Appendix E

Watershed Management and Flood Control

Appendix E WATERSHED MANAGEMENT AND FLOOD CONTROL

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Appendix E WATERSHED MANGEMENT AND FLOOD CONTROL

E.1 River System

(1) Division of river basin

Almost 98 % (25,421 km^2) of the national area is divided into three (3) main river basins of the Vardar, Crn Drim, and Strumica and four (4) major tributaries from the Vardar River of Treska, Pchinja, Bregalnica, and Crna. The remaining area (292 km^2) is divided into three small regions that include Lake Dojran, the Cironska & Lebnica River (flowing to Bulgaria), and the Juzna Morava River (flowing to Yugoslavia). The length of the Vardar River is around 300 km in Macedonia from Gevgelija to the origin. The longitudinal profile of the main stretch and major tributaries is illustrated in Figure E.1

The following table shows the surface areas of the above mentioned regions that represent the total national territory area of Macedonia:

Surface Areas of Major River Basin

River/Lake	Catchment Area (km^2)	% of Total Area
1. Vardar River		
Main Stream	6,813	26.5
Treska River	2,068	8.0
Pchinja River	2,373	9.2
Bregalnica River	4,307	16.8
Crna River	4,985	19.4
Sub-Total	20,546	79.9
2. Strumica River	1,520	5.9
3. Crn Drim River	3,355	13.0
Sub-Total (1 to 3)	25,421	98.8
4. Others		
Lake Dojran	120	0.5
Cironska & Lebnica River	128	0.5
Juzna Morava River	44	0.2
Sub-Total	292	1.2
Total (1 to 4)	25,713	10 0.0

(2) Division of Surface Water Areas among Main River Basins

Because of the geographical and international location of the river basins in Macedonia, the amount of available water within the territory of Macedonia is distributed in a different way that does not match the above mentioned area categories. With the extension of the Vardar River basin and its tributaries in the neighboring countries, three (3) extra sub-basin areas are included from the territory of Yugoslavia (Kosovo – the Lepenec River on Vardar and Prohor Pchinski – the Pchinja River) and Greece (Lerin – the Eleshka River). The following table shows the surface areas of the river basins that represent the potential of surface water in Macedonia:

Surface Area of River Basins in Macedonia

River/Lake	Catchment Area (km^2)	% Extra Area Included
1. Vardar River		
Main Stream	6,813	
Lepenec River	**690**	**2.7**
Treska River	2,068	
Pchinja River	2,373	
Pchinja River (Prohor Pchinski)	**471**	**1.8**
Bregalnica River	4,307	
Crna River	4,985	
Eleshka	905	**3.5**
Sub-Total	22,612	
2. Strumica River	1,520	
3. Crn Drim River	3,355	
Total (for extra sub-basin)	27,477	

On the other hand, two (2) sub-basin areas of the Cironska & Lebnica River (flowing to Bulgaria) and Juzna Morava River (flowing to Yugoslavia) are excluded as their catchment areas belong to the territory of the neighboring countries. Also, the area of Lake Dojran is excluded due to its small size of catchment area.

E.2 Watershed Management

E.2.1 Present Land Use

An intensive efforts of mapping by digital data on the current information of land use by MUPCE (now MUPC) by the technical assistance of PHARE Program, no official data available as of now. Only the map available to grasp practically the land use condition in the whole country is in the ATLAS Book (1:850,000) compiled with the vegetation and soil maps. According to the map, the country is classified into four (4) categories, i.e. cultivated land, pastures, forests and reforestation area.

E.2.2 Land Erosion and Debris Control

(1) Forest

As shown in the Table E.1, the total forest area is 953,322 ha in 1996 (Statistical Year Book 1997) sharing 37 % of the national territory. In Macedonia, activity of forest management is conducting by the Forest Management Organization that is supervised under the Forest Department in MAFWE. The major activities cover reforestation, control of illegal logging, and promoting logging industry etc.

(2) Outline of Erosion Condition

Most of the territory of Macedonia is vulnerable to erosion. Many researches and studies have been carried out to clarify countermeasures for attenuation of erosion in watershed. Among them, one of the most conspicuous outcome is erosion maps in scale of 1:50,000 of the country prepared by the Faculty of Forest in Sv. Kiril and Methodji University, Skopje (the Skopje University) and Water Development Institute, Skopje (WDI) (hereinafter referred as the "National Erosion Survey")

The study began in 1980 and preparation of erosion maps covering the entire national land in scale of 1:50,000 was completed by the end of 1997. The results of classification of erosion were compiled in a booklet and published as Part I in 1993. The erodable area is classified into five major categories by intensity and process of erosion. Each class has three sub categories concerned with the type of erosion such as deep erosion (gully erosion), mixed type erosion and minor surface erosion. According to the study, the area affected by erosion processes is 24,813.2km^2 or 96.5%, while only 899.8km^2 in the zone of accumulation of the deposit in the country. The area classified by five categories is as follows:

Area Classification by Erosion Process

Class	Erosion process	Area (km^2) (%)
I	Excessive erosion (gully erosion)	688.0 (2.8)
II	Significant erosion	1,832.4 (7.4)
III	Medium scale erosion	6,893.3 (27.8)
IV	Minor erosion	7,936.1 (32.0)
V	Insignificant erosion	7,463.5 (30.1)

Based on this, the area affected with severe erosion is considered in the Class I to III, which is equivalent to 9,413.6km^2 or 38.9% of the total affected area. The location identified as Class I by the survey is shown in Figure E.2.

(3) Sediment yield and deposition in watershed

The National Erosion Survey estimated the annual yield of debris in the watershed and volume of deposition of major reservoirs. The figures concerned with major reservoirs are summarized as shown in Table E.2. This table presents the characteristic feature of erodability in the watershed of the three major river basins. It is obvious that the watersheds in the Crn Drim River have relatively small yield rates compared with ones in the Vardar and Strumica River basins. Among the reservoirs in the Vardar, the yield rate of the Kalimanci, 1.00mm/year, is significantly high. The total sediment production in the territory of Macedonia is 16,955,132 m^3/year or 684.9m^3/year. The annual sediment deposition is 7,531,911m^3/year or 303.5m^3/year/km^2.

(4) Present debris control activities

MAFWE is proceeding to construct debris flow control structures such as low dam (concrete gravity or stone masonry) and screen type dam in parallel with reforestation in the watershed. The screen dams were constructed in order to trap stone and cobbles in the Kodzadzicka, Breshtancka, and Dolgash Rivers in the Zupa mountain range, eastern side of Debar reservoir. Further, in the Kamenica River that is one of tributaries flowing from north to the Kalimanci reservoir, total 18 units of concrete gravity dam were completed. These dams are demonstrating trapping efficiency to protect structures and channel formation in the downstream against the destructive debris flow. Three main countermeasures for debris and erosion control which is applied in common the country such as check dam, screen dam and tree planting (reforestation) are shown in Figures E.3 to E.5.

(5) Problem area

It should be noted that condition of macrophetic vegetation near the estuary of the Sateska River in Lake Ohrid is threatened by heavy siltation. The flow with high content of sediment discharges into the lake through the excavated new channel of the Sateska River. The Sateska River basin is located in the northern part of Ohrid in Debarca area. The catchment area and length of main stretch are 411km^2 and 37.7km, respectively.

Survey and study aimed to clarify the present status of erosion was jointly conducted by the Skopje University and WDI in 1995 to 1996. The study concluded that the sediment material from the Sateska River was diffused mainly north to south by wave and current in the Lake Ohrid. This movement distributes the eroded deposit toward outlet of the Crn Drim River in Struga. The watershed of the Sateska River is mostly classified in Class IV except some minor slopes classified in Class II. In order to introduce effective countermeasures in this watershed, GTZ carried out technical research. The findings in the areas concerned with surface erosion and requiring flood protection as well as drainage improvement are summarized in Table E.3 and shown the location in Figure E.6.

E.3 Flood Protection

E.3.1 Available Data

(1) Flood Damage Data/Information

In Macedonia, it was clarified that every Water Management Organization (WMO) obliges to submit a designated format of *Annual Report for Drainage Activities* to the Statistical Office. The format consists of three parts, (1) Flooded area and facilities, (2) Drainage activities and (3) Pumping stations. The Statistical Office estimates the total flood damage based on the annual report from each WMO annually.

(2) Related analysis and documents

Related document and information were collected regarding flood, as below:

1) Flood hydrographs in Nov.1962 and Nov.1979
2) Description regarding principal feature of flooding in Macedonia
3) Project Reports including flood analysis such as Irrigation System "Skopsko Pole", Book III Hydrology
4) A brochure of the Water Management Vardar – Skopje, 1928 – 1988
5) Mediterranean Cyclones and Catastrophic Floods in Republic of Macedonia, by Vitomir Dimitrievski, M.Sc. (in English)
6) Catastrophic Floods on November 1979 in SR of Macedonia (in Macedonian)
7) Study for Floods in Republic of Macedonia with Proposed Measures to prevent Floods and Other Observations, Water Development Institute, Skopje, 1982 (in Macedonian)
8) A Study about the Pelagonija Drainage System Condition and Suggested Measures for its Improving, by Water Development Institute, Skopje, 1977 (in Macedonian)

Recently Hydrometeorological Institute prepared a report of *Climate and Hydrology of Macedonia*. Flood hydrographs of the two most serious floods in 1962 and 1979, which caused nation-wide disasters, are presented in the report as well as description on principal feature of flooding in Macedonia.

E.3.2 Present Situation of Flood in Macedonia

In Macedonia, floods commonly occur in spring due to long and heavy rainfall in combination with snow melting in March to May, and due to heavy rainfall caused by depressions from Mediterranean Sea in November. The historical discharge records in past 30 years at major four stations of Skopje, Veles, Demir Kapija and Gevgelija represent these characteristics obviously as shown in Table E.4.

The flood prone areas in Macedonia are identified by Hydrometeorological Institute as listed below, and their locations are shown in Figure E.7.

(1) Vardar River Mainstream

Polog Ravine, Skopsko Pole plain, Basino village, Krivolak-Negotino stretches and stretches from Demir Kapija to the Macedonian-Greek border.

(2) Major Tributaries of Vardar River

1) Downstream portion of the Pena River at Tetovo
2) Lepenec River after Gen. Jankovic
3) Markova Reka near Batinci
4) Pcinja and Kumanovska Rivers before and downstream of their confluence
5) Kriva River near Trnovec and its downstream
6) Bregalnica River in Berovo and Delcevo regions
7) Lower Zletovska River
8) Babuna River upstream
9) Crna River from Dolnenci to Mariovo as well as Borotino River from Crniliste to the confluence

(3) Strumica River Basin

1) Radoviska River upstream of the water supply wells and downstream of Radovis
2) Oraovicka River downstream of Oraovica
3) Smiljanska River downstream of Podares
4) Strumica River after the confluence of the three tributaries above mentioned down to Smolarski Most bridge

(4) L.Ohrid and L.Prespa regions

1) Upper Prespa region from the Golema River and the Istocka River
2) Cerava River near the River mouth in L.Ohrid
3) Koselska River downstream of Kosel village
4) Lower Sateska River

E.3.3 Significant Flood Events

(1) Flood in Skopsko Pole

In the Vardar river basin, the most significant flood in terms of the peak discharge as well as magnitude of total discharge occurred on Nov.16 to 17, 1962 and the second occurred on Nov. 17 to18, 1979. The peak discharges of the two floods were recorded at 1,180 m^3/sec and 983 m^3/sec at Skopje. The hydrologic characteristics of the respective floods are summarized based on the discharge records and flood hydrographs showed in Figures E.8 and E.9 as tabulated in Table E.5. Further, the inundated areas in Skopje by these floods are delineated by the Water Management Vardar – Skopje as shown in Figures E.10 and E.11.

(2) Flood in Pelagonija

The inundated area in Pelagonija was 8,250 ha due to 1981 flood based on the map showing the inundated area by flood in 1962 and 1979 as well (the map is attached to the document of 8) abone). While, the areas inundated in 1962 and1979 are 25,000 ha and 23,125 ha respectively. Figure E.12 shows the inundated area by the three major floods.

After the 1981- flood, primary drainage canal was constructed to meet discharge of 20-year return period in the Pelagonija field. However, the drainage condition is not improved sufficiently yet due to inadequate capacity and coverage of secondary and tertiary canal network. This is caused by the bottleneck of the agricultural development in spite of the rich potential of the cultivation in the field. Figure E.13 shows the location of the existing drainage canal network with the area under surface erosion at outskirts of the field.

E.3.4 Present Condition regarding Flood Prevention in Urban Area of Skopje

After the flood in 1962, intensive river training works of the Vardar river in the urban area of Skopje have been carried out of which total length is 20.8 km. Most of the stretch has been completed except about 150 m stretch immediately downstream the confluence with the Treska River at east side of central part of Skopje. The carrying capacity of the river was designed to have same magnitude of the peak discharge, 1,180 m^3, experienced in 1962 flood.

On the other hand, in order to prevent Skopje metropolitan area from the flooding with more high reliability, Kozjak dam was primarily planned to decrease the peak discharge in the Vardar River by means creation of reservoir in the Treska River. According to the above document 7), retarding effect by the Kozjak dam at immediately down stream of the confluence with the Treska River is estimated as follows:

Estimation of Retarding Effects by Kozjak Dam

Unit:m^3/s

Return period	Without Kozjak dam	With Kozjak dam	Peak cut
2	300	260	40
5	580	450	130
10	760	570	190
100	1,330	930	200
300	1,600	1,150	450
1,000	1,900	1,400	500

E.3.5 Responsible Agency of Flood Prevention Activities

In Macedonia, administrative body responsible for flood prevention is the MAFWE in terms of budget to be obliged its allocation for practical activities performed by the agencies concerned.

In case that emerging a large scale of disaster is predicted, the Minister of Defence (Civil Defense Department) is responsible to command the MAFWE, WMO(s) and municipalities concerned to gather and decide immediate countermeasures to be taken. In the new Water Law enacted in February 1998, it is stipulated that the Action Plan for flood prevention and protection for the inundation area shall be prepared by the city of Skopje. Further, a copy of the Action Plan is to be submitted to the MAFWE and the Ministry of Defence.

The Law also guides that the WMO(s) and other legal entities responsible for management of dams and reservoirs are obliged to construct the protection embankment, to use and maintain these facilities in a manner of flood control as well as providing the natural disaster prevention.

Table E.1 Present Land Use

Classified Vegetation Areas

Vegetation	Area (1,000 ha)	
1. Forest Area		
1) Pure tree stands of deciduous trees	540	
2) Pure tree stands of conifers	79	
3) Mixed tree stands of deciduous trees	271	
4) Mixed tree stands of conifers	6	
5) Mixed tree stands of deciduous trees and conifer	57	
Subtotal (1)	953	(37%)
2. Agricultural Area		
1) Cultivable area	658	
2) Pastures	633	
3) Pond, reed beds and fishponds	1	
Subtotal (2)	1,292	(50%)
3. Other	326	(13%)
Total (1 to 3)	2,571	

Table E.2 Annual Sediment Volume and Deposition Volume in Major Reservoirs

River	Reservoir	Catchment area (km^2)	Annual sediment yield (m^3/year)	Annual sediment deposition (m^3)	Annual sheet erosion rate (mm/year)
Vardar	Glaznja	101	50,911	36,147	0.51
	Lipkovo	112	5,853	3,570	0.05
	Kalimanci	1,100	1,101,923	418,731	1.00
	Mantovo	180	71,159	27,752	0.40
	Tikvesh	5,361	2,675,969	1,019,341	0.50
Strumica	Vodoca	76	37,327	16,797	0.49
	Tulija	210	91,578	62,273	0.43
Crn Drim	Globochica	3,118	117,934	102,629	0.04
	Shpilje	4,198	807,672	563,154	0.19
	Mavrovo	322	16,580	9,119	0.05

Source: Erosion map, WDI- Skopje

Table E.3 Current Conditions and Required Countermeasures for Flood and Erosion Control (1/2)

No. of location(1	River basin/ location	Current condition	Countermesures undertaken/ structures construced	Anticipared problem or countermeasures required	Area/strucutres to be protected
1	Pena and Mazradracha Rivers	Debris flow is ccurring frequently.	Five screen (5) dams cinstructed in the period of 1982-85 in the Pena River. In the same period, one (1) dam of same type was also constructed in Mazradracha	Further structural measures are necessary to regulate debris flow.	Tetovo city and irrigation area
2	Dzhepishte River	Flush floods in 1993 and 1994 destroyed the all screen dams.	Two (2) concrete check dams and three screen dams (by concrete with steel) were constructed in 1981.	Further structural measures are necessary to regulate flush flood.	Tetovo irrigation area
3	Shara Mountains	In order to protect the Tetovo field against flush flood in full length from north to south, all torrents flowing into the field are to be regulated.		Technical studies and assessment are required.	Tetovo irrigation area
4	Skopje and its suburban area	At present no serious problem happens.	Total 12 torrents of the left side of the Vardar River and on Vodno Mountain with many facilities such as check dams and thresholds were constructed as well as reforestation in 1960's.		Skopje metropolitan area
5	Channel improvement of Vardar River in the downstream part of Skopsko Pole	During high stage flow in the Vardar River, the narrow gorge at Taor Canyon raises the water level in the urstream reaches. Trial excavation of the entrance at the gorge has been carried out by the LWMO-Vardar.			Eastern area neighboring Skopje metropolitan area and agricutural land
6	Markova and Kadina Rivers	Studies for erosion control in the watersheds of Markova and Kadina Rivers were prepared in 1989 and 1995 respectively including countermeasures for the Simonica torrent near Zelenikovo etc. However, there has not been realized any works on construction of facilities and reforesation according to the studies. Oreshani torrent on the left side of Vardar and Taor Canyon should be regulated as well.			Watersheds of Markova and Kadina Rivers
7	Ratevska River	A study for erosion protection in the watershed was prepared in 1990.			Ratevska dam and reservoir
8	Kamenichka River	Debris is contineously flushing out from small triburaties where no control structure exits.	Total 18 check dams were constructed to regulate debris flow.		Small-scale settlemens scattered along the river
9	Kalimanci reservoir	Coastal area of the reservoir is bared and supplies sediments into the reservoir. Same problem has been occurred in Debar reservoir.			Kalimanci reservoir
10	Vinica?	A sstudy of torrent protection was prepared in 1986.			Vinica
11	Bregalnica middle reaches (from Kochani to Shtip)	River bank erosion is appearing. It is deteriorating efficiciency of tapping irrigation water and threatening stability of structures.			Bregalnica irrigation system
12	Mantovo reservoir	Vrashtica torrent from the right side of the reservoir is to be regulated to protect intake structure. A sudy for protection was prepared in 1991.			Mantovo reservoir

Table E.4 Current Conditions and Required Countermeasures for Flood and Erosion Control (2/2)

No. of location[1]	River basin/ location	Current condition	Countermesures undertaken/ structures construced	Anticipared problem or countermeasures required	Area/strucutres to be protected
13	Selechka mountains in Crna River basin	Some numbers of erosion control structures were constructed.		To regulate torrents, additional erosion control structures are required.	Southern part of Pelagonija field
14	Pelagonija field	Drainage network (main canal) has been contructed in the field, but currently being not functioning well due to lack of maintenance and secondary and tertiary drainage canals.		Intensive improvement/rehabilitation of existing main canal is necessry as well as contruction of secondary and tertiary canal networks.	Pelagonija field
15	Kavadarci and its suburban area (Sopot II)	A detailed study of reforestation to prevent surface erosion was carried out in 1993.	Reforestation works for area of 200 ha has been completed in 1994.	Stuctural measures to protect the irrigation fields against erosion are required.	Tikvesh irrigation area
16	Vardar downstream reach (from Demir Kapija to Gevgelija)	A detailed study was prepared to prevent bank erosion that is currently expanded.		Several short streches are required urgent countermeasures to protect structures.	Agricultural land and national road
17	Konsko River (Gevgelija)	A detailed study for regulation and erosion protection of Konsko River was carried out in 1983.			Settlements and agricultural land
18	Ilovica dam and reservoir area (under planning)	There is on-going project to regulate torrents in Strumica region, in the area of proposed Ilovica dam and reservoir	Nine (9) check dams will be construceted with reforestation of 32 ha in the lower part of torrents. Out of it 24 ha has been completed.		Ilovica dam and reservoir (proppsed)
19	Galishte and Pelister montains		In the period between 1960 and 1970, erosion control facilities were constructed in Gelichica mountain on the side of Lake Ohrid and in Pelister (Baba) mountain on the side of Bitola field.		Settlements at skirts of the mountains
20	Koselska River (near Lake Ohrid)		Ten (10) check dams were constructed for erosion protection in 1960.		Ohrid town
21	Sateska River	Debris coming into Lake Ohrid from watershed of the Sateska River causes change of macroscopic vegetation along the lakeshore. In addition, the low terrin lying along the old river channel of the Sateska River is suffering from frequent inundation. German Government has committed to extend financial assistance for protection. The proposed plan consists of erosion protection for 1,400 ha with reforestation and construction of total 48 structures.	Short-cut channel was constructed to flow flood discharge into Lake Ohrid.	To accomplish the proposed project is major concern.	Lake Ohrid and agricultural land
22	Debar reservoir	There are three big torrents pourng into Debar reservoir, namely Kosovrasti, Dolgash and Avmatica. In 1988, construction of total six (6) concrete screen dams (two in each torrent) was	Screen dams for Kosovrasti and Dolgash have been completed.	Two (2) screen dams in the Avmatca River and reforestation at the fringe of the reservoir	Debar reservoir against sedimentation

Note: 1), "No. of location" coincides with the numbers showing in Figure 4.6.X.
Source: Based on the related study reports, result of field reconnaissance and interviews to MAFWE/LWMOs etc.

Table E.5 Annual Maximum Discharge at Major Gauging Stations in the Vardar River Basin (Instantaneous Peak)

	Skopje		T.Veles		Demir Kapija		Gevgelija	
Catchment (km2)	4,625		8,820		21,350		22,301	
Altitude (EL.m)	240		160		94		45	
Year	Max Q (m3/s)	Date	Max Q (m3/s)	Date	Max Q (m3/s)	Date	Max Q (m3/s)	Date
1961	439	20-May	340	21-May	415	22-May	n.a.	n.a.
1962	1,180	17-Nov	1,300	17-Nov	2,150	17-Nov	n.a.	n.a.
1963	673	13-Jan	875	14-Jan	1,800	6-Feb	n.a.	n.a.
1964	221	14-Nov	385	31-May	770	14-Nov	2,010	18-Nov
1965	231	16-Apr	395	4-Mar	870	5-Mar	926	17-Apr
1966	285	13-Feb	592	13-Feb	998	14-Feb	n.a.	n.a.
1967	195	22-May	267	23-May	688	23-May	n.a.	n.a.
1968	151	15-May	186	15-May	692	19-Feb	n.a.	n.a.
1969	232	24-Apr	333	24-Apr	492	16-Feb	550	16-Feb
1970	451	29-Mar	454	30-Mar	523	30-Mar	622	17-Mar
1971	359	1-Jan	326	30-Mar	709	2-Jan	632	31-Mar
1972	192	21-Apr	302	22-Apr	482	22-Apr	n.a.	n.a.
1973	226	5-May	342	5-Apr	540	6-Apr	n.a.	n.a.
1974	188	24-May	371	20-Feb	684	21-Feb	n.a.	n.a.
1975	248	2-Apr	256	3-Apr	313	3-Apr	n.a.	n.a.
1976	644	7-Jun	638	8-Jun	776	6-Dec	n.a.	n.a.
1977	246	15-Feb	454	15-Feb	595	16-Feb	n.a.	n.a.
1978	329	3-May	373	4-May	468	5-Apr	471	10-May
1979	983	19-Nov	1,180	20-Nov	1,550	20-Nov	1,748	20-Nov
1980	391	26-May	597	25-May	1,023	26-May	1,053	27-May
1981	404	20-Mar	451	25-Oct	1,070	21-Mar	1,157	22-Mar
1982	187	17-Apr	303	17-Apr	474	1-May	n.a.	n.a.
1983	264	18-Jun	381	18-Jun	584	18-Jun	638	18-Jun
1984	240	11-May	305	12-May	544	10-Feb	594	10-Feb
1985	264	22-Nov	316	28-Nov	547	28-Nov	597	28-Nov
1986	327	20-Feb	498	3-Feb	637	6-Mar	696	6-Mar
1987	202	7-May	521	1-Apr	1,128	3-Apr	1,235	3-Apr
1988	85	7-May	109	7-Apr	190	4-Dec	205	4-Dec
1989	148	17-May	277	17-May	367	18-May	400	18-May
1990	79	12-Apr	111	12-Apr	175	18-Jan	197	14-Dec

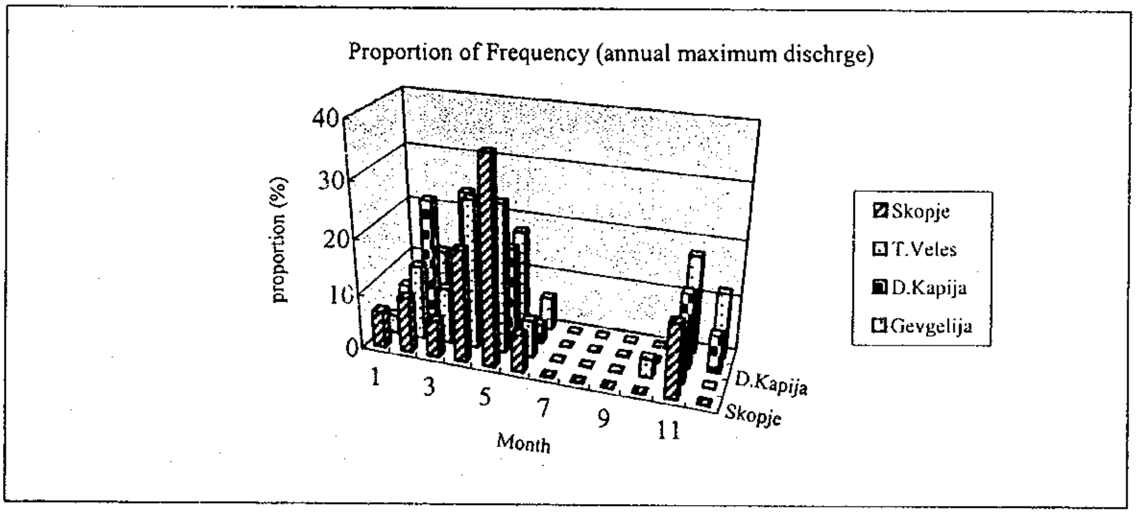


Table E.6 Hydrological Characteristics of Floods in 1962 and 1979

Items	November 1962	November 1979
1 Starting time of rising water level		
- Skopje	7:00 on 14 th	12:00 on 17th
- Gevgelija	18:00 on14 th	6:00 on 18 th
2 Time of occuring peak		
- Skopje	18:00 on 15 th	15:00 on 19 th
- Gevgelija	6:00 on 17 th	11:00 on 21 th
3 Duration of flood		
- Skopje	102 hrs	118 hrs
- Gevgelija	216 hrs	222 hrs
4 Time lag between Skopje and Gevgelij	36 hrs	44 hrs
5 Accumulated discharge		
- Skopje	113 mil.m^3	118 mil.m^3
- Gevgelija	460 mil.m^3	465 mil.m^3
6 Runoff depth		
- Skopje	24.4 mm	25.5 mm
- Gevgelija	20.6 mm	20.9 mm

Note : Catchment areas at Skopje and Gevgelija are 4,625 km^2 and 22,301 km^2 respectively.

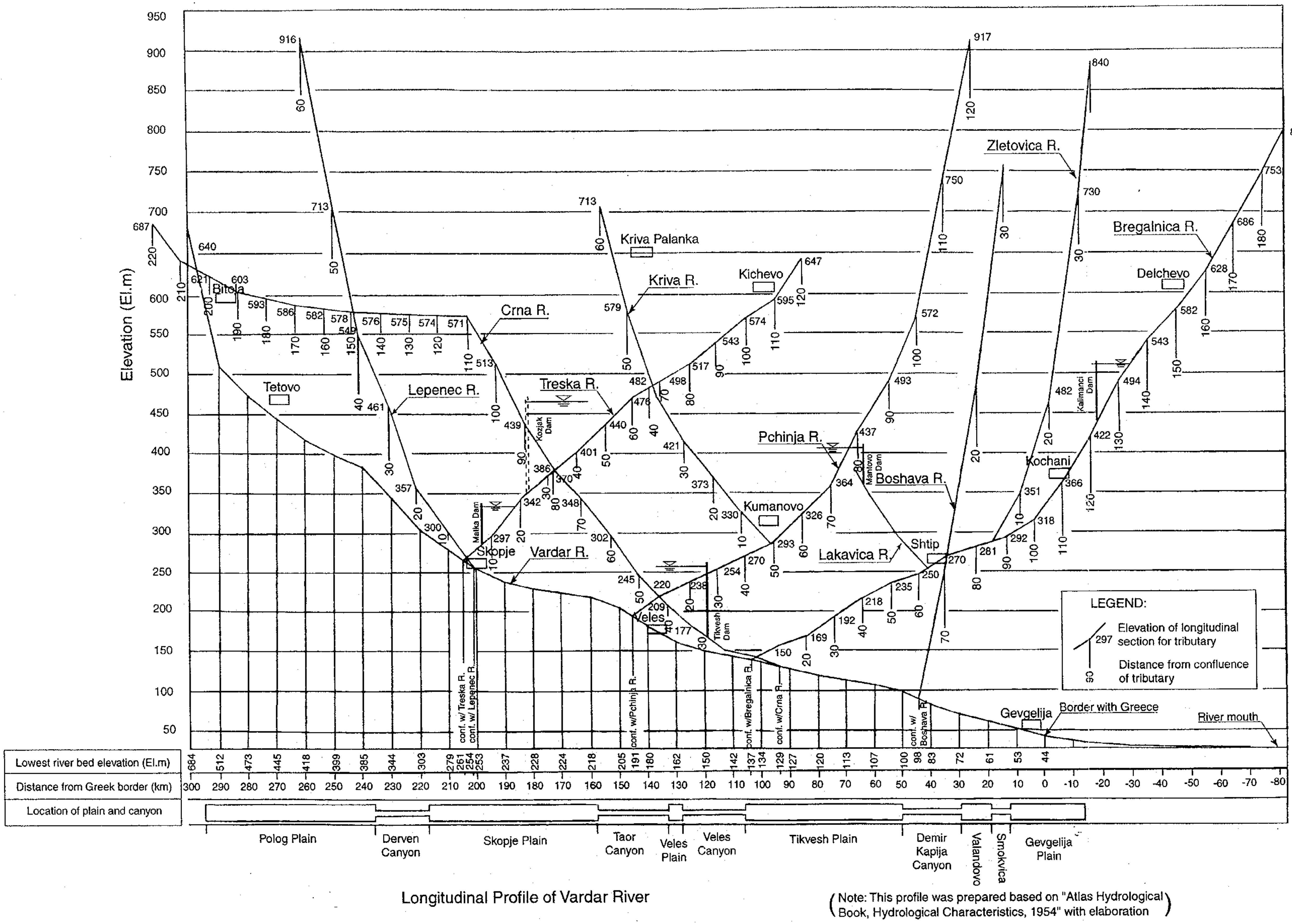


Figure E.1 Longitudinal Profile of Vardar River

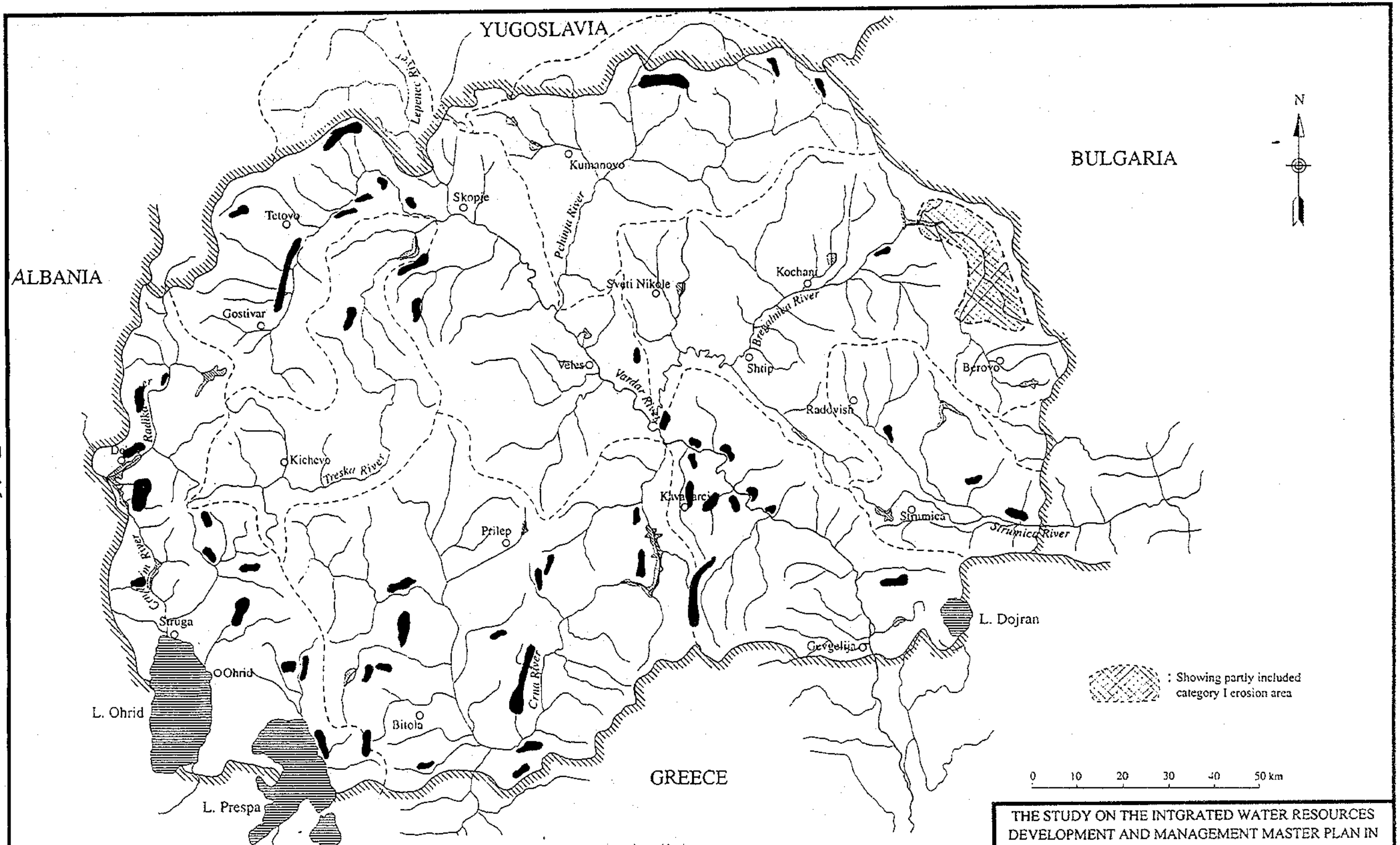


Figure E.2 Location Map of Potential Erosion Area (Class I)

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

JAPAN INTERNATIONAL COOPERATION AGENCY

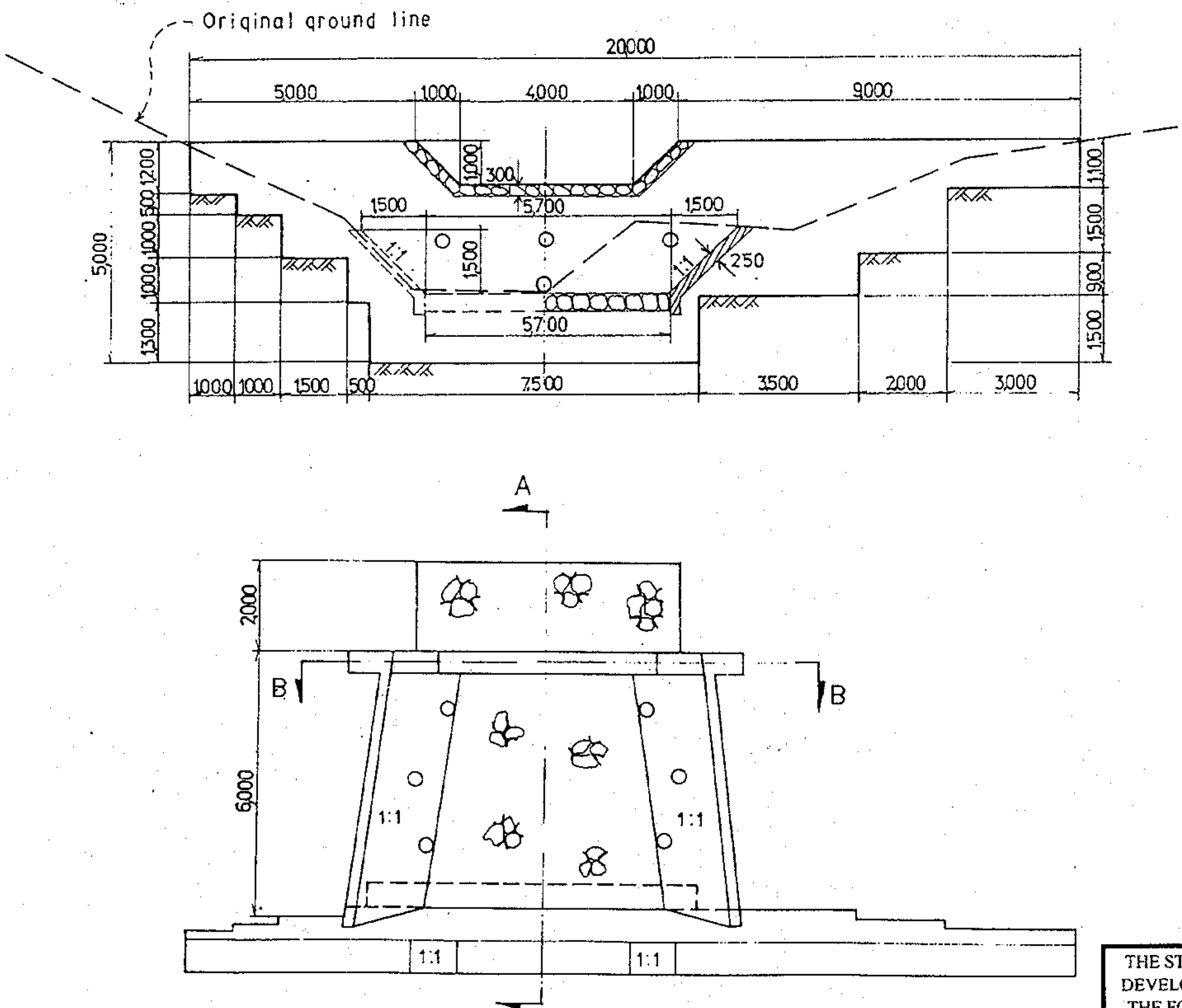
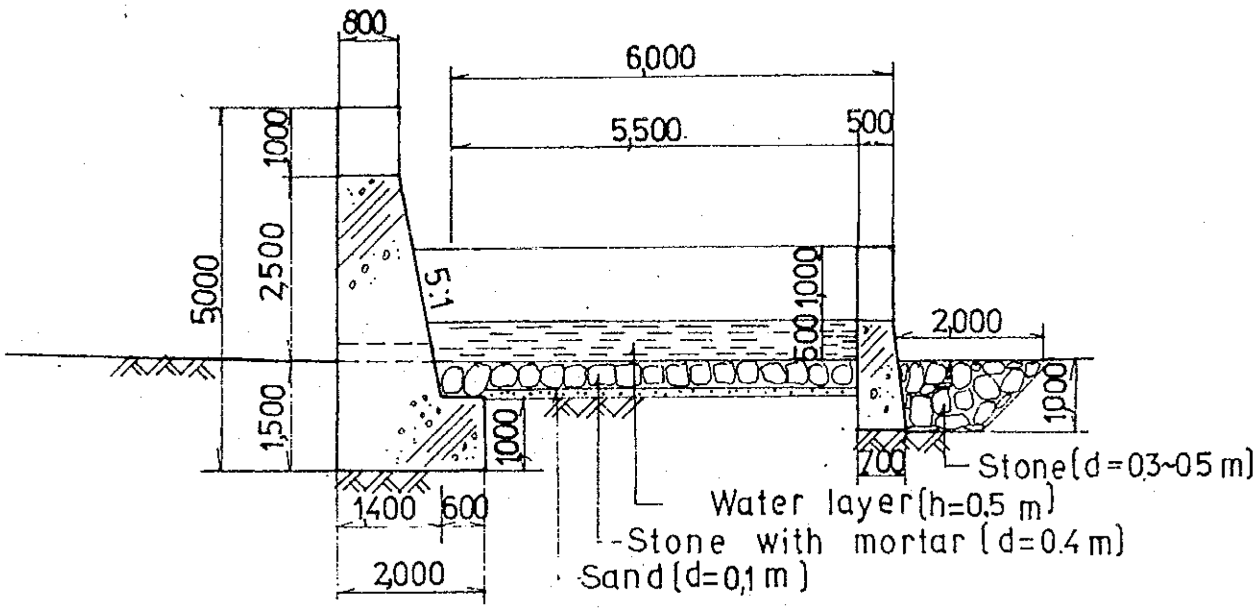


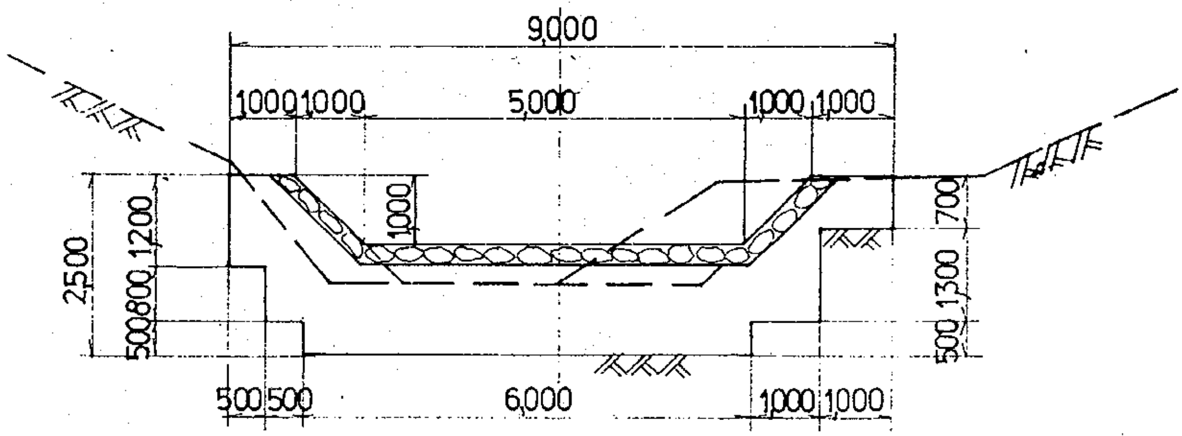
Figure E.3 Check Dam (1/2)

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

JAPAN INTERNATIONAL COOPERATION AGENCY



SECTION A-A



SECTION B-B

Figure E.3 Check Dam (2/2)

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

JAPAN INTERNATIONAL COOPERATION AGENCY

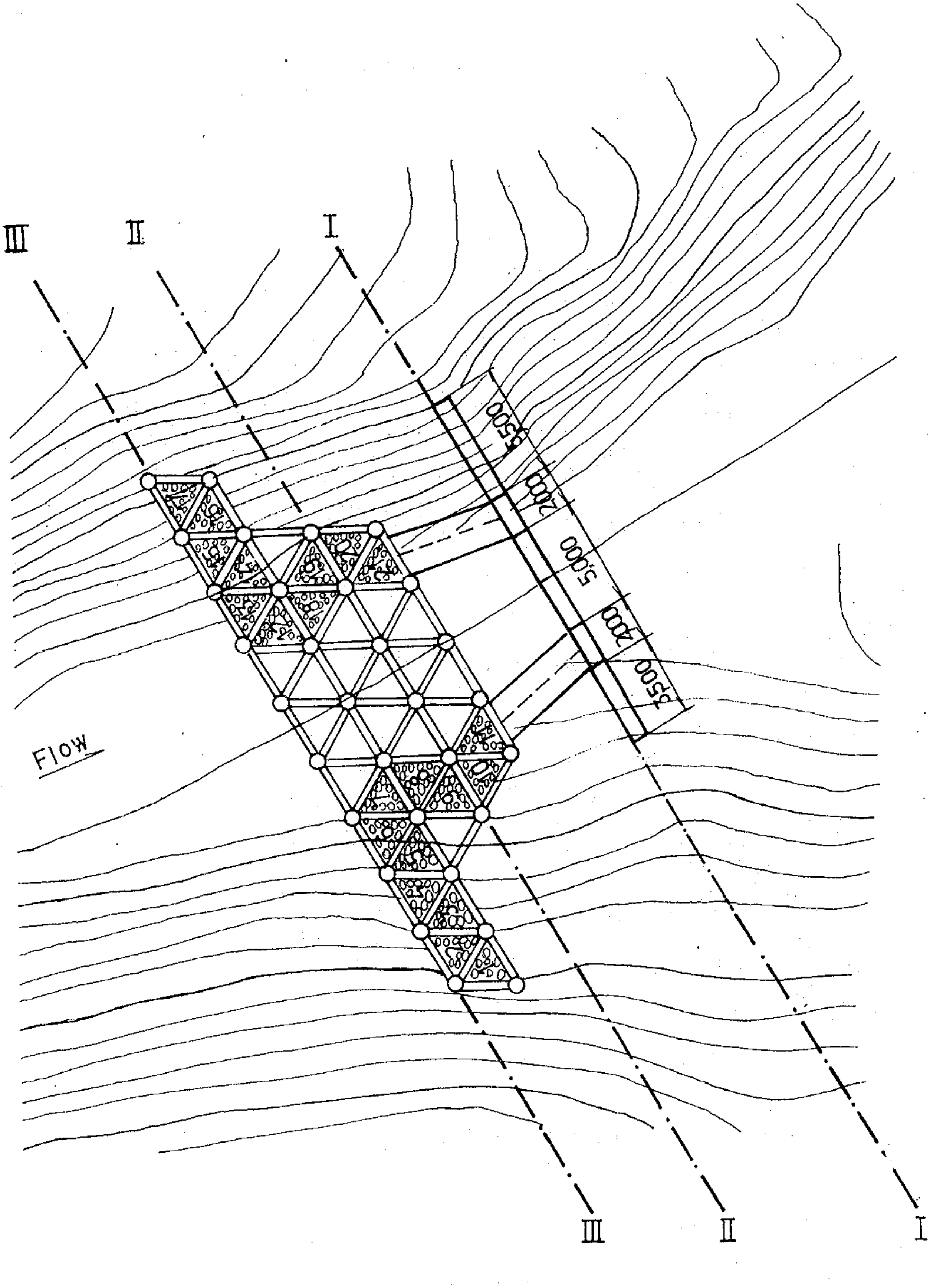
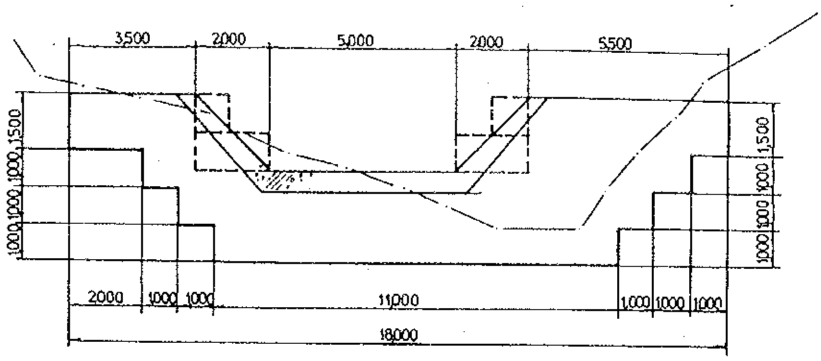


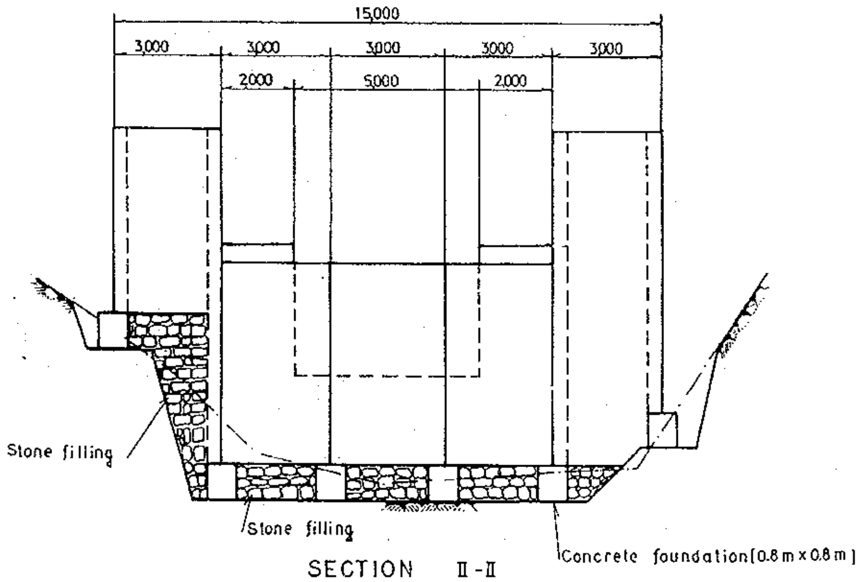
Figure E.4 Screen Dam (1/2)

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

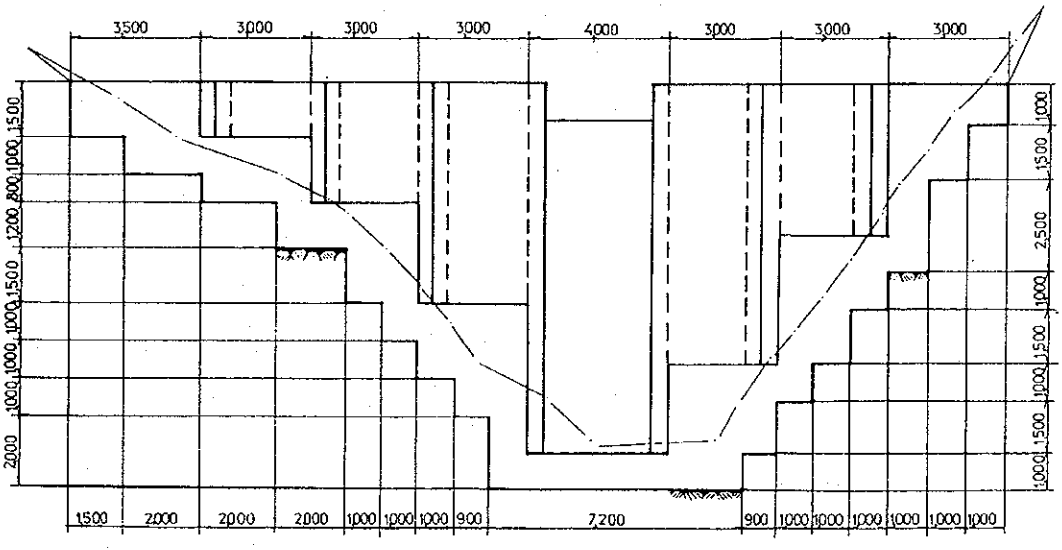
JAPAN INTERNATIONAL COOPERATION AGENCY



SECTION I-I



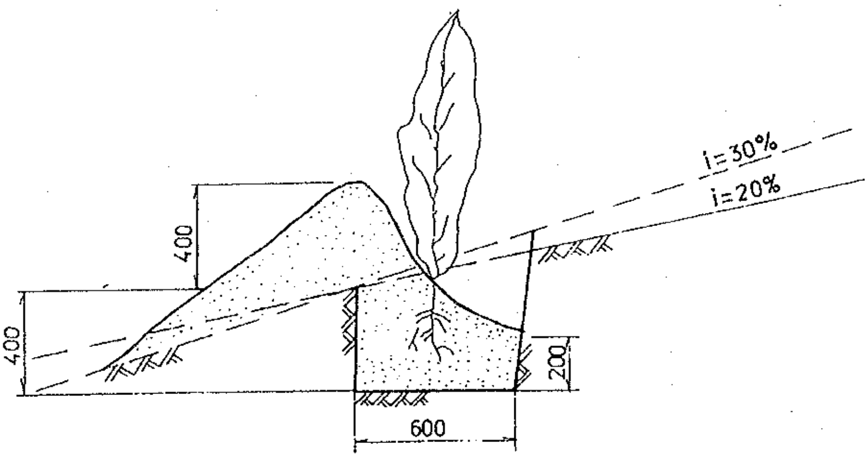
SECTION II-II



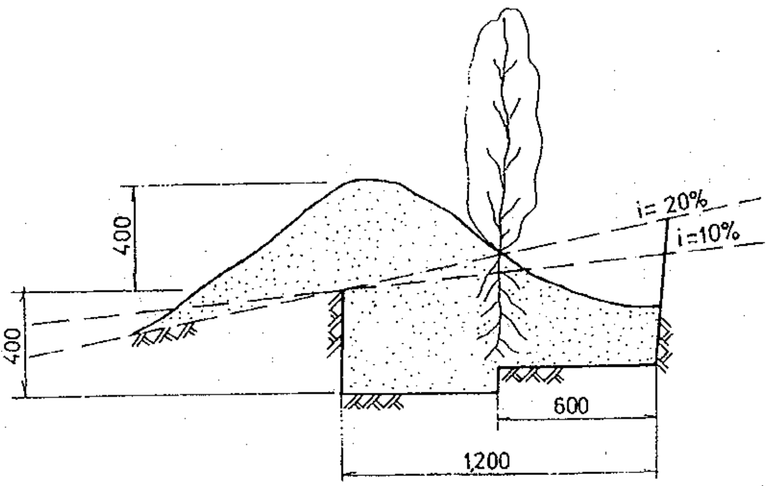
SECTION III-III

Figure E.4 Screen Dam (2/2)

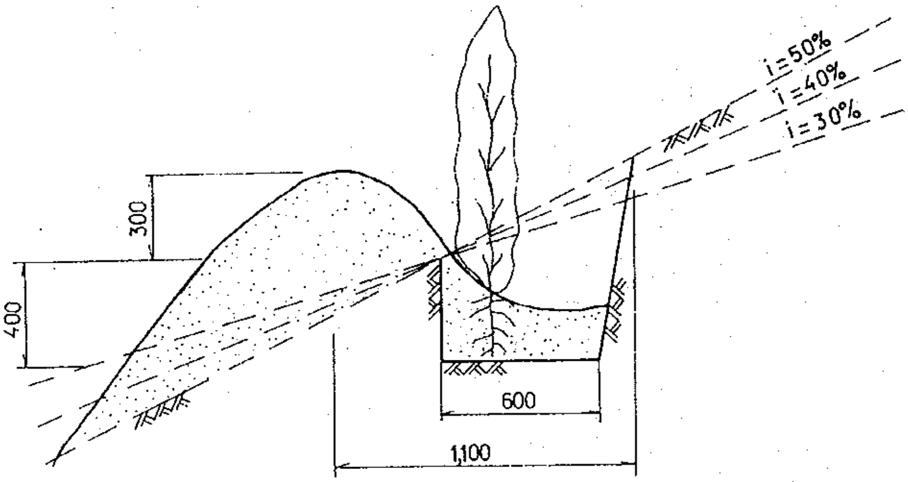
THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
JAPAN INTERNATIONAL COOPERATION AGENCY



CROSS SECTION OF MECHANICAL PREPARED
CONTOUR TRENCH WITH ONE PLOW



CROSS SECTION OF MECHANICAL PREPARED
CONTOUR TRENCH WITH TWO PLOWS

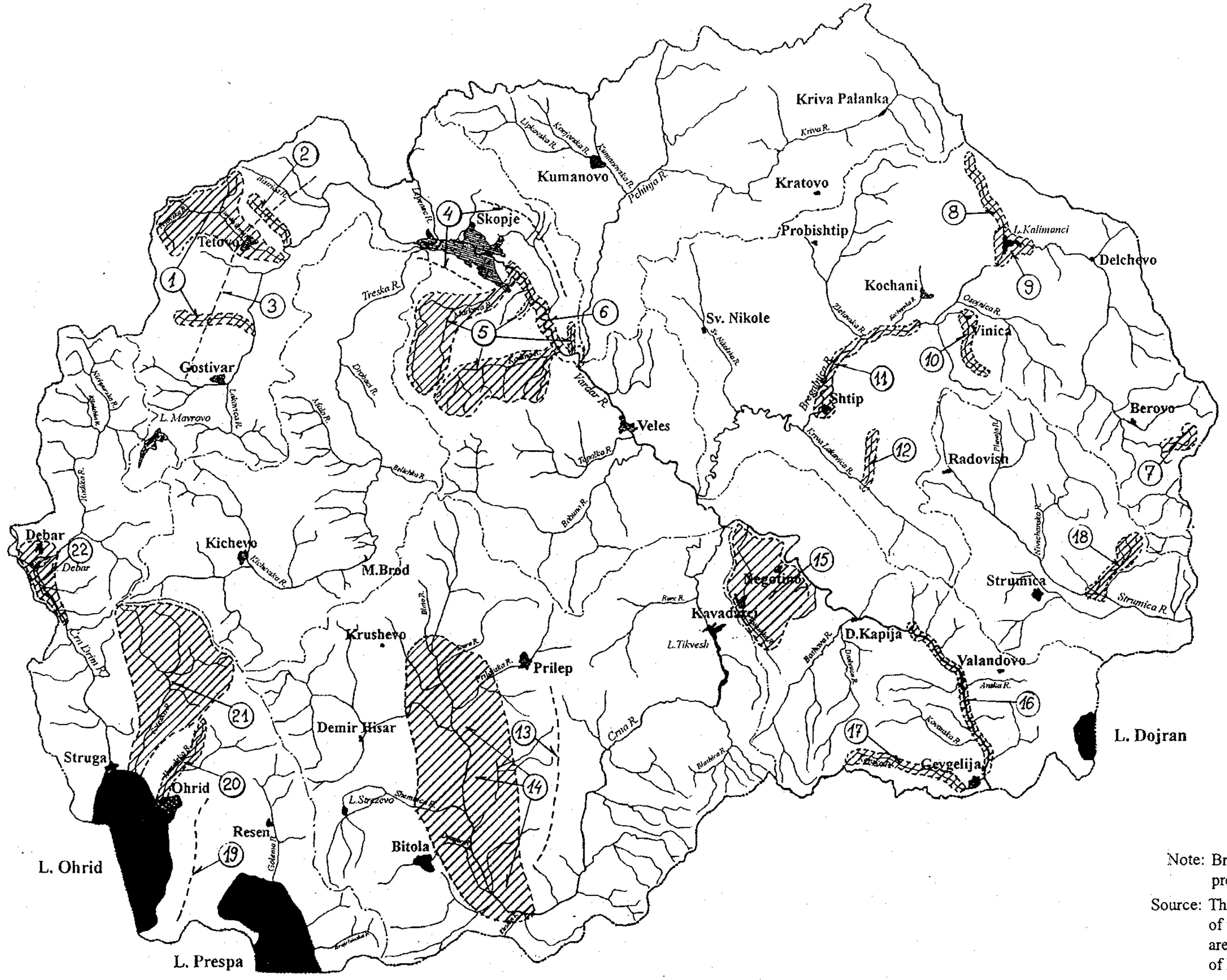


CROSS SECTION OF HANDMADE CONTOUR TRENCH

Figure E.5 Tree Planting

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

JAPAN INTERNATIONAL COOPERATION AGENCY



N

Note: Brief description for each area is presented in Table E3

Source: This map was prepared based on review of the related study reports for the specific areas, field reconnaisance and interviews of MAFWE/WMO etc.

Figure E.6 Location Map of Areas Requiring Countermeasures for Flood and Erosion Control

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

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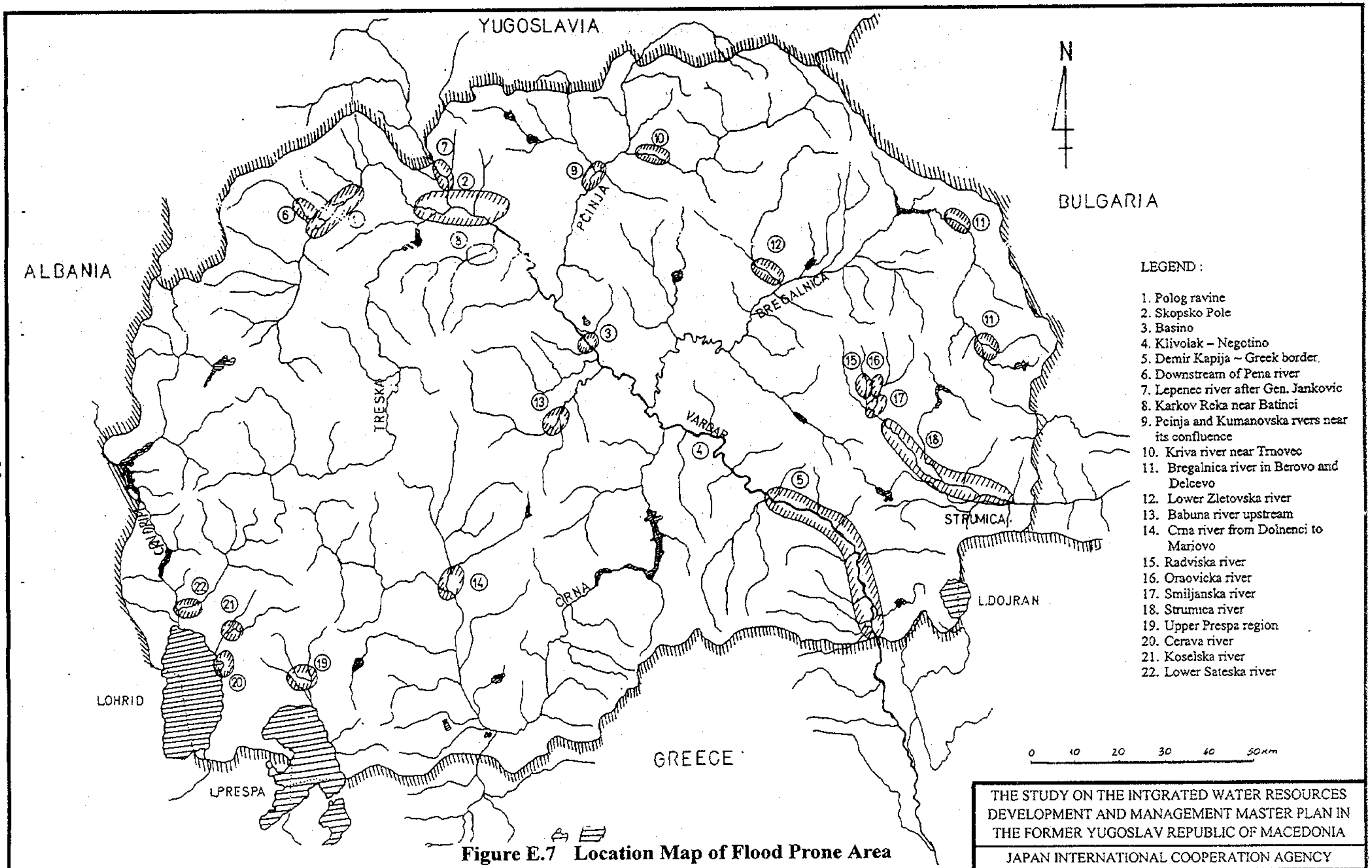

Figure E.7 Location Map of Flood Prone Area

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

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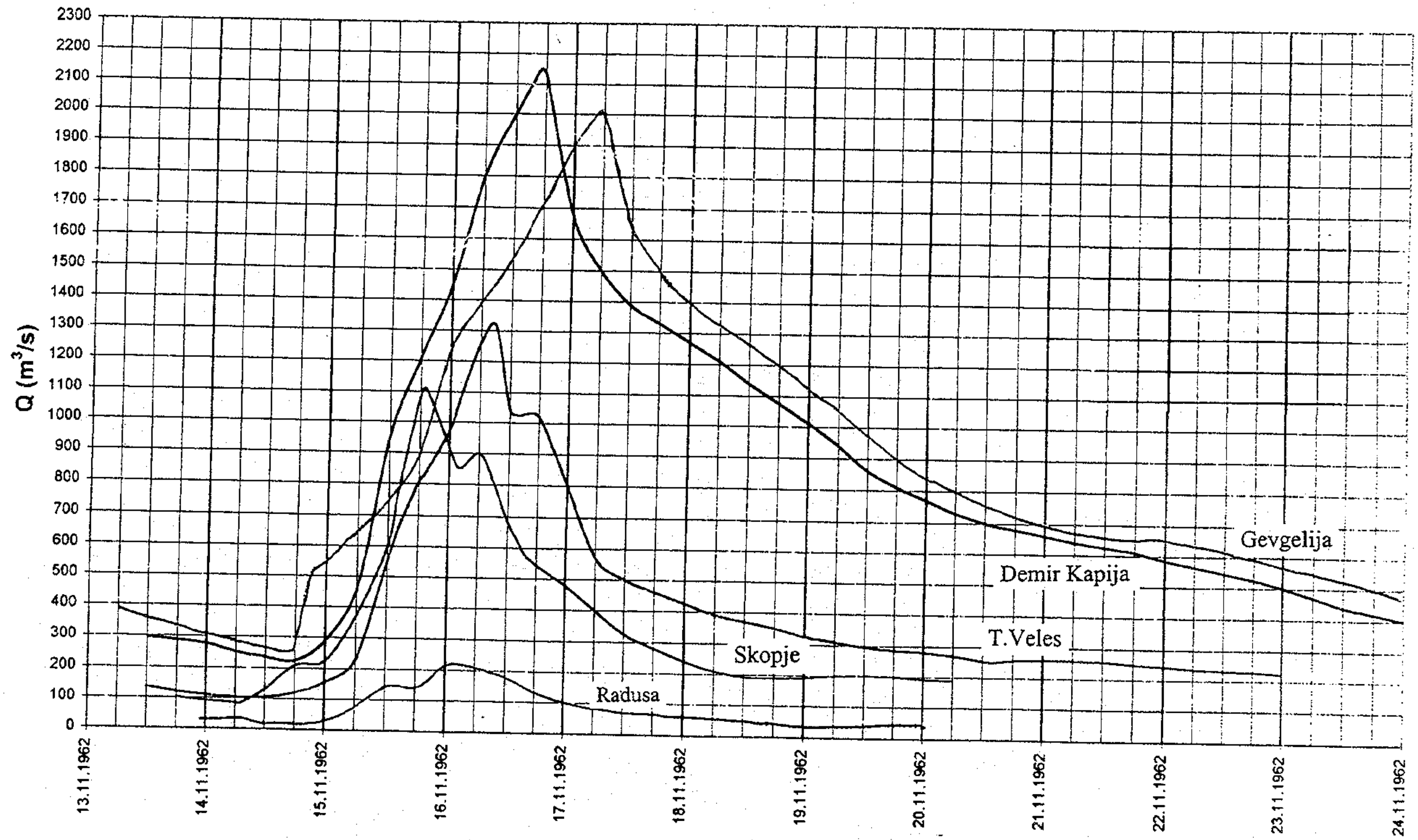
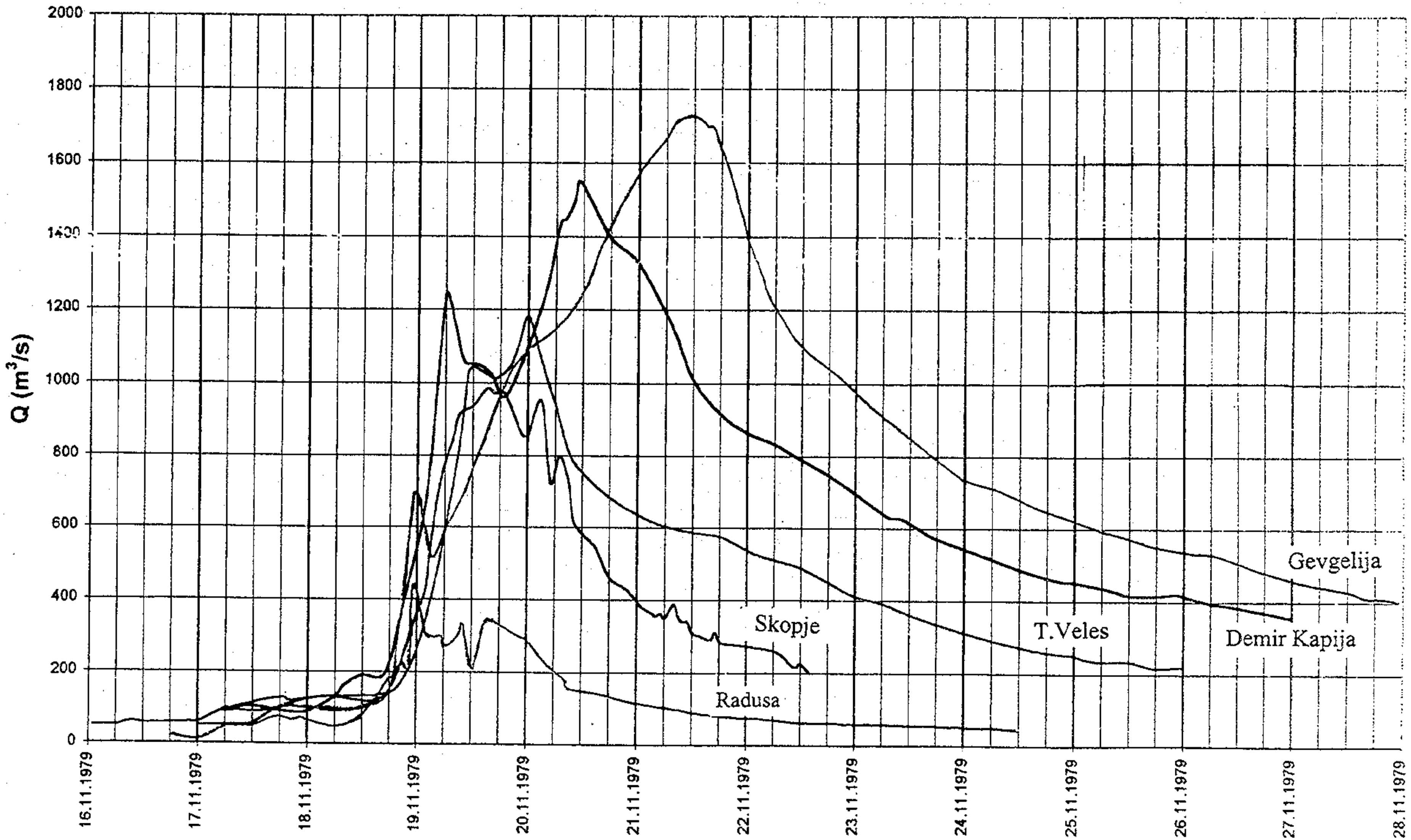


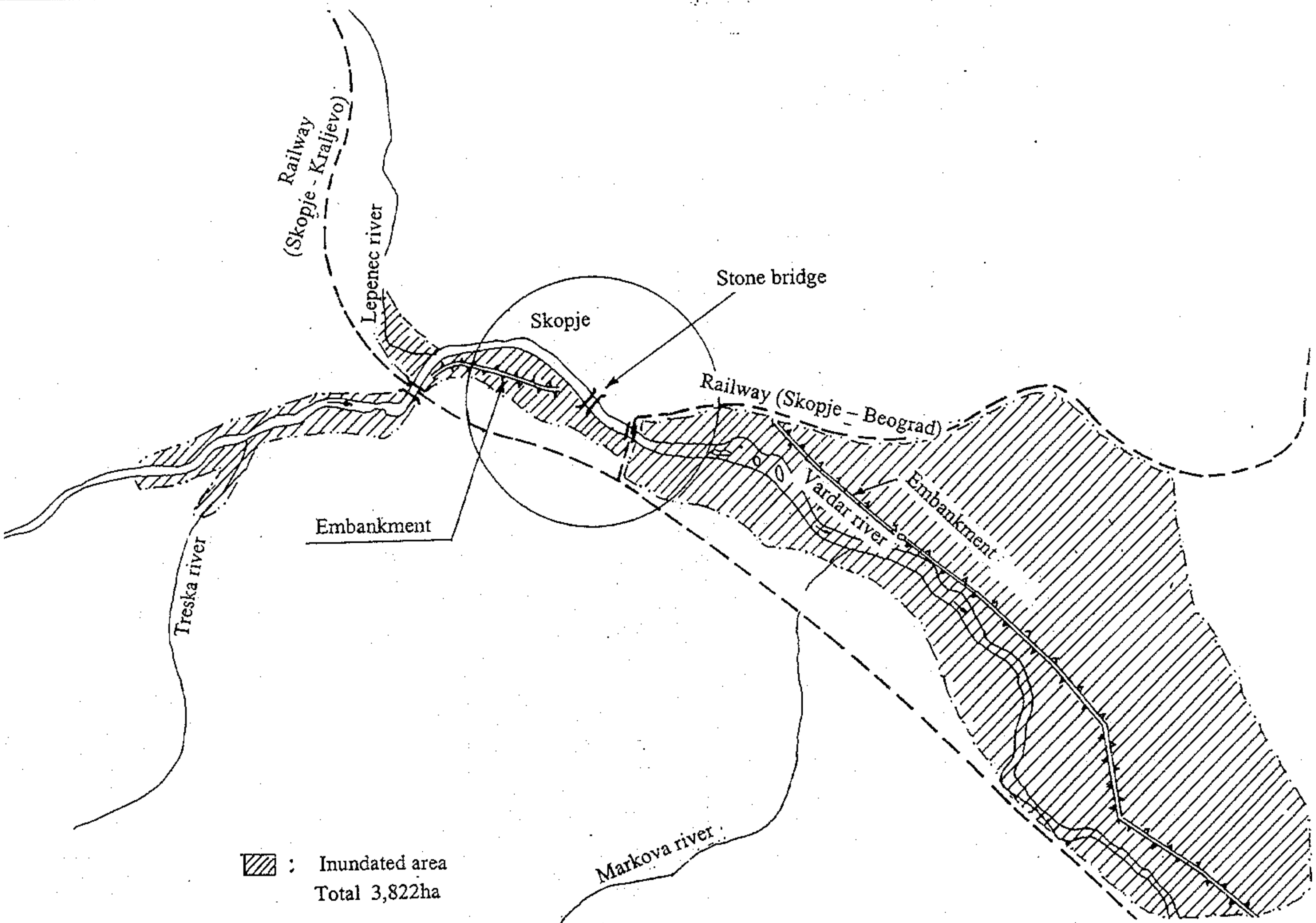
Source : "Climate and Hydrology of Macedonia" Volume Hydrology, Meteohydrological Institute, Feb.1998

Figure E.8 Flood Hydrograph of Vardar River in November 1962



Source : "Climate and Hydrology of Macedonia" Volume Hydrology, Meteohydrological Institute, Feb.1998

Figure E.9 Flood Hydrograph of Vardar River in November 1979



Source : *A brochure of the Water Management Vardar – Skopje 1925~1988*

Figure E.10 Inundated Area in Skopje due to 1962 Flood

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

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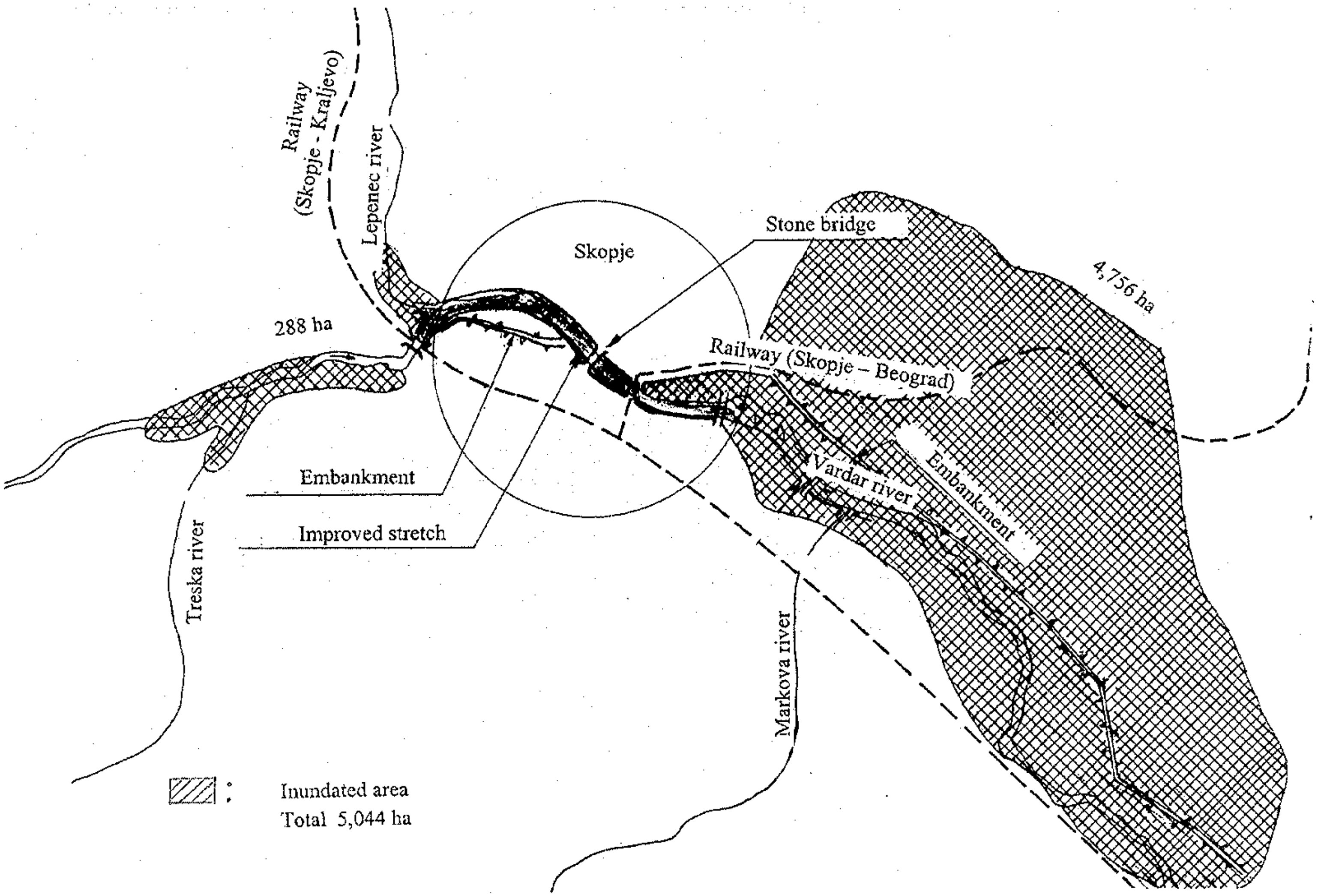

Source : *A brochure of the Water Management Vardar – Skopje 1925~1988*

Figure E.11 Inundated Area in Skopje due to 1979 Flood

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

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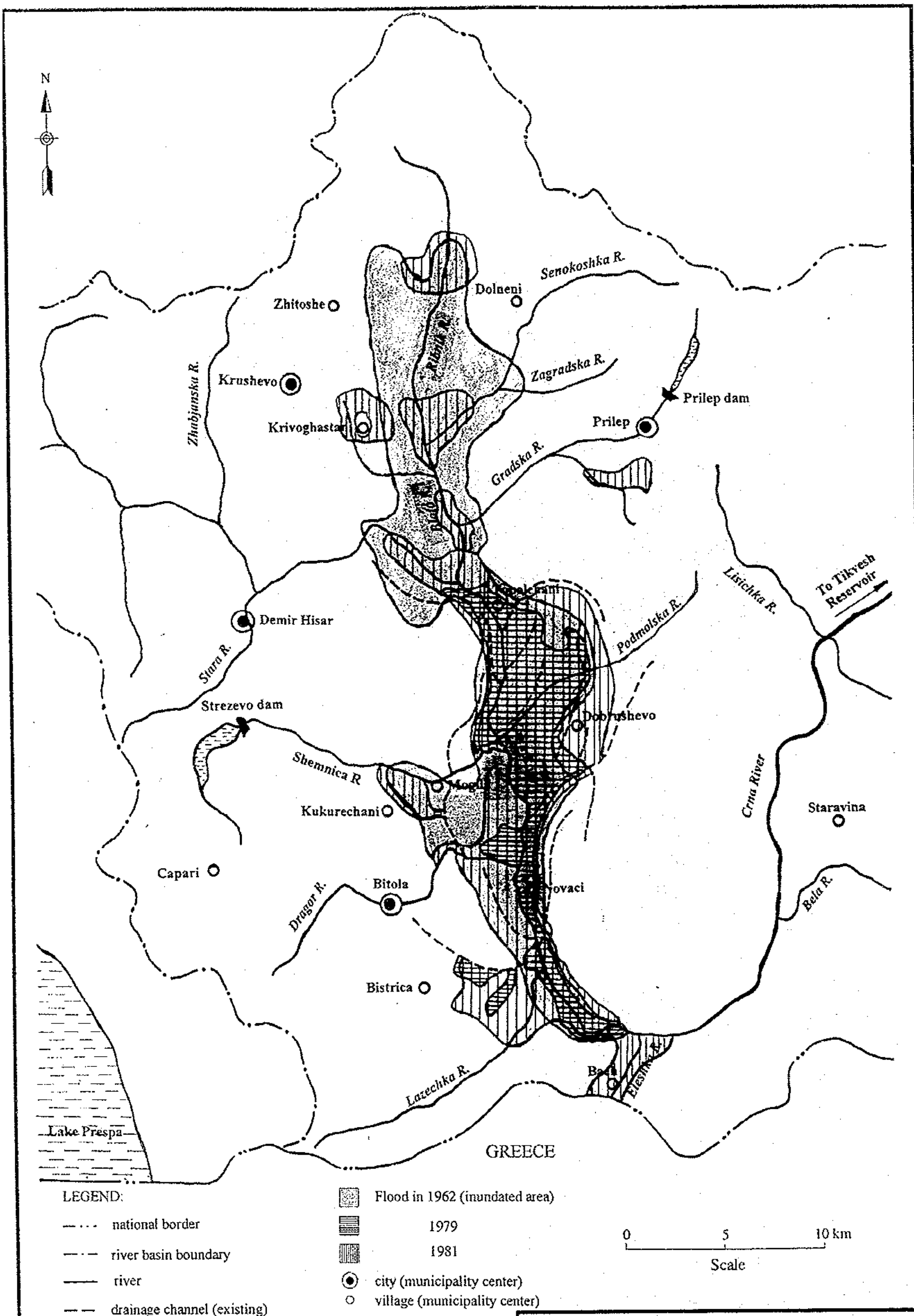


Figure E.12 Inundated Area by Major Floods in Pelagonija Field

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

JAPAN INTERNATIONAL COOPERATION AGENCY

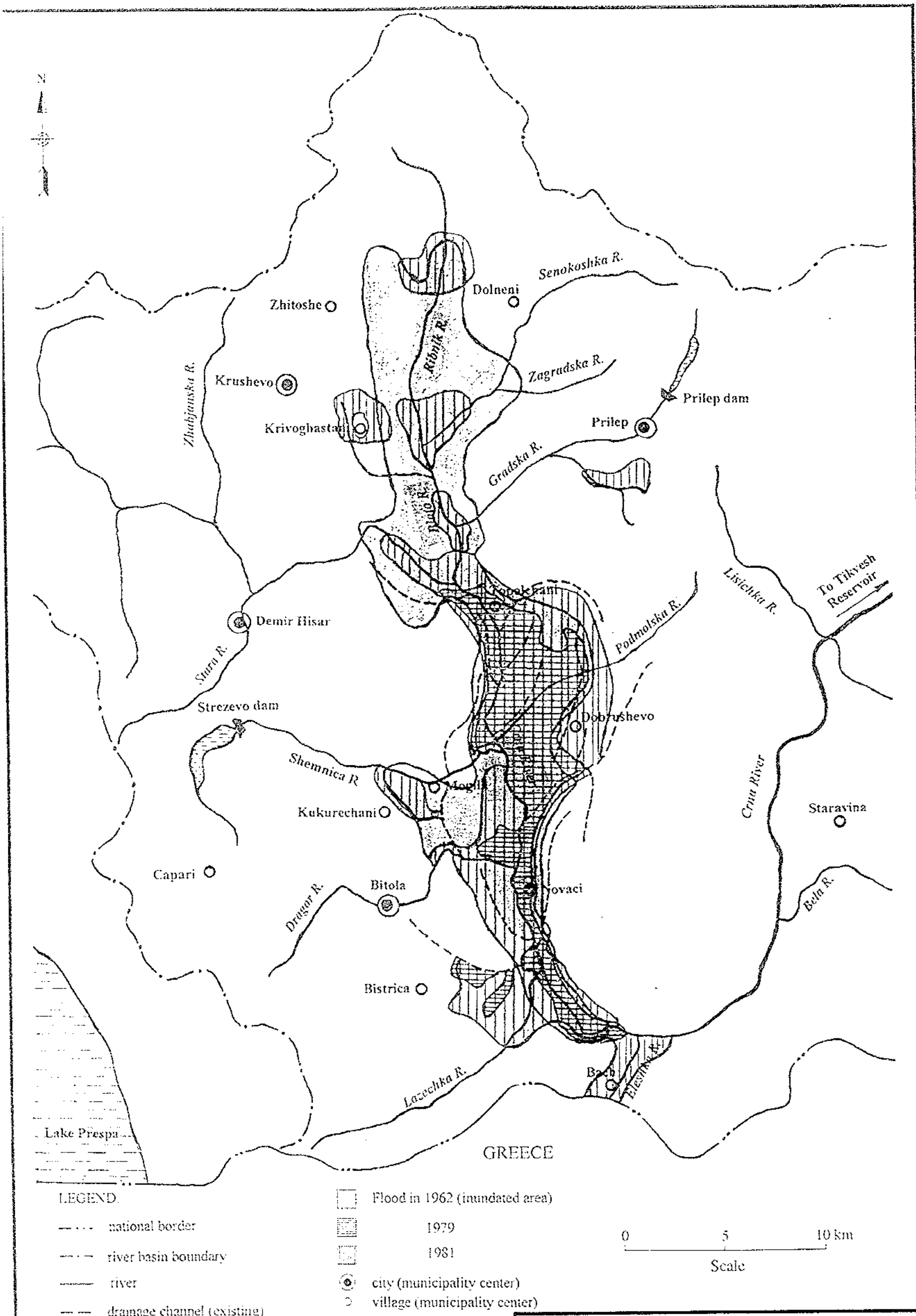
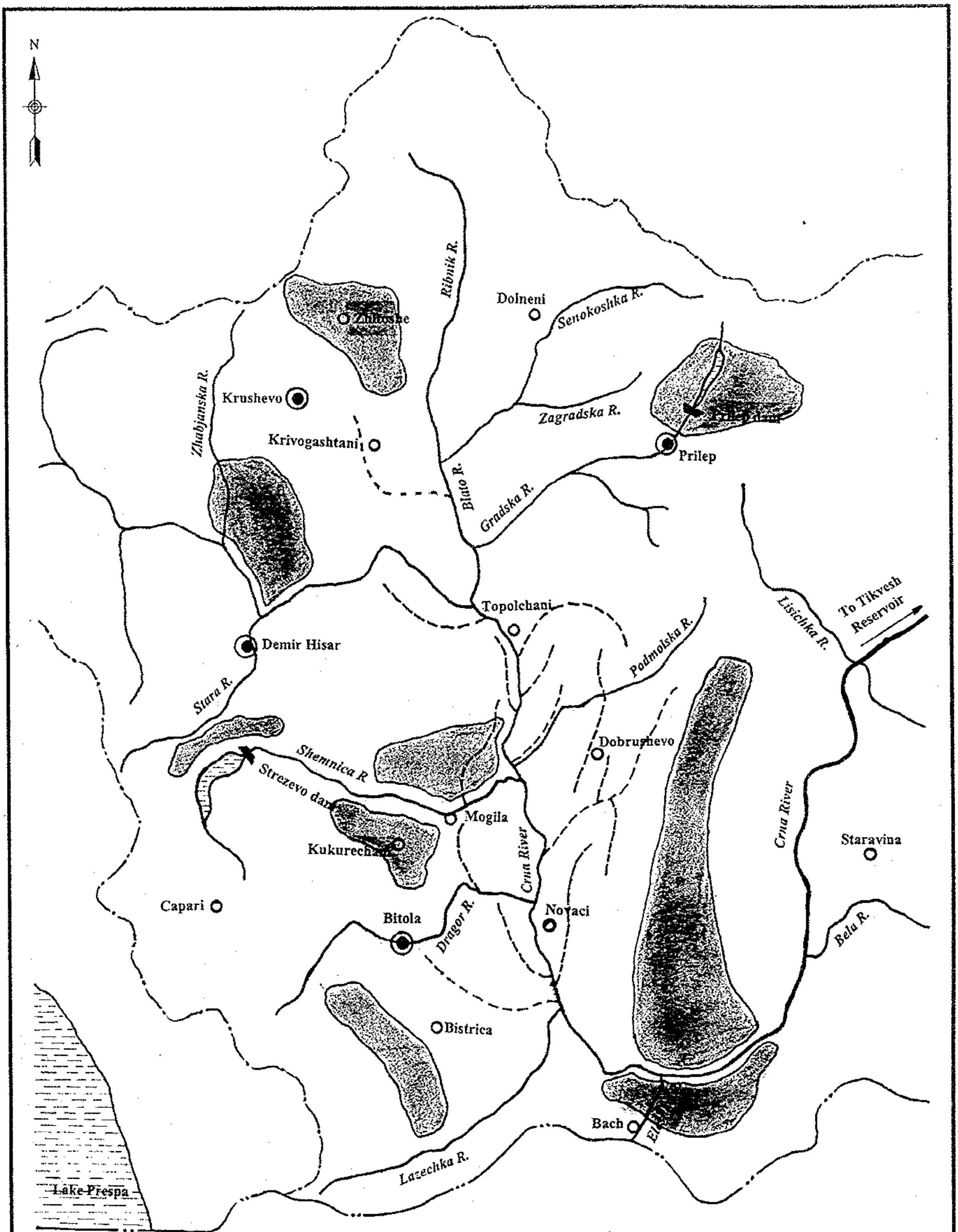


Figure E.12 Inundated Area by Major Floods in Pelagonija Field

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

JAPAN INTERNATIONAL COOPERATION AGENCY



LEGEND:

—···	national border		area under surface erosion (existing)
—·—	river basin boundary		lake
——	river	◉	city (municipality center)
— —	drainage channel (existing)	○	village (municipality center)

0 5 10 km

Scale

Figure E.13 Existing Drainage Canal in Pelagonija Field

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

JAPAN INTERNATIONAL COOPERATION AGENCY

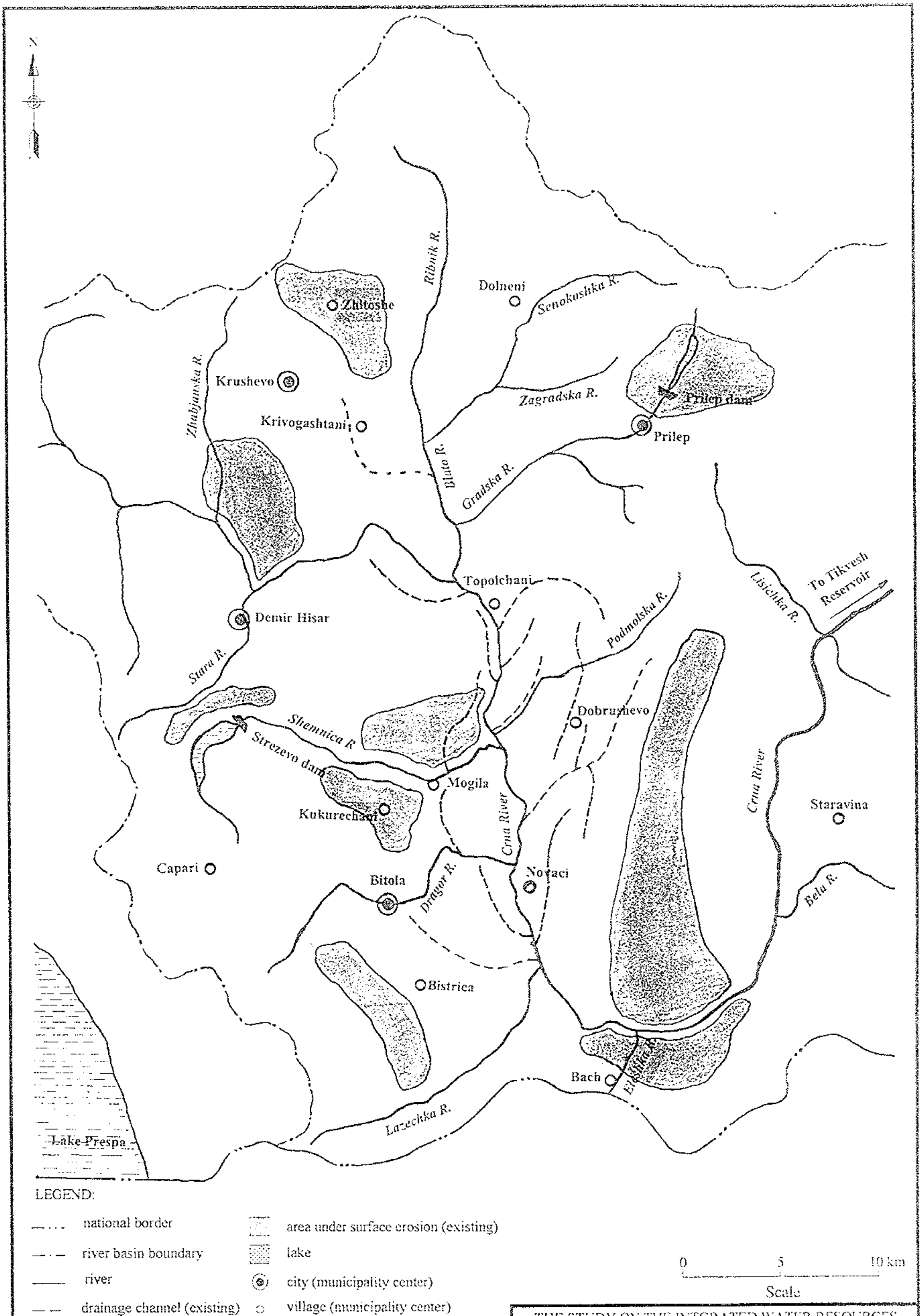


Figure E.13 Existing Drainage Canal in Pelagonija Field

THE STUDY ON THE INTGRATED WATER RESOURCES DEVELOPMENT AND MANAGEMENT MASTER PLAN IN THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA

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