CHAPTER 3. EXISTING STRUCTURAL MEASURES AND FUTURE PLANS FOR FLOOD CONTROL

3.1 Existing Structural Measures and Future Plans

There are almost no works and a program on structural measures so far against flood in the N'fis, Rheraya, Zat and R'dat Rivers, except road protection works such as revetment works and their foot protection. Structural measures against flood have been implemented in the Ourika River and the Issyl River. As the Ourika River has been important in terms of tourism as well as frequent and large flood damages, MOE (Ministry of Equipment) has mainly concentrated on the Ourika River to mitigate occurrence of debris flow as well as to enlarge flood carrying capacity. The Issyl River has often attacked the city of Marrakech, and then structural measures against flood have been carried out. Therefore, the existing structural measures and plans in the Ourika River and the Issyl River are described in the following sub-sections.

3.1.1 Issyl River

The areas damaged by floodwater of the Issyl River are divided into three (3) areas shown in the following table. Flood protection works in those areas could be characterized according to each topographical and social condition as described in the table. The existing and planning flood protection works in those areas are explained as follows: Refer to Fig.H.3.1.

Division of Flood Protection Works

Area	Place	Main Flood Protection Works
Upstream Area	Upstream of Rocade Canal	Protection works for agricultural land and forest against erosion (reforestation and erosion control
Tassoltante Area	Downstream of Rocade Canal to Golf Road in Sidi Youssef Ben Ali	Drainage channel against inundation
Marrakech Urban Area	Downstream of Golf Road in Sidi Youssef Ben Ali, Remparts Road and Ain Itti	Riverbed excavation and dykes against flooding

Note. Rocade canal was developed from the east to the west at the south of Marrakech, with the length of 118.5 km. The maximum peak discharge at the head of main canal is 20 m^3/sec.

(1) Upstream Area

In the Issyl River basin from the top of alluvial fan around Agadir-n-Tafent to Rocade Canal, some parts of agricultural land is the main flood-damaged properties. Some emergency dykes to protect the road R513 to Ourika are found along the main stream of the Issyl River. Physical and biological protection works on the river basin have implemented from 1972 to 1984, such as small banks to protect trees, small check dams with dry masonry and protection works for reforestation.

The future program will be realized throughout a period of 5 years and includes the following actions:

<u>Actions in the River Basin</u>

- In the upstream: 1) Reforestation, and 2) Erosion control works on reforestation area
- In the downstream (private domain): 1) Fruit plantation, 2) Green curtain of plantation against wind erosion, 3) Plantation around houses and villages, and 4) Ridge and ditch for redistribution of rainwater in a small area and raising the infiltration.

<u>Actions in the River Course</u>

- Gully protection works such as dry masonry sills, spur dyke (groyne) and plantation of fast-growing species
- A series of small dams for flood control and for water storage to be utilized

- Large infiltration sills

Source: "Study for the Plan of Issyl River Basin: Present Situation and Action Plan, Ministry of Agriculture, Rural Development and Maritime Fisheries, Sub-ministry in charge of Forestry, Regional Directorate of Water and Forest (DREF) in Haut Atlas- Marrakech, July 1998"

(2) Tassoltante Area

Inundation rather than flooding is superior in this area, because rainwater and river water flow down through many small creeks, which have no enough capacity resulting in poor drainage. Then intercepting drainage channel has been planned and constructed by ORMVAH, namely Tassoltante Intercepting Drainage Channel, in order to protect a part of Marrakech urban areas by gathering rainwater and floodwater and draining them to the Issyl River. However, due to the lack of drainage capacity, it is reported that this intercepting channel becomes the cause of floods in Harakat and Zemrane villages and other downstream localities.

Besides, ORMVAH planned drainage channels in the areas of Dar Al Haj Lahsane and the southeast of Agdal as follows:

- Dar Al Haj Lahsane (Constructed): In the east of the intersection of Rocade Canal and the Issyl River, drainage channels from the south to the north were setup draining water partly to the Issyl River and mainly to the Taroumit River.
- Southeast of Agdal (Planned): This area was planned to prepare main, secondary and tertiary drainage channels protecting agricultural land and villages. Collected water is drained to the Issyl River just upstream of the urban area of Sidi Youssef Ben Ali.

  Source: "Etude D'Equipement des Secteurs Centraux de la PTI du Haouz Central, Tranche-3, Avant Projet, Assainissement Externe, Julliet 1995, Office Regional de Mise en Valeur Agricole du Haouz Marrakech, Ministere de L'Agriculture et de la Mise en Valeur Agricolr"

Tassoltante area was damaged by the floods of April and May 1997, of which damages are; 1) 306 collapsed houses in 10 villages, 2) 8 villages inundated without damages, 3) inundation area of 113 ha and 4) flooding and damaging of some parts of Marrakech-Ourika road. To protect these damaged areas, the following recommendations are submitted:

- Enlarging the discharge capacity of the tributaries of Tassoltante and Akhachan
- Improvement of river-crossing works
- Arrangement of road-crossing drainages located at Marrakech-Ourika road
- Removing and prohibiting obstacles (garbage, buildings and farming activities) occupying watercourses.
- Re-organization of hydrographic networks (tributaries and creaks)
- Improvement of the said intercepting drainage channel

(3) Marrakech Urban Area

In the Marrakech urban areas, flood damages are liable to occur at the area between Golf Road and Remparts Road in Sidi Youssef Ben Ali, the area along the Remparts Road and the area of Ain Itti. The main course of the Issyl River was frequently flooded and has been damaging to the people and houses. Especially, some bridges disturb flood flow, resulting in overflowing, while all the existing bridges have the discharge capacity only with return period of less than 15-year.

(a) Existing Structural Measures

DPE-Marrakech carried out the river improvement works of the Issyl River in this area on October 1995, to achieve ensuring discharge capacity with 10-20 year return period,

spending Dhs. 6 millions for them. These works consist of:

- Widening of lower riverbed
- Eliminating obstacles (rubbles and rubbishes) in the river course
- Correcting the narrow pass due to the local presence of hard soils
- Dyke embankment
- Protection of riverbanks

However, there are three historical bridges that disturb flowing flood discharge but could not be removed.

(b) Future Plan of Structural Measures

The following recommendation were made for flood control measures:

Actions to be carried out quickly

1) Prohibition of all the garbage and rubbish deposit to the river
2) Excavation and floodwall at some critical points

Actions to be planned

1) Improvement of discharge capacity at the bridges
2) Continuous river course clearing
3) Environmental improvement and creating of green space

Source: the report "Etude de Protection de la Wilaya de Marrakech contre le Crues, Ministry of Agriculture, Equipment and Environment, General Directorate of Hydraulics, Directorate of Research and water Planning, Directorate of Tensift Hydraulic Region"

Besides, the following plans were also made for flood control measures:

- Excavation and river widening
- Dyke embankment
- Increase of river slope to strait meandering points
- Improvement of discharge capacity at the bridges and new bridge construction

Source : the report "Etude de Gestion des Retenues et de Protection des Berges, Mission II, Definition et Justification des Travaux D'amenagement, Oued Issyl Parrort Définitif, Juin 1992"

3.1.2 Ourika River

The following river works have been implemented in the Ourika River as a kind of emergency countermeasures; 1) blasting of large boulders (10,000 m^3), 2) riverbed excavation along 12 km long to ensure discharge capacity for floodwater, 3) riverbank formation and protection with large gravel and 4) revetment works to protect damaged road.

According to the report "Aménagements Hydrauliques Pour la Protection de la Vallee de l'Ourika Contre les Crues, Mission II, Définition et Justification des Aménagements de Protection", following structural measures are planned or are currently constructed as a drastic flood control measures in the Ourika River:

- Setti Fadma Flood Control Dam (presently Canceled)
- Check Dams in Tributaries (Under construction)
- Check Dams in the Main Rivers (Planning)
- Excavation and Flood Protection Wall along the River (Planning)

The above flood control measures in the Ourika River are summarized as follows: Refer to Fig.H.3.2.

(1) Setti Fadma Flood Control Dam

It was recommended to realize a dam immediately in the upstream of Setti Fadma, which is able to control large flood discharge by temporary storage. Dam storage capacity is 7.5 Mm^3 with the height of 90 m.

Geological survey on the right of the dam site was done and a specialized team of Department of Public Works studied the site. The results were achieved as follows:

- It was found that sedimentary filling was about 17 m depth on the dam site.
- Flood discharge volumes are 29 Mm^3 with return period of 100-year and 39 Mm^3 with that of 1,000-year. The dam site has only 1.3 Mm^3 of the storage volume with 60 m height and 7.5 Mm^3 with 90 m height. It is said that the dam site has inefficient topographic characteristics. Moreover this small capacity of the storage will easily derive full of sediment due to significant sediment discharge.
- The investment cost varies between Dhs. 70 millions for 60 m height of the dam and Dhs. 100 million for the maximum height of 75 m.

Consequently, the idea of realization of the dam in Setti Fadma was canceled and other solutions were recommended, such as a certain number of check dams, embankment works and bank protection works.

(2) Check Dams in Tributaries

There are 27 small check dams constructed in the Ourika River basin as of April 2000 to prevent outbreak of debris flow in the eight (8) tributaries, namely the Ighir, Romanchou I and II, Taghzrit, Taghzoute, Oussen, Tazitount and Ouzrou Rivers. These are listed in the following table and are pointed in Fig.H.3.2. Additionally in the Ourika River, six (6) check dams will be constructed in the tributaries of Taghzrit and Romanchou within the year of 2000 if the budget would be available. The specification of these planned check dams are not yet fixed.

(3) Check Dams in Main Rivers

Check dams in the main river course serve reducing the flood flow speed and bank erosion as well as sediment transportation. However sedimentation of the upstream of check dams might lead to a raise of water level and might cause more flooded land. The plan of one or several check dams in the main river course will be defined and included in the future program.

List of Small Check Dams in Ourika River

No.	Name of Check Dam	River	Height (m)	Dam Volume (m^3)	Cost (thousand Dhs)
10	Ighir	Ighir	5.00	550.0	451.0
2	Romanchou 1	Romanchou I Or Romanchou II	3.60	270.0	148.9
3	Romanchou 2		3.00	150.0	82.5
6	Romanchou 3		5.00	310.0	170.5
8	Romanchou 4		4.00	235.0	188.0
11	Romanchou 5		5.00	730.0	500.0
13	Romanchou 6		5.00	685.0	423.0
27	Romanchou 7		4.00	240.0	Under Construction
1	Taghzrit 1	Taghzrit	5.00	1030.0	567.0
9	Taghzrit 2		5.00	619.0	570.0
12	Taghzrit 3		5.00	960.0	590.0
14	Taghzrit 4		5.00	527.0	423.0
15	Taghzrit 5		5.00	426.0	317.0
16	Taghzrit 6		5.00	585.0	412.0
17	Taghzrit 7		5.00	457.0	310.0
18	Taghzrit 8		5.00	725.0	660.0
19	Taghzrit 9		5.00	726.5	661.0
20	Taghzrit 10		5.00	533.0	485.0
21	Taghzrit 11		5.00	380.5	346.0
22	Taghzrit 12		2.00	74.0	68.0
23	Taghzrit 13		2.00	612.0	557.0
24	Taghzrit 14		2.00	341.0	311.0
25	Taghzrit 15		-	-	-
26	Taghzoute	Taghzoute	4.00	213.0	-
5	Oussen	Oussen	4.00	370.0	203.5
4	Tazitount 1	Tazitount	5.00	570.0	313.5
7	Ouzrou	Ouzrou	3.00	122.0	67.1

Sources: Service Eau, DPE Al Haouz, MOE

(4) Excavation and Flood Protection Wall along the River

Certain sections of the road R513 linking Marrakech to Ourika Valley are exposed to inundation and erosion risks. Similarly, floods or debris flows from tributaries generally cause large damages to the road. Residential houses are also damaged in this vicinity. In fact, the road was severely damaged in two times, during the floods of August 1995 and April 1996.

The inundation map was analyzed to select the zones that are vulnerable to flooding and is necessary to be protected against flood. The four (4) reaches judged to be high risk zones were selected, namely Setti Fadma, Oulmes, Igrifoudeune and Aghbalou. Flood protection works proposed in these zones are summarized in the following table. Total construction cost is estimated Dhs. 30 millions.

Excavation and Flood Protection Wall along Ourika River

Zone	Flood Protection Measures	Specification
Setti Fadma	Excavation of narrow pass and small parapet wall	540 m in length
Oulmes	Flood Protection Wall	3-6 m in height, 743 m in length
Igrifoudeune	Flood Protection Wall	2-5 m in height, 730 m in length
Upstream of Aghbalou	Flood Protection Wall	3-6 m in height, 770 m in length
Downstream of Aghbalou	Flood Protection Wall	3-6 m in height, 768 m in length

3.2 Other Related Programs

3.2.1 National Plan of Protection against Floods

The "National Plan of Protection against Floods" loaned by the World Bank has been studied with the following aims:

1) The definition of flood types
2) The elaboration of syntheses documents on areas that present potential risks of floods
3) The analysis of the actual situation of the institutional frame and propositions of the improvement
4) The formulation of an action plan for combating floods, mainly in terms of regulating land occupation, defining technical measures of floods protection and in terms of the impact of protection works on environment conservation, the organization and reinforcement of flood alerts.

The study area covers all the Moroccan Kingdom Territory over 710,850 km². The principal basins relevant to the study are:

- Lukkos basin, Mediterranean coast and Tangier's
- Sebou Basins,
- Moulouya and Oued Kert Basins,
- Bou Regreg and Atlantic coast Basins,
- Oum Er RBIA Basins
- **Tensift Basin**
- Ksob-Lquezoullen Basins
- Souss-Massa Basins
- Southern Atlas Basins
- Sahara Basins

The study includes following three missions:

- Mission 1: Characterization of problems resulting from floods, and regulatory provisions for the control of land users in flood exposed areas.
  - Sub-mission 1-1: Classification of floods
  - Sub-mission 1-2: Complete inventory of sites that are prone to floods, description of sites and elaboration of hazards maps
  - Sub-mission 1-3: Prevention measures and definition of a priority order relating to protection works to be developed
- Mission 2: Institutional Frame
- Mission 3: Action Plan
  - Sub-mission 3-1: Setting forth a schedule for carrying out protection works, investments estimation and elaboration of financing plans.
  - Sub-mission 3-2: Flood alerts (Flow-flow analysis in large basins; Predicting flow in small basins) and water courses clearing (Prevention methods for clearing of solid wastes residues and of obstacles in rivers)

3.2.2 Dam Plan by the Nation

There are one (1) existing dam and twelve (12) dam plans in the Tensift River basin, listing in the following table and Fig.H.3.3. Of these dam plans, five (5) dams exist in the Study Area, namely Timalizéne Dam in the Ourika River, Moulay Brahim Dam in the Rheraya River, Wirgane Dam in the N'fis River, Ait Ziat Dam in the Zat River, and Imizer Dam in the R'dat River. Although the downstream of the N'fis River is out of the Study Area, it is noted that there exists Lalla Takerkoust Dam and that the plan of Amizmiz Dam has been studied as one of the dams in "the study on Regional Water Resources Development Plan" by JICA. It is also noted that Setti Fadma Dam was planned at the upstream of Setti Fadma in the Ourika River but it was discontinued because of geological and economic problems.

Although the dams are considered precious national hydraulic inheritance, they lost the storage capacity of 50 millions m^3 every year because of the sedimentation.

Existing and Planning Dams in Tensift River

Dam	River	Location	Purpose	Height (m)	Length (m)	Reservoir Volume (Million m^3)	Present Progress
Herissane	Lahr	A tributary of Tensift	Irrigation	48.0	-	-	Studying
Imizer	**R'dat**	**Study area**	**Irrigation, Flood Control**	**-**	**150.0**	**27.0**	**Studying**
Ait Ziat	**Zat**	**Study area**	**Irrigation, Potable Water**	**-**	**-**	**380.0**	**Studying**
Timalizéne	**Ourika**	**Study area**	**Irrigation**	**53.0**	**-**	**20.0**	**Identified site**
Moulay Brahim	**Rheraya**	**Study area**	**Irrigation**	**55.0**	**-**	**36.4**	**Identified site**
Wirgane	**N'fis**	**Study area**	**Portable Water to Marrakech**	**75.0**	**225.0**	**72.0**	**Studying**
Amizmiz	Amizmiz, N'fis	a tributary of N'fis	Irrigation	72.5	-	11.0	Studying
Lalla Takerkoust	N'fis	Downstream of N'fis	Irrigation, Portable water	71.0	500.0	69.0	Existing
Taskourt	El Mal	A tributary of Tensift	Irrigation	88.0	275.0	106.0	Studying
Boulaouane	Chi-Chaoua	A tributary of Tensift	-	92.5	615.0	113.0	Studying
Oulad Mansour	Tensift	Between R'dat and Zat	Irrigation	-	-	-	Studying
Sidi Bouidel	Tensift	Between N'fis and Rheraya	-	-	-	-	Studying
Talmest Dam	Tensift	Downstream	Irrigation	43.0	240.0	250.0	Identified site

Sources: Division Planification et Gestion de l'Eau, DRPE, MOE, arranged by JICA Study Team

3.2.3 Action Plan 1999-2003 in Water Sector

Directorate General of Water, Ministry of Equipment, established "Plan of Economic and Social Development 1999-2003", where "Action Plan 1999-2003 in Water Sector" was addressed. It includes various water resources development programs such as urban/rural drinking water, irrigation water, industrial water, hydro-electricity, and flood control. The following sub-sections summarize the contents of the action plan concerning mainly with flood control structural measures and dam plans within/around the study area.

(1) Policy

As one of the objectives of the national policy toward the development of water sector, it is stipulated to assure the protection of populations and goods against flood and inundation. It is described in this action plan that various dam plans proposed for water resources development should consider the land protection against flood and inundation as well. The implementation of "National Plan of Protection against Floods" is also included in this action plan.

(2) Dam Plan

(a) Large Dam Construction

There are eight (8) large dams programmed to construct during 1998-2003. Of these eight

large dams, the following two large dams include in the study area.

- Wirgane Dam on the N'fis River for drinking water to Marrakech (2001-2002)
- Imizer Dam on the R'dat River for irrigation water and flood control (2001-2003)

Note: () shows anticipated year for the start of works

(b) Medium and Small Dams

There are 24 medium and small dams permitted to construct, of which Amizmiz Dam in the N'fis River Basin for irrigation includes in the study area and is to be constructed as one of the medium dams. Besides, Herissane Dam in the Lahr River, Timalizéne Dam in the Ourika River and Moulay Brahim Dam in the Rheraya River are to be studied during 1999-2003.

(3) Program of Protection against Inundations

As the layout plans of rivers for the protection of urban centers against floods, six (6) projects are launched to construct and 13 projects are started to study. Flood protection works include flood control facilities, stabilization and heightening of riverbanks and river course arrangement. The Ourika Valley and Marrakech City (the Issyl River) is counted up among the ones of these project sites.

(4) Program of Study

Ait Ziat Dam on the Zat River for the development of irrigation water to Zat Perimeter and drinking water to Marrakech City will start to study during 1999-2003.

3.2.4 Reforestation and Erosion Control

The master plan of reforestation in Marrakech Region was formulated in 1996 including the study area. The reforestation schedule in/around the study area is shown in the following table and the locations are mapped in Fig.H.3.4. In the study area, there are two river basins where reforestation is planned, namely the Ourika River and the R'dat River. The reforestation are scheduled at Timenkar in the Ourika River basin with 299 ha annually from 2000 to 2006 (totally 2,093 ha) and at Majdallah and Ourgouz in the R'dat River basin with 618 ha annually from 2000 to 2006 (totally 3,389 ha).

Reforestation Schedule in the Study Area Unit: ha

River Basin	Location	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Total
Production												
R'dat	Majdallah	-	-	-	-	-	319	319	319	319	319	1,595
	Ourgouz	-	-	-	-	299	299	299	299	299	299	1,794
Ourika	Timenkar	-	-	-	299	299	299	299	299	299	299	2,093
N'fis	Ait Bourd	-	-	292	292	292	-	-	-	-	-	876
	Ait Ouzerkri	-	-	-	368	368	-	-	-	-	-	736
	Azgherfile	272	272	272	272	272	272	272	-	-	-	1,904
	Azgour	-	-	244	244	244	244	244	244	244	-	1,708
Sub-total : Production		272	272	808	1,475	1,774	1,433	1,433	1,161	1,161	917	10,706
Protection												
R'dat	Ait Owrir	54	54	54	54	54	54	54	54	54	54	540
N'fis	Bouskikira	-	-	285	285	285	285	-	-	-	-	1,140
	Ouzguita	260	260	-	-	-	-	-	-	-	-	520
Sub-total Protection		314	314	339	339	339	339	54	54	54	54	2,200
Grand Total		586	586	1,147	1,814	2,113	1,772	1,487	1,215	1,215	971	12,906

Source : Plan Diretor de Reboisement, Programme D'Intervention de Reboisement, Julliet 1996, Wilaya de Marrakech, Ministere de L'Agriculture et de la Mise en Valeur Agricol (MAMVA), Administration des Eaux et Forest et de la Conservation des Sols (AEFCS)

The master plan of reforestation includes a plan of erosion control works, improvement of pastureland and social development support (seeds, hydropower generation, technical support for handicraft and agriculture). The erosion control works have been also implemented in the study area. The main erosion control works are small check dams and hillside works, which are constructed mainly with dry masonry and rarely with gabion or wet masonry. The erosion control works implemented between July 1999 and August 2000 are concentrated in the Ourika River, which are summarized in the following table. In addition, the erosion control works of 126,000 m^3 are scheduled to construct in 2001 and 2002.

Erosion Control Works between July 1999 and August 2000

Rural Community	Location	Volume (m^3)	Number of Works
Setti Fadma	Imin-Taddert	966	100
	Tighazrit	2,345	251
	Tighazrit	1,500	91
	Tighazrit	700	70
	Iraghf	300	30
	Iraghf	600	Under Construction
	Timenkar	1,244	327
	Oum Lahoua	3,029	241
Oukaimedan	Ait Ameur	8,136	1,820
Total		17,826	2,930

3.2.5 Protection of the Road P2017 Linking Marrakech and Ourika

The terms of reference for "the Study of the Protection of the Road P2017 between KP46+000 and KP61+700" is summarized as follows:

- Mission I: Field reconnaissance
- Mission II: 1) Analysis of the cause of flood damages on existing road protection works
  2) Hydraulic study on discharge capacity, high water level/velocity and homogeneous sections of the river course
- Mission III: Feasibility study of protection project for the road P2017

CHAPTER 4. BASIC POLICY AND CRITERIA

4.1 Problems on Flood Control Measures

Based on site reconnaissance on flood damages, interviews with officers of DGH Rabat, ABH Tensift and DPE Al Haouz, as well as based on collecting materials and study reports, present problems concerning with structural measures for flood control are studied as follows:

4.1.1 Natural Conditions and Infrastructure

Present problems on flood damages in the Study Area from the viewpoint of natural conditions and infrastructure are understandable to be divided into two types, namely 1) mountainous rivers: the Ourika, Rheraya, R'dat, Zat and N'fis Rivers and 2) a plain river: the Issyl River. The present problems are itemized as follows:

Mountainous Rivers (Ourika, Rheraya, N'fis, Zat and R'dat Rivers)

1) **Sediment Runoff (Outwash) is Inexhaustible**: As the Study Area is of poor vegetations and of steep mountains as well as has possibility of local heavy rain in any place, sediment yield and sediment runoff inexhaustibly exist.

2) **Cutting Slope of Roads is Extremely Unstable**: Mountain roads in the Study Area are constructed cutting steep mountain slopes in many locations. Such the cutting slopes are very steep and the earth/rock material cut was simply abandoned to the valley beneath. In these parts of the road, slope collapse is liable to happen in heavy rain and it is very dangerous to pass through these roads. Collapsed sediment would close the traffic of the roads and become impossible to pass through them. Moreover, such large sediment could stop a river stream forming a natural dam.

3) **Debris Flow in Tributaries**: Almost all the tributaries could have debris flow in expectation. The debris flow from tributaries flushes away or damages human lives, houses and roads, as well as sometimes blocks flood flow at the confluence forming a natural dam.

4) **Narrow Pass in River Course**: The river width especially in the Ourika River and in some sections of the Rheraya River is often too small to discharge flood flow. Huge rocks are occasionally located in such narrow passes, in which there also are possibility to form a natural dam.

5) **Dangerous Abrupt Wave of Debris/Flood Flow**: When a natural dam stops flood discharge, river water level sometime become decreased in the downstream. After that, the natural dam is suddenly destroyed by floodwater energy and causes a few abrupt waves in the downstream. This phenomenon is very dangerous in the viewpoint of disaster prevention. Peoples who jumped to the conclusion that flood finished could step in the river and might be damaged by the abrupt waves. According to the report "Flood on August 17th 1995 in the province of Al Haouz", it is reported that at the upstream of Aghbalou, certain natural obstacles have accumulated large water volume, which become worse the downstream situation of flood damages after its collapse.

6) **Low Roads along Rivers**: Floodwater sometimes flows on a road in low height along narrow river passes as if the road would be a river itself. Such flood flow damages the road and flushes human lives, houses and vehicles.

7) **Few Evacuation Facilities**: In the Ourika and Rheraya Rivers, it is difficult especially for tourists to find evacuation place and route on the alert and warning against flood. When a severe flood disaster occurs with casualties, survivors are forced to be isolated each other. Peoples and vehicles that are running to evacuate may be attacked by floodwater flowing on the road. Rescue teams also

could not access to the areas of disaster and survivors' evacuation.

Plain River (Issyl River)

8) **Inundation in the Alluvial Fan**: Many small tributaries like a creek run through the alluvial fan of the Issyl River. It causes flood and inundation in some places due to inadequate drainage of rainwater and floodwater. These areas function as a retarding basin for the downstream city of Marrakech.

9) **Flooding in Urbanized Area**: A lack of discharge capacity at river courses and bridges in the Issyl River causes flood damages in the urbanized areas such as Sid Youssef Ben Ali and Remparts Road. When inadequate drainage in the upstream alluvial fan would have been improved, flood discharge of the Issyl River must have been increased and it would cause severer flood damages.

4.1.2 Current Structural Measures against Flood

Although large flood damages have repeatedly happened, drastic structural measures for flood control have not been implemented in the Study Area as mentioned in Chapter 3. Some emergency measures and some tentative structural measures were carried out in the Ourika and Issyl Rivers respectively. The following descriptions are the analysis about problems on such structural measures against flood:

1) **Small Check Dams at the Tributaries in the Ourika River**: Twenty-seven (27) small check dams were constructed on the eight (8) tributaries from Aghbalau to Tazzitount to prevent debris flow. These small check dams were set up only in the debris-flow-experienced tributaries and in possible places, thus priority order of the implementation should be put while setting up the Ourika River, taking future plan of structural measures into account. Besides, in the tributaries that flow into the main river across a principal road, flood and debris flows sometimes caused flood damages to the road.

2) **Riverbed Excavation, Road Reconstruction, Revetment Works, Foot Protections and Dykes in the Ourika River**: These works are mainly disaster restoration works after flood damages and are placed as emergent countermeasures. For example, in Aghbalau where the road was damaged, although road protection works in which large stones are gathered to the foot of revetment are being implemented, it could be easily imagined that floodwater would flow on the road and would flush away the road and houses because of narrow river width and low-height road. In Tazzitount where firm foot protection works are set up, it is estimated that this road would be easily inundated because the river width is narrow and the road height is only 2-3 m. These facts suggest the necessity of an adequate flood control plan with requested design scale and design flood discharge.

3) **To Learn by Disaster Experience**: Many of the existing flood protection structures seem to be disaster restoration works after the damages, and those works were planed and designed without learning disaster experience. These repaired works would be certainly damaged again when a similar flood would happen.

4) **Rocade Canal Disturbing Drainage of Rainwater and Floodwater**: In the alluvial fan of the Issyl River, the Rocade Canal disturbs drainage of rainwater and floodwater. The Canal was constructed in 1983 without adequate consideration of flood drainages, and this causes severer inundation damages in the upstream areas. It must be pointed that any related projects should be planned and designed in coordination with flood prevention authorities.

5) **Low Discharge Capacity in the Issyl River**: Embankment works and riverbed excavation at the city area of the Issyl River are of small scale and are limited to some places. Furthermore, several bridges including the historical footpath bridges were not improved, although they disturb flood flow and cause flooding.

6) **Few Flood Prevention Structural Measures in the Rheraya, N'fis, Zat and R'dat Rivers**: Some structural measures have been implemented in the Ourika and Issyl Rivers but few measures have been implemented in the Rheraya, N'fis, Zat and R'dat Rivers.

4.2 Basic Policy for Flood Control Measures

Taking account of the natural and social conditions of the river basins, as well as the past flood damages' features and the rivers' conditions, a basic policy for flood control measures in the Study Area is set up as follows:

1) **Suitable Flood Control Measures**: To protect inhabitants, tourists, houses, roads and farmlands, suitable flood control measures must be proposed for the target rivers in the Study Area, namely the Issyl, Ourika, Rheraya, N'fis, Zat and R'dat Rivers, against flood damages caused by debris flow, flood flow and inundation.

2) **Priority among the Target Rivers**: Flood control in the Issyl and Ourika Rivers is important and is a pressing need. The second is the Rheraya River, followed by the N'fis, Zat and R'dat Rivers. Of the six target river basins in the Study Area, the Issyl River basin shows the most advanced land use. There are many villages and farmlands in the mid-downstream as well as urban areas in the downstream where have been often attacked by flood and inundation caused by the Issyl River. Although the Ourika River is one of the important tourist spots, it is the most dangerous one in the six rivers being damaged by flood and debris flows. Besides, since the tourist spots of Imlil in the Rheraya River was significantly damaged by the 1995 flood, it is recognized that the Rheraya River is also important on flood control. The other rivers have features of relatively wide valley, less people living along the rivers, less importance as a tourist spot and limited flood/debris flow damages.

3) **Economically Feasible Measures**: Although economic evaluation on structural measures is not made in this conceptual plan, it is necessary to consider economic feasibility when planning. Large check dams or flood control dams could not be necessarily constructed in order to protect a house or a hectare farmland for instance. Thus, flood control measures are planned as economically feasible as possible, taking account of the current conditions of the local society and economy because the land use development according to rapid increase of population and economy could not be expected in the Study Area in the next decade at least.

4) **Consideration of Environment**: As structural measures sometimes have a great influence upon natural environment and social communities, it is necessary to consider natural and social environment when planning. Large dams or high dykes, for instance, might force resettlement and might cause a change of the eco-system as well as devastation of natural environment. The damages to tourism are also of the importance to be taken into account especially in the Ourika and Rheraya Rivers.

5) **Avoiding Direct Hit of Debris Flow**: As a debris flow usually gives a fatal blow, structural measures must be planned to avoid a direct hit of debris flow in order to protect inhabitants, tourists, houses and principal roads.

6) **Protection of Roads**: As flood damages to principal roads are remarkable in the Study Area, structural measures must be proposed to protect the principal roads from debris flow, flood flow and inundation.

7) **Protection of Riverside Farmland**: Since most of the low land along/in the mountainous five rivers is the precious plain land and is easily accessible to water, it is utilized as agricultural land, which is a important living means for the rural inhabitants. However, riverside land of 6 m width is stipulated as preparation of river protection according to the national regulation, and it would

cost huge budget and would take long period to totally protect the agricultural land along the rivers. Thus, inundation to a part of the riverside farmlands would be tolerated in the conceptual plan, considering economic feasibility.

8) **Erosion Control and Reforestation**: Restoration of vegetation is listed as one of the important flood control measures in the Study Area. The role of reforestation and erosion control to a river is itemized as follows; a) Decrease of peak flood discharge, b) Leveling of long-term river runoff, c) Control of sediment runoff.

9) **Prioritization of Structural Measures**: As flood control structural measures would take long period to be implemented, they must have been constructed according to their priority. Prioritization of structural measures is decided based on the following criteria; a) **Economic Feasibility**: Projects with high economic feasibility should be selected to realize earlier benefit, b) **Urgent Requirement**: Projects with urgent requirement for flood damage protection should be selected, c) **Less Social and Environmental Impact**: Projects with less social and environmental impact should be selected.

10) **Excess Design Flood Discharge**: It is reasonable to make a flood control plan that completely deals with design flood discharges. Meanwhile, the importance to flood control is the measures against an extraordinary discharge beyond the design flood discharge (excess flood control measures), because it could cause tremendous damages. The excess flood control measures are inevitably different from the ordinary flood control measures. In order to control extraordinary discharge beyond the design flood discharge, it is impossible to completely prevent flood damages. Thus, it is necessary to employ flood control measures that prevent significant damages even when an extraordinary discharge would happen.

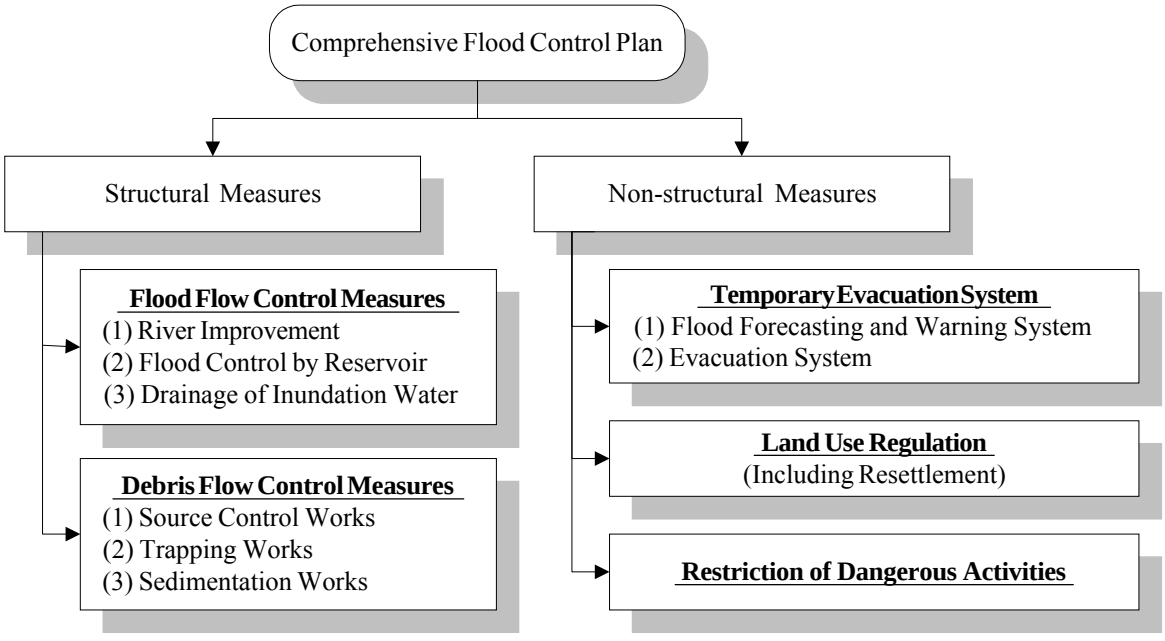
4.3 Criteria for Flood Control Measures

4.3.1 Significance of Flood Control Measures

Flood control is to protect the people and the national asset such as inhabitants and their lives, arable land and houses as well as infrastructure from damages by river flooding and inundation. Flood control measures should be planned as a part of social infrastructure setup, considering natural and social conditions of rivers and river basins. That is to say, the comprehensive river plan includes:

- River Basin Utilization Plan in the Background of Social Economy
- Comprehensive Flood Control Plan
- Water Resources Development Plan
- Sediment Management and Erosion Control Plan
- River Environment Management Program

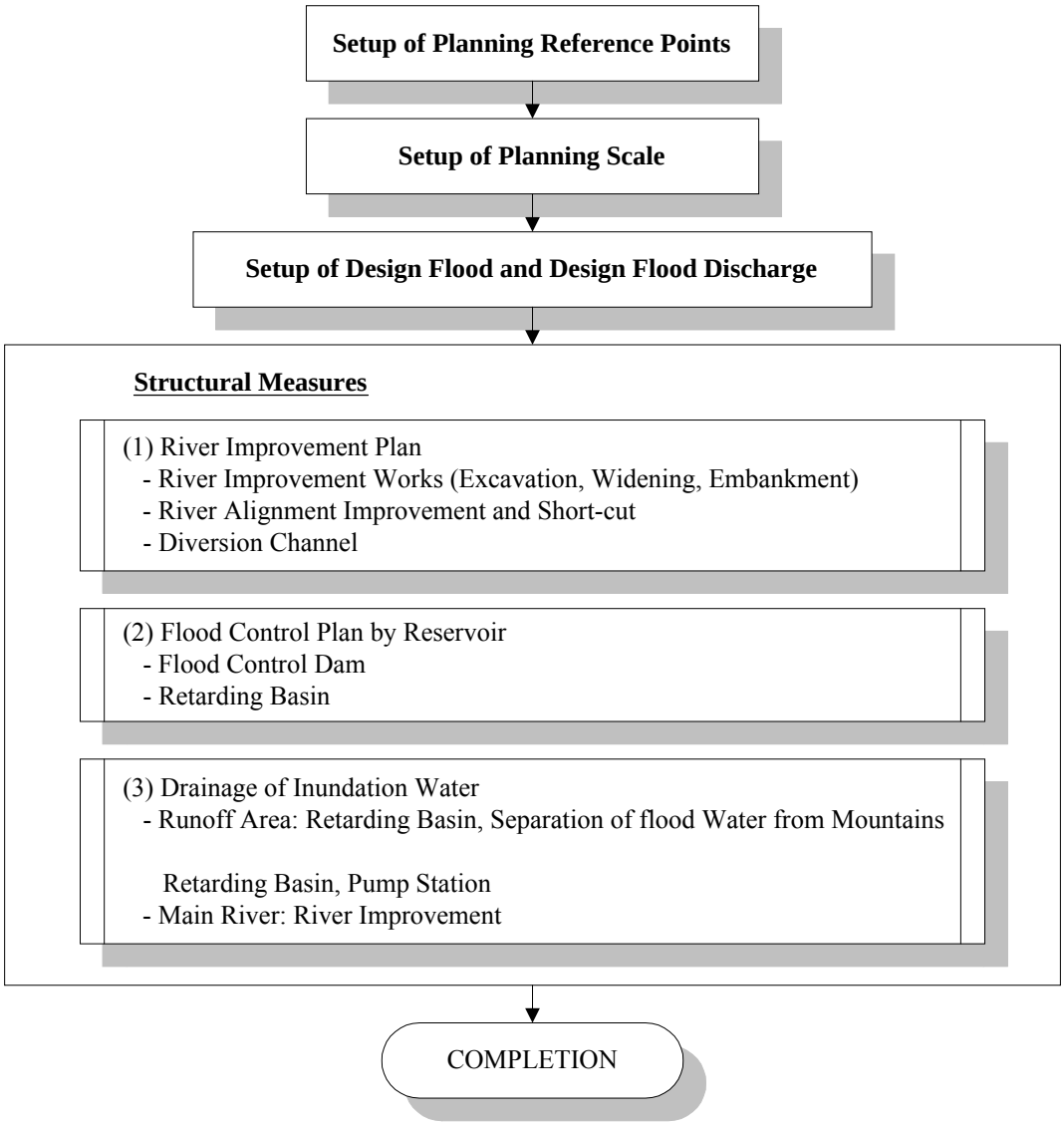
The targets of this study are Comprehensive Flood Control Plan and some of Sediment Management and Erosion Control Plan. Comprehensive flood control plan could be divided into structural measures and non-structural measures, as shown in the following figure. These measures demonstrate their effectiveness in combination with each other. The structural measures mainly consist of flood flow control measures and debris flow control measures. From the viewpoint of the assurance of people's life foundation, the structural measures should have a priority to be implemented but might need large cost and long period, and hence the non-structural measures are inevitable to be setup before or in parallel with the structural measures.



Composition of Comprehensive Flood Control Plan

4.3.2 Planning Procedure of Flood Flow Control Measures

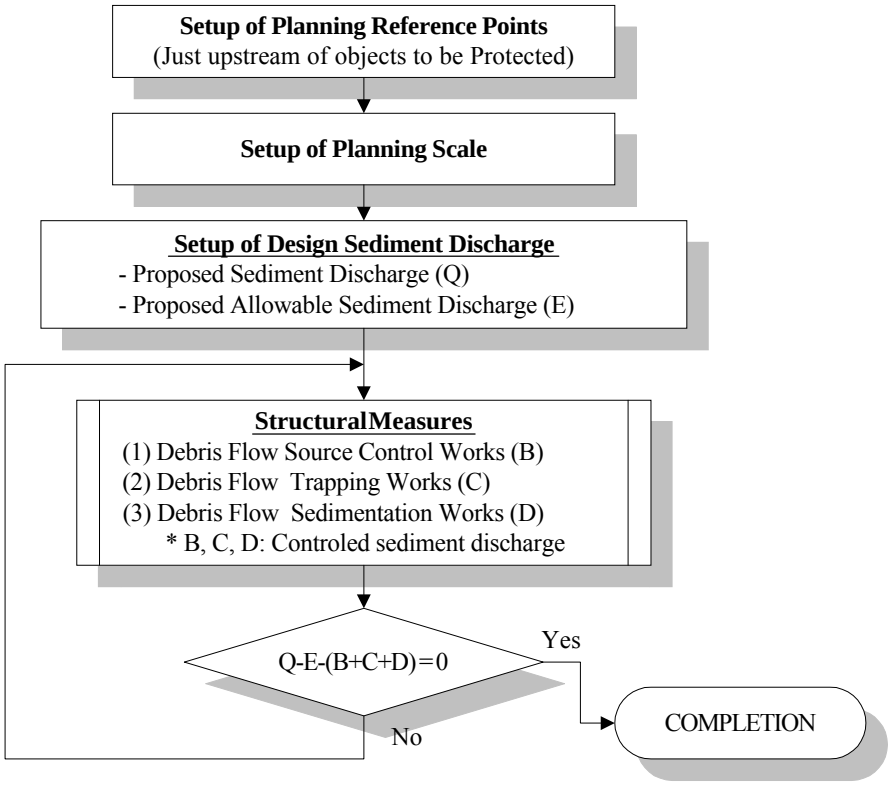
In order to prevent/mitigate river flood damages, flood flow control plan must be formulated so as to achieve the planned flood control effect against design flood, which is fundamental in the plan and is decided setting flood hydrograph and peak discharge at reference points. A planning procedure of flood flow control measures is shown in the following figure.



Planning Procedure of Flood Flow Control Measures

4.3.3 Debris Flow Control Measures

In debris flow control plan, specification of facilities such as a type and a scale is decided and the facilities are laid out on the vicinity vulnerable to debris flow. For this planning, as shown in the following figures, design sediment discharge based on planning reference points and planning scale is dealt with, rationally combining structural measures such as source control, trapping and sedimentation works for debris flow.



Debris Flow Control Plan

Debris flow could be divided from the viewpoints of structural measures into: 1) Debris Flow - sand and gravel type, 2) Mud Flow -mud type and 3) Earth Flow - the flow form between debris flow and tractional flow.

Debris flow of sand and gravel type and earth flow are judged to be superior in the Study Area, based on features of the rivers and the river basins. The outbreak, flow-down and sedimentation of these debris and earth flows occur mainly according to the gradient of the river as shown in the following table.

Classification of the State of Debris Flow According to River Gradient

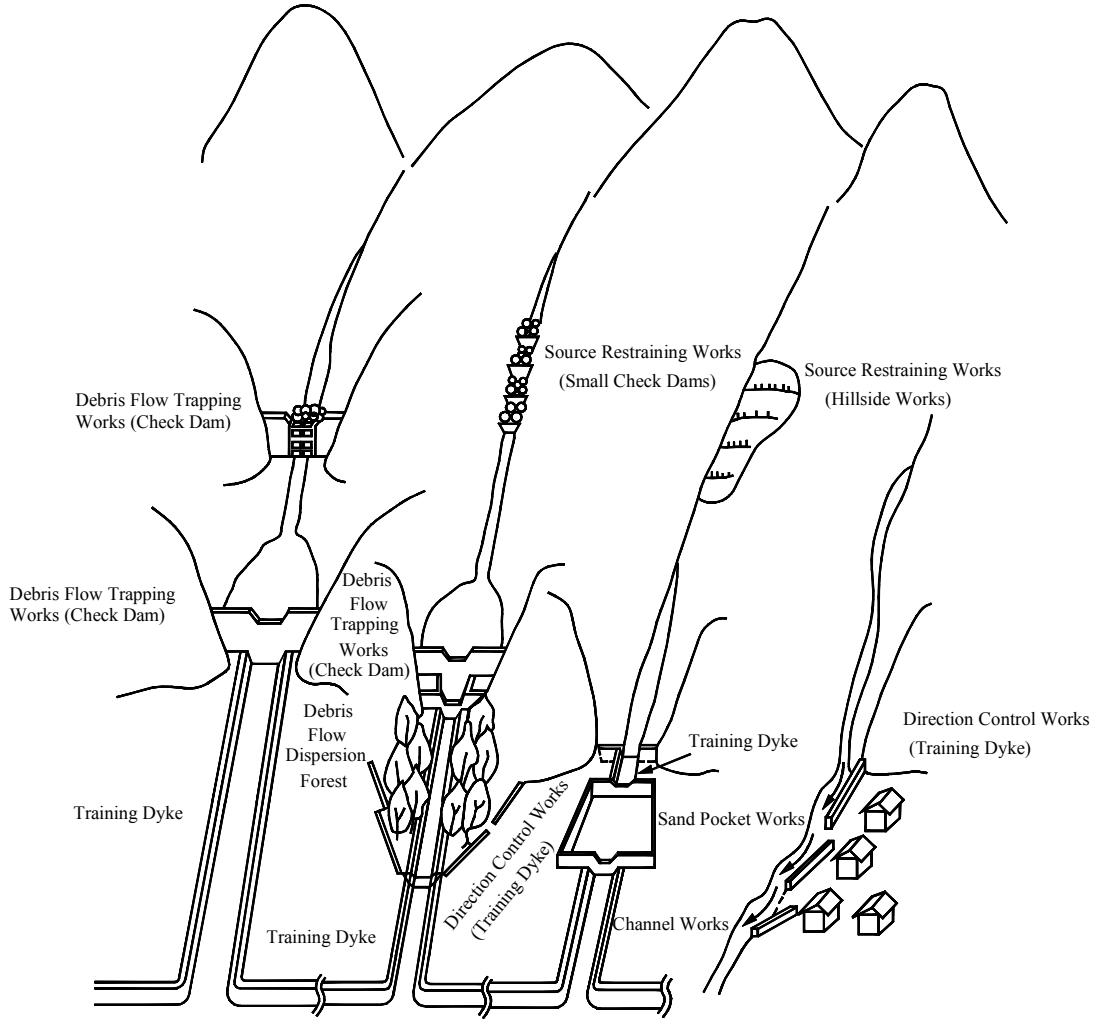
Location	River Gradient (θ)	Remarks
Outbreak Area	20 ° ≦θ	Outbreak section
Flow-down Area	15 ° ≦θ＜20 °	Outbreak section, Flow-down section
	10 ° ≦θ＜15 °	Flow-down and sedimentation section of debris flow, Flow-down section of earth flow
Sedimentation Area	3 ° ≦θ＜10 °	Sedimentation section of debris flow
	0 ° ≦θ＜3 °	Sedimentation section of earth flow

The measures against debris flow and earth flow are described in the following table, arranged based on the location and the events. Representative structural measures by locations are shown in the following figure and are listed up as follows:

- Outbreak Area: Small check dam, Hillside works, Normal check dam
- Flow-down Area: Normal check dam, Slit-type check dam, Consolidation dam (Groundsill), Training works, Channel works
- Sedimentation Area: Sand pocket, Normal check dam, Training works, Channel works

Debris Flow Control Measures

Location	Event	Measures	Function of Measures
Outbreak Area	Movement of riverbed sediment	Small check dam	To prevent sediment movement and slope collapse
	Scoring of riverside talus	Normal check dam, Small check dam, Groundsill	
	Land slide	Protection works against land slide	
	Slope collapse	Hillside works	
	Break of natural dam	Protection works against debris flow (all the above)	
Flow-down Area	Collision of debris flow front	Normal check dam (storage capacity), Slit-type check dam, Steel-structural check dam, Screen dam	To trap large stones of debris flow, Velocity dissipation, To stop debris flow front
	Flooding of debris flow front	Normal check dam (storage capacity)	To cut peak sediment load, Prevention of flooding of debris flow front
	Growth of debris flow	Low check dam series, Consolidation dam	To prevent spreading and scouring by debris flow
	Flooding by the flow followed to debris flow front	Normal check dam (storage capacity)	To cut sediment load
		Training dyke, Channel works	To prevent flooding
	Damage by driftwood	Driftwood control works	To trap driftwood
Sedimentation Area	Burring by sedimentation of debris flow	Sand pocket, Green (forest) belt	To restrict sedimentation range
		Large check dam, Sand pocket	To cut sediment load
	Direct hit of debris flow front	Normal check dam, Sand pocket	To stop debris flow front
	Flooding by the flow followed to debris flow front	Training dyke, Channel works	To control direction of debris flow
		Channel works	To prevent sedimentation on channel works and flooding to sheltered area



Schematic Debris Flow Control Measures

4.3.4 Planning Conditions

Before proceeding to the planning of the flood control structural measures, the following planning conditions are necessary to be set up, namely 1) Planning reference point, 2) Planning scale, 3) Objects to be protected, 4) Design sediment discharge and 5) Design flood discharge. This report does not make a complete master plan or a feasibility study but a conceptual plan for flood control structural measures. Thus, the said planning conditions are not necessarily set up but of which concept or views are explained in the following sub-sections.

(1) Planning Reference Point

Planning reference points for flood flow control measures are set up, for instance, at a discharge measurement point, a confluence of a large tributary, a bridge, or a structural planning point.

Planning reference points for debris flow control measures are the points at which design sediment discharge is decided. These points are set up, for instance, at the most downstream point of erosion and sediment control area, a point related to flood flow control measures, the most upstream point of objects to be protected, or a boundary point of a debris flow section and a tractional flow section. The debris flow section is the section with a gradient over about 1/30 (3 %).

(2) Planning Scale

Planning scale is set up generally according to an importance of the rivers, and also comprehensively taking into account the past flood damages and economic feasibility. Furthermore as it must depend on the national budget for flood control, realizable planning scale is necessary to be set up.

Return period of 10-year to 1,000-year is usually employed as planning scale for flood flow control plan, and that of 20-year to 100-year seems to be suitable for the target six rivers, according to the importance of the rivers and objects to be protected. For debris flow control measures, return period of 50-year to 100-year should be employed, while it is a little larger than the former because debris damages are destructive to people's lives. As mentioned in the basic policy for flood control measures, since the target six rivers have different social, economic and tourism conditions, the planning scales for the target rivers might be different from each other.

(3) Objects to be Protected

Objects to be protected in the Study Area are follows:

- Movable Objects: Inhabitants, Tourists, Cars and Cattle
- Immovable Objects: Houses, Roads, Bridges and Farmlands

An adequate flood forecasting and warning system could save movable objects but not immovable objects. Thus the objects to be protected by structural measures are set immovable objects such as mentioned above. Nevertheless not all the existing immovable objects could be saved because of an each economic feasibility of structural measures. For example, houses and farmlands located just beside a river course must be partly excluded, and it might be recommended that some houses located in very flood-vulnerable areas be resettled to ensure their safety. Moreover it might be also recommended that some roads and bridges be replaced to keep them safe against debris, flood and sediment flows.

(4) Design Sediment Discharge

The developing process of debris or earth flow could be categorized as follows:

1) To make flood flow develop to debris/sediment flow eroding river bed sediment
2) To switchover the sediment by slope collapse, as it is, to debris flow with floodwater
3) The sediment by slope collapse dams up a river section and forms a natural dam, which subsequently is broken away developing to debris flow.

Sediment discharge of debris flow caused by the item 1) can be estimated employing the investigation of riverbed material, but those caused by the items of 2) and 3) are difficult to be estimated since the location and the scale of slope collapse must be investigated. In the Study Area, every developing processes are possible to occur but the processes of 2) and 3) seem to be superior. Thus design sediment discharge must be set up taking into account both riverbed/riverside erosion and land collapse.

(5) Design Flood Discharge

Probable flood discharges at the main points of the target six rivers are shown in the following table. The specific flood discharges of the Issyl River are smaller than the other rivers because it is characterized by a plain river and basin inundation in the upstream.

Design flood discharge could be decided from the figures in the table according to the planning scale. It is noted for the Issyl River that flood discharge would become larger when river improvement works in the upstream would be progressed.

Probable Discharge

River	Station/ Location	Basin Area (km^2)	Probable Discharge with Return Period (m^3/s)							
			Probable Discharge (m^3/s)				Specific Discharge ($m^3/s/km^2$)			
			20-yr.	50-yr.	100-yr.	200-yr.	20-yr.	50-yr.	100-yr.	200-yr.
Issyl	Sidi Youssef Ben Ali	421	190	280	350	-	0.45	0.67	0.83	-
Ourika	Aghbalau	495	750	1,200	1,650	2,200	1.52	2.42	3.33	4.44
Rheraya	Tahanaout	221	230	390	560	800	1.04	1.76	2.53	3.62
N'fis	Imin El Hammam	1,256	1,220	2,040	2,880	3,950	0.97	1.62	2.29	3.14
	Iguir N'kouris	848	850	1,500	2,200	3,090	1.00	1.77	2.59	3.64
Zat	Taferiat	528	560	840	1,110	1,440	1.06	1.59	2.10	2.73
R'dat	Sidi Rahal	532	550	740	900	1,070	1.03	1.39	1.69	2.01

Source: 'Ajustments statistic de valeurs extremes de pluies et de debits dans le basin de Tensift-Qsob par le Logiciel EXTREM issued by ABHT/SHL, Dec 1999' and 'Etude de gestion des retenues et de protection des berges, Mission I, Etudes hydrauliques, Oued Issyl Rapport definiftif, Juin 1992'

CHAPTER 5. CONCEPTUAL PLAN OF STRUCTURAL MEASURES

5.1 Structural Measures Common to the Target Rivers

The target rivers have many common points in the viewpoints of natural conditions and flood damages, although each river has a different individuality. Within the specified river basin of the Study Area, the Ourika, Rheraya, N'fis, Zat and R'dat Rivers are mountainous rivers characterized by; 1) narrow or wide high valley, 2) steep slope of tributaries, 3) less vegetation resulting in gullies and slope collapse, 4) principal roads along the rivers, and 5) riverside farmland. Even the Issyl River as a plain river has some of these characteristics in the upstream mountain area. Therefore, the structural measures common to the target rivers will be planned in this section, being followed in the next section "8.5" by the structural measures for the individual rivers.

The following flood control structural measures common to all of the target rivers are proposed in this section:

1) Structural Measures in Potential Debris Flow Disaster Streams
2) Structural Measures for Riverside Road
3) Structural Measures in Riverside Farmland
4) Erosion Control Works for Hillside

5.1.1 Potential Debris Flow Disaster Streams

According to the debris hazard map formulated in this Study, the number of potential debris flow disaster streams by river and danger is shown in the following table. All the target rivers have many potential debris flow disaster streams, and two-third of them are categorized as the most dangerous stream.

Number of Potential Debris Flow Disaster Streams

River	Total	I ($\theta \geqq 15^o$, A$\geqq$5ha)	II ($\theta \geqq 15^o$, A<5ha)	III ($10^o \leqq \theta < 15^o$)	IV ($\theta < 10^o$)
Issyl	36	17	12	2	5
Ourika	330	267	52	9	2
Rheraya	145	111	26	5	3
N'fis	488	304	165	13	6
Zat	147	91	39	9	8
R'dat	285	170	106	7	2
Total	1,431 (100%)	960 (67%)	400 (28%)	45 (3%)	26 (2%)

Note. θ: stream slope, A: basin area, I to IV: classification by danger

Structural measures in potential debris flow disaster streams could be applied to all the five mountainous rivers and the upstream of the Issyl River. The mountain in these area is deep and steep, sediment runoff being almost unlimited, slope collapse being seen everywhere. Furthermore, dangerous abrupt waves, caused by flushing away a natural dam formed by debris flow from tributaries, seem to have happened in the past disasters. However, the land use is not advanced and vehicle roads do not reach most of the tributaries. Direct damages by debris and earth flows in the tributaries are limited to a part of roads, houses and riverside farmlands.

In order to perfectly control debris and earth flow, series of consolidation dams and check dams must be equipped in all the potential debris flow disaster streams. However, such large construction works could not be necessarily implemented because of economic infeasibility or inaccessibility of construction machinery. Thus, conceptual structural measures are proposed, clarifying potential debris flow disaster streams into the following two types of streams:

- Streams Accessible by Construction Machinery

Since it is easier to bring in construction machinery, large-scale works could be easy to construct and the cost will be reduced because of less temporary works cost.

- Streams Hardly Accessible by Construction Machinery

  Since it is difficult to bring in large-size construction machinery without construction of temporary road to a job site, it will cost more to construct large-scale works and it seems to be suitable to plan small-scale works or non-structural measures.

Based on the debris hazard map, the number of the above both streams is counted up and is shown in the following table. It is recognized that almost half of the total streams are hardly accessible by construction machinery.

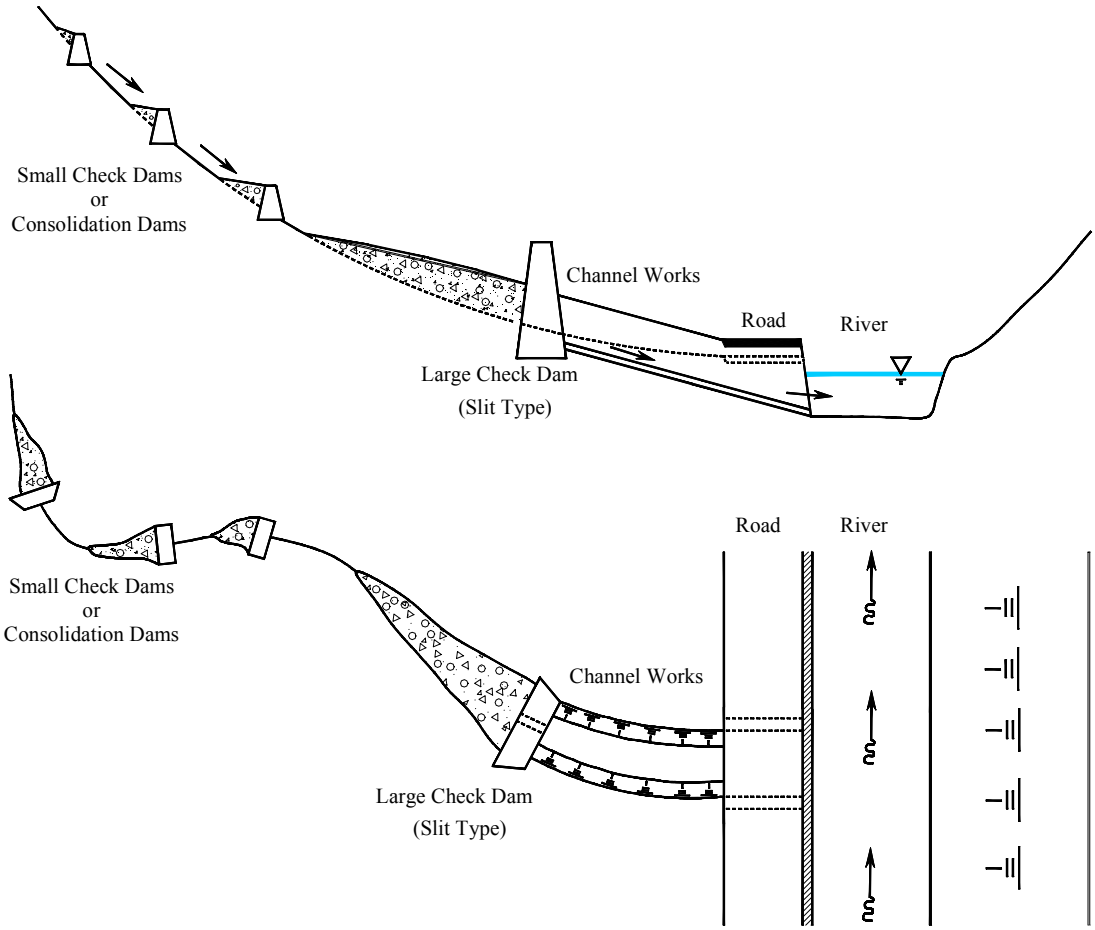
Number of Potential Debris Flow Disaster Streams by Accessibility

River	Total	Streams Accessible by Construction Machinery	Streams Hardly Accessible by Construction Machinery
Issyl	36	7 (19%)	29 (81%)
Ourika	330	142 (43%)	188 (57%)
Rheraya	145	108 (74%)	37 (26%)
N'fis	488	257 (53%)	231 (47%)
Zat	147	39 (24%)	108 (76%)
R'dat	285	152 (53%)	133 (47%)
Total	1,431	705 (49%)	726 (51%)

(1) Area Accessible by Construction Machinery

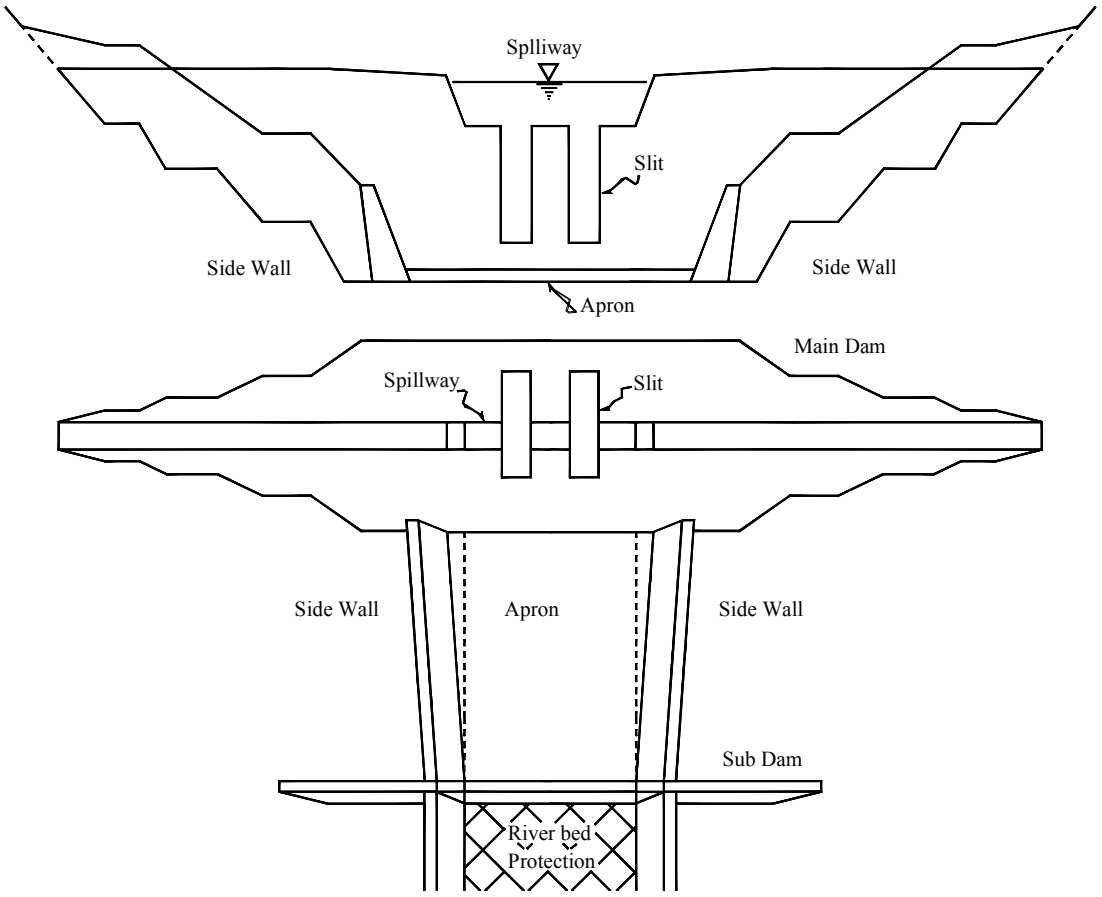
In potential debris flow disaster streams accessible by construction machinery, the following structural measures are proposed as shown in the following figure:

- At the outlet of the streams or at the just upstream of objects to be protected, a check dam with large sediment capacity is planned to trap debris flow.
- Small check dams are planned to stabilize the side slope and the bed of the stream.
- If a road crosses the stream, channel works to the main river or a crossing bridge are set up so that flood and debris flows could flow under the road/bridge.



Structural Measures in Potential Debris Flow Disaster Streams Accessible by Construction Machinery

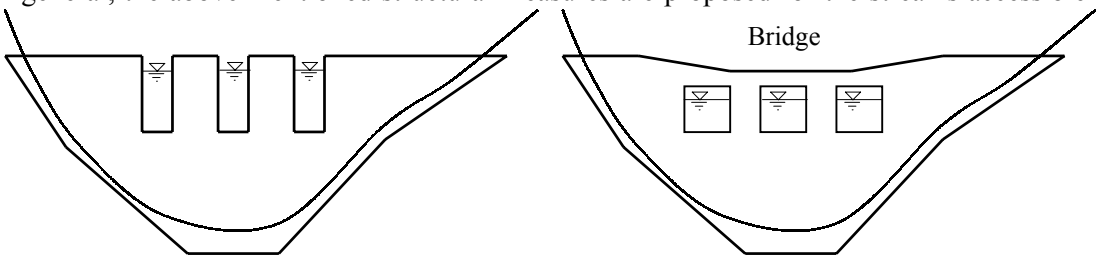
Although a vacant pocket for large sediment storage is very effective to control or to stop debris flow, a normal check dam might be inefficient when debris flow occur because the dam pocket might become full of sedimentation by floods with small or medium scale before a debris flow. To prevent this insufficiency, a slit-type check dam is proposed. A slit-type check dam has a function that sediment discharge of small and medium flood could be flown through the slits, ensuring a vacant pocket for sediment storage, and resulting in trapping large debris flow. After trapping debris flow, however, its sedimentation in the reservoir must be removed in preparation for a next debris flow. A slit-type check dam is shown as the following figure for instance.



Slit-type Check Dam

As for the form to be able to applied in the Study Area, the following two forms are proposed:

In general, the above-mentioned structural measures are proposed for the streams accessible by



a) Blockade Type Slit Check Dam
Check dam with slits that can run flood discharge but not debris flow.

b) Conduit Check Dam
Conduit Check Dam with conduits instead of slits in order to utilize the dam top as a road.

construction machinery. However, since there are so many (about 700) streams to be protected, it will take much cost and time to protect all the streams this way. Therefore, the following-mentioned measures in the streams hardly accessible by construction machinery should be also employed for low priority streams according to the degree of danger.

(2) Streams Hardly Accessible by Construction Machinery

In the streams hardly accessible by construction machinery, there are no principal roads but

houses to be protected. As a large check dam could not be constructed only by human strength, small check dams to stabilize the side slope and the streambed, or direction control works to keep debris flow away from houses are the only structural measures in this area. Therefore, non-structural measures must fulfill its important role in such areas. For example, flood forecasting and warning system is one of the non-structural measures. A rainfall gauge should be set up to forecast the outbreak of debris flow, and a wire sensor and warning system should be installed in one of small check dams to detect the occurrence of debris flow and to let it know to the residents.

5.1.2 Riverside Road

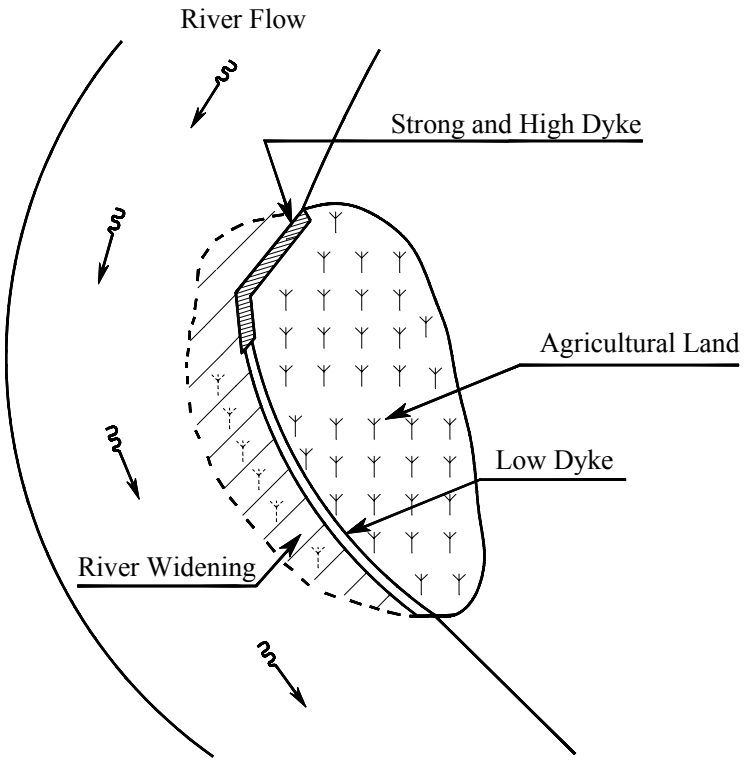
There are several riverside roads concerning with the Study Area, namely P2017 in the Ourika River, P2015 in the Rheraya River, R203 in the N'fis River and the national road N9 in the Zat and R'dat Rivers for instance. Some parts of such roads were inundated, and were washed away or damaged at water colliding fronts and narrow paths of the rivers. In those river sections, structural measures such as heightening of the roads as well as reinforcement of revetments and foot protections are the measures in general. Additionally the following structural measures should be planned being combined on a case-by-case basis with the general measures:

- In case that the other river side of the road is utilized as a farmland, river widening to the farmland side is recommended.
- Very firm foot protections and revetments should be planned at colliding fronts, and groynes also help to reduce flood flow energy at the upstream of the colliding fronts. But it is necessary to consider erosion by the change of flow direction to the other side.
- In case the river width is narrow and the road runs on low land, road rising works with high and strong retaining wall should be implemented, otherwise bridges also could be partly adopted.
- In case a road crosses a tributary, the road must be planned to cross the tributary so as not to be flushed away by a flood or debris flow, by means of tributary channel works or a box culvert under the road, or a small bridge over the tributary, for instance.

5.1.3 Riverside Farmland

As damaged farmlands extending along the rivers are located in the places that originally used to be river courses, flood damages and inundation could not be avoided there once a several years. If all the riverside farmlands would be protected from flood and debris flows, high embankment dykes with the flow capacity of design flood discharge would be needed all along the riverside farmlands, taking huge budget. On a basis of the basic policy mentioned in "the section 8.2", the structural measures on the riverside farmlands are proposed as the following manner:

1) A part of riverside farmlands might be diverted to a river-widening site to increase discharge capacity.
2) To protect riverside farmlands from debris damages, strong and high dyke is planed just upstream of the farmlands, since such debris damages are fatal to it and cause little chance of rehabilitation.
3) Low dyke is planned around riverside farmland to protect it from inundation but inundation of a part of the farmlands must be acceptable once in about ten years.



Flood Control Measures for Riverside Farmland

5.1.4 Erosion Control Works for Hillside

Erosion control works for hillside is the measures not for rivers but for mountain slopes. The upstream basin of the target rivers except the Issyl River has deep and steep slope with little vegetation producing huge amount of sediment yield. Soil erosion is caused by impacts of raindrops and surface tractional flows (rain-wash), sheet erosion or surface erosion. The surface erosion develops rills and gullies resulting in concentration of rainwater and increasing sediment discharge. Such large sediment yield could become causes of slope collapse, a natural dam, riverbed fluctuation, debris flow and sediment flow. The objective for erosion control works for hillside is to decrease such supply sources of sediment discharge.

Erosion control works include engineering works and plantation works. Reforestation is one of plantation works. In the reforestation master plan by ONF (Office National de Forests), about 55 km^2 of production forest are planned in the Ourika River and the Zat River in the Study Area. This reforestation area corresponds to 1.6 % of total study area 3,453 km^2. It is too small in the viewpoint of sediment control function. It is recommended that more reforestation efforts should be made. In parallel with reforestation, ONF has also implemented engineering works for erosion control, such as small sills and hillside works. These erosion control works should be strongly progressed combining both engineering works and plantation works in the Study Area, especially in the upstream basin of all the target rivers.

5.2 Issyl River

5.2.1 Policy of Structural Measures

Flood damages in the Issyl River are summarized as follows:

- Flood flow conveys much sand and gravel as tractional flow or earth flow, causing brocade of bridge and some debris damages to farmlands in the upstream.
- Small tributaries seem to inundate due to poor drainage capacity in the mid-upstream.
- The principal road PR2017 was inundated at the Tassoltante area and was flooded at the bridge across the Issyl River.
- The villages and farmlands upstream of Rocade Canal were inundated like a lake because of inadequate drainage capacity crossing Rocade Canal
- Tassoltante area from Rocade Canal to Sidi Youssef Ben Ali was inundated.
- The Issyl River flooded at Sidi Youssef Ben Ali and Remparts Road in Marrakech City.

To protect inhabitants, houses, farmland, villages and the main roads from the said flood damages, the following flood control measures in each area are proposed in the Issyl River.

1) Debris Flow Control Measures in the Upstream Mountain Basin
2) Flood Flow Control Measures in Mid-upstream (El. 900 m - Rocade Canal)
3) Flood Flow Control Measures in Rocade Canal
4) Flood Flow Control Measures in Tassoltante (Rocade Canal – Golf Road)
5) Flood Flow Control Measures in Marrakech Urban Area
6) Debris Flow Control Measures in Potential Debris Flow Disaster Streams
7) Erosion Control Works for Hillside

The measures of 6) and 7) are for the upstream mountain basin and have been already discussed in the section “5.1”. The items 1) to 5) will be studied in the following sub-sections: Refer to Fig. H.5.1.

5.2.2 Conceptual Structural Measures

(1) Debris Flow Control Measures in the Upstream Mountain Basin

A check dam is planned at the location of EL. 900 m that is the section changing the river gradient and located just upstream of the top of the alluvial fan. As this check dam has the catchment area of 45 km^2 equivalent to two thirds of the mountainous basin, the most part of sediment discharge could be trapped in cooperation with the measures for potential debris flow disaster streams. This check dam protects the main river in the downstream from debris damages.

(2) Flood Flow Control Measures in Mid-upstream (El. 900 m - Rocade Canal)

Few flood damages were reported in this area except flooding at the bridge of the road P2017. There are many small tributaries flowing from the southwest to northeast into the main river in the left side. This area is still to become advanced in land use and villages, and farmlands are few. The many small tributaries flow through this area repeating flooding and inundation during a flood.

Flood flow control measures for these small tributaries can be delayed until this area becomes advanced in land use because of few flood damages. The first importance of the measures is to increase discharge capacity of the main river of Issyl by the means of river excavation, river widening and small embankment dyke. Besides, the bridge of the road must be replaced to increase discharge capacity.

This area functions as a retarding basin for the downstream. Thus it is noted that the runoff rate would become larger resulting in larger peak discharge to the downstream, after river improvement is implemented in the main river and the tributaries.

(3) Flood Flow Control Measures in Rocade Canal

Rocade Canal was constructed considering flood drainages of the tributaries and the main river of Issyl from the south to the north. Some drainage channels for the tributaries can be found under Rocade Canal, and siphon works of the canal go under the Issyl River. However, since maintenance works seem not to be under good condition, the flow capacity of the drainage sections (Tassoltante tributary for instance) is so small that the south area of Rocade Canal was flooded and inundated.

Some drainage channel must be constructed under the Rocade Canal, integrating some tributaries flowing toward the canal. The siphon works under the main river of Issyl function as a submersible bridge and a groundsill. The Issyl River just upstream of the siphon is about 80 m in width and 350 m^3/s with 100-year return period could be flowed (I=1/100, n=0.040, h=1.5m). But as this wide river width is not continued both upstream and downstream, river improvement works such as river widening, embankment and river formation is necessary to assure river course continuity.

(4) Flood Flow Control Measures in Tassoltante (Rocade Canal - Golf Road)

Some flood flow control measures were planned and an intercepting drainage channel was realized in this area. In addition to these measures, small tributaries must be improved to assure flow capacity and to promote rainwater drainage. The most important measures are to assure flow capacity of the Issyl River and to lower floodwater level as the drainage points.

The width of the Issyl River is partly 20-30 m only in the sections from Rocade Canal to Sidi Youssef Ben Ali, so that it is obvious that discharge capacity is insufficient. It also gives evidence of the insufficient capacity that the Issyl River flooded to the right side in 1997 flood. Therefore, in the main river of Issyl from Rocade Canal to Sidi Youssef Ben Ali, river improvement works such as river widening, excavation and small embankment are planned to ensure enough discharge capacity with continuous river sections. Furthermore, longitudinal river plan is also important to avoid erosion or sedimentation of the riverbed.

Besides, inundation of the road P2017 is one of the large problems in this area. To improve this flood problem, both sides of street drain must be made larger and have continuity of the drain.

(5) Flood Flow Control Measures in Marrakech Urban Area

River improvement works were implemented in 1995 in the river sections of this area. It is reported that this works achieved to deal with flood with about 15-year return period. However, there exist two road bridges and three historical footpath bridges with insufficient discharge capacity. The three historical footpath bridges have only 2-4 m^2 of flow area or have only 20-40 m^3/s of discharge capacity even if assuming flood velocity of 10m/s. This flow capacity is far from probable discharge of 130 m^3/s with 10-year return period.

As the flood flow control measures in this area, the following measures are proposed to ensure discharge capacity; 1) riverbed excavation, river widening, embankment dyke with resettlement at some parts, 2) replacement of two road bridges, and 3) dealing with the three historical footpath bridges, for example, excavation of bypass river, rising elevation of these footpath bridges or replacement. In case that it is difficult to improve river sections and these bridges, a retarding basin in the mid-stream or a flood control dam in the upstream must be drastic measures for this area to mitigate flood damages.

Besides, many peoples are living in the Genoun Village along the right side of the Issyl River in the downstream end of Marrakech urban area. Few flood damages were happened in this area because the upstream discharge capacity of the Issyl River is small. However, as flood discharge would become larger when river improvement measures in Marrakech urban area were realized, these sections also must be improved, resulting in resettlement of the many inhabitants.

At last, it must be noted that runoff rate will become larger resulting in larger peak discharge to the downstream when the upstream basin would be developed, and that flood discharge would become increased by river improvement itself. In the flood flow control measures for the Issyl River, therefore, design flood discharge must be decided considering the increase of flood discharge according to basin development and river improvement.

5.2.3 Prioritization of Structural Measures

Summarizing the flood control structural measures discussed above, the overview of structural measures in the Issyl River is shown in the following table and Fig. H.5.1.

As mentioned in the section “4.2”, proposed structural measures should be implemented according to their priority, which would be set up based on a) Economic Feasibility, b) Urgent Requirement, and c) Less Social and Environmental Impact. In this study, rough priority could be set up as shown in the following table, classifying the proposed structural measures into 1) Emergent, 2) High Priority, and 3) Low Priority.

Overview of Structural Measures with Implementation Priority in the Issyl River

Classification	Location	Structural Measures	Priority	Main Function
Debris Flow Control Measures	Upstream mountain basin	- 1 check dam at the upstream of the top of alluvial fan	B	- Trapping debris flow and sediment
	Potential Debris Flow Disaster Streams	- Check dams - Small Check Dam	C C	- Trapping debris flow - Stabilizing riverbed
Flood Flow Control Measures	Mid-upstream (EL.900 m – Rocade Canal)	- River improvement for main river (river excavation, river widening, small embankment dyke) - Replacement of the bridge of P 2017	C B	- Increasing discharge capacity
	Rocade Canal	- Drainage channels under Rocade Canal - River improvement for main river (river excavation, river widening, small embankment dyke)	B B	- Increasing discharge capacity
	Tassoltante (Rocade – Golf Road)	- Intercepting drainage channel - River improvement for main river (river excavation, river widening, small embankment dyke) - Flow capacity improvement for tributaries (excavation)	B A B	- Draining rainwater and flooded water - Increasing discharge capacity
	Marrakech Urban Area	- River improvement for main river (river excavation, river widening, small embankment dyke) - Replacement of two principal road bridges - Dealing with the three historical footpath bridges	B A A	- Increasing discharge capacity - Bridge improvement
Erosion Control	All the basin especially upstream	- Reforestation and hillside works	B	- Source sediment control

Note: Emergent (A), High Priority (B), and Low Priority (C)

5.3 Ourika River

5.3.1 Policy of Structural Measures

Flood damages in the Ourika River are summarized as follows:

- Debris flow or earth flow occurred in the upstream, which flew flown down and attacked Setti Fadma in the form of debris, earth or flood flow, causing devastating damages to inhabitants, tourists, vehicles, houses and the principal road PR2017.

- Along the Ourika River from Setti Fadma to Aghbalau through Ourmes, flooding and inundation caused casualties of tourists and flushed away houses and the principal road PR2017.

- Debris flows from tributaries cut off traffic at many places of the principal road PR2017 along the Ourika River.

To protect inhabitants, tourists, houses and the road P2017 from the said flood damages, the following flood control measures are proposed in the Ourika River.

1) Debris Flow Control Measures in the upstream of Setti Fadma

2) Flood Flow Control Measures from Setti Fadma to Aghbalau

3) Debris Flow Control Measures in Potential Debris Flow Disaster Streams

4) Flood Flow Control Measures for Riverside Farmland

5) Erosion Control Works for Hillside

The items of 3), 4) and 5) have been already discussed in the section "5.1", and the items 1) and 2) will be studied in the following sub-sections:

5.3.2 Conceptual Structural Measures

(1) Debris Flow Control Measures in the Upstream of Setti Fadma

(a) Background to Structural Measures

The basin area upstream of Setti Fadma is 235 km^2 corresponding to 47 % of the Ourika River Basin in the Study Area. This upstream area is of low-advanced land use, in which total population, as shown in the following table, is estimated about 5,200 peoples according to our site reconnaissance and interviews.

Main Villages and Population in the Upstream of Setti Fadma

Villages	Households	Population (persons)
Agadir -n- Ait Boulmane	100	1,000
Tadrart	20	200
Anfli	60	600
Tiourdiou	50	500
Timichchi	20	200
Other 9 Villages Upstream	270	2,700
Total	520	5,200

No casualties were reported but a few houses and riverside farmland were washed away in 1995 and 1999 floods in this area. There are no principal roads along the river course. The flood damages in 1995 and 1999 at Setti Fadma were caused by the debris flow or the flood flow that happened in the upstream of Setti Fadma and that attacked Setti Fadma. Thus a debris flow control measures are judged most important in this area.

Less vegetation covers this area, where some small shrubs on the mountain and limited forest near villages can be only seen. Slope collapse, landslide and large-scale gullies can be found in many palaces. It must be said that intensive rainfall such as 1995 and 199 floods certainly could cause debris flow at any tributaries in this area. From the viewpoint of debris flow control measures in this area, series of small check dams and large check dams as well as hillside erosion control works are necessary to be set up, in order to control and trap debris flow and to make it not reach to the downstream. However, as this area has no roads for construction and a few dispersed objects to be protected, such measures mentioned above are understood to be economically infeasible. Therefore, the minimum conceivable structural measures are proposed in this study.

(b) Proposed Conceptual Structural Measures

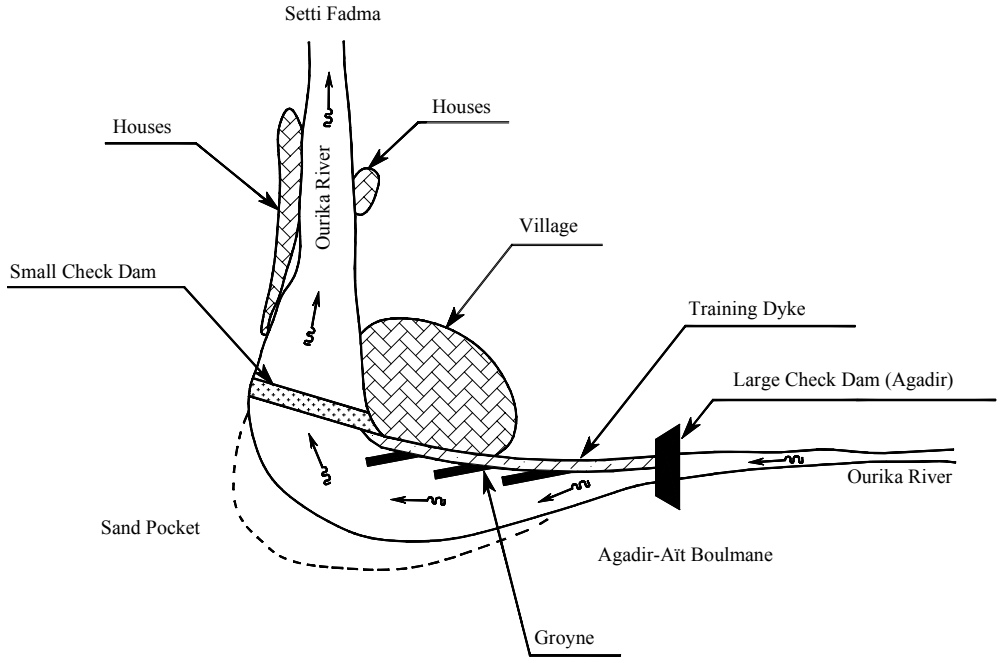
At the five locations in the tributaries and at two (2) locations in the main course, check dams with relatively large scale are proposed as shown in the following table and Fig. H.5.2.

Proposed Check Dams in the Upstream of the Ourika River

Location	River Name	Village	Catchment Area (km^2)
Main River	Ourika	Agadir –n- Ait Boulmane	226
	Ourika	Tiourdiou	30
Tributary	Unknown	Right tributary upstream of Agadir	6
	Chiker	Chiker	3
	Oufra	Tamatart	71
	Tadrart	Tadrart	7
	-n- Tifni	Tiourdiou	100

The objectives of these large check dams are to protect Setti Fadma from the direct hit of debris/earth flow, and they behave as trapping works of debris flow. The check dam in Agadir should be the especially largest dam because it is expected to trap debris flow as the last check dam downstream.

There forms a broad valley between Agadir and Setti Fadma, which is planned as a sand pocket works to reduce energy of debris/earth flow and to promote sedimentation as well as to protect houses along the river. The structural measures are composed of training dyke, groynes, a small check dam and a sand pocket, as shown in the following figure.



Proposed Debris Flow Control Measures at Agadir in the Ourika River

The paved road was prepared from Marrakech to Setti Fadma, and many tourists have been coming through this road to Setti Fadma. From Setti Fadma to Agadir -n- Ait Boulmane, a 4WD vehicle can manage to run. From Agadir to Tadrart, the vehicle road is presently out of use because of land collapse at some parts, although it could be run until the year 1999. However, this road could be utilized as a construction road after simple improvement and adequate maintenance. Therefore, there are few problems on the construction road to Tadrart. Only the following construction roads are needed for construction of the check dams; 1) Construction road to the check dam site from the Agadir-Tadrart Road, 2) About 2 km road to Tiourdiou from Tadrart. These construction

road must be utilized by the 4,000 residents living upstream of Tadrart as a precious public road after the construction of the check dams.

(2) Flood Flow Control Measures from Setti Fadma to Aghbalau

The area in which flood flow control measures must be planned is the sections of about 15 km between Setti Fadma and Aghbalau. The alternatives of the proposed structural measures for these sections are the following three measures:

a) River Improvement Works

b) River Improvement Works and Resettlement

c) River Improvement Works and Flood Control by Reservoir

Note: River improvement works include riverbed excavation, river widening, embankment dykes, revetment works and foot protection works as well as road rising.

Based on the following explanation on these structural measures, the alternative c) is judged to be proper under the current rough discussions. However, the most appropriate proposal must be adopted, taking into account technical, economic and environmental evaluations for detailed planning of the three proposals based on topographical maps and hydrological data.

(a) River Improvement Works

These are the structural measures that DGH plan for the Ourika River as flood flow control structural measures, in which river improvement works were planned with the fewest resettlements. The structural measures are composed of river excavation, river widening and embankment dykes.

Since the dykes have 2-6 m in height according to the plan, it is imagined that tourists could not see the river. It is a fatal disadvantage as the tourist spots, namely Setti Fadma and Oulmes for instance. Besides, it is expected that land use in the sheltered area will be advanced and it might cause more serious damages at the time of an extraordinary discharge beyond design flood.

(b) River Improvement Works and Resettlement

To ensure enough discharge capacity, necessary resettlement is promoted for river widening rather than the above plan, making the dyke height as low as possible. Riverbed excavation, road replacing, or improvement and enforcement of the road are also the measures for this plan.

In case that this plan would be adopted, enough compensation should be paid for inhabitants to be resettled and people engaged in the tourism industry as well as for suspension of business during construction. In parallel with river improvement, the present tourism spots could also be set up to make them reborn as more fascinated and safety places.

(c) River Improvement Works and Flood Control by Reservoir

The sections between Setti Fadma and Aghbalau have many narrow valleys, some of which are tourism spots. The two of river improvement works mentioned above could not deal with these places without high dykes and resettlement that would give a fatal blow to

the tourism industry. Thus a flood control dam could be a drastic flood control measures for the said sections.

Carrying out site reconnaissance in the Ourika River between Setti Fadma and Tiourdiou, three dam sites were identified, namely 1) Setti Fadma, 2) Agadir -n- Ait Boulmane and 3) Tadrart. Agadir -n- Ait Boulmane is the location in which Setti Fadma Dam used to be planned and to be discontinued because of topographical, geological and economical problems. These three dam sites are compared in the following table, and their locations are shown in Fig. H.5.3. The comparison is summarized as follows:

- **Dam volume** is smaller in the dam sites in Agadir and Tadrart because of steep valleys.

- **Dam reservoir** in Agadir is small owing to continuous steep valley, which needs higher dam. To the contrary, those in Setti Fadma and Tadrart could assure relatively large reservoir volume resulting in lower dam height.

- **Dam foundation** was estimated to be about 20 m deep in Agadir based on geological investigation as mentioned in the subsection "3.1.2". It is supposed to be deeper in Setti Fadma and to be shallower in Tadrart.

- **Catchment area** of the sites of Setti Fadma and Agadir are larger expecting effective flood control function.

- **Resettlement** in Agadir is nothing but is necessary in Setti Fadma and Tadrart.

Comparison of Dam Sites in the Ourika River Upstream of Setti Fadma

Item	Setti Fadma		Agadir –n- Ait Boulmane		Tadrart	
Catchment area	230 km^2	-	226 km^2	-	140 km^2	-
Topography	Relatively wide valley	B	Steep valley	A	Steep valley	A
Geology	Deep foundation	C	Relatively deep foundation	B	Not so deep foundation	A
Reservoir	Dam reservoir is large	A	Dam reservoir is small	C	Dam reservoir is relatively large	B
Dam height	Low	A	High	C	Middle	B
Flood control	Very efficient	A	Very efficient	A	Relatively efficient	B
Location	Near to Setti Fadma	A	Near to Setti Fadma	A	Far from Setti Fadma	B
Resettlement	About 80 households	C	No resettlement	A	About 60 households	B

Note: A: good, B: Fair, C: not good

The measures against reservoir sedimentation are one of the largest issues on the dam planning in the Ourika River. Large sediment discharge is expected, because the upstream basin of these proposed dams is very poor in vegetation, where landslide and slope collapse as well as large gullies could be seen. Therefore, debris flow control measures mentioned before are inevitable for the dam planning. Moreover, it is recommended that a check dam should be planned at the upstream end of the reservoir in order to reduce the sedimentation into the reservoir. Besides, the works to remove debris are requested when the check dam reservoir becomes full of sediment.

It is difficult at the stage of the conceptual plan to judge which dam site the best is. To make an adequate dam plan, it is necessary to investigate topography, geology, hydrology, structural design as well as economic and environmental evaluation based on topographical maps at least with a scale of 1/5,000 to be made for about 10 km between Setti Fadma and Timichchi.

5.3.3 Prioritization of Structural Measures

Summarizing the flood control structural measures discussed above, the overview of structural measures in the Ourika River is shown in the following table and Fig. H.5.2.

As mentioned in the section "4.2", proposed structural measures should be implemented according to their priority, which would be set up based on a) Economic Feasibility, b) Urgent Requirement, and c) Less Social and Environmental Impact. In this study, rough priority could be set up as shown in the following table, classifying the proposed structural measures into 1) Emergent, 2) High Priority, and 3) Low Priority.

Overview of Structural Measures with Implementation Priority in the Ourika River

Classification	Location	Structural Measures	Priority	Main Function
Debris Flow Control Measures	Upstream of Setti Fadma	- 5 check dams in the tributaries - 2 check dams in the main course	C B	- Trapping debris flow
	Between Setti Fadma and Agadir	- Sand pocket works (Training dykes, groynes, a small check dam and sand pocket)	B	- Direction control of debris flow - Sedimentation
	Potential Debris Flow Disaster Streams	- Check dams - Small Check Dam - Channel works to the main river	B C C	- Trapping of debris flow - Stabilizing riverbed - Flushing sediment
Flood Flow Control Measures	Setti Fadma, Agadir or Tadrart	- Dam and reservoir	B	- Flood Control
	Between Setti Fadma and Aghbalau	- River improvement works	A	- Increasing discharge capacity
	Road P2017 along the River	- Reinforcement of revetment and foot protection - River widening, groynes, retaining walls and bridges	B B	- Protection against flood flow
	Riverside farmland	- River widening - Strong and high dykes and low dykes	C C	- Protection against flood flow
Erosion Control	All the basin especially upstream	- Reforestation and hillside works	B	- Source sediment control

Note: Emergent (A), High Priority (B), and Low Priority (C)

5.4 Rheraya River

5.4.1 Policy of Structural Measures

Flood damages in the Rheraya River are summarized as follows:

- Debris flow was directly hit Imlil Village causing casualties and washing vehicles away.
- In Asni Village, several houses were partly damaged, and a bridge was partly washed away by the flood.
- Flood flow in Moulay Brahim caused casualties on the river, road inundation, and washed shops/restaurants away.
- Flood damages to the principal road PR2015
- Inundation and debris damages of farmland along the Rheraya River and the tributaries of Imlil and Tacheddirt

To protect inhabitants, tourists, houses and the road P2015 from the said flood damages, the following flood control measures are proposed in the Rheraya River.

1) Debris Flow Control Measures in the Upstream of Imlil
2) Debris Flow Control Measures in Imlil
3) Flood Flow Control Measures in Asni
4) Flood Flow Control Measures in Moulay Brahim
5) Debris Flow Control Measures in Potential Debris Flow Disaster Streams
6) Flood Flow Control Measures on the road P2015
7) Flood Flow Control Measures for Riverside Farmland
8) Erosion Control Works for Hillside

The items of 5), 6), 7) and 8) have been already discussed in the section "5.1", and the items 1), 2), 3) and 4) will be studied in the following sections:

5.4.2 Conceptual Structural Measures

(1) Debris Flow Control Measures in the Upstream of Imlil

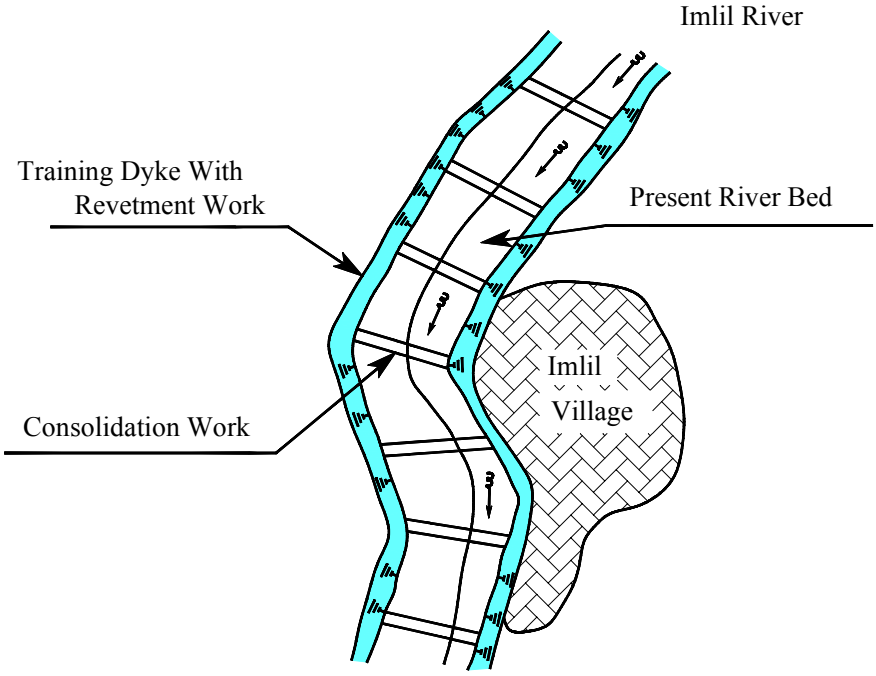
Two check dams, one in the Imlil River and the other in the right tributary of n'lmserdane, are planned in Aremd Village located upstream of Imlil, in order to protect Imlil Village from a direct hit of debris flow. Refer to Fig.H.5.3. As these check dams need vacant capacity to trap debris flow, a slit-type check dam is suitable referring to the discussion mentioned in the sub-section "5.1.1".

The check dam site in the Imlil River has the advantages of V-shaped valley and broad sedimentation area, but it is expected that about 20 households be resettled. In case of difficulty of resettlement, a check dam site could be found about 1 km upstream of the former site.

Nevertheless, as the latter site presents wide valley and relatively narrow sedimentation area, the both sites must be studied carefully.

(2) Debris Flow Control Measures in Imlil

The Imlil River near the upstream of Imlil Village shows very steep slope, which suggests debris flow could be caused by riverbed sediment movement or riverside erosion. Thus, the series of consolidation works are planned to stabilize the riverbed and the riverside. Besides, as the river width is narrow here, river widening to the right side and revetment works are planned to ensure the flow capacity and to protect it from riverside erosion. The structural measures against debris and flood flow in Imlil are schematically drawn in the following figure.



Structural Measures against Debris and Flood Flow in Imlil

(3) Flood Flow Control Measures in Asni

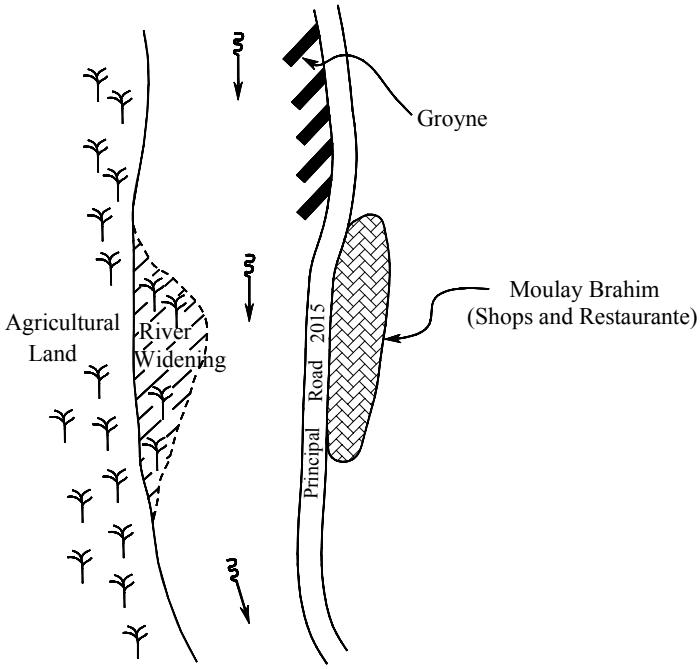
The width of the Rheraya River near Asni is broad enough to flow flood discharge in the river, but a few houses along the river were washed away and the bridge near the Saturday Market was partly broken. It is thought to be their causes that flood flow irregularly eroded the riverbed resulting in flow concentration to the houses and that flood flow eroded bridge piers breaking the bridge. The bridge is so important that the inhabitants are strongly requesting to be rehabilitated according to the chief of the Cercle Asni (Super Caid).

Taking into account the said circumstances, the following flood flow control measures are proposed:

- The series of groundsill are set up in order to stabilize riverbed materials.
- Conduit-type groundsill is adopted for one of the groundsills, of which the top is utilized as a public bridge.

(4) Flood Flow Control Measures in Moulay Brahim

The Rheraya River at Moulay Brahim, although the height of the road P2015 and the houses (shops and restaurants) is only 1 - 1.5 m above the riverbed, has broad river width and forms riverside farmland in the right side. The flood control measures here are to widen the river course to the riverside farmland and to ensure enough flow capacity. Groynes could also be set up in the left side to control flood flow direction to the right side. Refer to the following figures.



Structural Measures at Moulay Brahim

5.4.3 Prioritization of Structural Measures

Summarizing the flood control structural measures discussed above, the overview of structural measures in the Rheraya River is shown in the following table and Fig. H.5.3.

As mentioned in the section "4.2", proposed structural measures should be implemented according to their priority, which would be set up based on a) Economic Feasibility, b) Urgent Requirement, and c) Less Social and Environmental Impact. In this study, rough priority could be set up as shown in the following table, classifying the proposed structural measures into 1) Emergent, 2) High Priority, and 3) Low Priority.

Overview of Structural Measures with Implementation Priority in the Rheraya River

Classification	Location	Structures/Measures	Priority	Main Function
Debris Flow Control Measures	Upstream of Imlil	- 1 check dam in the Imlil River - 1 check dam in the tributary of n'lmserdane	B B	- Trapping debris flow
	Imlil	- River widening - Training dykes with revetment works - Series of consolidation works	A A A	- Consolidation of riverbed material - Increasing discharge capacity
	Potential Debris Flow Disaster Streams	- Check dams - Small Check Dam - Channel works to the main river	B C C	- Trapping of debris flow - Stabilizing riverbed - Flushing sediment
Flood Flow Control Measures	Asni	- Series of groundsills - Conduit-type groundsill as a bridge	C C	- Consolidation of riverbed material
	Moulay Brahim	- River widening - Groyne	C C	- Increasing discharge capacity - Flow direction control
	Road P2015 along the River	- Reinforcement of revetment and foot protection - River widening, groynes, retaining walls and bridges	B B	- Protection against flood flow
	Riverside farmland	- River widening - Strong and high dykes and low dykes	C C	- Protection against flood flow
Erosion Control	All the basin especially upstream	- Reforestation and hillside works	B	- Source sediment control

Note: Emergent (A), High Priority (B), and Low Priority (C)

5.5 N'fis, Zat and R'dat Rivers

5.5.1 N'fis River

Flood damages in the N'fis River are summarized as follows:

- The road R203 and its bridges were damaged by debris flows flushing down from the tributaries, namely Wirgane, Imigdal and Tasaft.
- Farmland along the main river was damaged by flood flow.
- There happened few or limited flood damages to houses and inhabitants, even to tourists.

Based on the said flood damages' conditions, the following flood control measures are proposed in the N'fis River.

1) Debris Flow Control Measures in Potential Debris Flow Disaster Streams
2) Flood Flow Control Measures on the Road R203
3) Flood Flow Control Measures for Riverside Farmland
4) Erosion Control Works for Hillside

These flood control measures were explained in the section "5.1". Summarizing the flood control structural measures, the overview of structural measures with priority in the N'fis River is shown in the following table.

Overview of Structural Measures with Implementation Priority in the N'fis River

Classification	Location	Structures/Measures	Priority	Main Function
Debris Flow Control Measures	Potential Debris Flow Disaster Streams incl. Wirgane, Imigdal and Tasaft Tributaries	- Check dams - Small Check Dam - Channel works to the main river	B C C	- Trapping of debris flow - Stabilizing riverbed - Flushing sediment
Flood Flow Control Measures	Road R203 along the River	- Reinforcement of revetment and foot protection - River widening, groynes, retaining walls and bridges	A B	- Protection against flood flow
	Riverside farmland	- River widening - Strong and high dykes and low dykes	C C	- Protection against flood flow
Erosion Control	All the basin especially upstream	- Reforestation and hillside works	B	- Source sediment control

Note: Emergent (A), High Priority (B), and Low Priority (C)

5.5.2 Zat River

Flood damages in the Zat River are summarized as follows:

- Flood and debris damages to houses and the principal road along the main river were not reported.
- Farmland along the main river was damaged by flood flow.
- Debris flow or land slide occurred in 1995 and flushed some houses and killed 9 inhabitants at the Tifarent Village in the Tighadwine tributary.
- In the other area, there happened few or limited flood damages to houses and inhabitants, even to tourists.

Based on the said flood damages' conditions, the following flood control measures are proposed in the Zat River.

1) Debris Flow Control Measures in Potential Debris Flow Disaster Streams
2) Flood Flow Control Measures for Riverside Farmland
3) Erosion Control Works for Hillside

These flood control measures were shown in the section "5.1". Summarizing the flood control structural measures, the overview of structural measures with priority in the Zat River is shown in the following table.

Overview of Structural Measures with Implementation Priority in the Zat River

Classification	Location	Structures/Measures	Priority	Main Function
Debris Flow Control Measures	Potential Debris Flow Disaster Streams	- Check dams - Small Check Dam - Channel works to the main river	B C C	- Trapping of debris flow - Stabilizing riverbed - Flushing sediment
	Tighadwine Tributary	- Small Check Dam	A	- Stabilizing riverbed
Flood Flow Control Measures	Riverside farmland	- River widening - Strong and high dykes and low dykes	C	- Protection against flood flow
Erosion Control	All the basin especially upstream	- Reforestation and hillside works	B	- Source sediment control

Note: Emergent (A), High Priority (B), and Low Priority (C)

5.5.3 R'dat River

Flood damages in the R'dat River are summarized as follows:

- Debris flow (or land slide) happened in Zerkten tributary and was deposited in the main river, which interrupted the traffic of the national road 9.
- In the Tazlyada Tributary, debris flow flushed away some houses and killed 10 inhabitants.
- Algu Village located in high mountain area was attacked by flood and three (3) houses were flushed away and six (6) inhabitants died.
- Farmland along the main river was damaged by flood flow.

Based on the said flood damages' conditions, the following flood control measures are proposed in the R'dat River.

1) Debris Flow Control Measures in Potential Debris Flow Disaster Streams
2) Flood Flow Control Measures for Riverside Farmland
3) Erosion Control Works for Hillside

These flood control measures were shown in the section "5.1". Summarizing the flood control structural measures, the overview of structural measures with priority in the R'dat River is shown in the following table.

Overview of Structural Measures with Implementation Priority in the R'dat River

Classification	Location	Structures/Measures	Priority	Main Function
Debris Flow Control Measures	Potential Debris Flow Disaster Streams incl. Zerkten and Tazlyada Tributaries	- Check dams - Small Check Dam - Channel works to the main river	B C C	- Trapping of debris flow - Stabilizing riverbed - Flushing sediment
Flood Flow Control Measures	Riverside farmland	- River widening - Strong and high dykes and low dykes	C C	- Protection against flood flow
Erosion Control	All the basin especially upstream	- Reforestation and hillside works	B	- Source sediment control

Note: Emergent (A), High Priority (B), and Low Priority (C)

CHAPTER 6. RECOMMENDATIONS

6.1 Recommendations on Structural Measures for Flood Disaster Prevention

(1) Detailed Investigation on Disaster Conditions

Detailed investigation on disaster conditions should be carried out just after a disaster happening. The items of the data collection could be listed as 1) disaster area, 2) disaster type, 3) area, depth and volume of sedimentation, 4) particle size, 5) flooded area, 6) flood depth, 7) flood discharge, 8) hydrograph, 9) rainfall (10 minute interval), and so on. These detailed disaster conditions could be utilized for the analysis, planning and design for flood/debris control works not only for the target areas but also for other similar areas.

(2) Land Collapse and Landslide

The study on measures against land collapse and landslide is out of the scheme in this Study. However, in the study area, land collapse and landslide happen and worsen the situation of flood and debris disasters. Thus, the plan and design for land collapse and landslide should be studied, in order to promote road safety, sediment runoff control and debris flow control.

(3) Study on Flood Control in the Downstream

In the downstream alluvial fan of the Ourika River and the Zat River, which is out of the Study Area, the rivers have been changing their paths and basins, repeating erosion and sedimentation. As a result, farmlands and inhabitants land are partly lost and communities themselves have faced danger to lose their life foundation. Although it is important in such areas to stabilize river paths at first, it might take much cost to implement merely flood control measures in such areas where are not currently advanced in land use. However, these areas are agricultural-potential areas and very near to Marrakech urban area as a consumer of agricultural products. Therefore, multi-purpose projects are recommended combining flood control with water resources development and irrigation. For example, Ait Ziat Dam and Timalizene Dam that have been planned in the Zat and Ourika Rivers respectively could be made as multi-purpose projects with flood control capacity in the reservoirs. A land consolidation project with irrigation water development could be also integrated a multi-purpose project with the flood control purpose.

(4) Necessity of Integrated Basin Development Plan

Although conceptual structural measures against flood/debris disaster have been planned in this Study, it is still on the way to the formulation of a master plan. In short, the Study includes only a rough proposal to flood/debris control. However, the Tensift River Basin has many issues to be solved, such as flood/debris damages in many places, irrigation agriculture, devastation of forestry and vegetation, tourism setup, rural poverty, and so on. Moreover, the nation has decided to formulate Tensift River Basin Agency in January 2001, in order to totally manage the basin environment of the nature and the society. Therefore, “Integrated Development Plan” for the Tensift River Basin is of urgent necessity.

6.2 Brief Information of the Study on Integrated Development Plan

(1) Project Summary

1) Title of the Project: The Study on Integrated Development Plan for Tensift River Basin in the Kingdom of Morocco

2) Name of the Ministry and Directory: Ministry of Equipment, Directorate General of Hydraulics

3) Type of Scheme: Development Study

4) Project Site: Tensift River Basin (Marrakech Region)

5) Issue (approach): Integrated River Basin Development

(2) Project Purpose

The Study Area is the Tensift River basin around Marrakech Region, which consists of 4 provinces and 3 prefectures with 2.9 millions of population in 1998. Marrakech is the center city of Tensift Economic Block. Al Haouz Province, where agriculture, forestry and tourism are the important industry, has the most serious socio-economic conditions. Marrakech is the one of tourism footholds in Morocco, where 1.2 millions tourists visited in 1999. The center of tourism is Marrakech town and Atlas Mountain. Although Marrakech Region is such an important area, infrastructure setup is still to be advanced such as flood control, water resources development, agriculture and tourism. Furthermore, the comprehensive basin development has been desired for mitigation of various problems that hinder the progress of region among which poverty constitutes a remarkable issue especially in the rural area. The very important issues are as follows:

1) Mitigation of Flood and Debris Flow Disasters

In the Ourika and Rheraya Rivers as the tourist center of Atlas, inhabitants, tourists and tourism facilities as well as roads and farmlands have been damaged like every year by flood and debris flows. The flood calamity might be happened, by which the continuance of the tourism industry seems to be in great peril. In the alluvial fan of the Issyl, Ourika and Zat Rivers, farmlands and villages have been damaged by inundation and erosion. Furthermore, the Issyl River has been giving severe flood damages to urban inhabitants in Marrakech City. As such debris and flood damages have given a great blow on rural inhabitant, agriculture and tourism industry, emergent flood control structural measures are needed.

2) Water Resources Development and Rural Development

The left side of the Tensift River has many fertile lands, and is irrigated by Rocade canal taking water from the other river basin, developing irrigation agriculture. However, since water resources development within the Tensift River Basin is not progressing, the broad farmlands must depend on rain fed agriculture. Furthermore, as the alluvial fan of the Issyl, Ourika and Zat Rivers has been damaged by flood and inundation, the stable agriculture is strongly required. Thus, the agricultural productivity and the self-sufficient rate in food could be increased, and the rural society and economy become possible to be developed, according to the implementation of water resources development and flood/inundation control measures in parallel.

3) Management of River Basin and River Space

The Haouz Province in the Atlas Mountain is prospering in forestry, but it is reported that the basin is devastated and 600 km^2 or 22 % of the forest area has become naked land because of human

activities or land collapse. These devastated conditions aggravate to cause debris flows and disasters. Thus the reforestation and erosion control in the upstream basin are effective to protect river disaster, as well as to promote upraising of forest industry. Moreover, since the tourism spots along the rivers in Atlas are suffering from debris and flood disasters, it could be possible to set up infrastructure of the tourism spots on a parallel with flood control measures. That is to say, the rural economy could be activated as progressing the management of the river basins and the river spaces.

As mentioned above, this development study is implemented with the first objective of flood control and water resources development for the Tensift River originated in the Atlas Mountain, in parallel, with the objectives of infrastructure setup for agriculture and forestry as well as comprehensive rural development. The targets of this development study to solve the above issues are; 1) to formulate a Master Plan on Comprehensive Development for Tensift River Basin, and 2) to conduct a Feasibility Study for the priority projects proposed in the master plan.

(3) Scope of Works

1) Field investigation and material collecting on social, economic and natural conditions and related plans
2) Formulation of a Master Plan on Comprehensive Development and technical, economical, social and environmental evaluation
3) Proposal of priority projects
4) Field investigation and material collecting for the feasibility study
5) Planning and evaluation of the priority projects
6) Formulation of the implementation program

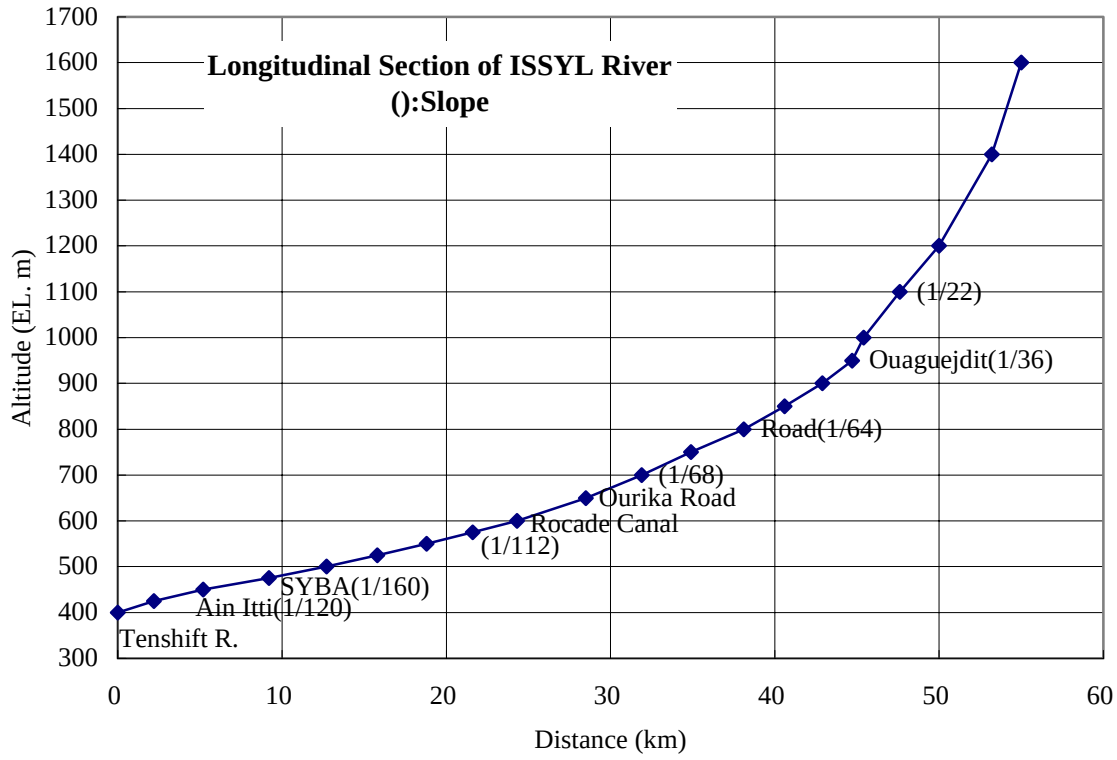
APPENDIX

ANNEX-1

LONGITUDINAL SECTION OF MAIN RIVERS

Longitudinal Section of ISSYL River

No.	Unit Distance (km)	Distance (km)	Altitude (EL.m)	Gradient (degrees)	Note
1	-	0.0	400		Confluence of Tensift River
2	2.2	2.2	425	1/ 88 (0.65)	
3	3.0	5.2	450	1/ 120 (0.48)	Ain Itti
4	4.0	9.2	475	1/ 160 (0.36)	Sidi Youssef Ben Ali
5	3.5	12.7	500	1/ 140 (0.41)	
6	3.1	15.8	525	1/ 124 (0.46)	
7	3.0	18.8	550	1/ 120 (0.48)	
8	2.8	21.6	575	1/ 112 (0.51)	
9	2.7	24.3	600	1/ 108 (0.53)	Rocade Canal (EL.595)
10	4.2	28.5	650	1/ 84 (0.68)	Ourika Road (EL.635)
11	3.4	31.9	700	1/ 68 (0.84)	
12	3.0	34.9	750	1/ 60 (0.96)	
13	3.2	38.1	800	1/ 64 (0.90)	Road at Aguelmous
14	2.5	40.6	850	1/ 50 (1.15)	
15	2.3	42.9	900	1/ 46 (1.25)	
16	1.8	44.7	950	1/ 36 (1.59)	Ouaguejdit
17	0.7	45.4	1000	1/ 14 (4.09)	
18	2.2	47.6	1100	1/ 22 (2.60)	
19	2.4	50.0	1200	1/ 24 (2.39)	
20	3.2	53.2	1400	1/ 16 (3.58)	
21	1.8	55.0	1600	1/ 9 (6.34)	



Longitudinal Section of OURIKA River

No.	Unit Distance (km)	Distance (km)	Altitude (EL.m)	Gradient (degrees)	Note
1	-	0.0	998		Aghbalou
2	0.3	0.3	1005	1/ 43 (1.34)	Confluence of Tarzaza R.
3	2.0	2.3	1057	1/ 38 (1.49)	
4	3.1	5.4	1147	1/ 34 (1.66)	Iraghf
5	1.0	6.4	1175	1/ 36 (1.60)	
6	0.1	6.5	1178	1/ 33 (1.72)	
7	2.4	8.9	1242	1/ 38 (1.53)	Tazzitount
8	1.9	10.8	1300	1/ 33 (1.75)	Imi-n-Taddert
9	1.7	12.5	1355	1/ 31 (1.85)	Ait Barka
10	1.8	14.3	1415	1/ 30 (1.91)	Setti Fadma
11	1.5	15.8	1480	1/ 23 (2.48)	Agadir
12	2.4	18.2	1600	1/ 20 (2.86)	
13	1.8	20.0	1690	1/ 20 (2.86)	Tadrart
14	2.0	22.0	1800	1/ 18 (3.15)	Tiourdiou
15	21.8	43.8	3753	1/ 11 (5.12)	TICHKI
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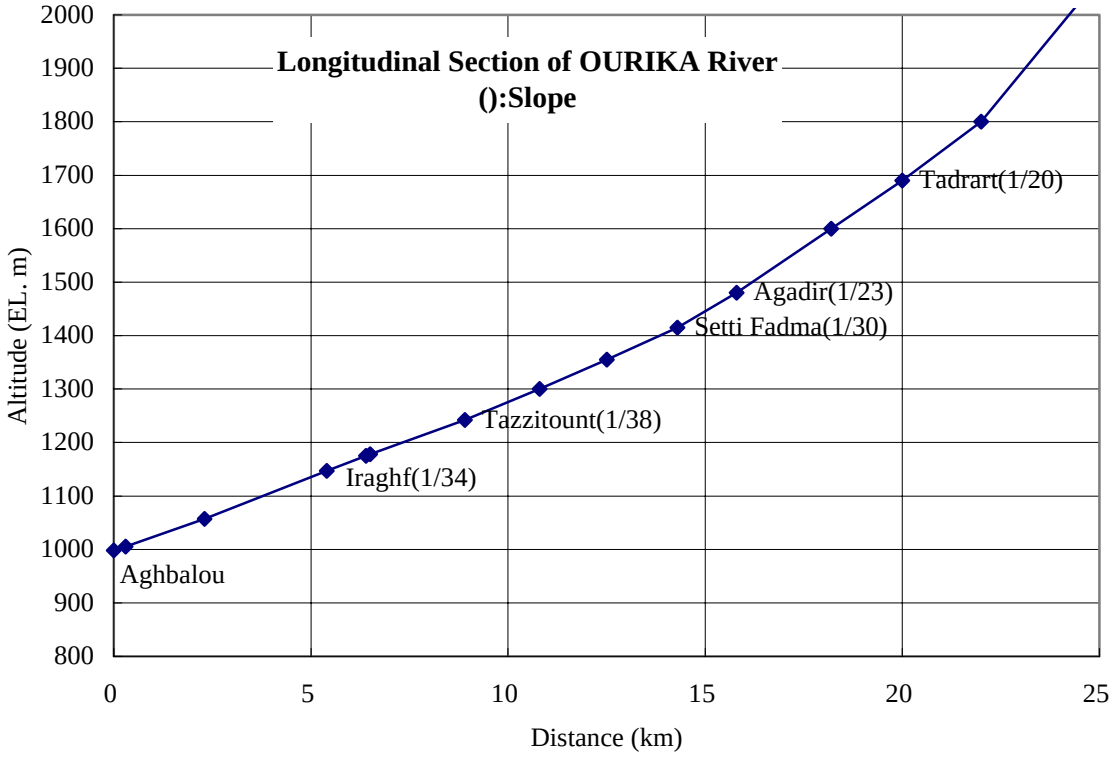

Longitudinal Section of RHERAYA River

No.	Unit Distance (km)	Distance (km)	Altitude (EL.m)	Gradient (degrees)	Note
1	-	0.0	1010		Tahanaout
2	5.3	5.3	1150	1/ 38 (1.51)	Asni
3	3.2	8.5	1244	1/ 34 (1.68)	Confluence of Tacheddirt R.
4	3.0	11.5	1357	1/ 27 (2.16)	Imi Oughlad
5	4.5	16.0	1560	1/ 22 (2.58)	
6	2.8	18.8	1780	1/ 13 (4.49)	Imlil
7	1.4	20.2	1930	1/ 9 (6.12)	Around
8	17.4	37.6	4167	1/ 8 (7.33)	TOUBKAL
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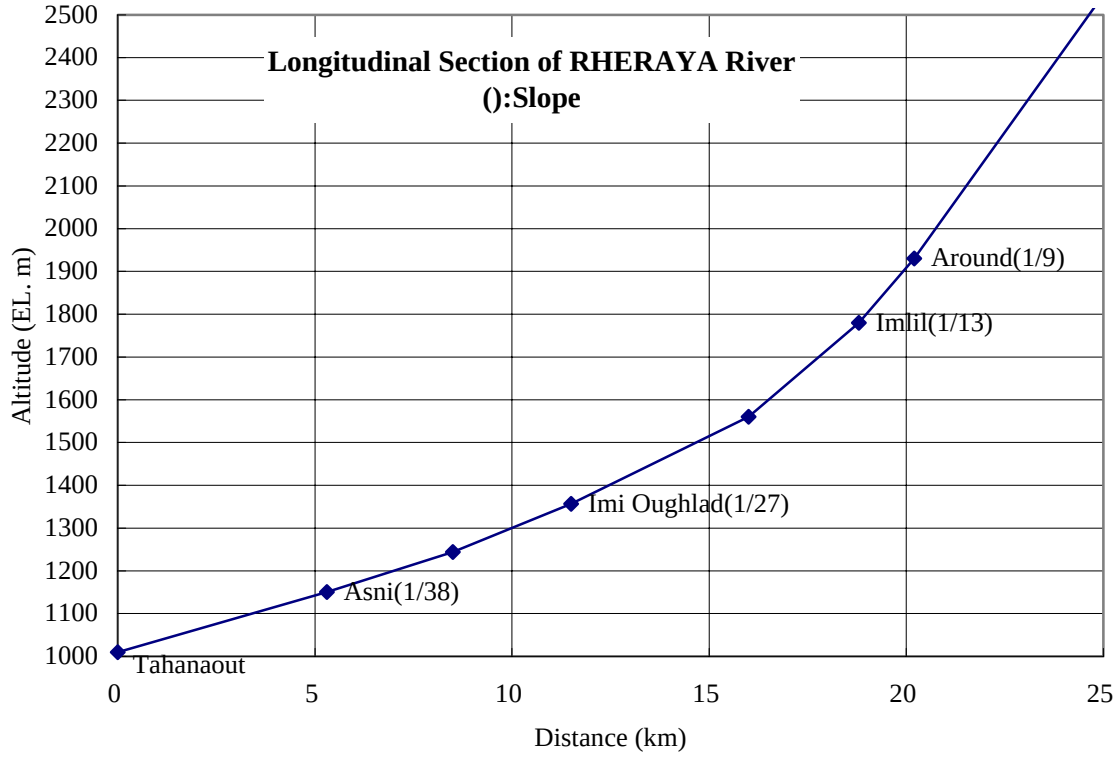

Longitudinal Section of N'FIS River

No.	Unit Distance (km)	Distance (km)	Altitude (EL.m)	Gradient (degrees)	Note
1	-	0.0	739		Imin El Hammam
2	4.1	4.1	813	1/ 55 (1.03)	
3	2.4	6.5	840	1/ 89 (0.64)	Confluence of Wirgan R.
4	7.0	13.5	905	1/ 108 (0.53)	
5	4.0	17.5	940	1/ 114 (0.50)	Imigdal
6	2.5	20.0	965	1/ 100 (0.57)	Confluence of Hsayn R.
7	14.0	34.0	1115	1/ 93 (0.61)	
8	5.1	39.1	1160	1/ 113 (0.51)	Ijoukak
9	4.9	44.0	1200	1/ 123 (0.47)	
10	4.8	48.8	1240	1/ 120 (0.48)	Mzouzit
11	23.2	72.0	1615	1/ 62 (0.93)	
12	5.2	77.2	1706	1/ 57 (1.00)	
13	4.6	81.8	1805	1/ 46 (1.23)	
14	5.0	86.8	1988	1/ 27 (2.10)	
15	3.9	90.7	2151	1/ 24 (2.39)	
16	7.7	98.4	2473	1/ 24 (2.40)	
17	5.1	103.5	2696	1/ 23 (2.50)	
18	2.3	105.8	3078	1/ 6 (9.43)	
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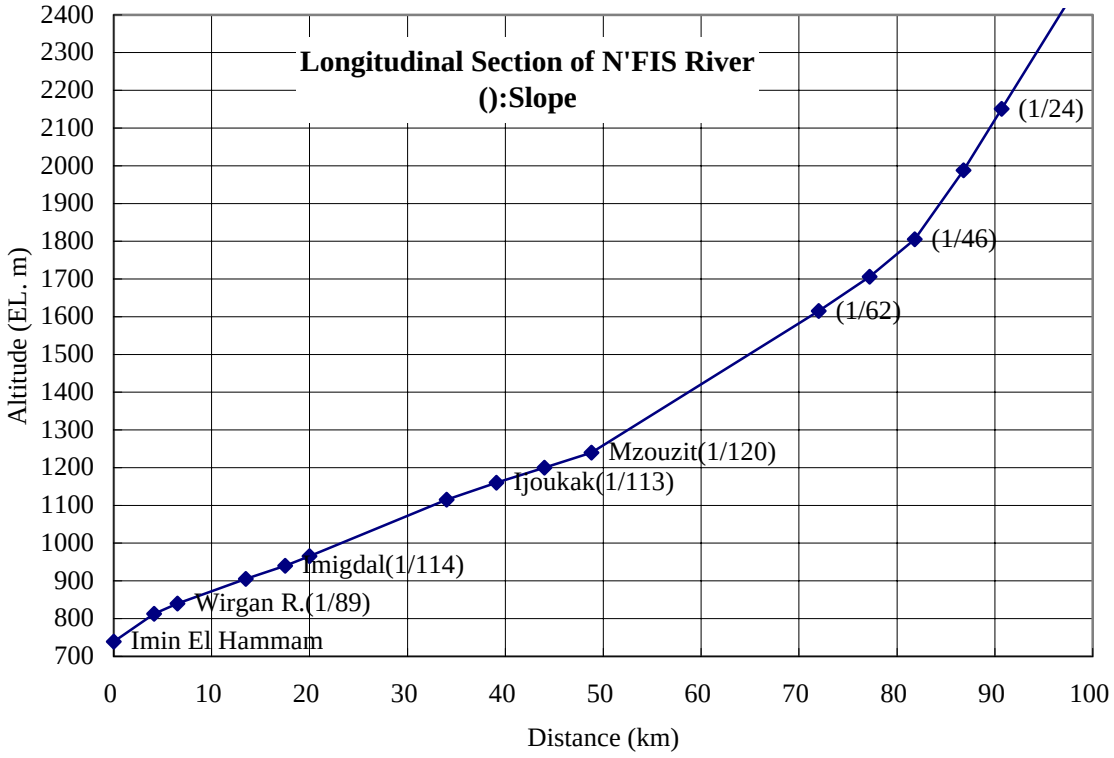
21					



Longitudinal Section of ZAT River

No.	Unit Distance (km)	Distance (km)	Altitude (EL.m)	Gradient (degrees)	Note
1	-	0.0	760		Taferiat
2	16.3	16.3	1040	1/ 58 (0.98)	Alba Tighedouine
3	4.2	20.5	1114	1/ 57 (1.01)	Confluence of Tighadwine R.
4	4.1	24.6	1225	1/ 37 (1.55)	
5	3.3	27.9	1314	1/ 37 (1.55)	Azgour
6	2.7	30.6	1377	1/ 43 (1.34)	
7	3.1	33.7	1478	1/ 31 (1.87)	Tizert
8	1.5	35.2	1511	1/ 45 (1.26)	
9	3.2	38.4	1658	1/ 22 (2.63)	
10	5.8	44.2	1851	1/ 30 (1.91)	
11	3.0	47.2	1971	1/ 25 (2.29)	
12	7.0	54.2	2467	1/ 14 (4.06)	
13	2.8	57.0	2798	1/ 8 (6.7)	
14	5.0	62.0	3868	1/ 5 (12.1)	
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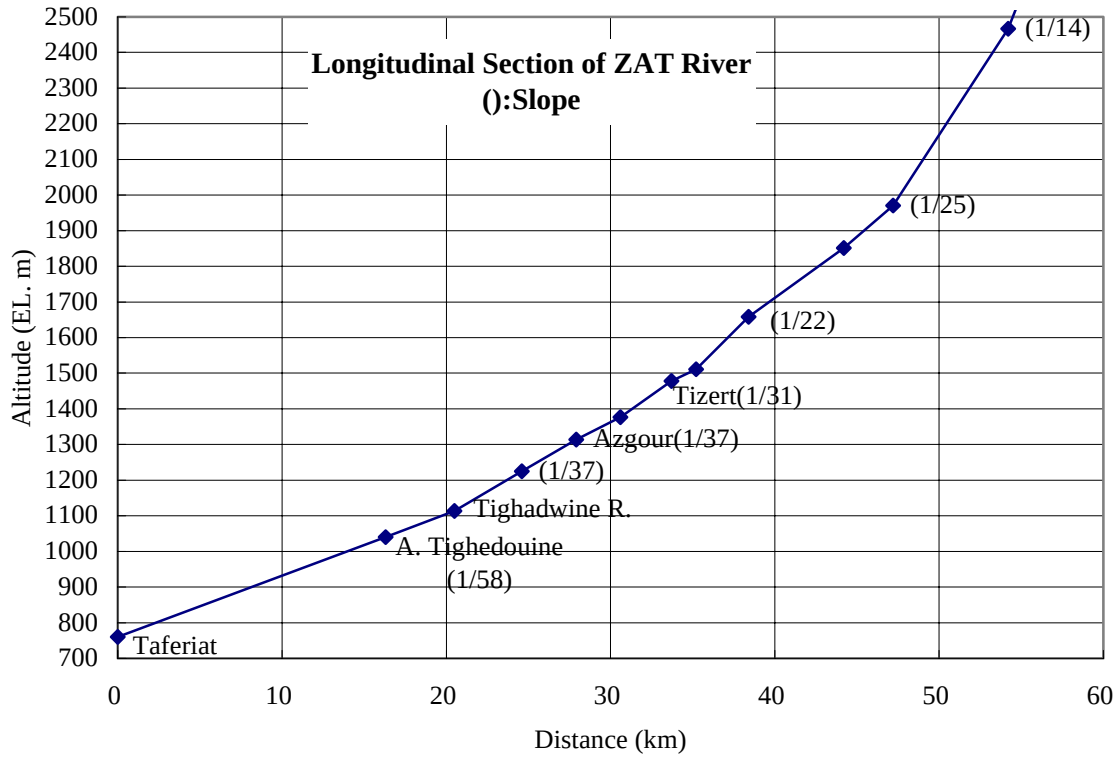

Longitudinal Section of R'DAT River

No.	Unit Distance (km)	Distance (km)	Altitude (EL.m)	Gradient		Note
1	-	0.0	690			Sidi Rahal
2	6.3	6.3	768	1/ 81	(0.71)	
3	8.5	14.8	894	1/ 67	(0.85)	Confluence of Tissert R.
4	9.6	24.4	1120	1/ 42	(1.35)	Confluence of Infradane R.
5	4.0	28.4	1269	1/ 27	(2.13)	Confluence of Tazlyada R.
6	8.0	36.4	1455	1/ 43	(1.33)	
7	5.7	42.1	1610	1/ 37	(1.56)	
8	2.6	44.7	1700	1/ 29	(1.98)	
9	1.2	45.9	1800	1/ 12	(4.77)	
10	0.5	46.4	1900	1/ 5	(11.3)	
11	3.4	49.8	2686	1/ 4	(13.0)	Tizi-n-Tichka
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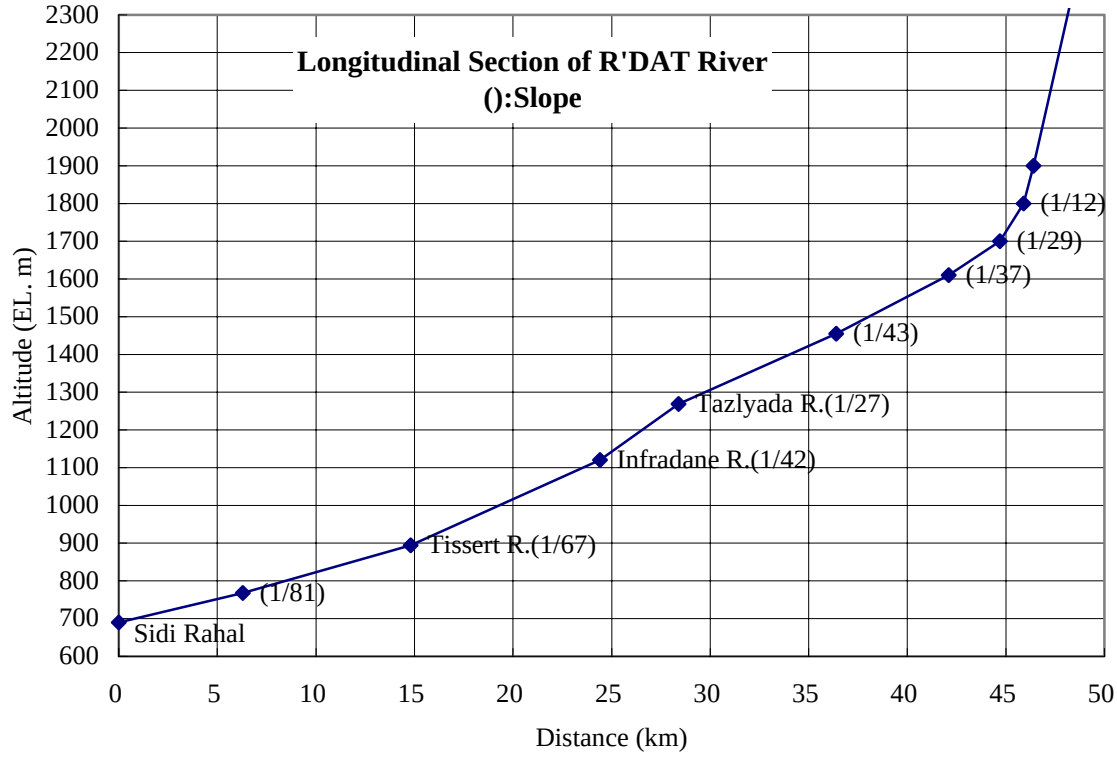


ANNEX-2

PHOTOGRAPHS

ISSYL RIVER

[Photo-I1] Bridge located at the top of alluvial fan of the Issyl River, Downstream view

[Photo-I2] Road Bridge of SR513 across the Issyl River, Downstream view

[Photo-I3] Upstream view from the bridge, right side of the river is the main direction of overflowing. Small dyke protection works can be seen.

[Photo-I4] Issyl River from the left side, This is the siphon works of Rocade canal.

[Photo-I5] Irrigation channel across Issyl River, too small flow capacity here.

[Photo-I6] End of Tassoltante Intercepting Drainage Canal to Issyl River, Upstream view

ISSYL RIVER

[Photo-I7] Downstream view of the Issyl River at the outlet of Tassoltante Intercepting Drainage Canal

[Photo-I8] The first bridge across Issyl River in Sidi Youssef Ben Ali, downstream view. It is sometime broken by flood.

[Photo-I9] Downstream view of Issyl River at Sidi Youssef Ben Ali. Many houses were frequently broken in this areas by flood.

[Photo-I10] The second bridge in Sidi Youssef Ben Ali, downstream view of Issyl River, Dyke protection along the both sides

[Photo-I11] Issyl River at Bab Aylan in Sidi Youssef Ben Ali, Downstream view, Dyke protection along the both sides

[Photo-I12] Footpath bridge of the Issyl River at Ain Itti, Upstream view

OURIKA RIVER

[Photo-O1] Ourika River at Aghbalou, Upstream view, Road level is very low comparing the riverbed. Emergent river improvement works

[Photo-O2] Ourika River at Aghbalou, Downstream view, Road level is very low comparing the riverbed. Emergent improvement works

[Photo-O3] Small check dams in Tighazrit Tributary, Upstream view

[Photo-O4] Downstream view from the first check dam, floodwater directly flow down on the road to the main river.

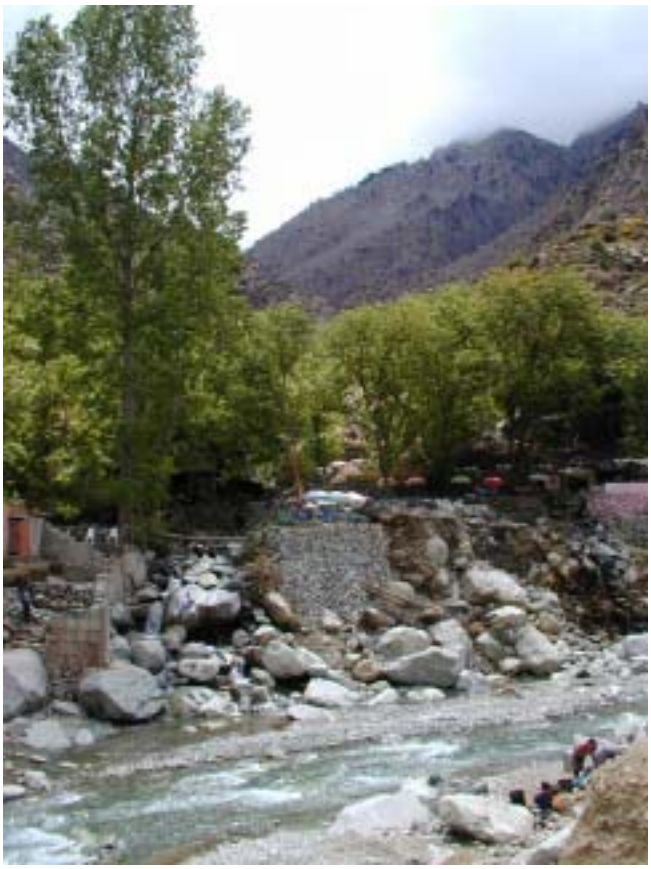
[Photo-O5] Ourmes Village, a tourism spot in Ourika River. Some peoples died due to the 1995 flood.

[Photo-O6] Road protection works at Tazitount Village

OURIKA RIVER

[Photo-O7] Setti Fadma Village, Upstream view

[Photo-O8] Setti Fadma Village, Downstream view, Large stones obstruct flowing floodwater. This road might be a watercourse when flood.



[Photo-O9] Setti Fadma Village is the main tourism spot like this photo. Some tourists died due to 1995 flood. Assif -n- Oufra Tributary

[Photo-O10] Downstream view of Ourika River from Agadir -n- Ait Boulmane Village, Large sedimentation in wide valley, Dam plan existed but abandoned.

[Photo-O11] Upstream view of Ourika River, the Villages of Anfli and Tiourdiou are seen.

RHERAYA RIVER

[Photo-R1] The top of alluvial fan of Rheraya River, A house and a bridge were washed away.

[Photo-R2] Upstream view from the top of alluvial fan of Rheraya River, the river is wide.

[Photo-R3] Tahannaout Gauging Station, Downstream view.

[Photo-R4] Upstream view from Tahannaout Gauging Station

[Photo-R5] Upstream view of the Rheraya River at Moulay Brahim

[Photo-R6] Upstream view of the Rheraya River, the Bridge broken by Flood 1995 at Asni near Saturday Market

RHERAYA RIVER

[Photo-R7] Confluence of 2 rivers, namely Imlil River and Tacheddirt River, Upstream view

[Photo-R8] Downstream view of the Imlil River, Parking at Imlil, many cars were washed away by 1995 Flood

[Photo-R9] Flood damages on August 1995, referred from the museum.

[Photo-R10] Downstream view of the Imlil River from Imlil Village, Left tributary of Mzik is seen.

[Photo-R11] Downstream view of Imlil River at Aroumd

[Photo-R12] Upstream view of the Imlil River from Aroumd, Here could be a sand pocket.

N’FIS RIVER

[Photo-N1] The debris flow occurred in the Wirgane Tributary of the N’fis River on August 1995 and flushed away a part of the bridge. Downstream view.

[Photo-N2] Upstream view from the bridge in the Wirgane Tributary

[Photo-N3] Much deposit from the Imigdal Tributary can be seen. The small bridge was broken and the road was damaged by the debris flow on August 1995.

[Photo-N4] Upstream view of the N’fis River at the Imigdal Tributary

[Photo-N5] Upstream view of the Tasaft Tributary, debris flow was happened.

[Photo-N6] Downstream view of the N’fis River at the Tasaft Tributary

ZAT RIVER

[Photo-Z1] Upstream View of the L'hager River at Kritou Village in 15 km east southeast of Marrakech, Tyipical flood damages in the downstream area

[Photo-Z2] Upstream View of the Bourouihat River, Gabion works are being constructed.

[Photo-Z3] Upstream View of the L'hager River at Kritou Village in 15 km east southeast of Marrakech, Typical flood damages in the downstream area

[Photo-Z4] Gabion dykes at the just upstream of the bridge, Upstream view, There used to be a market in the left side of the gabion works.

[Photo-Z5] Upstream view of the Zat River from the bridge of the road to Warzazard

[Photo-Z6] The restaurant located in the upstream-right side of the bridge was damaged by 1995 flood.

ZAT RIVER

[Photo-Z7] Upstream view of the Zat River at the most downstream of the study area

[Photo-Z8] Downstream view of the Zat River at Arba Tighedouine Village

[Photo-Z9] Upstream view of the Zat River from just the upstream of Arba Tighedouine Village

[Photo-Z10] Tarat Tributary of the Zat River

[Photo-Z11] Tifarent Village in the Tighadwine tributary of the Zat River, Debris flow destroyed many houses and killed 9 inhabitants in 1995.

[Photo-Z12] Near the confluence of the Tighadwine tributary of the Zat River, A school here was also destroyed by 1995 flood.

R’DAT RIVER

[Photo-D1] Sidi Rahhal Gauging Station in the R’dat River, A part of the weir was broken by the 1999 flood.

[Photo-D2] Upstream view from Sidi Rahhal Gauging Station

[Photo-D3] The Zerkten Tributary, the left tributary of the R’dat River, debris flow (or land slide) happened here.

[Photo-D4] The Tazlyada Tributary, the left tributary of the R’dat River, the debris flow happened here on October 1999 and killed 10 inhabitants. Much sedimentation still can be seen.

[Photo-D5] Upstream view of the Tazlyada Tributary

[Photo-D6] Downstream view of the Tazlyada Tributary

R’DAT RIVER

[Photo-D7] The R’dat River in Algu Village, Downstream view, three (3) houses were flushed away and six (6) inhabitants were died due to the 1999 flood.

[Photo-D8] Upstream view of the R’dat River in Algu Village

[Photo-D8] Downstream view of the R’dat River in Algu Village

TABLES

Table H.1.1 Specification of Rivers and Tributaries Except the Issyl River

No.	River/Basin	Distance (km)	Baisn Area (km^2)	Altitude (EL.m)		Length (km)	Gradient	Nearby Village
				Lowest	Highest			
0	Ourika	0	501.4	998	3753	43.8	1/ 15.90	Aghbalou
1	Assif Tarzaza	0.3	108.4	1005	3616	23.6	1/ 9.04	Aghbalou
2	Cha'bat Ighazri -n- Touglkhir	2.3	10	1057	2486	5.8	1/ 4.06	Taljarft
3	Cha'bat Tighazrit	5.4	11.9	1147	2577	6.1	1/ 4.27	Irghat
4	Assif -n- Oussane	6.4	10.8	1175	2326	6.3	1/ 5.47	
5	Cha'bat Tachmacht	6.5	6.8	1178	2577	6.1	1/ 4.36	
6	Assif Walighane	8.9	30.7	1242	2712	8.5	1/ 5.78	Tazzitount
7	Assif Wigrane	10.8	7.3	1300	2800	5.4	1/ 3.60	Imi-n-Taddart
8	unknown	12.5	35.9	1355	3107	8.9	1/ 5.08	Ait Barka
9	Assif -n- Oufra	18.2	70.5	1600	3900	20.6	1/ 8.96	Tamatert
10	Assif Isgouarne	22	29.8	1800	3616	8.2	1/ 4.52	Tiourdiou
11	Assif -n- Tinnzer	22	100.4	1800	3753	21.8	1/ 11.16	Tiourdiou
1-1	Assif Ikis	4	29.1	1204	3064	9.2	1/ 4.95	Agdir al Khemas
0	Rheraya	0.0	224.2	1010	4167	31.1	1/ 9.85	M. Brahim
1	Tacheddirt River	8.5	88.0	1244	3882	19.6	1/ 7.43	Tansghart
2	Unknown	16.0	6.2	1560	2467	3.6	1/ 3.97	Matat
3	Unknown	18.8	8.4	1780	3800	5.2	1/ 2.57	Imlil
4	Imlil River	18.8	42.7	1780	4167	12.3	1/ 5.15	Imlil
1-1	Assif Tidli	5.9	14.4	1450	3273	7.2	1/ 3.95	Tinoughar
1-2	Assif Imenane	10.6	36.2	1800	3882	9.0	1/ 4.32	Ikis
0	N'fis	0.0	1282.4	739	3882	97.2	1/ 30.93	Ouchfilene
1	Assif Amassine	4.1	56.3	813	2187	12.5	1/ 9.10	Radier
2	Wirgan River	6.5	94.7	839	4015	23.5	1/ 7.40	Wirgane
3	Assif Zagraoun	13.5	28.2	910	2833	11.2	1/ 5.82	Emesquine
4	Assif Imigdal	17.5	78.7	940	3490	17.4	1/ 6.82	Imigdal
5	Assif Ait Hsayn	20.0	85.5	965	3280	13.6	1/ 5.87	Imidel
6	unknown	34.0	27.2	1115	3000	8.6	1/ 4.56	Rikt
7	Assif -n- Ougandis	39.1	217.4	1160	4015	27.6	1/ 9.67	Ijoukak
8	unknown	44.0	30.5	1200	2859	7.7	1/ 4.64	Awrir-Gouj Ruines
9	Assif Ougamt	48.8	158.1	1240	3616	24.8	1/ 10.44	Mzauzit
10	Assif -n- Oumsour	72.0	52.8	1615	3616	10.3	1/ 5.15	Lemkait
11	Assif N'fis	72.0	121.3	1615	3882	25.2	1/ 11.12	Lemkait
0	Zat	0.0	444.3	760	3868	59.9	1/ 19.27	Talbanine
1	Cha'bat Tarat	16.3	62.8	1040	2726	15.9	1/ 9.43	Arba Tighedouine
2	Oued Tighadwine	20.5	25.3	1114	2739	7.6	1/ 4.68	Mriouat
3	Oued Yagour	24.6	51.5	1225	3595	15.0	1/ 6.33	Ait Slimane
4	Oued Afoughal	27.9	46.0	1314	3578	12.7	1/ 5.61	Azgour
5	Oued Iikiys	30.6	9.6	1377	2750	5.0	1/ 3.64	Ta'alwiyt
6	Assif -n- Tiqqi	33.7	11.8	1478	3578	6.5	1/ 3.10	Tizart
7	Oued Ansa	35.2	16.5	1511	3073	6.4	1/ 4.10	Imiyrgn
8	Oued Zat	35.2	93.1	1511	3868	26.8	1/ 11.37	Imiyrgn
0	R'dat	0.0	540.0	690	3578	51.8	1/ 17.94	Sidi Rahal
1	Oued Imarirhene	6.3	58.7	768	2183	19.2	1/ 13.57	Iwizar
2	Oued Tissert	14.8	16.3	894	2135	8.9	1/ 7.17	Dar el Oued
3	Assif -n- Infradane	24.4	209.7	1120	2936	23.4	1/ 12.89	Tijaddant
4	Oued Tazliyda	28.4	19.8	1269	2620	6.3	1/ 4.66	Tabahaggat
5	Talat -n- Inwain	36.4	14.5	1455	2739	4.9	1/ 3.82	Tilnint
6	Assif Isirs	42.1	22.7	1610	2790	8.9	1/ 7.54	
7	Assif -n- Imouzzar	42.1	27.2	1610	2686	7.7	1/ 7.16	
1-1	Oued Tihizat	4.1	18.7	820	1861	10.8	1/ 10.37	Adouz
3-1	Assif -n- Infradane	3.6	79.9	1205	2936	20.0	1/ 11.55	Al Mahrouz
3-2	Oued Iswal	3.6	118.3	1205	3087	23.5	1/ 12.49	Al Mahrouz