JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

[illegible]
THE REPUBLIC OF HUNGARY

THE STUDY
ON
ENVIRONMENTAL IMPROVEMENT
OF
LAKE BALATON
IN
THE REPUBLIC OF HUNGARY

FINAL REPORT

SUPPORTING REPORT

MARCH 1999

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PRIME MINISTER'S OFFICE
THE REPUBLIC OF HUNGARY

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Foreign Currency Exchange Rates Applied in the Study

Currency	Exchange Rate/US$
Hungarian Forint (HUF)	211.945
Japanese Yen (J.Yen)	132.800
German Mark (DM)	1.81360

(Average rate from January to June 1998)

Note: Following numerical notation is adopted in the Report:

Decimal marker : "." (Period)
Digit separator : "," (Comma)

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REVIEW ON ACTION PROGRAM FOR LAKE ENVIRONMENTAL IMPROVEMENT

The government resolution 1068/1996, the present valid version of so-called the action program, integrates previous efforts for environmental improvement of Lake Balaton, and covers almost all fields related to this purpose. The action program consists of following components.

1 INTERNAL AND EXTERNAL POLLUTION LOADS REDUCTION

1.1 SEWERAGE SYSTEM DEVELOPMENT

The items 1.1 and 1.2 of the resolution 1068/1996 requests to develop sewerage systems in the whole catchment area of the lake, especially in the recreational areas, in compliance with the provisions of the resolution 2100/1995. The resolution 2100/1995 orders followings.

- In the recreational area capacity of sewage treatment plants should increase by 20,000 m^3/d up to 1995 and achieve 150,000 m^3/d.
- 95 % of all towns and all lakeside villages should be covered by sewerage systems by 2005.
- 60 % of all background villages with more than 1,000 inhabitants should be covered by sewerage systems by 2010.
- Nutrients reduction efficiency should achieve 95 % for the effluent directly discharged into the lake, and 80 % for the effluent indirectly discharged into the lake.

Present conditions concerning sewerage system development are as follows.

(1) Off-site Systems

The first sewerage systems in the catchment area of Lake Balaton were installed in Badacsony and Keszthely in the 1960's. Sewerage systems of the catchment area of Lake Balaton are classified into two (2) zones, lakeside sewerage system zone and other sewerage system zone. The lakeside sewerage system zone consists of seven (7) sewerage system regions as shown in *Figure A.1*. Almost all lakeside resort areas except Balatonakali have already been covered by sewerage systems.

Wastewater treated in the region I, II, VI and VII is to be discharged to outside of the catchment area. Wastewater treated in the region IV is to be discharged to the Lower Kis-Balaton.

At present, 42 sewage treatment plants are in operation, as listed in *Tables A.1* and *A.2*. Main features of the existing sewerage systems in the study area are summarized as below.

Zone	Present Capacity of Wastewater Treatment Plants (m^3/day)		
	Secondary Tr.	Secondary Tr.+ P removal	Total
Lakeside	52,100	34,500	86,600
Other Area	5,000	26,400	31,400
Total	57,100	60,900	118,000

A development plan of sewerage system up to 2010 in the Study Area has been prepared by KHVM as shown in *Table A.3*. According to the plan, future sewerage systems are summarized as below.

Zone	Future Capacity of Wastewater Treatment Plants (m^3/day)		
	Secondary Tr.	Secondary Tr.+ P removal	Total
Lakeside	81,000	72,200	153,200
Other Area	-	46,500	46,500
Total	81,000	118,700	199,700

Total capacity of treatment plant is planned to be approximately 200.000 m^3/day in the year 2010, which means a total capacity will increase by 70%. Main sewage treatment plants are planned to be 31 plants. All treatment plants except region I, II, VI and VII are planned to have a phosphorus removal process.

(2) On-site Facilities

In Balatonakali, tourism wastewater is treated by on-site treatment facilities. Removal efficiency of the facilities are as follows.

Name of On-site Facilities	Year	Treated Wastewater		
		Quantity (m^3/day)	Quality (mg/l)	
			COD	T-P
Holiday Camping	1994	150	28	1.33
	1995	49	30	1.17
	1996	97	30	1.10
Diana Camping	1994	20	36	2.00
	1995	59	41	1.32
	1996	16	31	0.98

Note: operating term is from June to August.

In the non-sewerage area, black water (human excreta) is generally treated by cesspools. Wastewater from the cesspool infiltrates into underground. Therefore, pollution load of human wastes does not directly discharge to water bodies. However, there is a possibility of groundwater contamination caused by cesspools. Gray water from kitchen and bath is directly discharged into rivers or drainage ditches, or infiltrates into underground, however, it seems there are no canals nor ditches polluted by gray water.

1.2 KIS-BALATON

The item 1.3 of the resolution 1068/1996 requests to continue the Kis-Balaton Phase II project, with revision of the plan. The resolution 2100/1995 gives a top priority to this project and orders to complete it by the end of 1999.

(1) History

Before the construction of the Siófok channel-gate in 1863, Kis-Balaton as well as the Lower Zala River Valley formed a lake just as the existing Keszthely Bay, and the water level fluctuated depending on the out-flow of the Zala River. Because of the remarkable degradation of the water quality of Lake Balaton, the utilization of the filtering function of Kis-Balaton was considered as a countermeasure with the aim of water quality improvement in the middle of 1960's. When "Water Management and Development Program of Lake Balaton" was instituted in 1971; the water management measures for the whole catchment area of Lake Balaton were indicated in its opening statement.

The Council of Ministers gave an agreement to the program for the water quality improvement system including the restoration of Lake Balaton in 1976. In mid-1970's, the national government started to consolidate the plan to realize the above-mentioned water quality improvement system. The through-flow system (proposed by NYUDU VIZIG) was adopted, which consists of two reservoirs and consequently has 120 days of retention time.

(2) Present Situation

Outline of the Kis-Balaton is as follows.

a. Upper Reservoir (Lake Hídvégi)

Surface Area : $18km^2$,
Max. Water Depth : 1.1m (average)
Operational High Water Level : 106.5m B.f.

b. Lower Reservoir (Lake Fenéki)

Surface Area : more than $50km^2$
Max. Water Depth: 1.1m (average)
Operational High Water Level : 105.7m B.f.

Upper Reservoir (Lake Hídvégi) started to operate in June 1985. Lower Reservoir (Lake Fenéki) is still under construction.

Recently, two engineering proposals were made to revise the original plan. The one is by the study of EU/PHARE and the other is the Revision Plan by Hungarian experts team.

The former one is related to the countermeasures against the problems of probability of the overtopping/breaking of both main and internal embankments and the breakdown of the water control structures.

The latter one has mainly proposed the following modifications.

- Ingói copse is managed in an independent way. It does not participate either in P retention or in flood protection functions for the reason of nature conservation.
- Sávoly and Vörs areas are not divided. Their primary function is phosphorus retention.
- Loading target prescribed for Lake Balaton cannot be realized by construction of the Lower Reservoir as a single measure. In order to meet the target conditions, external load must be reduced by an introduction of an effluent standard of 0.5mg(T-P)/l at the sewage treatment plant such as Zalaegerszeg or Keszthely, and 50 % of load reduction of non-point agricultural source.

According to the Hungarian experts team, during a decade of the Upper Reservoir's operation, the reservoir had an average retention efficiency of 42 %. Before 1991, the efficiency varied between 40 % and 60 %. In 1991, phosphorus precipitation process was introduced to the sewage treatment plant of

Zalaegerszeg. As a result of this and partly due to the long drought between 1991 and 1995, a T-P retention efficiency has dropped dramatically to 20 % after 1991. If present T-P loading does not increase and phytoplankton slowly turn P deficient, T-P retention of the Upper Reservoir may reach 30~35 %.

As for the Lower Reservoir, the expected long-term P retention is 30~40 %. However, the short-term P retention would be low, because net seasonal P release cannot be excluded.

1.3 DREDGING OF KESZTHELY BAY

The item 1.4 of the resolution 1068/1996 requests to continue the dredging work in Keszthely Bay, to render complex researches for establishing water quality oriented future dredging strategy, and to dispose of dredged sediment without endangering natural environment, public health, municipal development, and agriculture. The resolution 2100/1995 orders to complete the work by the end of 1999.

(1) History

Since the early sixties, dredging of Lake Balaton has been more and more hurried based on the opinion of an interdisciplinary research team led by K. Szesztay, that the phosphorus load accumulates in well-defined parts of the lake bottom. The need for dredging firstly appeared in the Keszthely Bay.

In 1992, EU/PHARE granted a dredger to make it possible to remove the upper sediment layer without disturbing the consolidated harmless strata. The dredger (known as the "MASTER") launched in Siófok in 1992, which has a length of 30.6 m, a breadth of 6.34 m, a draft of 1.2 m on average and a maximum dredging depth of 5.5 m. It is operated by the Lake Balaton Local Branch Office of KDT VIZIG. The dredger works for 10 hours a day and about 8 months a year from March to November. Its special feature is that it has a mobility as well as an ability of the thin layer dredging. It can dredge with a speed of 40~50m every 2~2.5 hours swinging its 25 m wide suction-pump, and can discharge the dredged sediment to the maximum distance of 5 km using its discharging pipe-lines with a diameter of 400 mm. Its average dredging capacity is known as 300~400 m^3/h.

(2) Present Situation

The areas already dredged were 54.4 ha (year 1992), 31.5 ha (1993), 10 ha (1994), 157.8 ha (1995), 182 ha (1996). The dredged area in 1997 are estimated to be 178 ha and about 180 ha a year in the near future. A total dredging area, as shown in *Figure A.2*, is planned to be 2400 ha and the dredging layer is 0.2 m thick on average. Planned total dredging volume of the bottom sediment is

4,800,000 m^3. The dredging area has been planned on the basis of the map which shows highly polluted area with phosphorus. However, the dredging area ,especially its center area is to be reconsidered.

Thirteen disposal sites of the dredged bottom sediment are also shown in *Figure A.2.* The greater parts of the disposal sites are on the land of low productivity including wetlands and marshy areas. The dredged sediment is discharged into the disposal ponds that is mainly surrounded by man-made embankments.

1.4 RUN-OFF CONTROL FACILITIES

The item 1.5 of the resolution 1068/1996 requests to reduce pollution loads from non-point sources according to the resolution 2100/1995. The resolution 2100/1995 orders to continue construction of run-off control facilities.

Presently, there are 17 run-off control facilities installed in the catchment area. Twenty one (15) facilities are installed in canals or rivers, and the others are installed in the agricultural areas of Zanka and Balatonfenyves. Functions of the facilities are classified into the following six (6) categories.

- Sedimentation
- Screen
- Filtration by gravel
- Filtration / adsorption by grass (reed, cattail, etc.)
- Infiltration
- Oil separator

Outlines of the facilities in canal / river in the catchment area are shown in *Table A.4,* and their locations are shown in *Figure A.3.* In general, these facilities have not been well maintained.

1.5 AGRICULTURAL POLLUTION LOADS MANAGEMENT

The item 1.6 of the resolution 1068/1996 requests to reduce pollution loads from agricultural sources.

(1) Management of Livestock Wastewater

Livestock breeding is strictly controlled in the Balaton catchment area from the view point of environmental protection. New animal farms are not allowed and measures against environmental pollution are enforced on the existing farms. These restrictions for environmental protection sharply reduced the number of livestock and stock breeders.

Small-scale stock breeders seem to have no treatment facilities for their wastewater. However dung is utilized for materials of compost and soil improvement and livestock wastewater does not seem to discharge into Lake Balaton.

(2) Study on Melioration and Afforestation

Ministry of Agriculture (FM) commissioned a complex study of melioration and afforestation in the catchment area of Lake Balaton to Agrober Rt. The study has been completed in 1995.

(3) Soil Conservation Monitoring System

Agrochemical Research Institute of Hungarian Academy of Science (MTA TAKI) has collected various soil data for the purpose of soil conservation.

(4) Feasibility Study on Melioration and Afforestation

FM selected three areas for the feasibility study on melioration and afforestation for reducing pollution loads discharged to the lake. The feasibility study was planned to be conducted in this year, however, due to financial difficulty it has not been realized.

1.6 FISHING ACTIVITY MANAGEMENT

The item 1.7 of the resolution 1068/1996 requests to control fishing activity from the view point of nature conservation and water quality protection.

A private fishing is only done by anglers with license. Commercial fishing is also controlled by FM through the Balaton Fishing Incorporation.

2 SHORE PROTECTION AND REGULATION

The item 2 of the resolution 1068/1996 requests to make vegetation map, to establish new regulations on management of reed belt, and to rehabilitate reed belt.

2.1 CONSERVATION OF REED BELT

The national government (KDT VIZIG) have had a research activity in 1994-1996, in corporation with an university relating to the planting reeds on Lake Balaton. The contents of the research are composed of two parts. The first part is the confirmation of the existing situation about reed bushes in Lake Balaton. This research made it clear that reed bushes have been remarkably reduced. An acreage of the existing reed bushes was summed up about 87 ha by the research during 1984-1993. Another part is the experimental research related to the possibility of replanting reeds. The experiences and the results through the research show that a success of reed-planting basically depends on the effectiveness of protection against waves and icing.

There may be a slight chance for plants to survive without these protections. It seems practical that reeds should be planted on land at the first stage and then planting should be gradually advanced toward the lake. The effectiveness of the planting also depends on the conditions of water quality and its bed. Thick organic, nutrient-rich and loose sediment is suggested to be removed. Algae and dead reed which cover the water bed is also suggested to be removed. The best condition for planting reeds is a sandy lake bed. During the planting process, it is necessary to fasten the plants to an extended degree so that it can not be flown.

2.2 SHORE PROTECTION STRUCTURES

The resolution 2100/1995 restricts construction of shore protection structures (embankments) to protect recreational areas, to eliminate solid waste disposal sites, and to finalize temporary shore protection structures. Shore protecton structures were built primarily on the southern shore in order to prevent erosion , to protect the settlements and to assure the use of shores. Present situation of the shore protection works are given in *Table A.5.*

In the case of Lake Balaton, the lake water area defined by its water-depth deeper than -1m (based on 104.8 m B.f.) belongs to the national government and is directly managed by the national government (KDT VIZIG). The beach area defined by its water-depth less than -1m belongs to mainly the national government, but the management bodies are complicated as shown in *Table A.5.* Popular way is that the national or the city governments build the shore protection structures by themselves or these governments leave the management of shore regulation in the hands of special institutions which are the agencies of these governments.

Recently, the total length of shores where the shore regulation was completed and/or the rip-rap was implemented has come to 107.5 km (equivalent to 44 % of the whole shore length of Lake Balaton).

Looking to the types of shore protection structures, 85 % of the regulated shores is a conventional type. This type of structure might be superior to other types with regards to the costs of construction and maintenance as well as technical advantage.

Following to the opinions that existing shore structure should be replaced by an eco-friendly type, the water authority (KDT VIZIG) has continued to pay efforts to develop such types of structures. However, severe natural conditions (including icing, high waves, beach erosion and so-on) make it difficult to adopt the eco-friendly type.

3 PREPARATION OF NEW REGIONAL DEVELOPMENT PLAN

The item 3 of the resolution 1068/1996 requests to revise the present Balaton regional development plan (BRRT) with taking into account of the whole catchment area of the lake.

From the second version approved in 1979, the BRRT has employed measures restricting and controlling land use and construction activities in the Balaton recreational area. Present BRRT (the third version BRRT), which was submitted to the government in 1985, reviews development of the Balaton recreational area over the past 30 years, and forms the framework of the regional plan giving high priority to lake water quality improvement.

The new BRRT (the fourth version) is now under preparation. Recently the VÁTI, the City Planning Institute of the Hungarian Society of Regional Development and Urbanization, has submitted a draft of the new BRRT to the Ministerial Council.

4 SOLID WASTE MANAGEMENT

The item 4 of the resolution 1068/1996 requests to establish a concept of solid waste management and to make its implementation schedule. So far in the Study Area a development of solid waste management systems have not significantly advanced.

5 OTHERS

The resolution 1068/1996 covers non-structural measures which are necessary for and facilitate the implementation of above measures and provide a basis of further steps. These measures are as follows.

Item 5.	Prioritization of proposed components
Item 6.	Financial and institutional study
Item 7.	Establishment of the basis for evaluation and future revision
Item 8.	Preparation of middle term investment plan
Item 9.	Establishment of Balaton National Park Foundation
Item 10.	Submission of the Progress Report
Item 11.	Establishment of funds for research activities
Item 12.	Involvement of local governments

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Table A.1 Existing Sewage Treatment Plants in the Study Area

Location		Capacity (cu.m/day)		Year of begin operation	Recipient water body	Catchment
		Installed	Record (1996)			
1	Balatonfüred	8,000	-	1988	Veszprémi-Séd	other
2	Balatonudvari	-	-	-	L.Balaton	L.Balaton
3	Zánka	-	610	-	L.Balaton	L.Balaton
4	Révfülöp	3,200	1,300	1978	L.Balaton	L.Balaton
5	Badacsonytomaj	500	192	1986	L.Balaton	L.Balaton
6	Badacsony	600	426	1966	L.Balaton	L.Balaton
7	Badacsonytördemic	2,000	-	-	L.Balaton	L.Balaton
8	Szigliget	200	-	1983	Tapolca patak	L.Balaton
9	Tapolca	5,000	4,200	1975	Tapolca patak	L.Balaton
10	Balatongyörök	1,000	566	1976	L.Balaton	L.Balaton
11	Keszthely	21,500	12,000	1967	Kis-Balaton II	L.Balaton
12	Héviz	2,850	-	1982	Oberek csatoma	L.Balaton
13	Balatonberény	400	271	1983	L.Balaton	L.Balaton
14	Balatonújlak	4,000	2,338	1989	Nyugati övcsat.	L.Balaton
15	Marcali	4,000	2,153	1970	Nyugati övcsat.	L.Balaton
16	Kéthely	40	-	-	Nyugati övcsat.	L.Balaton
17	Maesztegnyô	10	-	-	Nyugati övcsat.	L.Balaton
18	Balatonlelle	14,400	-	1986	Koppány patak	other
19	Balatonboglár	-	-	-	L.Balaton	L.Balaton
20	Siófok	32,500	-	1977	Sió	other
21	Balatonakarattya	5,100	-	1974	Sóslápi patak	other
22	Balatonfüzfô	12,000	-	1982	Veszprémi-Séd	other
23	Sármellék	150	118	1996	Kenderáztató cs.	L.Balaton
24	Balatonfôkajár	2,500	-	1996	Sósiápi patak	other
25	Zalakaros	1,000	390	-	Kiskomáromi cs.	L.Balaton
26	Zalaszentgrót Varosi	1,500	518	-	Nadas patak	L.Balaton
27	Zalaegerszeg Varosi	25,000	15,800	-	Zala	L.Balaton
28	Zalaapáti	-	125	-	Zalaapáti patak	L.Balaton
29	Zalakomár	200	116	-	Kiskomáromi cs.	L.Balaton
30	Aszófô	-	16	-	Aszófô Séd	L.Balaton
31	Balatonakali	-	97	-	L.Balaton	L.Balaton
32	Nagyvázsony	-	-	-	Vázsonyi Séd	L.Balaton
33	Várvölgy	45	-	-	Gyöngyös patak	L.Balaton
34	Vállus	20	-	-	Gyöngyös patak	L.Balaton
35	Türje	100	-	-	Nádas patak	L.Balaton
36	Zalacsány	100	-	-	Örvéryes patak	L.Balaton
37	Hahót	100	-	-	Hahót övcsat.	L.Balaton
38	Bucsuszentlászló	50	-	-	Szévíz	L.Balaton
39	Gersekarát	200	-	-	Zala	L.Balaton
40	Hegyhátszentjakab	140	-	-	Szentjakabi patak	L.Balaton
41	Zalalövô	200	-	-	Zala	L.Balaton
42	Zalacséb	100	-	-	Velencei patak	L.Balaton

Table A.2 Effluents of Sewage Treatment Plants (1/2)

Treatment Plant	Recipient water body	Catchment area	Capacity (cu.m/day)		Water quantity (cu.m/day)	COD (mg/l)	T-P (mg/l)
Zánka Gyermekudul Centrum	Balaton	Zánka	-	before s.	300	14	0.14
				on season	610	12	0.65
				after s.	570	15	0.36
				average	493	14	0.38
Révfülöp	Balaton	Révfülöp	3,200	before s.	1,000	12	0.80
				on season	1,300	18	0.48
				after s.	1,500	10	0.38
				average	1,267	13	0.55
Badacsonytomaj	Badacsonytomaji árok	Badacsonytomaji árok	500	before s.	180	15	0.90
				on season	192	29	0.82
				after s.	300	18	1.10
				average	224	21	0.94
Tapolca varos	Tapolca patak	Tapolca	5,000	before s.	4,300	26	1.20
				on season	4,200	21	0.70
				after s.	4,200	23	1.10
				average	4,233	23	1.00
Badacsony	Balaton	Badacsony	800	before s.	450	21	0.90
				on season	428	37	0.80
				after s.	420	18	0.40
				average	433	25	0.70
Balatonakali Holiday Camping	Balaton	Balatonakari	-	before s.	0	-	-
				on season	97	30	1.10
				after s.	0	-	-
				average	32	10	0.37
Diana Camping	Aszófi sed	Aszófi	-	before s.	0	-	-
				on season	16	31	0.98
				after s.	0	-	-
				average	5	10	0.33
Balatonújlak	Nyugati övcsat.	Balatonújlak	4,000	before s.	2,216	47	0.90
				on season	2,338	72	2.50
				after s.	2,218	47	0.90
				average	2,257	55	1.43
Marcali	Nyugati övcsat.	Marcali	4,000	before s.	2,153	36	0.50
				on season	2,153	36	0.50
				after s.	2,153	36	0.50
				average	2,153	36	0.50
Balatonberény	Talaj	Balatonberény	400	before s.	194	31	0.50
				on season	271	47	1.80
				after s.	194	31	0.50
				average	220	36	0.93
Balatongyörök	Balaton	Balatongyörök	1,000	before s.	566	38	1.00
				on season	566	35	1.60
				after s.	566	30	1.00
				average	566	34	1.20

Table A.2 Effluents of Sewage Treatment Plants (2/2)

Treatment Plant	Recipient water body	Catchment area	Capacity (cu.m/day)		Water quantity (cu.m/day)	COD (mg/l)	T-P (mg/l)
Keszthely	Keszthelyi hatararok	Keszthely	21,500	before s.	12,000	52	2.30
				on season	12,000	48	4.20
				after s.	12,000	32	2.30
				average	12,000	44	2.93
Hévíz angolna	Oberek csatorna	Hévíz	2,850	before s.	2,210	10	0.20
				on season	1,253	10	0.20
				after s.	2,210	10	0.20
				average	1,891	10	0.20
Zalakaros	Kiskomaromi csatorna	Zalakaros	-	before s.	325	43	0.70
				on season	390	43	0.70
				after s.	325	43	3.80
				average	347	43	1.73
Zalaszentgrót Varosi	Nadas patak	Zalaszentgrót	-	before s.	518	48	0.54
				on season	518	48	0.54
				after s.	518	48	0.54
				average	518	48	0.54
Zalaegerszeg Varosi	Zala	Zalaegerszeg	-	before s.	15,800	39	1.00
				on season	15,800	39	1.00
				after s.	15,800	39	1.00
				average	15,800	39	1.00
Zalaapáti	Zalaapáti patak	Zalaapáti	-	before s.	125	62	3.75
				on season	125	45	3.00
				after s.	125	35	5.80
				average	125	47	4.18
Zalakomár	Kisomaromi csatorna	Zalakomár	-	before s.	116	130	1.75
				on season	116	63	1.75
				after s.	116	130	1.75
				average	116	108	1.75
Sármellék	Kenderaztato csatorn	Sármellék	-	before s.	118	95	3.60
				on season	118	87	3.60
				after s.	118	40	1.40
				average	118	74	2.87

note : before s. : Before season
on season : On season
after s. : After season
average : Average

Table A.3 Sewerage Development Plan in 2010 (1/4)

No.	Municipality	Population (2010)		Design Wastewater Flow (cu.m/day)				Treatment Plant	Recipient Water Body
		permanent	tourist	Residencial	Tourism	Industry / Institutional	Total		
Z- 2	Öriszentpéter	1,327	0	133	0	0	133	Öriszentpéter	L.Balaton
V- 18	Badacsonytomaj	3,000	15,000	450	2,250	0	2,700		
V- 12	Balatontördemic	900	2,500	135	375	0	510		
V- 8	Szigliget	1,100	2,000	165	300	0	465		
V- 7	Hegymagas	298	120	44	18	0	62		
V- 17	Káptalantóti	670	450	100	68	0	168		
V- 12	Kisapáti	450	400	68	60	0	128		
V- 13	Nemesgulács	1,200	0	180	0	0	180		
V- 6	Raposka	245	180	37	27	0	64		
V- 50	Vászoly	250	700	38	105	0	143		
-	Total	8,113	21,350	1,217	3,203	0	4,420	Badacsonytörd	L.Balaton
V- 61	Balatonfüred	10,066	26,000	2,013	5,200	0	7,213		
V- 61	Balatonfüred	5,033	12,000	1,007	2,400	0	3,407		
V- 55	Aszófô	347	800	52	120	0	172		
V- 49	Balatonakali	640	1,700	96	255	0	351		
V- 52	Balatonudvari	319	1,100	47	165	0	212		
V- 60	Csopak	5,030	12,000	1,007	2,400	0	3,407		
V- 56	Örvényes	250	4,500	38	675	0	713		
V- 62	Palóznak	350	700	53	105	0	158		
V- 57	Tihany	1,320	2,300	198	345	0	543		
V- 67	Balatonalmádi	9,000	25,500	1,800	5,110	0	6,910		
V- 66/63	Alsóörs - Lovas	1,880	7,000	282	1,050	0	1,332		
V- 68	Balatonfüzfô	4,400	8,000	880	1,600	0	2,480		
V- 54	Balatonszôlôs	600	1,000	90	150	0	240		
V- 65	Felsôörs	1,050	700	158	105	0	263		
-	Total	40,285	103,300	7,721	19,680	0	27,401	Balatonfüzfô	Other
V- 69	Balatonkenese	3,758	20,500	752	4,100	0	4,852		
V- 70	Balatonvilágos	975	8,300	195	1,660	0	1,855		
-	Total	4,733	28,800	947	5,760	0	6,707	Balatonkenese	Other
S- 14	Balatonszentgyörgy	1,800	200	270	30	0	300	Balatonújlaki	L.Balaton
S- 40	Fonyód	5,700	40,000	850	6,000	0	6,850	Fonyód / Látrány	L.Balaton
S- 45	Somogysárd	1,500	0	200	0	0	200	Hetes	L.Balaton
S- 3	Inke	1,362	0	136	0	0	136	Inke	L.Balaton
Z- 144	Keszthely	22,000	20,000	3,300	3,000	2,300	8,600		

Table A.3 Sewerage Development Plan in 2010 (2/4)

No.	Municipality	Population (2010)		Design Wastewater Flow (cu.m/day)				Treatment Plant	Recipient Water Body
		permanent	tourist	Residencial	Tourism	Industry / Institutional	Total		
Z- 143	Hévíz	4,400	20,000	660	3,000	1,000	4,660		
V- 5	Balatonederics	1,166	2,000	175	300	0	475		
S- 26	Balatonmáriafürdô	2,100	22,000	300	3,300	0	3,600		
S- 20	Balatonkeresztúr	700	11,400	100	1,700	0	1,800		
S- 20	Balatonkeresztúr	1,650	15,000	250	2,250	0	2,500		
S- 13	Balatonberény	1,250	8,500	200	1,300	0	1,500		
Z- 148	Gyenesdiás	2,500	8,500	375	1,275	0	1,650		
Z- 149	Vonyarcvashegy	1,760	10,000	264	1,500	0	1,764		
Z- 150	Balatongyörök	680	6,400	102	960	0	1,062		
V- 5	Balatonederics	1,250	2,500	188	375	0	563		
Z- 126	Alsópáhok	1,350	1,000	204	150	0	354		
Z- 124	Felsôpáhok	560	200	84	30	0	114		
Z- 142	Cserszegtomaj	1,550	3,000	233	450	0	683		
Z- 4	Nemesvita	388	350	58	53	0	111		
Z- 22	Kéthely	2,800	2,000	350	250	60	660		
Z- 21	Balatonújlak	670	1,200	80	150	0	230		
Z- 31	Somogyszentpál	900	900	110	110	160	380		
Z- 36	Táska	590	0	70	0	90	160		
Z- 141	Rezi	1,080	0	108	0	0	108		
-	Total	49,344	134,950	7,211	20,153	3,610	30,974	Keszthely	L.Balaton
V- 23	Kékkút	120	50	18	8	0	26	Kékkút	L.Balaton
S- 55	Balatonlelle	5,500	58,400	850	8,750	0	9,600		
S- 81	Balatonboglár	6,500	30,000	1,000	4,500	600	6,100		
S- 47	Lengyeltóti	3,400	0	700	0	0	700		
S- 63	Látrány	1,400	1,300	150	150	0	300		
S- 57	Szôlôsgyörök	1,300	500	150	60	0	210		
S- 46	Ordacsehi	900	420	110	50	0	160		
-	Total	19,000	90,620	2,960	13,510	600	17,070	Látrány	Other
S- 27	Marcali	13,100	0	2,650	0	550	3,200		
S- 30	Maesztegnyô	1,600	1,200	200	150	0	350		
-	Total	14,700	1,200	2,850	150	550	3,550	Marcali	L.Balaton
S- 39	Nagybajom	3,900	100	450	10	0	460	Nagybajom	L.Balaton
Z- 94	Nagykapornak	1,012	0	101	0	0	101	Nagykapornak	L.Balaton
V- 48	Barnag	153	50	23	8	0	31		

Table A.3 Sewerage Development Plan in 2010 (3/4)

No.	Municipality	Population (2010)		Design Wastewater Flow (cu.m/day)				Treatment Plant	Recipient Water Body
		permanent	tourist	Residencial	Tourism	Industry / Institutional	Total		
V- 27	Kapolcs	490	150	74	23	0	97		
V- 45	Mencshely	300	150	45	23	0	68		
V- 20	Monostorapáti	1,300	30	195	5	0	200		
V- 43	Nagyvázsony	2,000	150	300	23	0	323		
V- 26	Taliándörögd	850	180	128	27	0	155		
V- 51	Tótvázsony	1,600	0	240	0	0	240		
V- 44	Vöröstó	147	60	22	9	0	31		
-	Total	6,840	770	1,027	118	0	1,145	Nagyvázsony	L.Balaton
S- 41	Buzsák	1,700	1,000	200	100	0	300		
S- 54	Mezôcsokonya	1,200	0	150	0	0	150		
S- 49	Öreglak	2,000	50	250	10	0	260		
S- 62	Somogyjád	1,800	0	200	0	0	200		
S- 50	Somogyvár	2,100	0	250	0	0	250		
S- 52	Bodrog	480	40	60	10	0	70		
S- 61	Osztopán	980	20	120	10	0	130		
-	Total	10,260	1,110	1,230	130	0	1,360	Osztopán	L.Balaton
Z- 63	Pölöske	1,005	0	101	0	0	101		
Z- 81	Zalaszentmihály	1,180	0	118	0	0	118		
-	Total	2,185	0	219	0	0	219	Pacsa	L.Balaton
V- 50	Pécsely	800	400	120	60	0	180	Pécsely	L.Balaton
Z- 71	Pókaszepetk	1,004	0	100	0	0	100	Pókaszepetk	L.Balaton
V- 25	Ábrahámhegy	534	1,502	80	225	0	305		
V- 31	Balatonrendes	172	186	26	28	0	54		
V- 36	Balatonszepezd	1,280	17,500	192	2,625	0	2,817		
V- 32	Révfülöp	1,280	17,500	192	2,625	0	2,817		
V- 42	Zánka	901	4,600	135	690	0	825		
V- 30	Kôvágóörs	1,100	5,000	165	750	0	915		
V- 29	Köveskál	800	500	120	75	0	195		
-	Total	6,067	46,788	910	7,018	0	7,928	Révfülöp	L.Balaton
S- 79	Siófok	25,000	95,000	3,750	14,250	0	18,000		
V- 70	Balatonvilágos	325	1,500	48	225	0	273		
-	Total	25,325	96,500	3,798	14,475	0	18,273	Siófok	Other
S- 72	Balatonszárszó	2,200	21,000	330	3,150	0	3,480		
S- 67	Balatonöszöd	560	5,000	100	750	0	850		

Table A.3 Sewerage Development Plan in 2010 (4/4)

No.	Municipality	Population (2010)		Design Wastewater Flow (cu.m/day)				Treatment Plant	Recipient Water Body
		permanent	tourist	Residencial	Tourism	Industry / Institutional	Total		
S- 66	Balatonszemes	1,800	22,000	250	3,300	0	3,550	Szólád	Other
-	Total	4,560	48,000	680	7,200	0	7,880		
Z- 128	Zalavár	1,052	200	105	20	0	125	Sármellék	L.Balaton
Z- 127	Sármellék	1,820	200	182	20	0	202		
-	Total	2,872	400	287	40	0	327		
V- 9	Tapolca	19,256	0	3,851	0	0	3,851	Tapolca	L.Balaton
V- 11	Gyulakeszi	800	0	120	0	0	120		
V- 3	Lesencefalu	340	0	51	0	0	51		
V- 1	Lesenceistvánd-Uzsa	1,100	500	165	75	0	240		
V- 2	Lesencctomaj	1,200	70	180	11	0	191		
V- 10	Zalahaláp	2,000	350	300	45	0	345		
-	Total	24,696	920	4,667	131	0	4,798		
V- 64	Szentkirályszabadja	2,000	0	300	0	0	300	Veszprém	Other
V- 59	Veszprémfajsz	272	0	41	0	0	41		
-	Total	2,272	0	341	0	0	341		
Z- 146	Várvölgy	1,101	0	110	0	0	110	Várvölgy	L.Balaton
Z- 145	Zalaszántó	1,036	0	104	0	0	104		
-	Total	2,137	0	214	0	0	214		
Z- 43	Zalaegerszeg	61,520	0	14,400	0	8,000	22,400	Zalaegerszeg	L.Balaton
Z- 48	Söjtör	1,680	0	168	0	0	168		
Z- 56	Egervár	1,006	0	101	0	0	101		
-	Total	64,206	0	14,669	0	8,000	22,669		
Z- 134	Galambok	1,280	200	128	20	0	148	Zalakaros	L.Balaton
Z- 135	Zalakomár	3,200	0	384	0	30	414	Zalakomár	L.Balaton
Z- 98	Zalaszentgrót	8,035	0	1,200	0	400	1,600	Zalaszentgrót	L.Balaton
S- 73	Balatonföldvár	2,500	20,000	400	3,000	0	3,400	Zamárdi	Other
S- 77	Zamárdi	2,480	35,000	350	5,250	0	5,600		
S- 78	Balatonendréd	1,450	800	150	100	0	250		
S- 74	Kôröshegy	2,400	2,100	300	250	0	550		
-	Total	8,830	57,900	1,200	8,600	0	9,800		
-	Total	327,465	673,558	56,238	106,296	13,190	175,724		

Table A.4 Run-off Control Facilities in the Study Area

Location			Outline	Function	Year of construction	Catchment area		Operation / Maintenance			
No.	Area name	Drainage / River name				Land Use	Area (sq.km)	Length of river (km)	KDT Vizig	City govern.	Water company
1	Balatonkenese	Árok	Deposit catcher 3 m(w) x 5 m(L) x1.5 m (D)	Sedimentation	1980	Residential area with sewerage system	not clear	1.5	-	B.kenese	-
2	Balatonkenese	Bakó street ditch	Deposit catcher (5 m(w) x 10 m(L))	Sedimentation/ Filtration	1997	Residential area with sewerage system	4.57	4.0	-	B.kenese	-
3	Balatonalmádi	Vörösbérényi Séd	Deposit catcher	Sedimentation	1982	Agricultural / Residential area	14.0	5.4	-	B.almadi (2.1 km)	Pápakörnyéki W.C. (3.3 km)
4	Balatonalmádi	Remete Árok	Deposit catcher (3 m(w) x 10 m(L))	Screen Sedimentation	1980	Residential area with sewerage system	16.8	2.5	-	-	Pápakörnyéki W.C.
5	Paloznak	Lovasi Séd	Filter field (6.35 ha)	Sedimentation/ Filtration by grass(reed, cattail)	1985	Agricultural / Residential area	21.0	7.7	-	-	Balaton highland W.C.
6	Balatonfüred	Kéki river	Deposit catcher / Filter field (10 m(w) x 15 m(L))	Sedimentation/ Filtration by grass(reed, cattail)	-	Agricultural / Residential area	11.8	4.0	-	B.füred	-
7	Örvéryes	Örvényesi Séd	Deposit catcher / Filter field (Horseshoe - shaped 20 m (w) x 20 m(L))	Sedimentation/ Filtration by grass(reed, cattail)	1984	Agricultural / Residential area	19.9	8.4	KDT (0.8 km)	Örvéryes (3.5 km)	Balaton highland W.C. (4.1 km)
8	Balatonrendes	Burnót patak	Deposit catcher (10 m (w) x 30 m(L))	Sedimentation	1995	Agricultural / Residential area	82.2	18.2	KDT	-	-
9	Szigliget – Balatonederics	Tapolca patak	Oil and deposit catcher 5 m (w) x 20 m(L)	Screen Sedimentation	1983 - 1987	Agricultural / Residential area	39.5	10.8	KDT (6.8 km)	Tapolca (4.0 km)	-
10	Szigliget – Balatonederics	Kélöles patak	Oil and deposit catcher 5 m (w) x 20 m(L)	Screen Sedimentation	1983 - 1987	Agricultural / Residential area	37.7	20.4	KDT (7.0 km)	Tapolca (0.6 km)	Balaton highland W.C. (12.8 km)
11	Szigliget – Balatonederics	Lesence patak	Reedy field (100 ha)	Sedimentation/ Filtration by grass(reed, cattail)	1987	Agricultural / Residential area	100.5	23.3	KDT (15.0 km)	-	Agricultural Industry (8.3 km)
12	Szigliget – Balatonederics	Nemesvitai ditch	Reedy field (100 ha)	Sedimentation/ Filtration by grass(reed, cattail)	1987	Agricultural / Residential area	6.3	5.5	KDT (2.5 km)	-	Balaton highland W.C. (3.0 km)
13	Keszthely	Szent László árok	Infiltration Pond (5 m (w) x 100 m(L))	Sedimentation/ Infiltration	-	Agricultural / Residential area	not clear	not clear	not clear		
14	Fonyód	Keleti Bozót csatorna	Pond with Pump station	Sedimentation	-	Agricultural area	not clear	not clear	not clear		
15	Zamárdi – Siófok	Cinege patak	Fish pond (37.6 ha)	Sedimentation	-	Agricultural area	18.7	6.9	-	-	South Balaton Water comp.

Table A.5 Present Situation of Shore Regulation/Protection Works in Lake Balaton

Distribution of regulated shores by county

unit: kilometer

County	Regulation Completed	Rip-rap	Total
Veszprém	27.1	12.8	39.9
Somogy	52.2	10.5	62.2
Zala	4.7	0.2	4.9
Total	84.0	23.5	107.5

Distribution of regulated shores by managing organization

unit: kilometer

Managing Organization	County			
	Veszprém	Somogy	Zala	Total
Water Sector	1.0	16.7	0.5	18.2
Council	10.6	8.9	3.2	22.7
Institution	22.0	21.7	1.2	44.9
Private	6.3	15.2	-	21.7
Total	39.9	62.5	4.9	107.5

Total length of the shore : 235 km

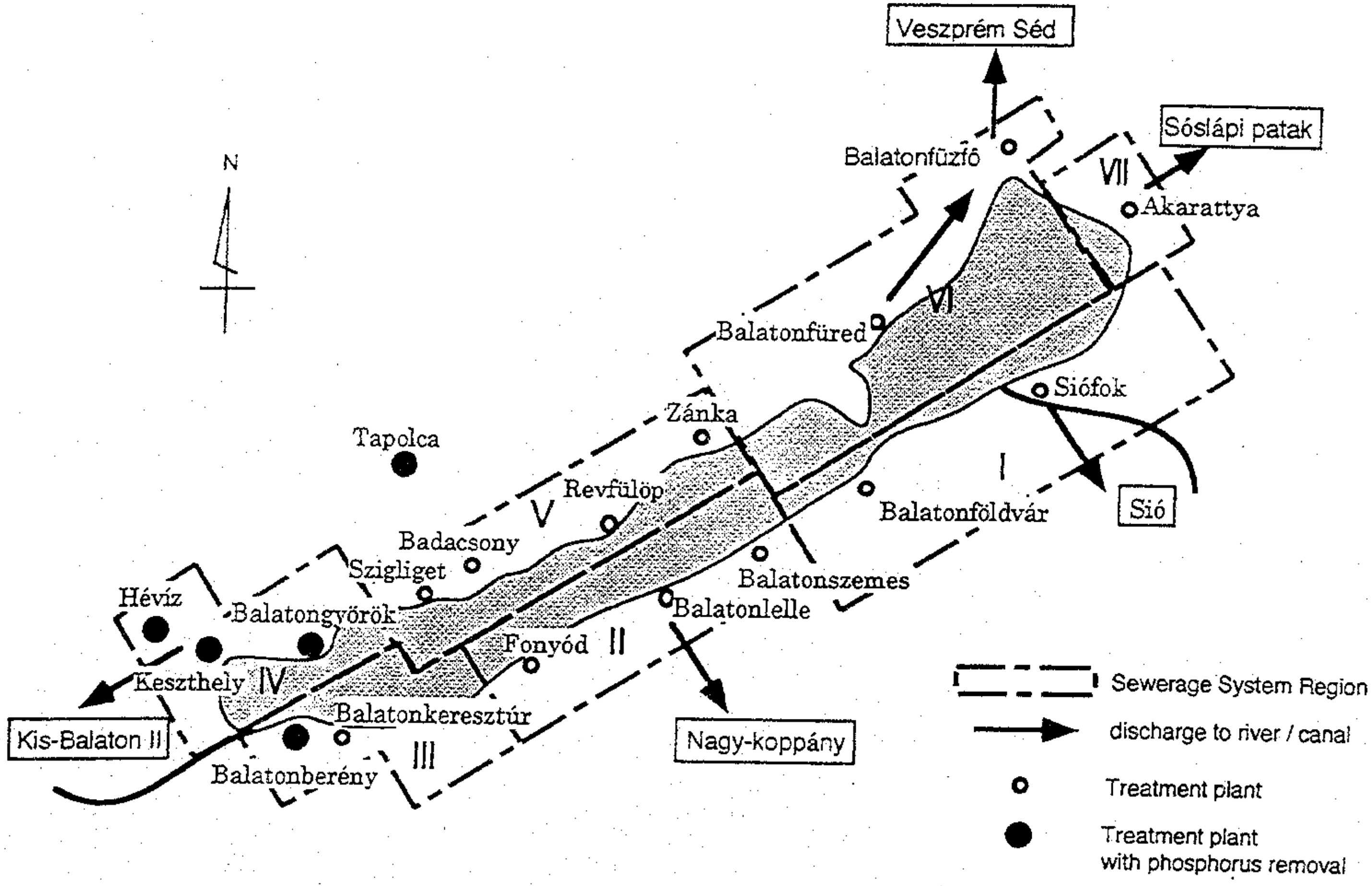

Figure A.1 Sewerage System Region in the Lakeside Area

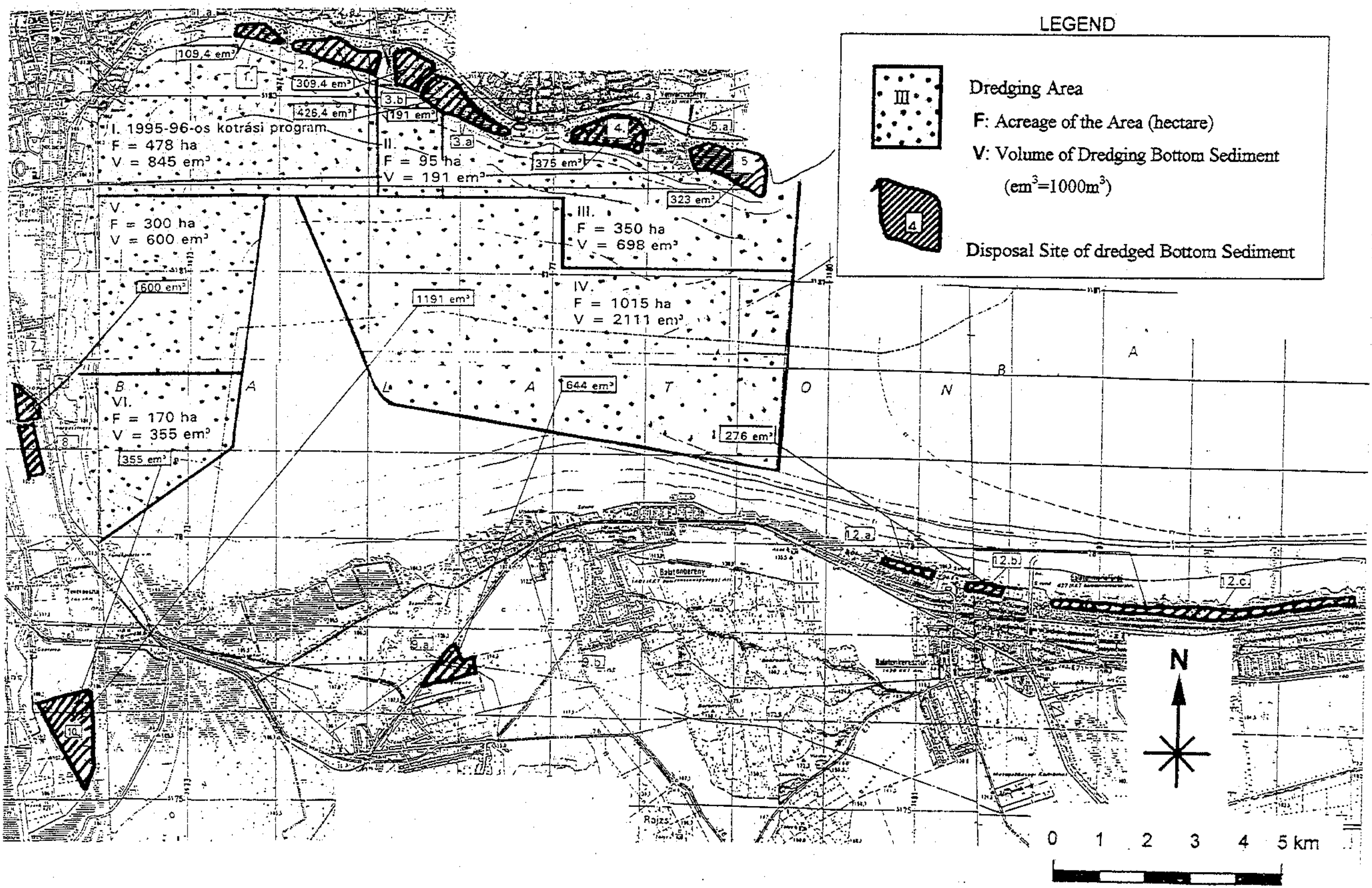

Figure A.2 Planned Dredging Area and Disposal Sites of Dredged Bottom Sediment in Keszthely Bay

No.	Area name	Drainage / River name
1	Balatonkenese	Árok
2	Balatonkenese	Bakó street ditch
3	Balatonalmádi	Vörösbérényi Séd
4	Balatonalmádi	Remete Árok
5	Paloznak	Lovasi Séd
6	Balatonfüred	Kéki river
7	Örvéryes	Örvényesi Séd
8	Balatonrendes	Burnót patak
9	Szigliget -- Balatonederics	Tapolca patak
10	Szigliget -- Balatonederics	Kélöles patak
11	Szigliget -- Balatonederics	Lesence patak
12	Szigliget -- Balatonederics	Nemesvitai ditch
13	Keszthely	Szent László árok
14	Fonyód	Keleti Bozót csatorna
15	Zamárdi -- Siófok	Cinege patak

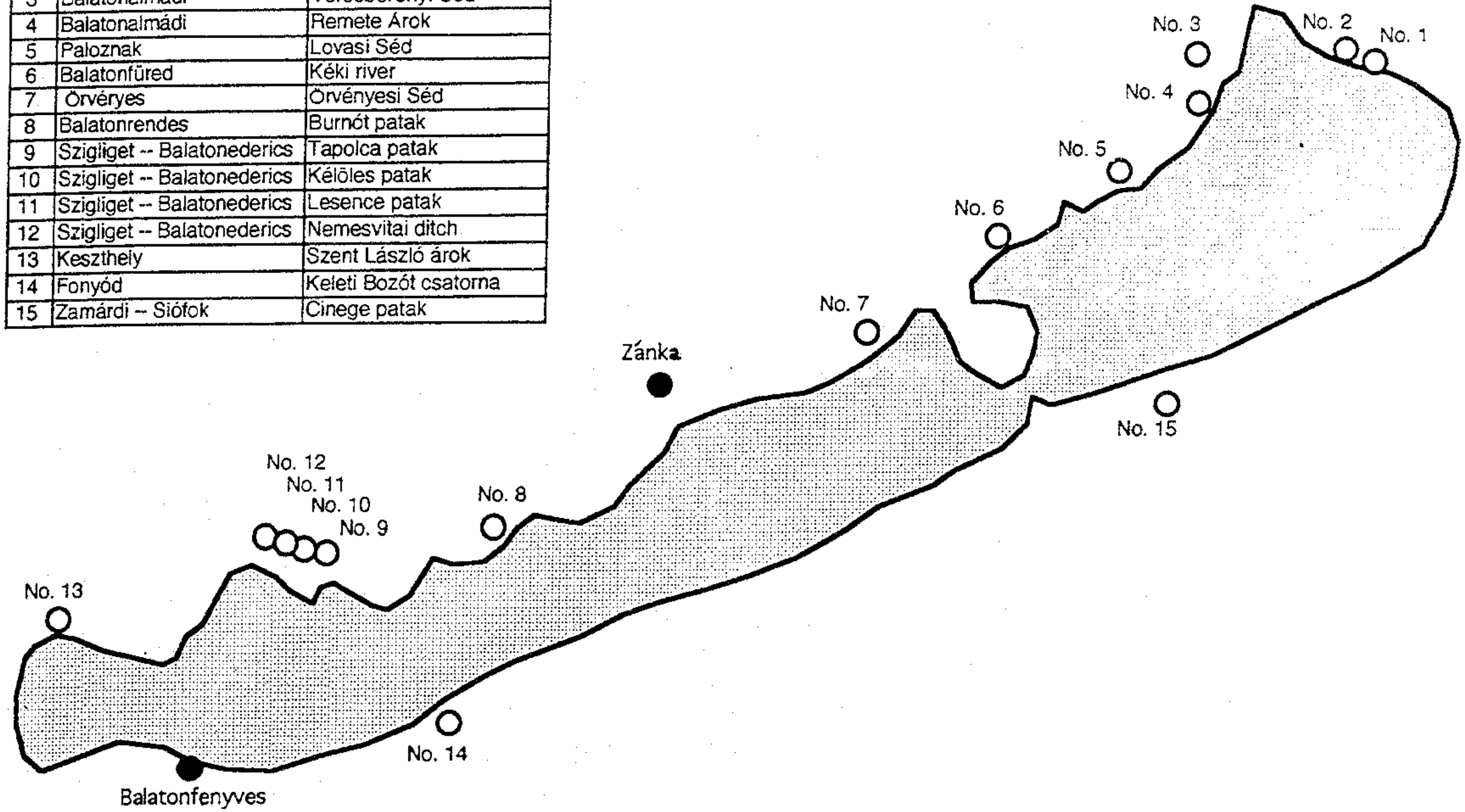

Figure A.3 Location of Run-off Control Facilities

APPENDIX - B

POLLUTION LOAD ANALYSIS

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POLLUTION LOAD ANALYSIS

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POLLUTION LOAD ANALYSIS

1. CONCEPT OF AN IMPROVED POLLUTION LOAD ANALYSIS

1.1 ESTIMATION OF THE EFFECT OF FLASH FLOODS

Streams and rivers of the northern and southern sub-watershed are short and run roughly parallel to each other. Since most of them are steep, their flow times are extremely short. Mean discharges are low, but rainstorms can result in up to several hundred times increase lasting for just a few hours. Since the sampling frequency of such streams is 14 to 28 days, most of such flash floods remain non-sampled for several years. Some model experiments by Jolánkai [1] in the past on Tetves patak proved that flash floods lasting a few hours may carry loads equivalent to several days to several weeks of average conditions.

It is well known, that pollutant loads increase with discharge (and also depend on other factors).

Load estimation methods can be classified into two fundamental groups, i.e. direct estimation methods and continuous concentration estimation methods [9]. The former means the direct use of observed data to evaluate an integral. The continuous estimation methods produce a continuous concentration or load function in time, or as function of a variable with known time function. One version of this method is the use of so-called rating curve, an explicit relation between load (or concentration) and discharge (and/or other variables).

Load-discharge relations of various forms can be found in literature (linear, power functions, etc. [10]). Jolánkai and Hock [1] conducted a statistical analysis of small rivers and tested various relations. They supposed that the load of various phosphorous and nitrogen forms depends on the discharge, its derivative with respect to time, water temperature, and Julian day, and tested various functions carrying out regression analysis. Although results are not conclusive the limited number of data in case of flood conditions, simple forms, such as linear functions resulted in almost as good correlation as more complicated functions including all the four independent variables. Also, he found that results obtained for a specific year cannot be fully generalized or transferred to another year.

In order to have an estimate on the pollutant load of a specific river to Lake Balaton the idea of the above described load-discharge ($L=f(Q)$) correlation (development of a rating curve) was applied. Monitoring data were used to establish the $L=f(Q)$ function, and digitized water level data and the respective water level-discharge calibration curves (H-Q curves) were used to calculate the load as a function of time. The water level data were acquired from the Siófok Office of the Central Transdanubian Water Authority (KDT VIZIG). The water level data were digitized taking into account the changes in the level, i.e. there are more frequent data when the derivative of the level is large. Depending on the size and flood wave patterns of a particular river, some 1000 to 6000 data points/year were available, reducing uncertainty of the discharge value to minimum. All tributaries with continuous level recorders were included into the analysis except Arácsi séd since the latter is not included in the water quality monitoring network and no water quality data were available.

As examples, annual discharges of Kéki patak and Burnót patak, as well as two huge flood waves on Tetves patak are shown in *Figure B.1*.

Water quality parameters included were total phosphorous (TP), total nitrogen (TN), and chemical oxygen demand determined by the dichromate method (COD).

The correlation between L and Q was searched in a parabolic form suggested by Jolánkai[4, 5], i. e. $L = p + bQ + sQ^2$. Constants of this expression has physical meaning, i.e. b represents a natural background of load, p represents point sources, and s represents surface runoff. The analysis included the years of 1994 and 1995 together, in order to get more data points, since these two years were selected for the calibration and validation of the water quality simulation model of Lake Balaton. Number of data points changed between 24 and 50. In case the parabolic best fit did not result in a monotonously increasing function, or produced negative loads at very low discharges, other functions such as linear or third order polynomial were used or negative values of coefficients were allowed. The JICA team is in aware of the fact, that the above functions may not have theoretical basis, and more detailed statistical analysis together with data covering flood conditions may be required, but they may prove useful for the purpose of this study, i.e. to analyze and include the effect of flash floods into the pollution load analysis and provide the two-dimensional water quality model of Lake Balaton with daily or even more frequent load estimates.

Best fit curves with data points are shown in *Figures B.2 to B.10*. As it can be seen, for most of the rivers, and most of the water quality parameters, parabolic approximation gave satisfactory results. Correlation is very poor for Tapolca patak. The probable reason that it is seriously influenced by the effluents of the Tapolca Sewage Treatment plant. From the 30 correlation coefficients, 23 exceed 0.75, showing a strong relation between discharge and pollutant load. The correlation is strongest for COD, and weakest for TP.

1.2 COMPARISON OF VARIOUS ESTIMATION METHOD OF LOADS DISCHARGE BASED ON MONITORING DATA

Method of pollutant load estimation based on the monitoring data is the simplest standard method widely used in cases when data are available with sufficient frequency. According to this method (M1), flow rates and concentrations of the water quality database were used and integrated over the year with a time step determined by sampling frequency (2 to 4 weeks). The formula used for the calculations is as follows:

$$L = \sum_{i=1}^{n} \frac{1}{2}\left(c_i Q_i + c_{i+1} Q_{i+1}\right)\left(t_{i+1} - t_i\right) \qquad (1)$$

where ***L*** is the annual load, kg/year; ***n*** is the number of data (sampling); ***c*** is the concentration of a given pollutant, kg/m3; ***Q*** is the discharge of the river at the time of sampling; ***t*** is the time of sample collection.

A drawback of this method is that it may not include high discharge rates because the low frequency of sampling results in low probability to catch short term transients in discharge.

For the purpose of comparison, another estimation method was used (M2) for the tributaries for which continuous water level monitoring data were available. According to this method, total annual discharge volumes were determined from the continuous water level recordings, by integrating over the year with time steps from several minutes to several hours. The annual discharge volumes determined by this method are more accurate than those from the monitoring database. Then the annual discharge volumes were multiplied by the yearly average pollutant concentration. The formula for calculation is as follows:

$$L = \left\{ \sum_{i=1}^{n} \frac{1}{2}\left(Q_i + Q_{i+1}\right)\left(t_{i+1} - t_i\right) \right\} * \frac{1}{k} \sum_{j=1}^{k} c_j \qquad (2)$$

where *n* is the number of discharge data in a year, and *k* is the number of water quality data in a year. In this particular case, *n*>>*k*.

Although the discharge volume determined by this method is correct, disadvantage of this method is that the mean concentration may not be representative of the year.

The third method of estimation (M3) used the continuous discharge data, and the relevant L-f(Q) relation determined as described in section 1.1. The formula for Method 3 is as follows:

$$L = \left\{ \sum_{i=1}^{n} \frac{1}{2} \left\{ \left(f(Q_i) + f(Q_{i+1}) \right\} \left(t_{i+1} - t_i \right) \right\} \qquad (3)$$

where $f(Q_i) = L_i = p + bQ_i + sQ_i^2$ or other similar load-discharge function. (Refer to section 1.1.)

Results of the load estimates are summarized in *Tables B.1* to *B.3*. As it is shown in these tables, the different methods resulted in different loads, but the differences are not the same for all the rivers. The ratio R of the loads determined by M3 (including the effect of flash floods) and M1 (conventional method) is well over unity for Kéki patak and Tetves patak for both years, and all three water quality parameters. This finding agrees well with the findings of Jolánkai for Tetves patak, and with the nature of Kéki patak, where flash flood waves generally last less than 2 hours (refer to *Figure B.1*). One more surprising finding is the large year-on-year change in R for these two streams. However, if averages of R for all the small rivers of the analysis are considered, the difference from unity is not so high. Average of R for both years and the three water quality parameters is 1.53. This means that the pollutant loads are underestimated by some 50% for the small rivers and streams of the southern and northern sub-watersheds.

The above results indicate less underestimation than predicted in the study of Jolánkai [1] who suggested that some 3 to 4 fold underestimation is well possible. This slight contradiction may originate from various facts, and it may even be no contradiction at all. The study in question was largely based on experimental results obtained on Tetves patak, which shows the largest R values in this analysis too (some 2 to 6-fold underestimation). Also, there are very few monitoring data on other rivers covering flood conditions when the discharge exceeds the base flow by one order of magnitude or more. Therefore, the correlations between Q and L found are largely based on low flow condition data, resulting in an inherent under-estimation.

Another point of interest is the year-on-year change in R (some 10 % to several 100%) for almost all of the rivers. This fact sheds light on the inherent uncertainties of load estimation based on the present monitoring system, since the results of the standard estimation method (M1) are largely dependent on the random nature of discharge. Namely, in certain years, when many flood waves are sampled by chance, severe over estimation may occur, as opposed to other years when no flood waves are caught. A plausible solution to this problem may be the increase of the frequency of sampling. The consequent increased analytical costs may be minimized by reducing the analytical items of the extra samples to some critical parameters such as TN, TP, PO-4 P and COD.

Another solution may be the analysis of multi-annual discharge patterns of the streams and rivers, and changing the sampling schedule accordingly. High loads always occur in case of high discharge conditions, so there is no reason to take frequent samples in months in which the mean discharge is low and there is little or no probability of thunderstorms.

2. ANALYSIS OF RUNOFF EVENTS

2.1 RESULTS OF JICA MONITORING STATIONS

JICA installed five water quality and water level monitoring stations equipped with automatic sample collectors in order to collect data on runoff events on four water courses: Burnót patak (upstream and downstream), Kéki patak, Baricskadûlôi árok, Tetves patak. Water level and various water quality parameters were continuously measured and data were recorded in data loggers with 5 min frequency. Auto-samplers were started by rain intensity signal. The main purpose was to quantitatively determine the contribution of flood events to the annual pollutant load to Lake Balaton.

Monitoring data were collected from the second half of August to the middle of October. Measured water quality parameters were as follows: dissolved oxygen(DO), temperature (T), conductivity (CON), turbidity (TU), and pH. Water level was also measured and discharges were calculated from the measuring profile (precision of the calculations was checked by flow velocity measurements).

(1) Analysis of Continuous Monitoring Data

Graphs of monitoring data are shown in *Figure B.11* to *Figure B.16*. Although there were no significant flood events in the study period, some information of interest can be seen in these figures.

1) Burnót patak

Two monitoring stations were installed on the watershed. One at the exit point of the river from the Káli medence (Káli Basin) near the village of Salföld, and another near to the river mouth in Abrahámhegy. The purpose of such a setup was to estimate the influence of a completely non-sewered residential area on the water quality. Land use in the upstream watershed is basically non-residential.

Dissolved oxygen and temperature show typical diurnal patterns at both locations, with no anoxic conditions detected in the study period. The pH values show diurnal variation at the downstream station, but little change at the upstream station. Reason of this might be the increased phytoplankton activity downstream the river. For the whole period, electric conductivity shows extreme high changes at the downstream location, but very low values, and practically no variation at the upstream location. The change in conductivity does not seem to correlate with precipitation. These facts might suggest the existence of several unidentified point sources, such as overflows of septic tanks and cesspools, etc.

Turbidity shows a different pattern with little change downstream and some ten-fold changes upstream. The upstream changes can be attributed to the operations of a small scale sand mine industries some 150 m upstream of the station. Discharged fine sand particles may cause the turbidity. Right downstream the station, there is a sedimentation facility with vegetation in it, where the sand-caused turbidity is removed. Water level data show some periodical changes with flat double peaks in every few days at both locations. The level changes do not necessarily coincide with the minor rain events during the experimental period. The level change patterns indicate typical pumping operations with fixed discharge. Such discharges may originate from the mentioned sand mine or from a mineral water bottling company (Theodora Quelle) at Kékkút.

2) Kéki patak

Dissolved oxygen and temperature show typical diurnal patterns. Anoxic conditions were detected for only a few hours period after a runoff event. The pH values do not show diurnal variation. For the whole period, electric conductivity shows little changes. Turbidity increases in case of runoff events, and does not return to normal level for relatively long periods. Also, there are increases in turbidity without apparent reasons.

3) Baricska dûlôi árok

This water course is a temporary one draining a mainly urban area. Unfortunately, the very little precipitation in the experimental period did not result in any noticeable discharge. Therefore, it is of little meaning to discuss water quality.

4) Tetves patak

Dissolved oxygen and temperature show diurnal patterns. No anoxic conditions were detected. The pH values do not show diurnal variation. Reason of this might be the increased phytoplankton activity downstream the river. For the whole period, electric conductivity shows no changes. Turbidity increases for no apparent reasons, and remains high for several hours. Although there were a few minor rain events, water level remained practically unchanged.

(2) Auto-sampler Data

1) Burnót patak

The auto-samplers of the two locations were activated on a total of five occasions (twice upstream and three times downstream). However, due to extremely low water levels, sampling was successfully completed only in four cases. Unfortunately, simultaneous sampling at the two stations did not happen, consequently the load contribution of the residential area (Ábrahámhegy) without sewer system cannot be estimated directly. Nevertheless, water quality data of the upstream and downstream sampling points are shown in *Figure B.17* and *Figure B.18* for different days. Although water discharge changes only slightly in the sampling period (some 40% increase), at the downstream station, TP concentration and TDP concentration increase considerably in a short period. Peak TP exceeds 1200 mg/m3, and the mean is well over 400 mg/m^3. In case of the upstream station, the TP peak after a rain event is some 500 mg/m^3, and the mean is around 200 mg/m^3. Suspended solids increase at the downstream station considerably (up to 250 mg/L), but quickly returns to the normal level of some 20 mg/L. At the upstream station, normal level of SS is around 100 mg/L which is in line with the higher turbidity. The influence of the residential area is apparent in case of COD and TN as well.

2) Kéki patak

The auto-sampler was not activated during the experimental period.

3) Tetves patak

The auto-sampler was activated during a 20 min intensive shower, but the water level din not change. Suspended solids and total phosphorous increased some 2-fold but returned to normal level in less than an hour period. The precipitation did not result in surface runoff *(Figure B.19)*.

4) Baricska dûlôi árok

There was no noticeable water flow during the experimental period, and the auto-sampler was activated only once. Concerning the water quality data, the only fact worth to mention is the high TP concentration (some 2 mg/L). This might be the result of the vicinity of the main road No.71 *(Figure B.20)*.

2.2 ESTIMATION OF UNIT LOADS FROM RUNOFF EVENTS

NYDT KÖFE and DDT KÖFE carried out experimental programs on urban runoff from May to November of 1997 [11, 12]. Runoffs after significant precipitation events were sampled and analyzed several times in May, June, and November. NYDT KÖFE measured daily precipitation, a large number of water quality parameters and discharge at four small watersheds in the city of Keszthely. This work provides valuable information on urban runoff. Unfortunately, discharges were not determined for the entire flood waves, especially data of the tailings of peaks are missing in most of the cases. Probably this is the cause of the fact, that runoff rates were assumed instead of direct calculation. Nevertheless, part of the data could be used to determine runoff rates and unit pollutant loads for TP, TN and COD. Data calculated by the JICA study team from the raw data are shown in *Table B.4.* It should be noted, that the assumed runoff rates are actually the same as the calculated ones. Unit loads are rather high, and are rather similar to the values used in the non-point source load analysis.

In the Fonyód experiment, DDT KÖFE determined rain intensity, daily precipitation, and a number of water quality parameters, but did not measure discharges. As a consequence, runoff rates had to be assumed. Unit loads calculated from the data are shown in *Table B.5.* The runoff rates assumed by DDT KÖFE are slightly lower than in case of Keszthely. Recalculation using the runoff rates of Keszthely are shown in *Table B.6.* The loads determined for Fonyód are lower than those for Keszthely. This can be attributed to the less urbanized area, and the existence of a park and forested area in the watershed.

3. ANALYSIS OF SUB-CATCHMENTS BY MEANS OF GIS

The whole Lake catchment area was divided into 89 sub-catchments. Delineation of sub-catchments was based on the actual geographical watershed borders and on the locations of the water quality monitoring points ("Törzshálózat" and local monitoring points). Sub-catchments could be classified based on slope categories, land use pattern, soil type, erosion potential, etc.

3.1 STUDY OF THE EFFECT OF NON-POINT SOURCE CONTROL MEASURES ON THE INDIVIDUAL WATERSHEDS

A user interface was developed (refer to *Figure B.21*) to make possible to set the unit area pollutant loads for various land use categories. The unit area loads (kg/ha/year) can be set within the range of literature data [1]. By modifying the unit area loads for those land use categories where control measures may be relatively easily implemented through the change of fertilization and cultivation practices (arable land, vineyard and orchard, pasture) without major capital investment, the ratio of the generated loads for the individual sub-catchments can be categorized and displayed to show the sub-catchments sensitive to such control measures. Unit area loads of total phosphorus (kg/ha/year) for the two load scenarios were as follows (scenario1/scenario2) : Urban area 2.7/2.7; Arable land 0.79/3.0; Pasture: 0.55/2.8; Forest: 0.3/0.3; Vineyard and orchard: 0.79/5.3. The smaller numbers are considered to be close to the present conditions while the larger ones correspond to intensive agricultural cultivation practices. The map produced in this way is shown in *Figure B.22.*

3.2 STUDY OF THE EFFECTIVENESS OF SEWAGE TREATMENT UPGRADING ON SUB-CATCHMENT LEVEL

Present sewage treatment conditions and 100 % sewerage plus 95% phosphorus removal (roughly corresponding to the 0.6 mg/L effluent level) were considered. Ratios of the generated point source loads and total generated loads were compared for the two cases (leaving non-point source loads unchanged). The difference in the ratios of the two scenarios were expressed in percentage, categorized, and are shown in a map of the catchment area (*Figure B.23)*.

3.3 CATEGORIZATION OF SUB-CATCHMENTS BASED ON POLLUTANT DELIVERY RATIOS

Unit area loads were set to constant values, and generated non-point source loads were calculated. In addition, point source loads were calculated considering the present sewage treatment conditions. Delivered loads were calculated from water discharge data using the rating curves (Load = f (discharge) for the individual water courses. Delivery ratios (=delivered load/generated load) were calculated for each watershed, and categorized. The emerging map is shown in *Figure B.24*.

3.4 RELATION BETWEEN LAND USE CHARACTERISTICS AND RUNOFF LOADS

The magnitude of surface run-off load accompanying precipitation depends on the land use pattern, size of the catchment area, shape, slope and soil type and characteristics of the area.

Based on GIS and other type of data analyses, the following land characteristics were selected to further analyze the effects of land characteristics of the sub-catchments on load run-off:

- Population density
- Average flow path (characteristic length) = square root of area.
- Average slope ot the ratio of the area of more than 3 degree slope
- Average organic matter content
- Soil erosion potential
- Fraction of residential area (city, town, recreational area)

The calculated correlation coefficients of these characteristics of the sub-catchments (except Zala), are shown in *Table B.7*. The correlation coefficient between population density and urban surface area is high. Positive correlation was also found between soil erosion potential and vineyard area, and negative correlation soil erosion potential and soil organic matter content. Positive correlation was found between forested area and slope.

The relation between these characteristics and the run-off load were studied for 8 rivers for which abundant discharge and water quality data were available for the years of 1994 and 1995. Data used for this analysis are shown in *Table B.8*. Correlation coefficients for each characteristics are shown in *Table B.9*.

Considering these correlations, Unit area discharge, COD load, T-N load, T-P load has strong correlation with population density. This indicates that loads from areas of intensive human activity are high. Furthermore, there is correlation between discharge, COD load, T-N load and characteristic length of sub-catchment, but the latter do not correlate with T-P. COD load, T-N load has a negative correlation to soil erosion potential.

Generally, the larger the slope the higher the unit area discharge (and load) is, but the results show rather the opposite. This can be attributed to the fact, that most of the steep terrain is covered by forest characterized by low discharge rate and low unit area loads.

Using these data, a multiple regression analysis has been attempted, result of which are shown in *Figure B.25*.

The discharge volume per unit surface area has a strong relation with the four variables of population density, characteristic length, ratio of slope area greater than 3 degrees to the total area, and the fraction of residential area.

The negative correlation with slope area is attributed to the positive correlation between the forest area of large water retention capacity and slope.

The loads of COD, T-N, and T-P were attempted to be explained by the 5 variables of population density, characteristic length, ratio of slope area, soil erosion potential and fraction of residential area.

The regression equations for 1994 are good, but there is some scattering for 1995. Especially, the data point for Tetves patak is separated from the regression line. (This can be attributed to the uncertainty of the estimation of load based on rating curves, since there were 3 extraordinarily large flood events on Tetves patak in 1995, and the actual load may well be overestimated).

In this way, by using land characteristics as index variables for the multiple regression analysis of load estimation it is possible to estimate discharge and load of individual sub-watersheds. In the future, by including more rivers with correct discharge values and loads, the accuracy of the regression equations can be improved, and loads from sub-catchments with no water quality monitoring or discharge data can be estimated. In addition, the regression equations can be integrated into the GIS database resulting in a statistical model for load estimation.

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