5.2-5.
3) In the side channel of Zone 2 side, a single sluice gate will be installed. Typical structural drawings are shown on Figure XXX.

(3) Drainage Gate

Double 3mB x 3mH gates will be installed so that the new cross section has the same width and downflow capacity as that of the existing channel. Figure 5.2-9 is a typical structural drawing of the new gates.

5.2.5. Flood Control Basin

A retarding basin control building will be built at the location of the diversion channel control gate. Water level indicators will also be installed upstream and downstream of said gate and on the upstream side of the side channel. Water levels will be confirmed by verifying water level indicators to control the apertures of gates. Currently, there is a control building to control the existing gate, but it has fallen into disrepair, so it will be demolished and rebuilt.

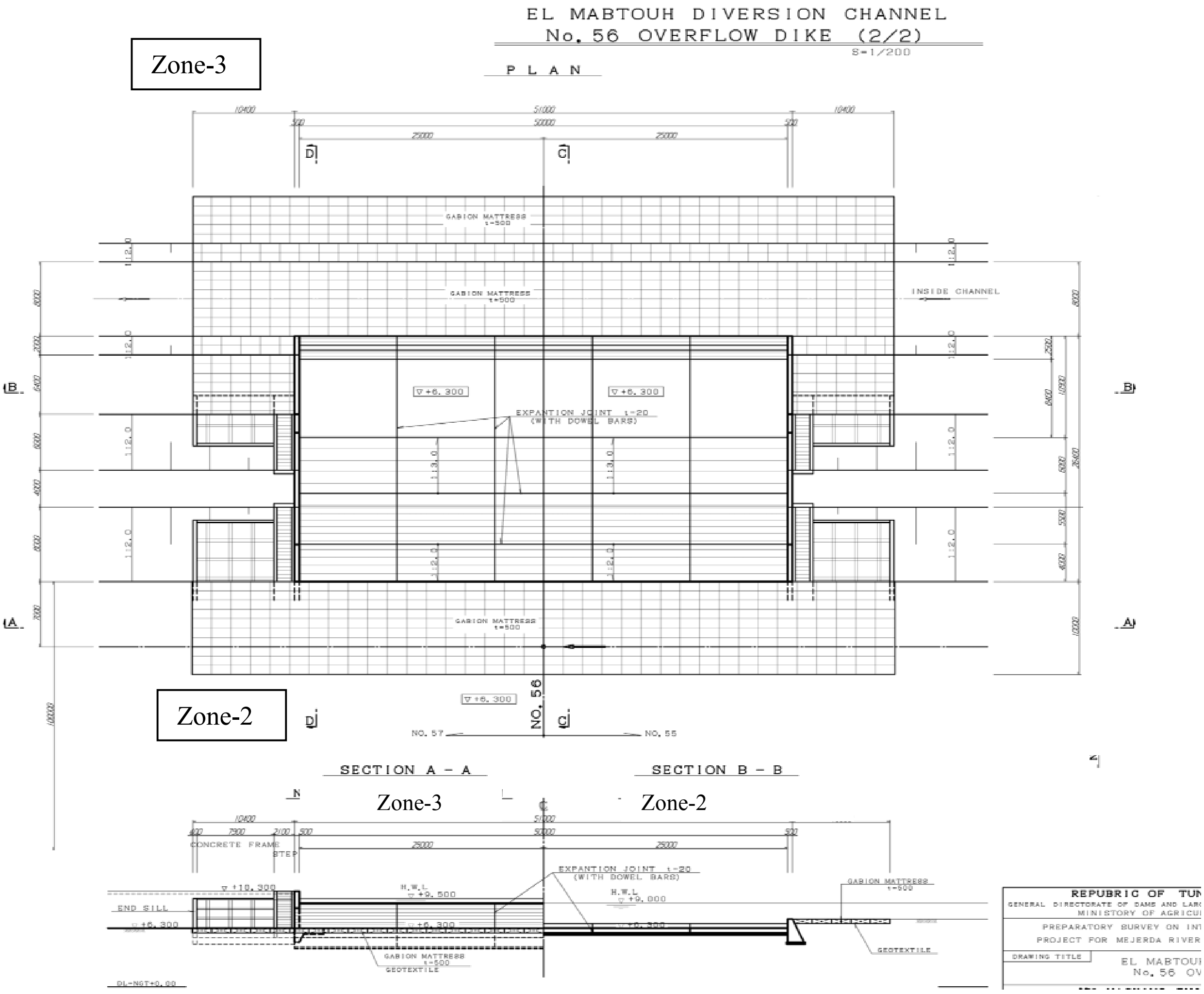


Figure 5.2-4: Typical Drawing of Overflow Dike

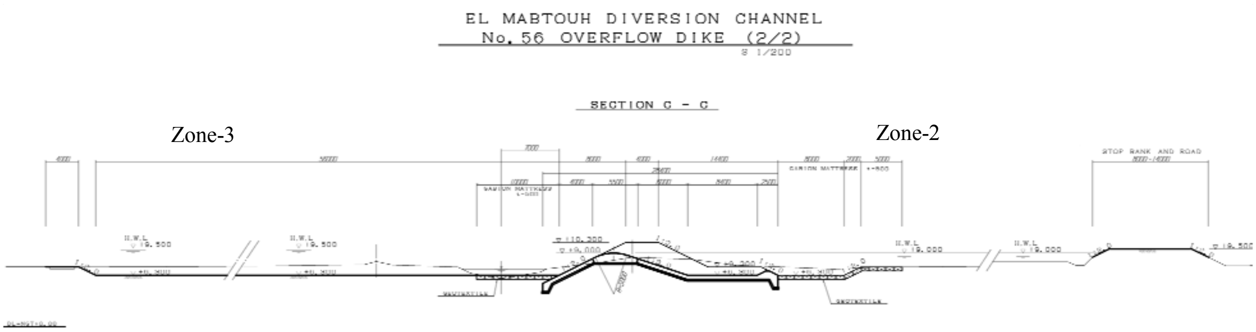


Figure 5.2-5: Typical Drawing of Overflow Dike

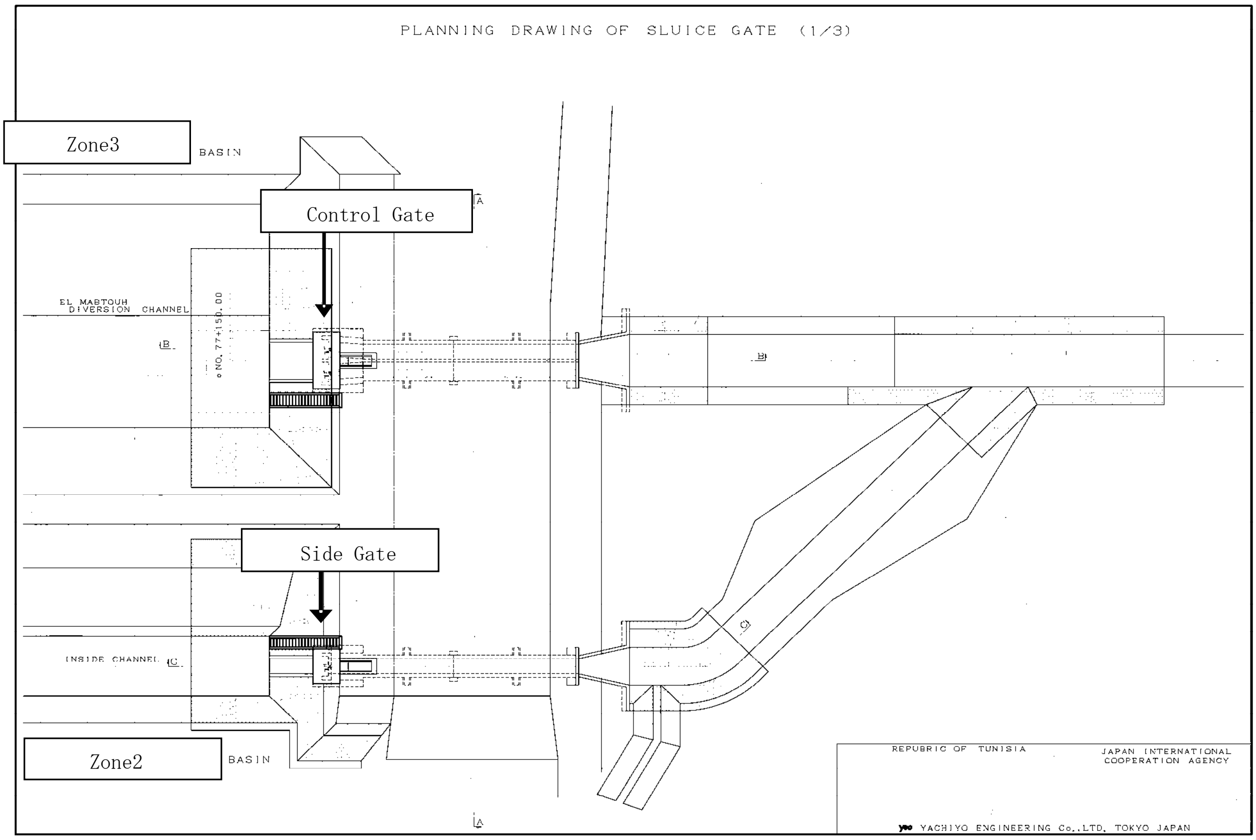


Figure 5.2-6: Typical Drawing of Flow Control Facilities (1) Plans

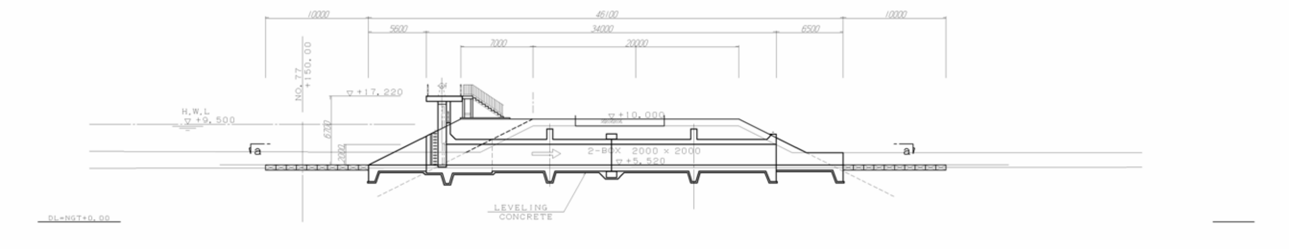


Figure 5.2-7: Typical Drawing of Flow Control Facilities (2) Diversion Channel Gate

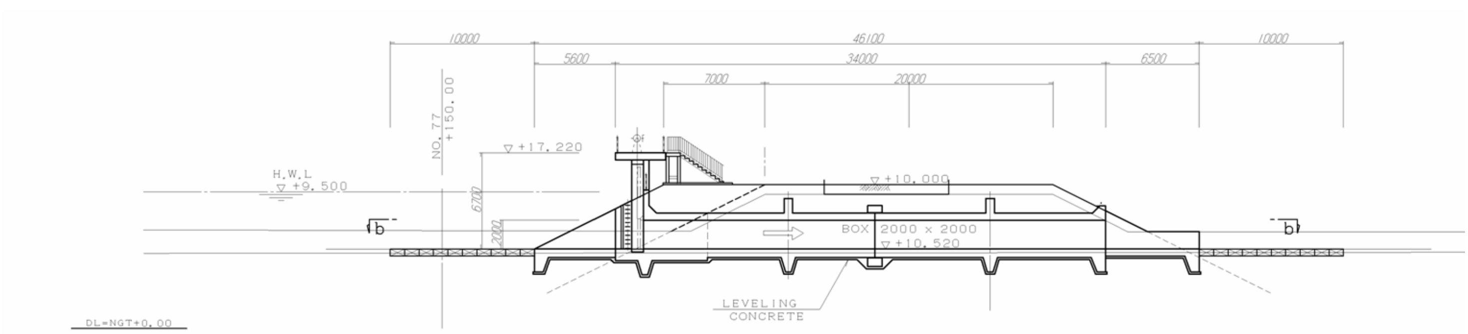


Figure 5.2-8: Typical Drawing of Flow Control Facilities (2) Side Channel Gate

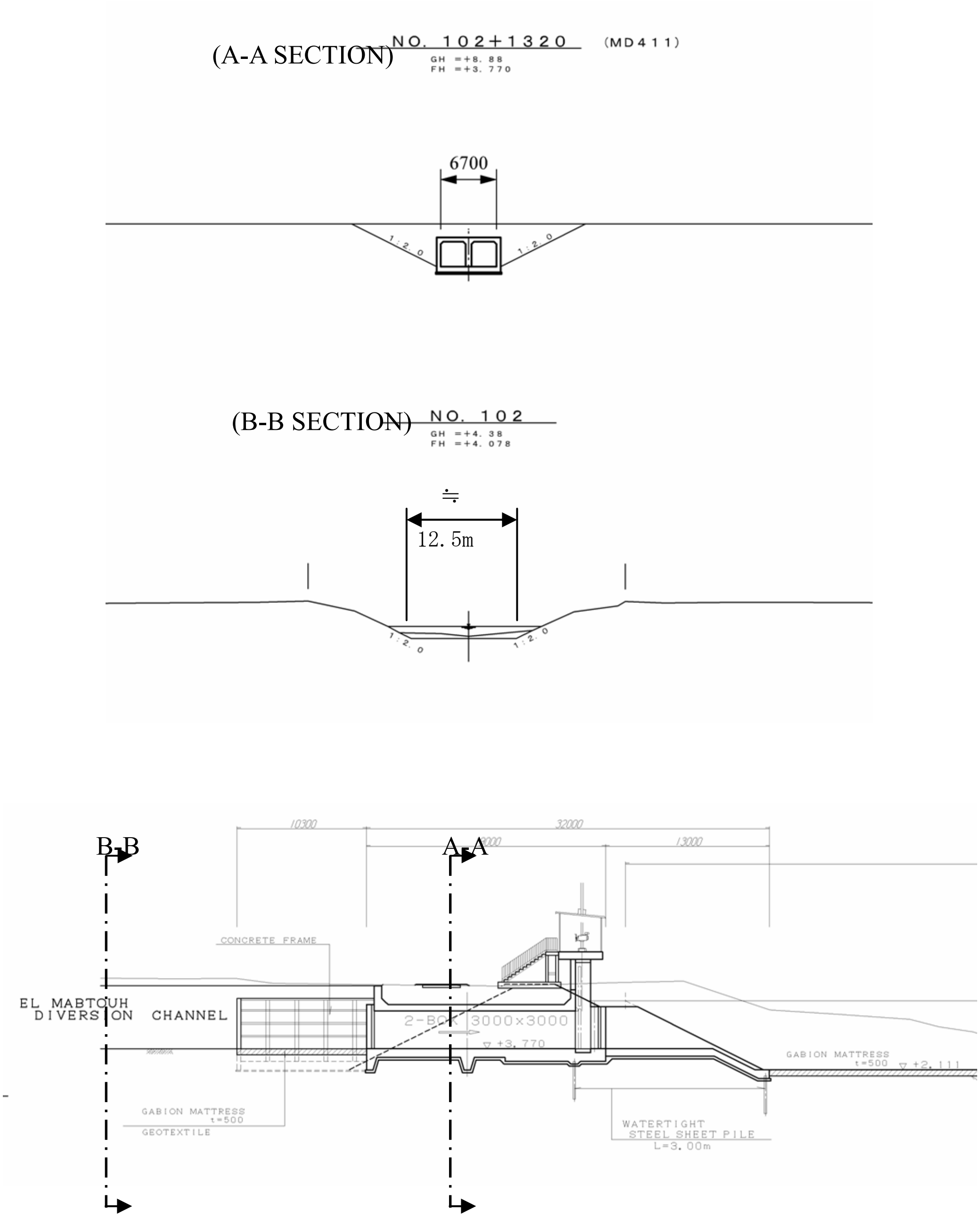


Figure 5.2-9: Typical Structural Drawing of Channel Near Confluence and New Drainage Gate Cross Section

5.2.6 Other Incidental Facilities

The following facilities will be built together with those mentioned above as Tunisian side requested us in the discussion to conserve and renew the current retarding system.

i) Newly install or rebuild 28 sluiceways planned in Master Plan
ii) Rebuild exiting 1 overflow weir with gates (for free operation from Zone 3 to Zone 2)
iii) Rebuild existing overflow weirs which are broken (earthen overflow weir from Zone 3 to Zone 1 which can be broken in case of emergency)
iv) Raise levee height of water channel of east-west direction which intersects a newly built discharge channel (construction of the dikes for backwater), Raiding of L=5.6m and H=1m
v) Upgrade the water discharge gate existed at the junction point of east-west water channel flow end and Mejerda River

The locations of the above-mentioned facilities are shown on **Figure 5.2-11**. Facility ii) will be constructed next to the overflow weir of retarding basin and Facility iii) will be constructed in the north-south direction on the north side of the flow control facility. Typical structural drawings are shown on **Figure 5.2-12**.

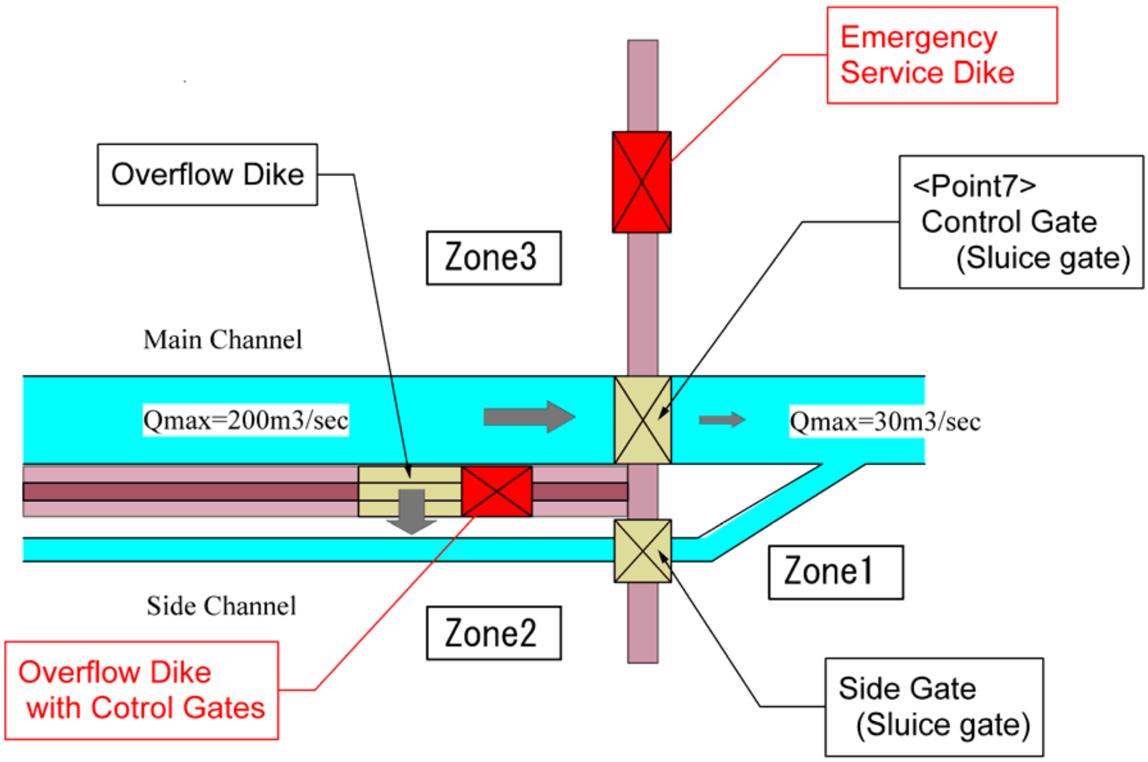


Figure 5.2-10: Explanatory Drawing of Facility Layout ii) and iii)

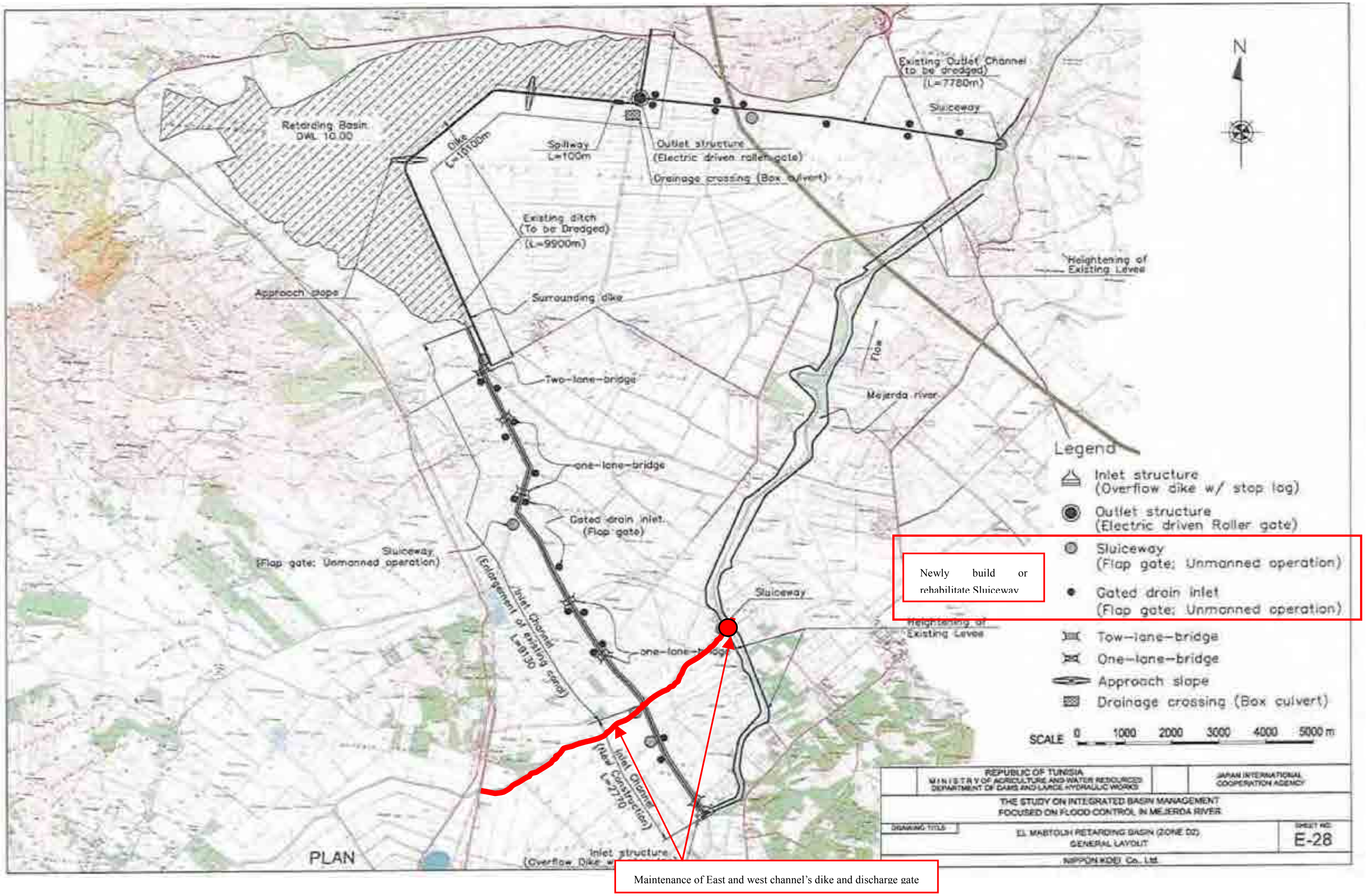


Figure 5.2-11 Location Map of Other Incidental Facilities

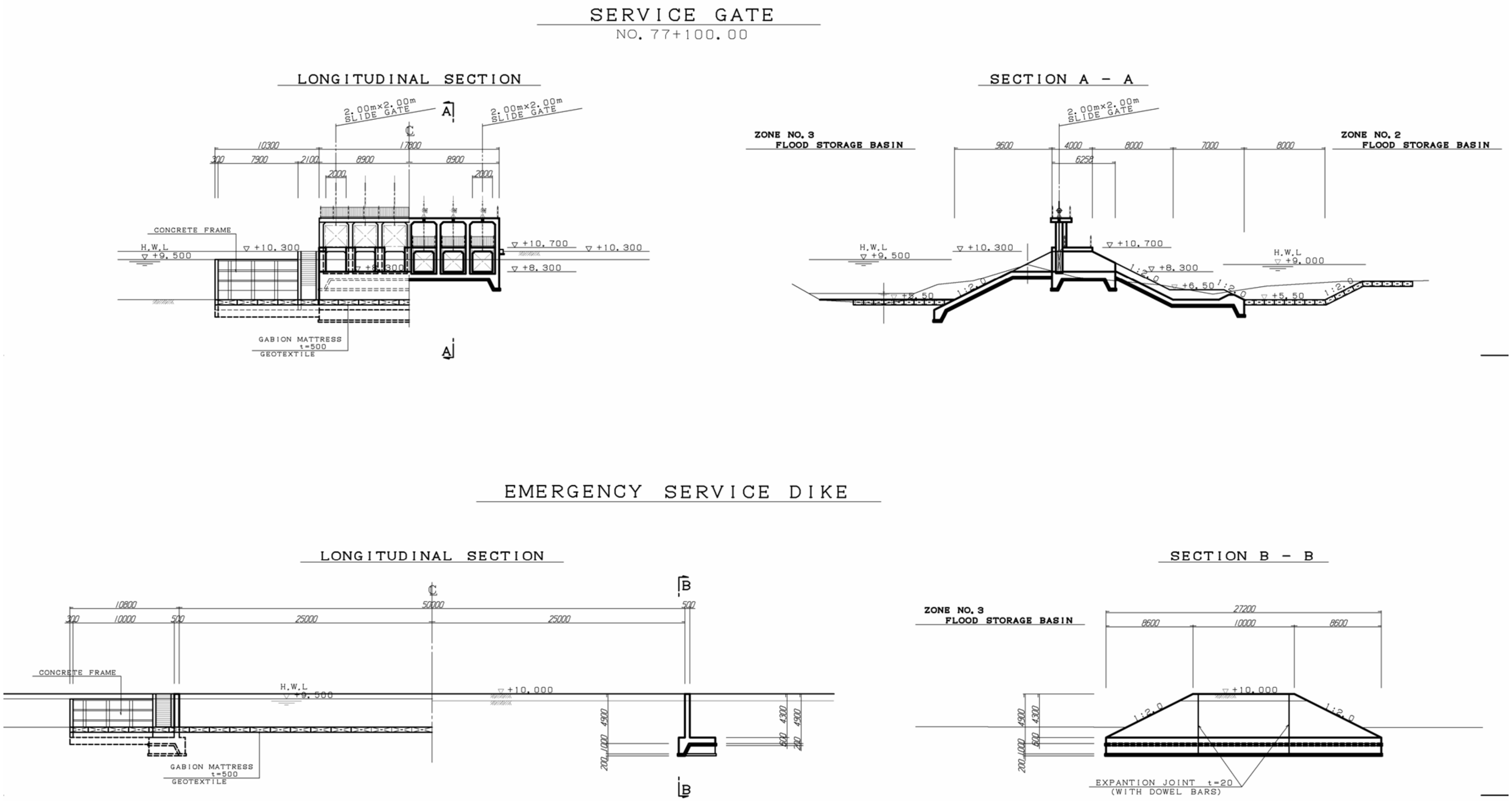


Figure 5.2-12 Other Incidental Facilities (2/2)

5.3 Non-Structural Measures

5.3.1 Need for Non-Structural Measures

Non-structural measures cost less to finance as well as can be devised and acted upon more quickly than structural measures. They are effective as measures for flooding that exceeds the design flood. The design flood for this Project is a 10-year flood, and it is important to consider flooding that exceeds the design flood, so non-structural measures will be carried out.

Table 5.3-1: Sidi Salem Dam Flood Control System

Classification	Main Investigation Programs
a. Data Acquisition	1) Data on rainfall, water levels, dam reservoir levels and dam inflow and outflow rates 2) Options for floods subject to investigation (for three floods, including the largest)
b. Sidi Salem Dam Control Operation Regulation Review	1) Full understanding of flood control methods 2) Full understanding of gate opening and outflow discharge
c. Flood Control Method Investigation	1) Flood control calculations under existing control regulations 2) Flood control calculations under revised operation regulations (draft) 3) Investigation of flood control capacity, gate opening 4) Operation/response when design scale is exceeded
d. Operation Regulation Revision Proposals	1) Organizing flood control calculation results 2) Proposing revisions to operation regulations

Source: JICA Survey Team

Table 5.3-2: Planned Programs to Improve Alarm System and Increase Community Awareness of Flood Fighting

Programs	Purpose	Envisioned Method/Measures
a. Improvement of Warning Communication System	Improve Waning System among local Governments and Local Communities	1) Dissemination of Flood Information thorough TV, radio and on the web-site 2) Utilizing SMS for Warning and Information Exchange 3) Up-grading of existing Transmission System(Warning by Patrol and Network of IMADA)
b. Training for Improving Ability and Awareness Training on Flood Mitigation in Local Communities	Enhance Ability and Awareness on Flood Mitigation in Local Communities	1) Review of Existing Blue Plan Dissemination of Possible Inundation Areas a. Review on Evacuation Center, Inundation Areas b. Evacuation route in the Blue Plan c. Review and Check for Flood Activity Plan and Equipment 2) Drill of Flood Fighting Activities 3) Preparation and Dissemination of Flood Maps 4) Proposal of New Flood Prevention Plan (Blue Plan)

Table 5.3-3: Programs for Organization and Institution Reorganization and Capability Development

Investigation Programs	Target Organization or Facility	Main Investigation Points
a. Strengthening of Organization & Institution for Flood Management	DGRE, DGBGTH	1) Strengthening prominent flood management and river management organizations 2) Splitting river management and control with Ministry of Equipment 3) Splitting coordination, management and control with the Irrigation Department 4) Advising reorganization proposals
Preparation of Management Standards & Guidelines for River Facilities	Mejerda River, Dams located in the Mejerda Basin, El Mabtouh Retarding Basin	1) Coordinating flood protection plans with water use (for irrigation and drinking) 2) River management and dam management plans 3) Establishing guidelines (river, retarding basin operation/management)