JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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[illegible] OF HUNGARY

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

FINAL REPORT

SUMMARY

MARCH 1999

PACIFIC CONSULTANTS INTERNATIONAL
[illegible] OCEANOGRAPHICAL CONSULTANT CO., LTD.

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

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)

PREFACE

In response to a request from the Government of the Republic of Hungary, the Government of Japan decided to conduct the Study on the Environmental Improvement of Lake Balaton in the Republic of Hungary and entrusted the study to the Japan International Cooperation Agency.

JICA selected and dispatched a study team headed by Mr. Akira Takechi of Pacific Consultants International and composed of Pacific Consultants International and Shin-Nippon Meteorological & Oceanographical Consultant Co., Ltd. to the Republic of Hungary, five times between January 1997 and January 1999. In addition, JICA set up an advisory committee headed by Mr. Senro Imai, Development Specialist of Japan International Cooperation Agency, between January 1997 and January 1999, which examined the Study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of the Republic of Hungary, and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

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

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Hungary for their close cooperation extended to the study.

March 1999

Kimio Fujita
President
Japan International Cooperation Agency

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

March, 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "The Study on Environmental Improvement of Lake Balaton in the Republic of Hungary". This report has been prepared by the Study Team in accordance with the contracts signed on 22 January 1997, 15 May 1997, 10 February 1998 and 8 June 1998 between the Japan International Cooperation Agency and the Joint Study Team of Pacific Consultants International and Shin-Nippon Meteorological & Oceanographical Consultant Co., Ltd.

The report examines the existing conditions of Lake Balaton and its catchment area, develops a pollution load database and a water quality simulation model, and presents a comprehensive plan for the improvement of Lake Balaton environment and results of a feasibility study on the reduction of pollution loads from non-point sources proposed in the comprehensive plan.

The report consists of the Summary, Main Report, Supporting Report and Data Book. The Summary summarizes the results of all studies. The Main Report contains the existing conditions, database, water quality simulation model , comprehensive plan and results of the feasibility study, and conclusions and recommendations. The Supporting Report includes technical details of contents of the Main Report. In addition, Data Book have been prepared and is submitted herewith.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, Environment Agency and Embassy of Japan in Hungary, and also to officials and individuals of the Republic of Hungary for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the improvement of Lake Balaton and that friendly relations of both countries be promoted further by this occasion.

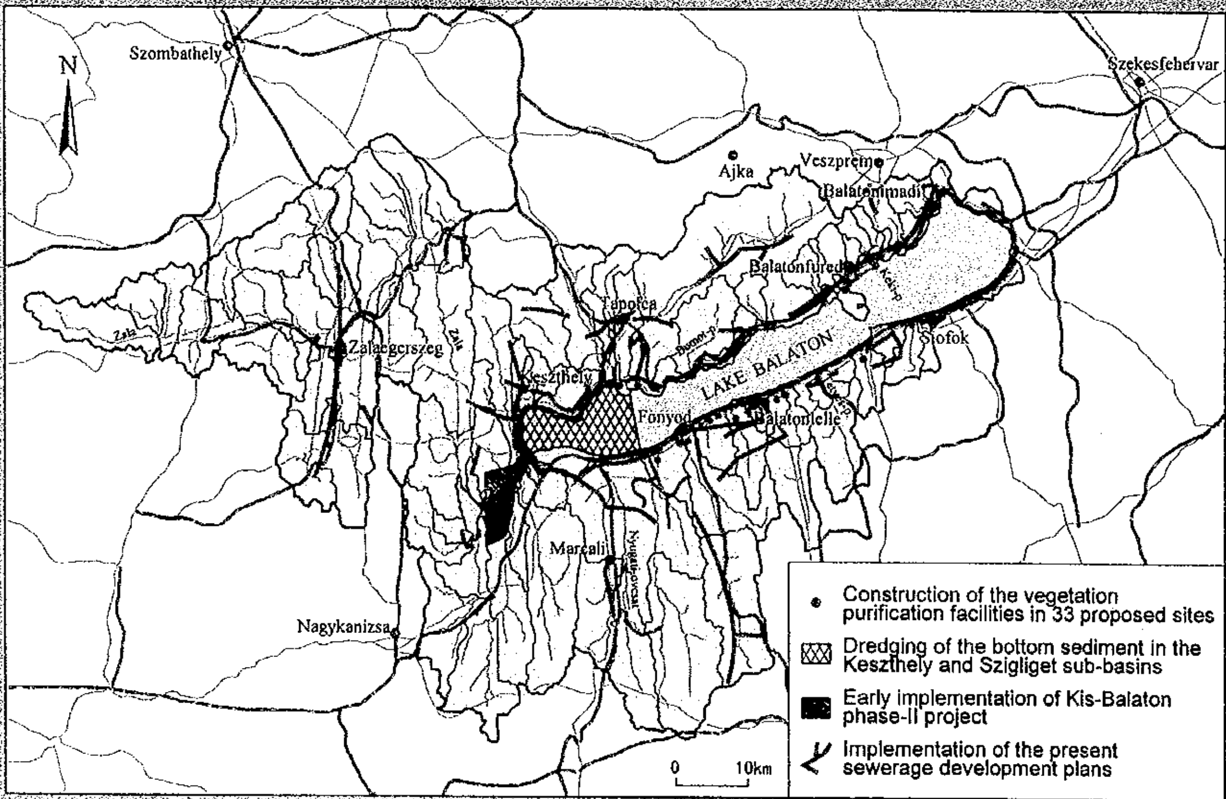
Yours faithfully,

Akira Takechi
Team Leader

Institutional Approach

- Organization of Balaton Policy Making Unit, which is a responsible organization for the management of information, policy making and coordination of every organization related to Lake Balaton issues
- Encouragement of involvement of residents
- Study on the environmental utilization charge

Structural Approach



Non-Structural Approach

- Promotion of the environmental education and campaigns
- Introduction of product charge
- Establishment of the legislative framework for the sewerage house connection and on-site sewage treatment

Proposed Comprehensive Plan

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

EXECUTIVE SUMMARY

INTRODUCTION

In Hungary, which is an inland country, Lake Balaton is one of the most important water resources providing inestimable benefits to the nation. The lake has been utilized for tourism, recreation, fisheries, water supply, etc since last century. In recent years, however, the degradation of the lake water quality due to the progress of eutrophication has been threatening the sustainable use of this precious water resource.

This study was conducted by the Study Team of the Japan International Cooperation Agency (JICA) in cooperation with the Prime Minister's of the Republic of Hungary from January 1997 to March 1999, with following objectives,

i) To formulate the comprehensive plan for environmental improvement measures for Lake Balaton,

ii) To conduct a feasibility study on the urgent project to be selected from a component of the above-mentioned comprehensive plan, and

iii) To carry out technology transfer to the counterpart personnel of the Government of the Republic of Hungary in the course of the Study,

ANALYSIS OF EXISTING CONDITIONS

In the Study, a pollution load database (PLDB) and a water quality simulation model (WQSM) were developed to be used for the analysis of existing conditions and evaluation of structural measures in the Comprehensive Plan in the Study, as well as to provide the decision making tools for the future.

PLDB was designed to have following two functions;

- a database function for accumulation of relevant data, and
- a simulation function for estimation of pollution loads discharge based on the database.

WQSM was developed as a fully two dimensional water quality model to represent occurrences of a summer algal peak, which is a major cause of water quality problems related to eutrophication, and its spatial distribution.

Using PLDB and WQSM, the Study revealed that i) pollution loads to the lake are predominated by those from non-point sources (80% of the total), ii) an occurrence of the algal summer peak depends on physical conditions such as water temperature and solar radiation rather than nutrient concentrations, and iii) control of the internal pollution loads would be more effective to mitigate the eutrophication problems than control of external pollution loads.

COMPREHENSIVE PLAN

The target year was set up as 2010 and the targets of the improvement were determined as follow:

Target Area (Basin)	Water Quality (Trophic Category)	
	Recent Situation	Target
Keszthely	"Hypertrophic" or "Eutrophic"	"Eutrophic"
Szigliget	"Hypertrophic" or "Eutrophic"	slightly "Eutrophic"
Szemes	"Eutrophic"	"Mesotrophic"
Siófok	"Eutrophic" or "Mesotrophic"	"Mesotrophic"

The Comprehensive Plan consists of following approaches:

- Structural approach
- Non-structural approach
- Institutional approach

Each approach consists of measures and activities in the table below:

Approach	Measures and Activities
Institutional	- Organization of Balaton Policy Making Unit, which is a responsible organization for the management of information, policy making and coordination of every organization related to Lake Balaton issues. - Encouragement of involvement of residents - Study on the environmental utilization charge
Structural	- Implementation of the present sewerage development plans in the catchment areas. - Early implementation of Kis-Balaton phase-II project. - Dredging of the bottom sediment in the Keszthely and Szigliget sub-basins. - Construction of the vegetation purification facilities in 33 proposed sites.
Non-structural	- Promotion of the environmental education and campaigns. - Introduction of product charge - Establishment of the legislative framework for the sewerage house connection and on-site sewage treatment.

Project costs were estimated for the structural measures in the proposed Comprehensive Plan, and, among them, the implementation of the sewerage development projects and

Kis-Balaton phase-II project were eliminated from the estimation because these projects are now under preparation by the Hungarian side. Project costs were estimated at HUF 5.8 billion for the construction and HUF 751 million per year for the operation.

Improvement effects by the projects were evaluated by adopting a probability of achieving the targets. The probabilities to achieve the targeted trophic state in the Keszthely and Szigliget sub-basins were improved as follows:

Sub-basin	Present Probability	Probability after Project	Improvement
Keszthely	23%	35%	12%
Szigliget	43%	58%	15%

The results of the economic analysis indicated that EIRR is over 12%, which is used as a norm for decision making of many World Bank projects, thus, this project can be regarded as viable.

For the environmental impact aspect, while the structural measures accompany construction works and dredging operation and they may cause impacts to the environment, it was judged to be controlled within an acceptable level by proper countermeasures.

FEASIBILITY STUDY ON NON-POINT SOURCE POLLUTION LOAD CONTOROL

Selected project area are as follows:

① River purification facility (vegetation purification method)

Nyugati-ovcsatorna river
Keleti-bozot river

② Urban runoff purification facility (coagulation sedimentation method)

Keszthely urban runoff area (Szent Imre/Büdös river)

Quick effect may not be expected from external load reduction by the above projects. However, external load is undoubtedly an origin of internal load and the effect of its control may be slow but steady like preventive medicine.

It was concluded that the vegetation purification method is the most cost-effective. The total investment cost of the feasibility study projects is about 1,248 million HUF for six (6) years and annual O/M cost is 75.2 million HUF. The amount of cost falls within the central government's budget and the Central Environmental Fund allocated for Lake Balaton area.

CONCLUSION AND RECOMENDATION

The Study revealed that significant improvement of the trophic condition of Lake Balaton would not be expected by the reduction of external and internal pollution loads. However, it should be much stressed that the present lake conditions are a gift from every effort that has been made during these several decades by various organizations concerned to Lake Balaton. The eutrophication is an irreversible process of natural lakes. Although people may not be able to turn back or to stop the process, people could slow down the speed of the process. Therefore, it is necessary to continue the efforts, which have been made, to reduce the external and internal loads and outputs of the Study should be utilized to integrate the efforts efficiently and effectively.

In this line, it was recommended that an organization responsible for the Lake Balaton management be set up by incorporating the concepts of Policy Making Process, which includes the management of relevant data and information, preparation of scenarios for the improvement and coordination to materialize the scenarios.

For the structural measures, the implementation of Kis-Balaton Projects Phase II and the sewerage development were strongly recommended and also the dredging was recommended as a more effective measure for a short term effect, while the control of non-point source loads by the vegetation purification was recommended expecting a long term effect.

To encourage the contribution by residents and private sectors to the lake improvement, environmental education and campaigns, fines and subsidy were recommended.

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

SUMMARY

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Lake Balaton is the largest lake in Central Europe located in the central western part of Hungary. In Hungary, which is an inland country, Lake Balaton is one of the most important water resources providing inestimable benefits to the nation. The lake has been utilized for tourism, recreation, fisheries, water supply, etc. In recent years, however, the degradation of the lake water quality has been threatening the sustainable use of this precious water resource.

In 1983, the Hungarian Government launched a Comprehensive Water Management Program (BVFP) as a first government policy for the improvement of water quality of the lake. In June 1994, the government issued Resolution No.1049 concerning the action plan for the environmental protection of Lake Balaton and the improvement of its water quality. Although the action plan covers almost all areas related to the improvement of the lake environment, there is a need of a comprehensive plan in which those activities are properly evaluated and prioritized in order to rationalize required investments.

Under these circumstances, this study was conducted by the Study Team of the Japan International Cooperation Agency (JICA) in cooperation with the Prime Minister's Office to formulate a comprehensive plan for the environmental improvement of Lake Balaton and a feasibility study on a high priority project from the comprehensive plan from January 1997 to March 1999.

The objectives of the Study are as follows:

i) To formulate the comprehensive plan for environmental improvement measures for Lake Balaton,

ii) To conduct a feasibility study on the urgent and/or priority project(s) to be selected from a component(s) of the above-mentioned comprehensive plan, and

iii) To carry out technology transfer to the counterpart personnel of the Government of the Republic of Hungary in the course of the Study.

The Study area covers the water body of Lake Balaton with about 600 km^2 of surface area and its whole catchment area with 5,800 km^2 of area, as shown in *Figure 1.1*.

The study reports prepared are as follows:

- Main Report
- Supporting Report
- Summary Report
- Data Book

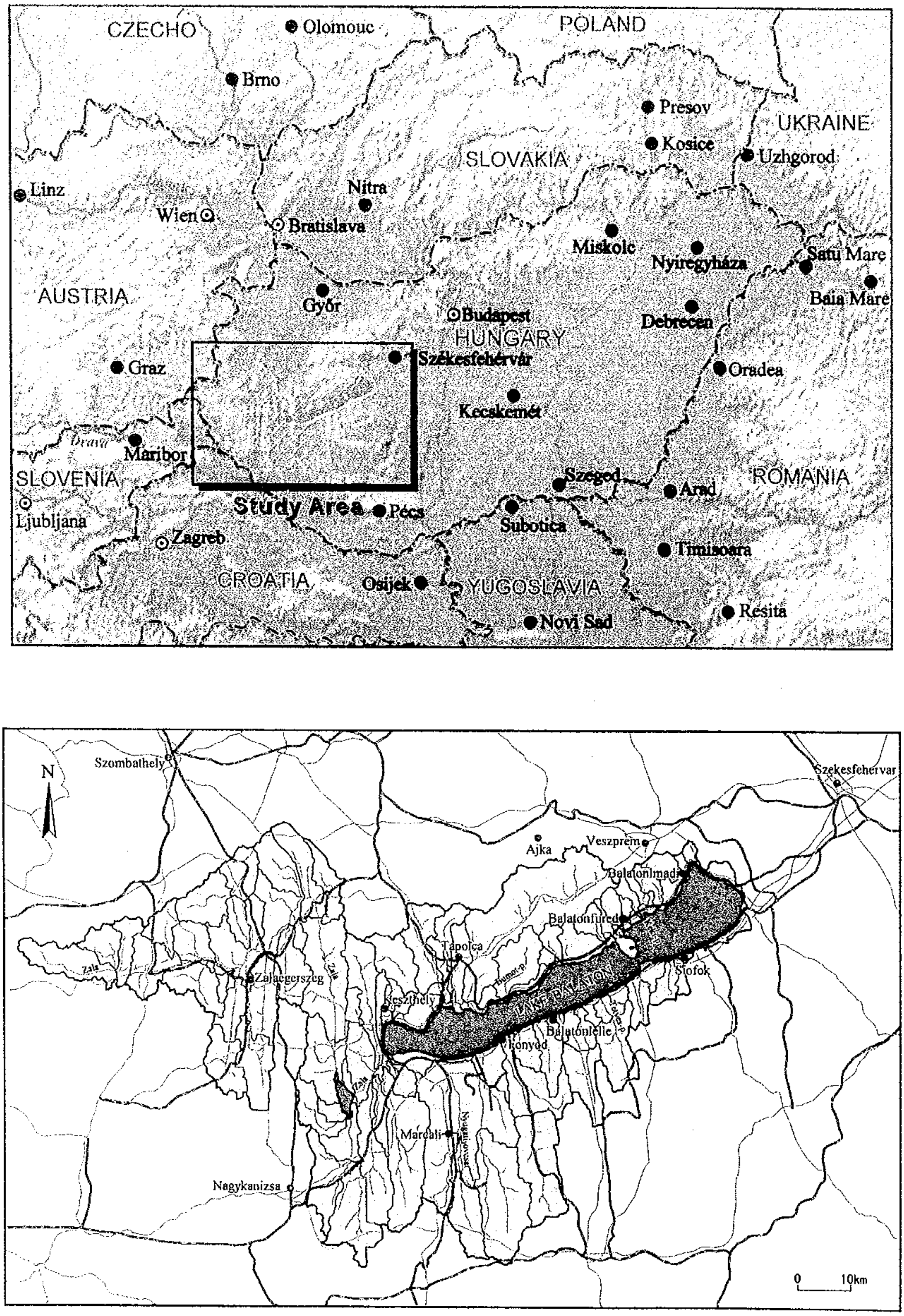


Figure 1.1 Study Area

2. DEVELOPMENT OF DECISION MAKING TOOLS

The Comprehensive Plan is defined to be a plan provided with tools for decision making to prioritize possible measures for the lake improvement and to distribute the resources among each component listed in the Action Program. In the Study, pollution load database (PLDB) and water quality simulation model (WQSM) were developed to be used for the evaluation of structural measures in the Comprehensive Plan in the Study, as well as to provide the decision making tools for the future.

2.1 POLLUTION LOAD DATABASE (PLDB)

PLDB is required to be a tool for an estimation of pollution loads discharged into the lake (pollution loads discharge), and it has closely linked two functions; a database function for accumulation of relevant data, and a simulation function for estimation of pollution loads discharge.

The design of PLDB is determined by a method of pollution load analysis. The method specifies both which data should be accumulated, and which algorithm should be applied for the load estimation.

The calculated pollution loads discharge, a main output of PLDB, is one of input data of WQSM. Compatible data format between PLDB and WQSM is proposed to avoid a redundant data processing.

(1) Structure of PLDB

PLDB is designed to have following two functions;

- a database function for accumulation of relevant data, and
- a simulation function for estimation of pollution loads discharge based on the database.

An analysis of non-point source pollution loads requires spatial data like a land use map or a delineation map of sub-catchment areas as well as various tabulated data. To handle both spatial data and tabulated data simultaneously, a geographical information system (GIS) is introduced.

PLDB is developed with the GIS software Arc/Info version 7.2.1 on a DEC Alpha Station 255 equipped with 128 MB RAM and 6 GB hard disk.

1) Data

Following base digital maps and data have been accumulated in PLDB.

Spatial data	Basic topographic map (DTA 50 Digital Topographic Map Set, 1:50,000) from KDT-KÖFE
	Elevation contour map (1:100,000) from FÖMI
	Land cover map (Corine Land Cover Database, 1:100,000) from FÖMI
	Soil characteristics map (AGROTOPO, 1:100,000) from MTA TAKI
	Satellite images (LANDSAT TM and SPOT) from FÖMI
	Detailed soil map (detailed field records, 1:25,000) from MTA TAKI
	Satellite images (LANDSAT TM and SPOT) from FÖMI
	Map of hydro-physical properties of soils (1:100,000) from MTA TAKI
	Erosion map (1:100,000) from MTA TAKI
Tabulated Data	National Land Use Inventory from FÖMI
	Population of sub-catchment acquired from PLM
	Information of point sources acquired from PLM

2) Derived digital maps by JICA Study Team

Various digital maps are derived by overlaying and analyzing collected spatial and tabulated data using GIS. Most important derived maps for the pollution load analysis are the re-categorized landuse maps and the meshed population data.

3) User Interface for Pollution Loads Simulation

A user interface for pollution loads simulation was developed as a part of PLDB. The user interface applies customization with AML (Arc/Info Macro Language) and some commands of the GRID module so that the user can easily render an estimation of pollution loads generation by setting the unit pollution loads generation for each land use category, and an estimation of pollution loads discharge by setting the runoff ratio for each sub-catchment area.

(2) Pollution Load Analysis

The applied method consists of following steps.

i) Estimation of pollution loads generation.
ii) Estimation of pollution loads discharge from the tributaries measured by KÖFEs and VIZIGs.
iii) Estimation of runoff ratio by comparing the results of *i)* and *ii)*.
iv) Estimation of pollution loads discharge from the whole catchment area using the results of *i)* and *iii)*.

1) Estimation of pollution loads generation

Sources of pollution loads were classified as follows:

Point source:
- domestic wastewater (black water from human metabolism, and gray water from household activities)
- industrial wastewater (discharge from factories and livestock farms)

Non-point source:
- rural runoff (runoff rainwater containing fertilizers, herbicides and pesticides, eroded soil, etc.)
- urban runoff (runoff rain water containing roof and road depositions)
- atmospheric deposition

For point source pollution loads, Pollution Load Map by KÖFE (PLM) estimates pollution loads generation from sewage treatment plants by analyzing effluent quantity and quality. Concerning livestock breeding, the JICA Study Team concluded that all of the manure is utilized for composting or soil improvement, and no wastewater is discharged to the lake.

Analysis of non-point sources pollution loads generation is carried out on the 24 sub-catchment areas delineated according to PLM. The land use pattern is determined by overlaying the re-categorized land use map and the delineation map of sub-catchment.

The unit pollution loads generation of each land use category is determined based on Japanese empirical value, which as shown below:

	COD_{Cr} (kg/ha/year)	TN (kg/ha/year)	TP (kg/ha/year)
Urban Area	282.0	19.7	2.70
Arable Land	20.6	29.6	0.79
Pasture and Meadow	31.8	16.6	0.55
Forest	43.0	3.6	0.30
Vineyard and Orchard	20.6	29.6	0.79
Marshland and Water Body (Atmospheric deposition)	113.8	17.7	1.06

2) Estimation of pollution loads discharges by existing monitoring data

Pollution load discharges, including during flush events, were estimated from river flow (converted from water levels by H-Q curves) and rating curves between the pollution load discharge and river flow obtained from the selected 10 tributaries.

3) Estimation of runoff ratio

Runoff ratios for the selected 10 rivers were calculated from the estimated pollution load generation and pollution load discharges. For the remaining rivers, the adopted runoff ratios are as follows:

CODcr: 0.4, T-N: 0.4, T-P: 0.2

For the direct catchment areas, 0.8 of runoff ratio is assumed uniformly for the three parameters.

4) Estimation of pollution loads discharge

Pollution loads discharges for each sub-catchment area are obtained by multiplying the estimated pollution load generation by the runoff ratios. Estimated pollution load discharge for 1994 and 1995 are as follows:

1994

	Point Source Load			Non-point Source Load			Total Load		
	TP (kg/yr)	TN (kg/yr)	COD_{Cr} (ton/yr)	TP (kg/yr)	TN (kg/yr)	COD_{Cr} (ton/yr)	TP (kg/yr)	TN (kg/yr)	COD_{Cr} (ton/yr)
Northern Catchment Area	3,168 (3%)	142,826 (5%)	66 (0%)	24,238 (24%)	546,575 (19%)	2,885 (17%)	27,406 (27%)	689,401 (24%)	2,951 (18%)
Southern Catchment Area	1,406 (1%)	32,581 (1%)	63 (0%)	29,516 (0%)	1,150,763 (41%)	3,107 (19%)	30,921 (30%)	1,183,344 (42%)	3,171 (19%)
Zala Catchment Area	13,887 (14%)	348,205 (12%)	421 (3%)	29,696 (29%)	593,384 (21%)	10,056 (61%)	43,583 (43%)	941,589 (33%)	10,477 (63%)
Total Catchment Area	18,460 (18%)	523,612 (19%)	550 (3%)	83,450 (82%)	2,290,722 (81%)	16,048 (97%)	101,910 (100%)	2,814,334 (100%)	16,598 (100%)

1995

	Point Source Load			Non-point Source Load			Total Load		
	TP (kg/yr)	TN (kg/yr)	COD_{Cr} (ton/yr)	TP (kg/yr)	TN (kg/yr)	COD_{Cr} (ton/yr)	TP (kg/yr)	TN (kg/yr)	COD_{Cr} (ton/yr)
Northern Catchment Area	2,342 (2%)	109,284 (4%)	49 (0%)	25,543 (24%)	610,971 (21%)	2,658 (15%)	27,885 (26%)	720,255 (25%)	2,707 (15%)
Southern Catchment Area	1,240 (1%)	39,158 (1%)	64 (0%)	31,569 (29%)	1,173,617 (40%)	3,378 (19%)	32,809 (31%)	1,212,775 (42%)	3,441 (19%)
Zala Catchment Area	16,387 (15%)	351,522 (12%)	433 (2%)	30,434 (28%)	633,994 (22%)	11,188 (63%)	46,821 (44%)	985,516 (34%)	11,621 (65%)
Total Catchment Area	19,968 (19%)	499,964 (17%)	545 (3%)	87,547 (81%)	2,418,582 (83%)	17,224 (97%)	107,515 (100%)	2,918,546 (100%)	17,769 (100%)

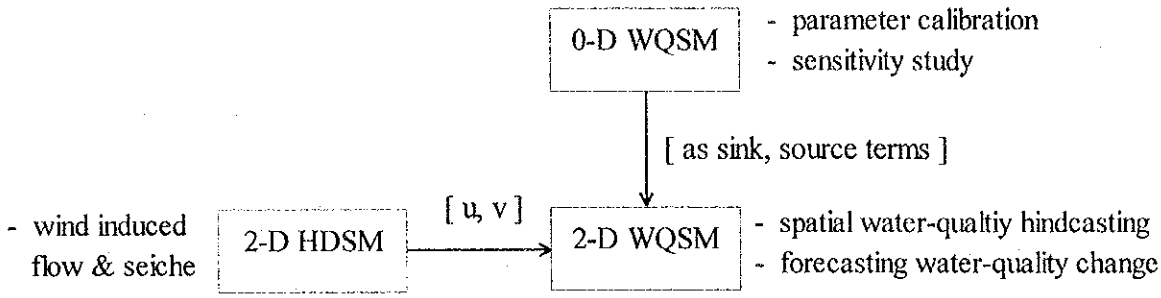
2.2 WATER QUALITY SIMULATION MODEL (WQSM)

(1) Structure of WQSM

WQSM is developed as a fully two dimensional water quality model aiming to investigate the impact of various nutrient loads and to assess the effects of eutrophication abatement measures.

WQSM consists of two sub-components, *i.e.* a two-dimensional hydrodynamics model (2-D HDSM) and a completely mixed algal dynamics model (0-D WQSM).

The conceptual structure of WQSM is shown below:



The mass transport sub-model is driven by unsteady flow field generated by 2-D HDSM. Upon satisfactory calibration and verification, all the sub-models have been integrated to form WQSM.

(2) Two-dimensional Hydrodynamics Model (2-D HDSM)

1) Governing Equations

The governing equations for the hydrodynamics model consist of the unsteady nonlinear version of the depth-integrated shallow water equations, including convective acceleration, quadratic bottom friction, surface wind shear stress, and Corioli's effect. *Table 2.1* shows the set of governing equations for the hydrodynamics component.

2) Numerical Method

The computational scheme employs the Finite Element Method (FEM) for its convenience in variable and arbitrary local resolution refinement as well as in detailed boundary-fitting capability. In addition, the "mass lumping" technique is applied to achieve optimal computational efficiency by eliminating matrix operations. The spatial resolution is of order of 10 to 100 meter, utilizing 7199 triangular elements of variable size. The final FEM discretization of Lake Balaton is shown in *Figure 2.1*. Using a workstation equipped with a DEC Alpha 433 Mhz CPU, a real-time simulation for 4 days with a 20-second time step takes approximately 12 minutes.

3) Calibration and Verification

2-D HDSM has been calibrated using wind data and water-level record taken during the storm events of March 31 to April 3, 1994, July 8 to 9, 1963 and May 26 to 30, 1993.

Based on the sensitivity analysis for the storm event of March 31 to April 3, 1994, the bottom roughness has been optimized at n=0.02, and the Wu's (1973) wind drag coefficient as a function of wind speed has been selected for subsequent computations. *Figure 2.2* shows results of the sensitivity analysis of Manning's roughness coefficient.

Table 2.1 Two Dimensional Hydrodynamics Equations

$$\frac{\partial H}{\partial t}+\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}=0 \cdots\cdots (1)$$

$$\frac{\partial q_x}{\partial t}+\frac{\partial}{\partial x}\left(\frac{q_x^2}{H}\right)+\frac{\partial}{\partial y}\left(\frac{q_x q_y}{H}\right) = -\frac{\partial N_p}{\partial x}+\frac{1}{\rho}\left(\frac{\partial N_{xx}}{\partial x}+\frac{\partial N_{yx}}{\partial y}\right)+fq_y+\frac{1}{\rho}\left(\tau_{sx}-\tau_{bx}\right)+g\eta\frac{\partial h}{\partial x} \cdots\cdots (2)$$

$$\frac{\partial q_y}{\partial t}+\frac{\partial}{\partial x}\left(\frac{q_x q_y}{H}\right)+\frac{\partial}{\partial y}\left(\frac{q_y^2}{H}\right) = -\frac{\partial N_p}{\partial y}+\frac{1}{\rho}\left(\frac{\partial N_{yy}}{\partial y}+\frac{\partial N_{xy}}{\partial x}\right)-fq_x+\frac{1}{\rho}\left(\tau_{sy}-\tau_{by}\right)+g\eta\frac{\partial h}{\partial y} \cdots\cdots (3)$$

$$N_{ij}=\left\langle \tau_{ij}+\rho u_i' u_j' \right\rangle \equiv \int_{-h}^{\eta}\left(\tau_{ij}+\rho u_i' u_j'\right)dz \cong \rho\varepsilon_{ij}\left(\frac{\partial q_i}{\partial x_j}+\frac{\partial q_j}{\partial x_i}\right) \quad ;(i,j=x,y) \cdots (4)$$

$$N_p = g\eta h+\frac{1}{2}g\eta^2 \cdots\cdots (5)$$

$$\tau_{sx}=\rho_{air}C_D U^2 cos\theta_w \cdots\cdots (6) \qquad \tau_{sy}=\rho_{air}C_D U^2 sin\theta_w \cdots\cdots (7)$$

$$\tau_{bx}=\frac{C_f \rho q_x\sqrt{q_x^2+q_y^2}}{H^2} \cdots\cdots (8) \qquad \tau_{by}=\frac{C_f \rho q_y\sqrt{q_x^2+q_y^2}}{H^2} \cdots\cdots (9)$$

where q_i =mass flux per unit width; h =depth; η =surface elevation; $H=h+\eta$; f =Corioli's parameter; g =gravitational acceleration; ε =eddy viscosity; ρ_{air} =air density; τ_s =wind stress; τ_b =bottom shear stress; U =wind speed at 10 m above the water surface; C_D =drag coefficient (Wu, 1973); θ_w =angle between the wind direction and the x axis; friction coefficient $C_f=n^2gH^{-1/3}$; n =Manning's roughness coefficient.

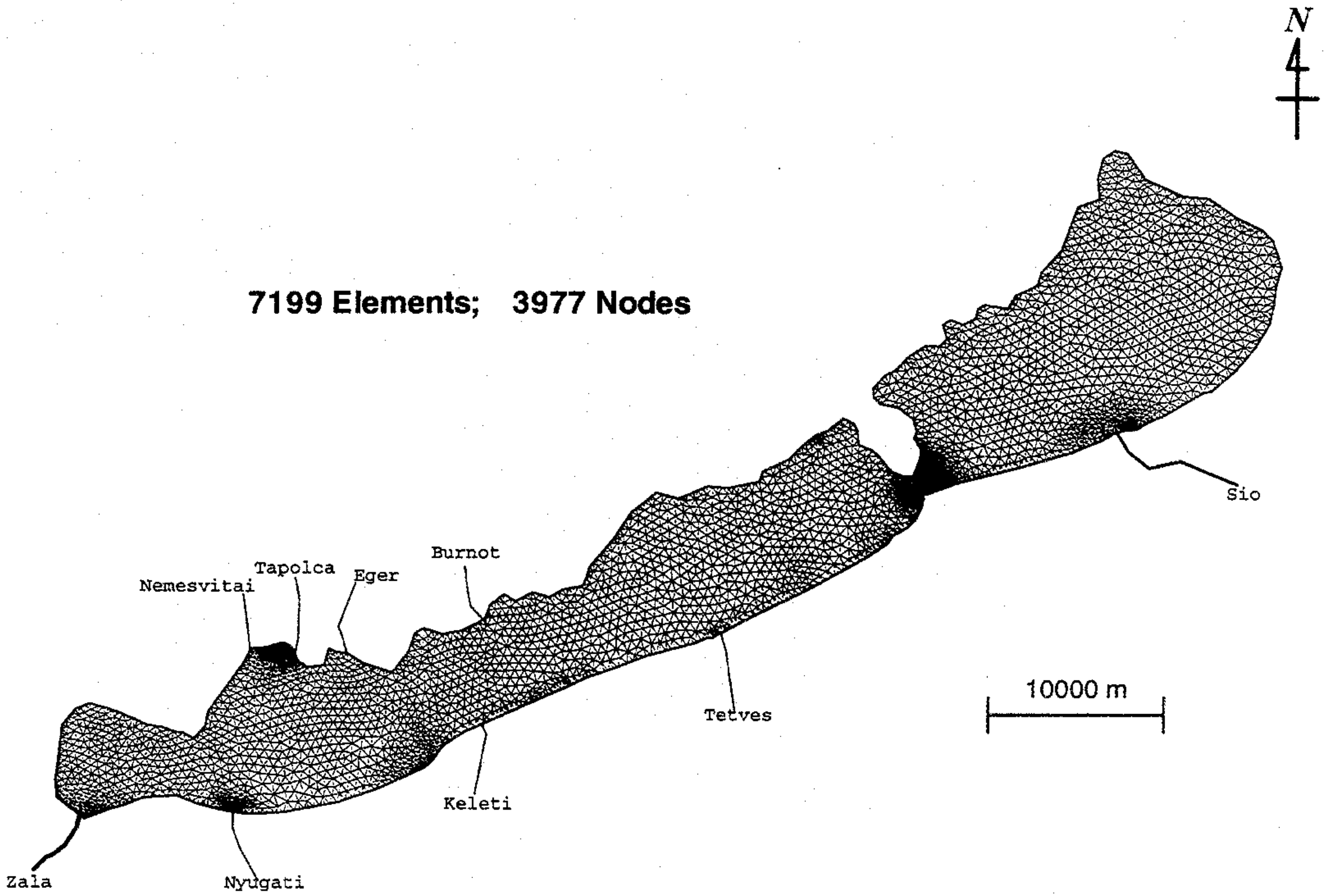


Figure 2.1 Finite Element Mesh for Lake Balaton

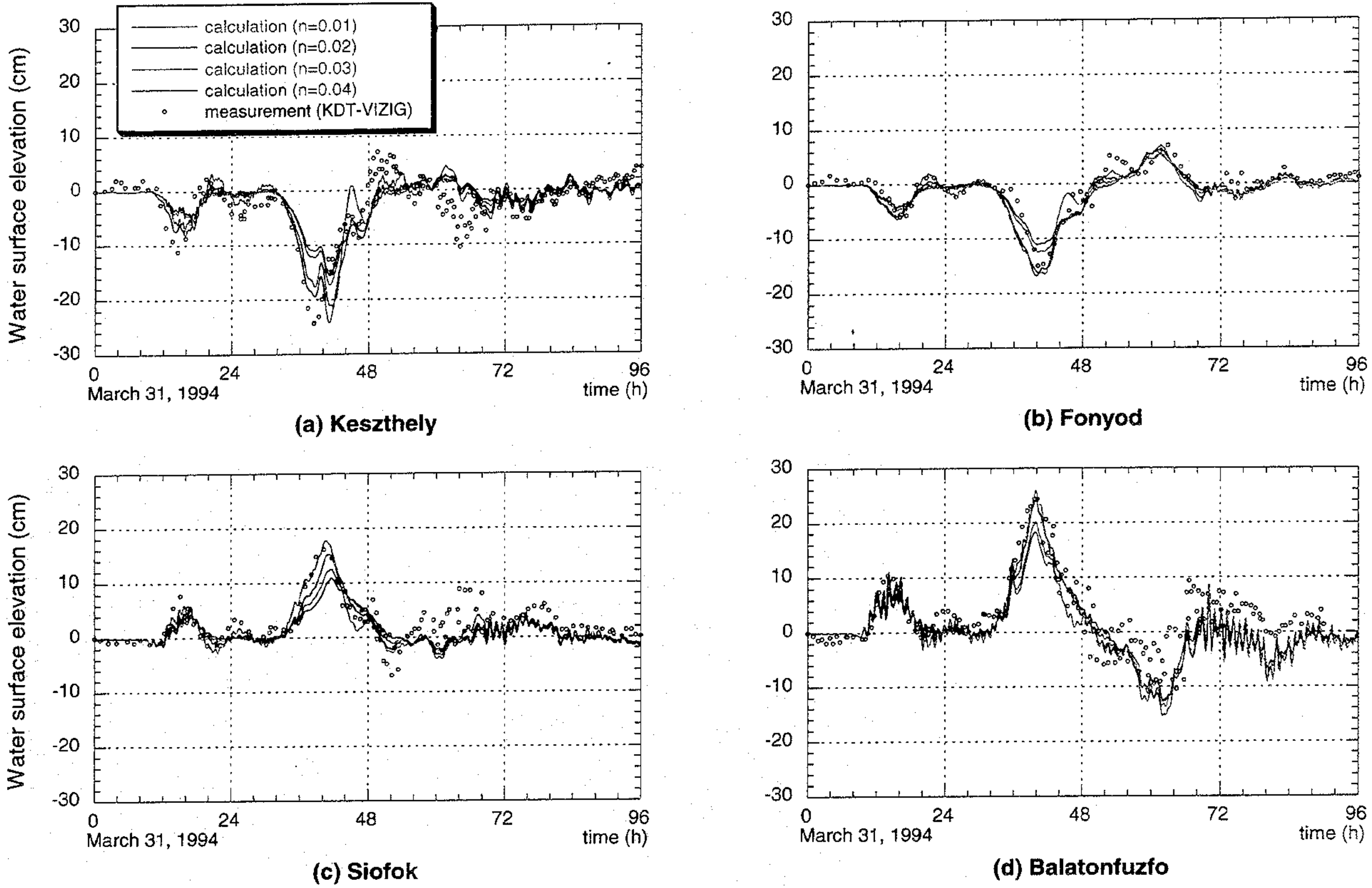


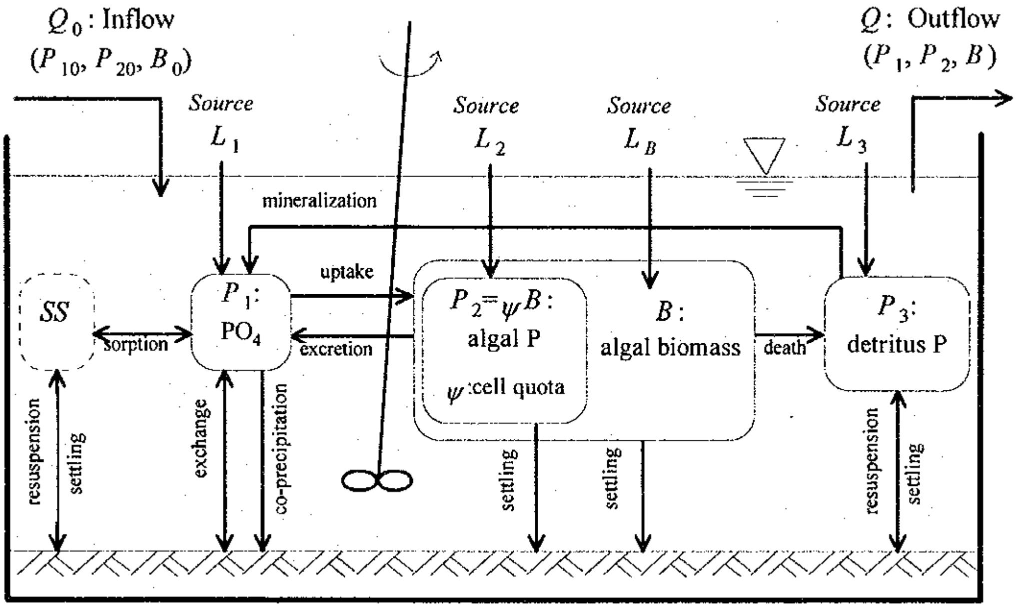
Figure 2.2 Sensitivity of Predicted Seiche to Manning's Roughness Coefficient

(3) Completely-mixed Biogeochemical Model (0-D WQSM)

1) Framework of 0-D WQSM

Since the growth of heterocytic cyanobacteria such as *C. raciborskii* is not limited by nitrogen, 0-D WQSM is a phosphorus cycle model as found in the previous models. 0-D WQSM consists of four variable components, *i.e.* orthophosphate (PO_4-P), phytoplankton-P, detrital-P, and algal dry-weight biomass. In addition, the suspended sediment concentration that relates to the P-sorption processes and the light transmission are dealt with as variables.

The conceptual structure of 0-D WQSM is referred to the figure below, and its governing equations are shown in *Table 2.2*.



2) Input Data

The input data for 0-D WQSM include the daily loads from Zala River, direct runoff, and atmospheric deposition; hourly wind; water-temperature measured once a day at 7:00 am; daily total solar radiation; and daily water level.

Table 2.2 Completely-mixed Biogeochemical Model Equations

Dissolved inorganic phosphorus: P_1 [mg-P/m^3]

$$\frac{dP_1}{dt} = -k_f P_1 - k_u \frac{P_1 B}{P_{1k} + P_1} \frac{\psi_{max} - \psi}{\psi_{max} - \psi_{min}} + k_m \theta_m^{T_w - 20} P_3 + (1 - f_{op}) d_p \theta_p^{T_w - 20} P_2 + Sop(SS) + c_{ex}(P_{eq} \theta_m^{T_w - 20} - P_1) + L_1$$

Algal phosphorus: P_2 [mg-P/m^3]

$$\frac{dP_2}{dt} = -k_f P_2 + k_u \frac{P_1 B}{P_{1k} + P_1} \frac{\psi_{max} - \psi}{\psi_{max} - \psi_{min}} - d_p \theta_p^{T_w - 20} P_2 - \frac{v_{s4}}{h} P_2 + L_2$$

Algal biomass: B [mg dry-wt/m^3]

$$\frac{dB}{dt} = -k_f B + \mu_{\max} f(\psi) f(I) f(T) B - d_p \theta_p^{T_w - 20} B - \frac{v_{s4}}{h} B + L_B$$

Detrital phosphorus: P_3 [mg-P/m^3]

$$\frac{dP_3}{dt} = -k_f P_3 + f_{op} d_p \theta_p^{T_w - 20} P_2 - k_m \theta_m^{T_w - 20} P_3 - \frac{v_{s3}}{h}(1 - r) P_3 + L_3$$

Chla [mg/m^3]

$$Chla = B / (\frac{\alpha I_{opt}}{\mu_{\max} e} c_{b/c})$$

where

k_f: flushing rate
k_u: maximum uptake rate
P_{1k}: half-saturation constant for uptake
ψ: cell quota, $\psi = P_2/B$
ψ_{max}, ψ_{min}: maximum and minimum cell qotas
d_p: mortality rate
θ_p: temperature factor for mortality
v_{s3}: settling rate of detritus
v_{s4}: settling rate of algae
h: depth
L_i: external loads
μ_{max}: maximum specific growth rate
$f(\psi)$: cell quota growth limiting factor,
α: initial slope of P-I curve
I_{opt}: optimum light intensity

$$f(T) = \exp[-2.3 \left(\frac{T - T_{opt}}{T_x - T_{opt}} \right)^2]$$

$$T_x = T_{min} \quad for \quad T \leq T_{opt}$$
$$= T_{max} \quad for \quad T > T_{opt}$$

c_{ex}: exchange coefficient of the sediment phosphorus release
P_{eq}: equilibrium concentration of the sediment phosphorus release
$c_{b/c}$: ratio of algal biomass to carbon

$f(\psi) = 1 - \psi_{min}/\psi$
$f(T)$: temperature limiting factor
T_{min}: minimum temperature for algal growth
T_{max}: maximum temperature for algal growth
T_{opt}: optimal temperature for algal growth
$f(I)$: light limiting factor (see *Table* 5.3)
k_m: mineralization rate
θ_m: temperature factor for mineralization
$Sop(SS)$:sorption as a function of suspended sediments
f_{op}: fraction of organic phosphorus in TP contained in dead phytoplankton
γ: fraction of detritus that is dissolved

3) Calibration

Figure 2.3 shows calculated *Chla* in 1994 using the standard parameter values. A hindcast of *Chla* in 1995 was also performed using the same parameter values, as shown in *Figure 2.4*.

(4) Two Dimensional Water Quality Model (WQSM)

1) General Framework

A two-dimensional mass transport model has been developed, and 0-D WQSM has been incorporated into the mass transport model to form the two-dimensional water quality model (WQSM).

The computational method for WQSM also utilizes the finite element method that is compatible with 2-D HDSM and shares the same mesh.

2) Input Database

The input database is consisting of following data.

- Daily loads from major rivers
- Distributed direct runoff from 19 sub-regions
- Atmospheric deposition loads
- Hourly wind at the Keszthely and the Siófok stations
- Daily water-temperature at four stations in each basin
- Daily total solar radiation at the Keszthely station
- Daily precipitation at the Balatonakali and the Balatonszemes stations

(5) Water Quality Simulation by WQSM

Figures 2.5 and *2.6* show the computed *Chla* distributions in 1994 and 1995 when *Chla* levels reached the maximum during the respective year. As seen in both the Figures, the maximum *Chla* concentrations occurred in the Keszthely basin, while the minimum spread over the Siófok basin.

WQSM has been confirmed to be able to hindcast *Chla* concentrations in 1994 and 1995, the two contrasting years in terms of algal productivity. WQSM is, therefore, believed to be qualified for prediction of *Chla* to a variety of weather and nutrient-load conditions.

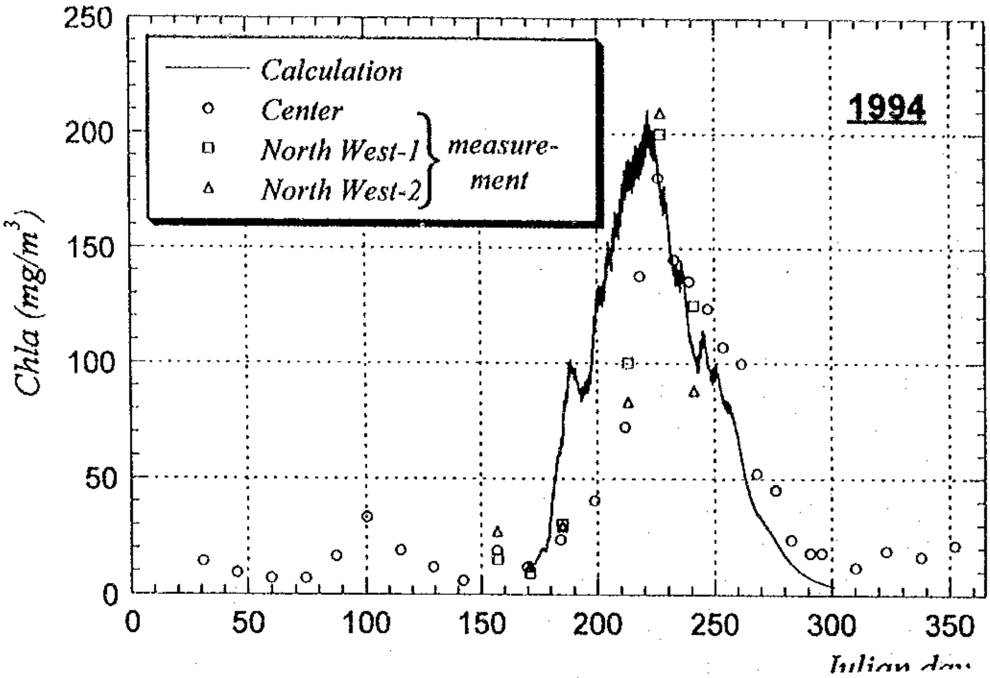


Figure 2.3 Chlorophyll-a Hindcast Compared with Measurements (Présing and KDT KÖFE) in 1994

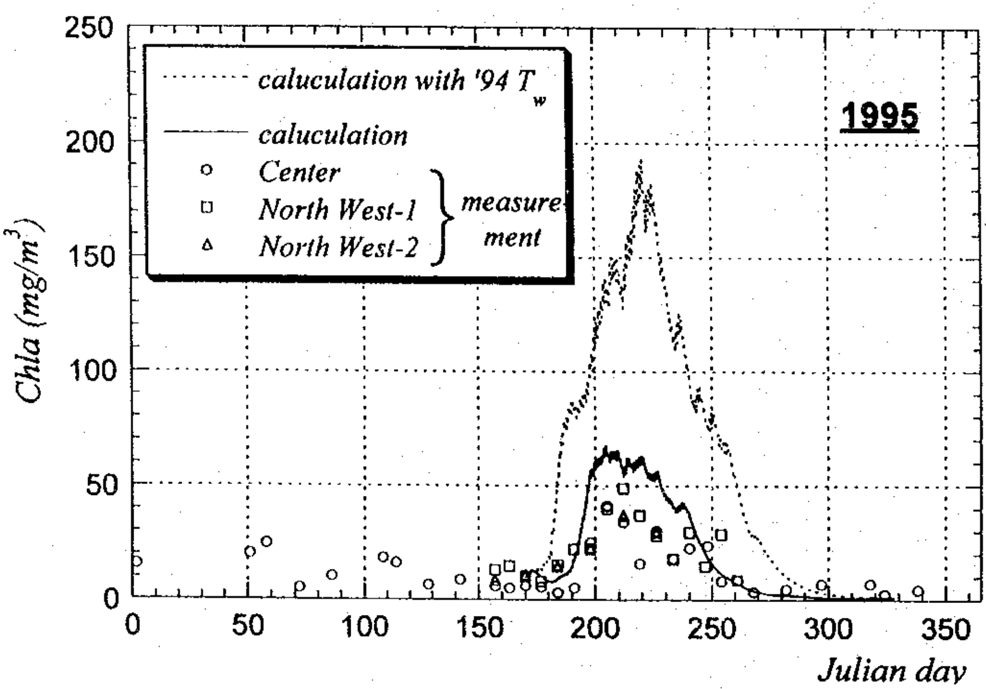


Figure 2.4 Chlorophyll-a Hindcast Compared with Measurements (KDT KÖFE) in 1995

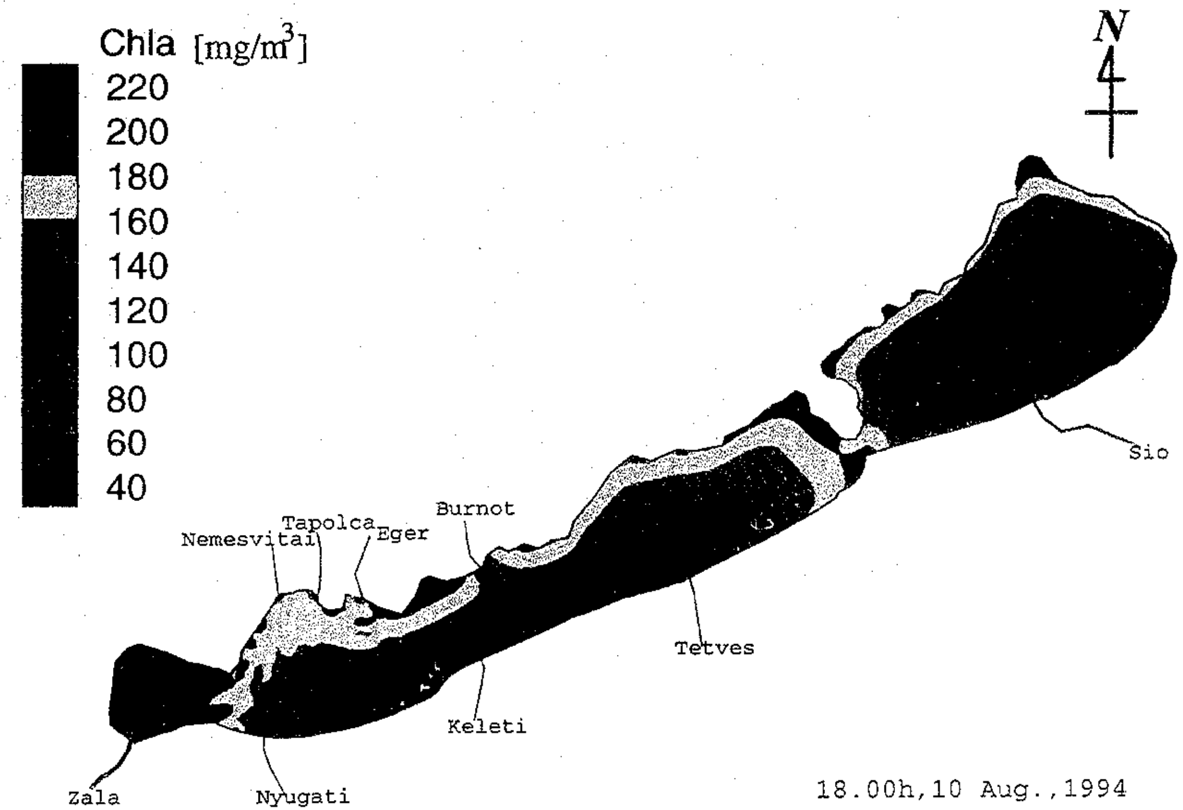


Figure 2.5 Chlorophyll-a Distribution at the Time of Peak Bloom in Keszthely Bay in 1994

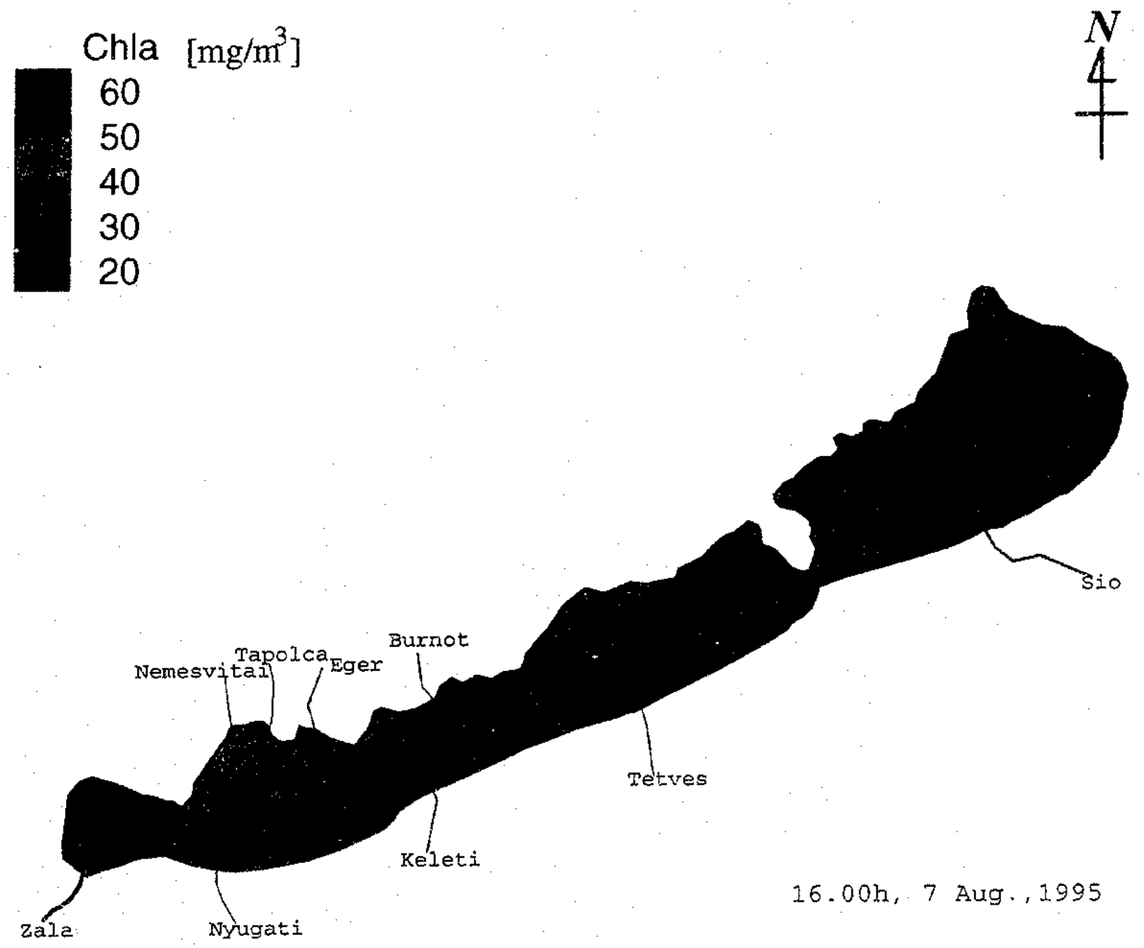


Figure 2.6 Chlorophyll-a Distribution at the Time of Peak Bloom in Keszthely Bay in 1995

3 COMPREHENSIVE PLAN

3.1 FRAMEWORK OF COMPREHANSIVE PLAN

(1) Targets

The target year is set up as 2010.

The targets of the improvement are determined following the existing plan "Water Management Development Program for Lake Balaton from 1995 to 2000" (Resolution No.2100/1995). Target water qualities are converted into trophic categories based on the classification of OECD as shown below:

Target Area (Basin)	Water Quality (Trophic Category)	
	Recent Situation	Target
Keszthely	"Hypertrophic" or "Eutrophic"	"Eutrophic"
Szigliget	"Hypertrophic" or "Eutrophic"	slightly "Eutrophic"
Szemes	"Eutrophic"	"Mesotrophic"
Siófok	"Eutrophic" or "Mesotrophic"	"Mesotrophic"

The target is not necessarily possible water quality levels to be realized by possible technology, but desirable level to be recovered within a decade.

(2) Future Conditions

The future socio-economic conditions in Comprehensive Plan are assumed to be same as the present. Following three facts may be a keyword in the prediction of the Hungarian future conditions:

- Hungary is a country well developed and industrialized in past.
- Hungarian economy is in the transitional state since its adopting market economy.
- Hungary will join EU in the near future.

3.2 CONCEPTS OF COMPREHENSIVE PLAN

From the view point of governmental side, possible efforts to improve the Lake environment are composed of following three components:

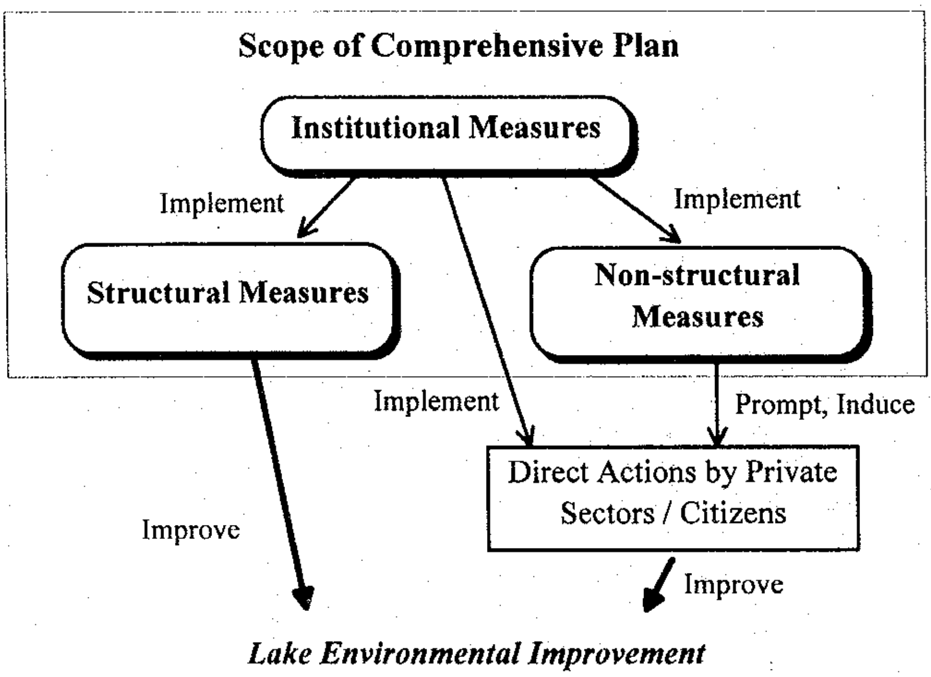
- Structural measures
- Non-structural measures
- Institutional measures

In the Study, a structural measure is defined as the measure taken by the governmental side to physically improve Lake Balaton environment.

A non-structural measure is defined as the measure aiming to motivate citizens or private sector to take some actions directly improving water quality (hereinafter referred to as "direct actions").

Institutional measures are required to provide an institutional framework which make implementation of the above mentioned measures possible.

The above-mentioned definition is illustrated as follows.



3.3 STRUCTURAL APPROACH

Technical approach to the improvement of the lake environmental improvement in Comprehensive Plan is summarized as follows:

- To improve lake water quality by reduction of nutrient load.
- To continue present or planned improvement measures.
- Among them, to put higher priority on the implementation and development of non-point source nutrient load reduction measures.
- Also, to put higher priority on the internal load reduction measures.

(1) Measures for External Loads Reduction

1) Non-point Source Loads

Following methods were studied and a vegetation purification method was selected as a suitable method.

- settling reservoir method
- coagulation sedimentation method
- anaerobic-aerobic activated sludge method
- mixture of coagulation and activated sludge method
- soil infiltration method
- crystallization for phosphorous removal method
- vegetation purification method

The vegetation purification at selected 33 rivers and pumping stations was proposed.

2) Point Source Loads

In the catchment area of Lake Balaton, pollution loads of point sources are considerably controlled and treated. Therefore only the followings are considered as remaining measures for point source loads.

- Further development of sewerage systems
- Upgrading/improvement of sewage treatment level
- Strengthening wastewater discharge regulations

(2) Measures for Internal Loads Reduction

Following methods were studied and dredging in the Keszthely and Szigliget sub-basin was proposed.

- Sediment removal (Dredging)
- Sediment cover
- Phosphorus inactivation

3.4 NONSTRUCTURAL APPROACH

Basic tools of non-structural measures to control activities, such as regulations for wastewater quality, landuse and development activities, have been established and effective in the catchment areas. A next step of the non-structural approach is to motivate citizens and private sectors to take actions for the environmental improvement.

Following measures are proposed as non-structural measures to motivate the citizens' and private sectors' direct actions.

Following measures are proposed as non-structural measures to motivate the citizens' and private sectors' direct actions.

- Promotion of the environmental education and campaigns.
- Establishment of legislative framework for the sewerage house connection and on-site sewage treatment.
- Introduction of product charge.

3.5 INSTITUTIONAL APPROACH

(1) Policy Making Process (PMP)

Objectives of the institutional measures are to build up the leadership for integration of various efforts by various players, and to promote public participation. To build up the leadership, an organization responsible for the lake environment improvement should control following policy making processes as its competence.

- Intensive accumulation of relevant data
- Information pool of activities and plans related to the lake environmental improvement
- Preparation of scenarios for the lake environmental improvement through analysis on collected data and information
- Selection of the optimal scenario
- Formulation (or revision) of comprehensive plan which is technically, economically and financially feasible
- Implementation of the comprehensive plan

Schematic diagram of the above processes is summarized in *Figures 3.1* as Balaton Policy Making Process. The PMP intends to leave the existing activities under the current competence. Instead, it aims to promote better information flow from relevant organizations and to gather them at one core that is equipped with the decision-making tools. It also intends to work out policies for the improvement based on the gathered information with help of the decision making tools and carries out them by coordinating the relevant organizations.

Public participation in environmental improvement is important for redress of policy making process and for citizens involvement in operation and maintenance of structural measures.

(2) Balaton Policy Making Unit (BPMU)

BPMU is proposed as an executing organization of PMP. Its major roles are as follows:

- Data accumulation and information pool
- Revision or formulation of Comprehensive Plan
- Implementation of Comprehensive Plan
- Public information and Public participation

3.6 PROPOSED COMPREHENSIVE PLAN

(1) Components of the Comprehensive Plan

Each approach consists of measures and activities in the table below:

Components of the Proposed Comprehensive Plan

Approach	Measures and Activities
Institutional	- Organization of Balaton Policy Making Unit, which is a responsible organization for the management of information, policy making and coordination of every organization related to Lake Balaton issues. - Encouragement of involvement of residents - Study on the environmental utilization charge
Structural	- Implementation of the present sewerage development plans in the catchment areas. - Early implementation of Kis-Balaton phase-II project. - Dredging of the bottom sediment in the Keszthely and Szigliget sub-basins. - Construction of the vegetation purification facilities in 33 proposed sites.
Non-structural	- Promotion of the environmental education and campaigns. - Introduction of product charge - Establishment of the legislative framework for the sewerage house connection and on-site sewage treatment.

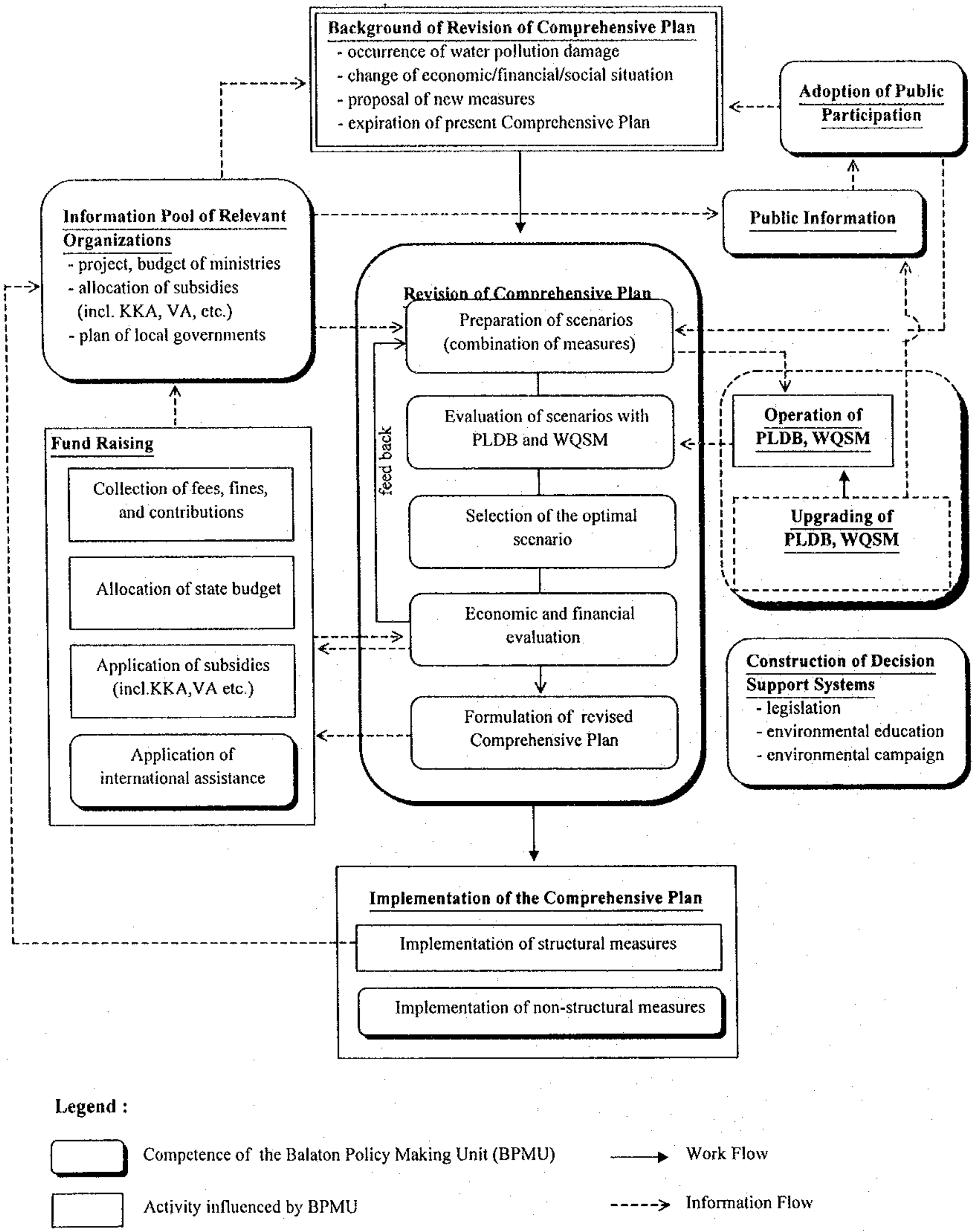


Figure 3.1 Schematic Diagram of Balaton Policy Making Process

(2) Project Costs

Project costs are estimated for the structural measures in the proposed Comprehensive Plan, and, among them, the implementation of the sewerage development projects and Kis-Balaton phase-II project are eliminated from the estimation because these projects are now under preparation by the Hungarian side.

Based on the estimated costs for the dredging and the vegetation purification facility, project costs are estimated as shown in the table below.

Project Cost (Construction and Procurement)

(1000HUF)

A.	Construction Cost (Vegetation purification facility	3,537,434
B.	Procurement Cost (Dredging)	1,782,000
C.	Engineering Services ((5% of A)+Survey Cost)	191,698
D.	Contingency (5% of (A+B+C))	275,557
Total of Initial Cost		**5,786,688**

Project Cost (Operation)

(1000HUF/Year)

Vegetation purification facility	256,933
Dredging	494,497
Total of Operation Cost	751,430

(3) Implementation Program

The implementation program of the project is proposed as shown in *Table 3.1*.

(4) Financial Plan

Assuming the following loan terms and repayment conditions of the World Bank, financing and repayment schedule was calculated as shown *Table 3.2*.

Maturity: 15 years
Grace period: 5 years
Interest: LIBOR (5.207% p.a. quoted on 1 October, 1998) plus 2%

Table 3.1 Imprementation Schedule for Comprehensive Plan

		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Vegetation Purificatio	Survey, Design, Contract Process	- - -	- - -	- - -								
	Cinege patak									—		
	Fuzfoi sed								—			
	Vorosberenyi sed			—								
	Lovasi sed				—							
	Csopaki sed						—					
	Aracsi sed					—						
	Keki patak						—					
	Szolosi sed					—						
	Tavi(Aszofoi sed)				—							
	Orvenyesi sed							—				
	Csorszai patak						—					
	Horogi sed							—				
	Burnot patak							—				
	Eger patak		—									
	Tapolca patak		—									
	Ketoles patak		—									
	Vilagos patak			—								
	Lesence patak			—								
	Nemesvital ovarok			—								
	Endredi patak									—		
	Koroshegyi sed									—		
	Nagymetszes patak				—							
	Tetves patak						—					
	A-B-Ccsatorna			—								
	Forro arok			—								
	Jamai patak								—			
	Keleti-Nyugati-Focsatorna		—									
	Keleti bozot			—	—							
	(Pogany volgyiviz)											
	Nyugati ovcsatorna		—	—								
	Balatonfenyves							—	—			
	Balatonlelle				—							
	Ordacsehi								—			
	Beletelep						—					
Dredging	Keszthely basin	—	—	—	—	—	—	—	- - -	- - -	- - -	
	Szigliget Basin	—	—	—	—	—	—	—	—	—	—	

Table 3.2 Financing and Repayment Schedule

(1,000 US$)

Year	Borrowing [1]	Repayment [2]	Balance [3]	Interest [4]	Debt Service
2001	8,828		8,828	318	318
2002	1,936		10,764	706	706
2003	2,476		13,239	865	865
2004	2,054		15,293	1,028	1,028
2005	760		16,053	1,130	1,130
2006	1,943	883	17,113	1,195	2,078
2007	1,116	1,076	17,153	1,235	2,311
2008		1,324	15,829	1,188	2,512
2009		1,529	14,299	1,086	2,615
2010		1,605	12,694	973	2,578
2011		1,800	10,895	850	2,650
2012		1,911	8,983	716	2,627
2013		1,911	7,072	579	2,490
2014		1,911	5,161	441	2,352
2015		1,911	3,250	303	2,214
2016		1,028	2,221	197	1,226
2017		835	1,387	130	965
2018		587	799	79	666
2019		382	417	44	426
2020		306	112	19	325
2021		112	0	4	116
2022		0	0	0	0
Total Amount	19,112	19,112	-	13,085	32,197

Assumptions : 1) Disbursement at middle of each year.
2) Starts after 5 years of grace period. Repayment at middle of year.
3) Balance at the end of the year.
4) Semi-annually payment at 7.207% p.a.

(5) Project Evaluation

1) Improvement effects

The trophic state is represented as a probability of the chlorophyll-a concentration. The probabilities to achieve the targeted trophic state in the Keszthely and Szigliget sub-basins are improved as follows:

Sub-basin	Present Probability	Probability after Project	Improvement
Keszthely	23 %	35 %	12 %
Szigliget	43 %	58 %	15 %

2) Economic analysis

The results of the analysis are summarized below. As EIRR is over 12%, which is used as a norm for decision making of many World Bank projects, this project can be regarded as viable.

Indices	Result of Analysis
EIRR	12.62%
B/C	1.0394
NPV (12%)	1,724 thousand US$

3) Technical Aspect

The dredging project proposed is an extension and expansion of the current dredging project. The proposed vegetation purification is also a modification of the current non-point source load control. Therefore, there is no new technology in the proposed projects.

Since there is no established method for the non-point source load control, the proposed vegetation purification should be considered as a pilot project to investigate more efficient and more effective methods. This will contribute to the environmental improvement of lakes in the world, as well we to Lake Balaton.

4) Environmental Impact Aspect

The Comprehensive Plan is a plan to improve the environmental conditions of Lake Balaton. Therefore, the Plan will contribute to the environmental improvement. However, the structural measures accompany construction works and dredging operation. These may cause impacts to the environment. It was judged to be controlled within an acceptable level by proper countermeasures.

4. FEASIBILITY STUDY

4.1 SELECTION OF FEASIBILITY STUDY PROJECT

The project for constructing the vegetation purification facilities is studied in this chapter. Other measures are excluded from the feasible study, although the priority of those measures is undoubtedly high or higher.

Because Kis-Balaton phase-II project has been considered in detail by the Hungarian side on the level of a feasibility study, and has just been waiting the final decision of the central government. As for the sewerage development, it is an on-going project which has already materialized some facilities. It is not a question of engineering but financing whether the project will attain the goal or not. Dredging bottom sediment of the lake is also on-going project, and the target area and the depth to be dredged are to be reconsidered by the Hungarian side according to a precise study. Therefore the feasibility study on the dredging project should be carried out after the reconsideration.

Selected project area are as follows and their locations are shown in *Figure 4.1*.

① River purification facility (vegetation purification method)

Nyugati-övcsatorna river
Keleti-bozot river

② Urban runoff purification facility (coagulation sedimentation method)

Keszthely urban runoff area (Szent Imre/Büdös river)

4.2 DESIGNING OF FACILITIES

(1) Nyugati-övcsatorna (Vegetation purification facility)

The location of the project site is shown in *Figure4.2*. The proposed site is the central government's land. General layout of the facilities is shown in *Figure 4.3*.

(2) Keleti bozot (Vegetation purification facility)

The location of the project site is shown in *Figure4.4*. The proposed site is the central government's land. General layout of the facilities is shown in *Figure 4.5*.

(3) Szent Imre/Büdös (Urban runoff purification facility)

The location of the project site is shown in *Figure 4.6*. It is located near the river mouth and downstream from the confluence of Szent Imre river and Büdös river. Considering the limitation of available land for constructing the facility, the coagulation sedimentation is applied as the second best method. General layout of the facilities is shown in *Figure 4.7*.

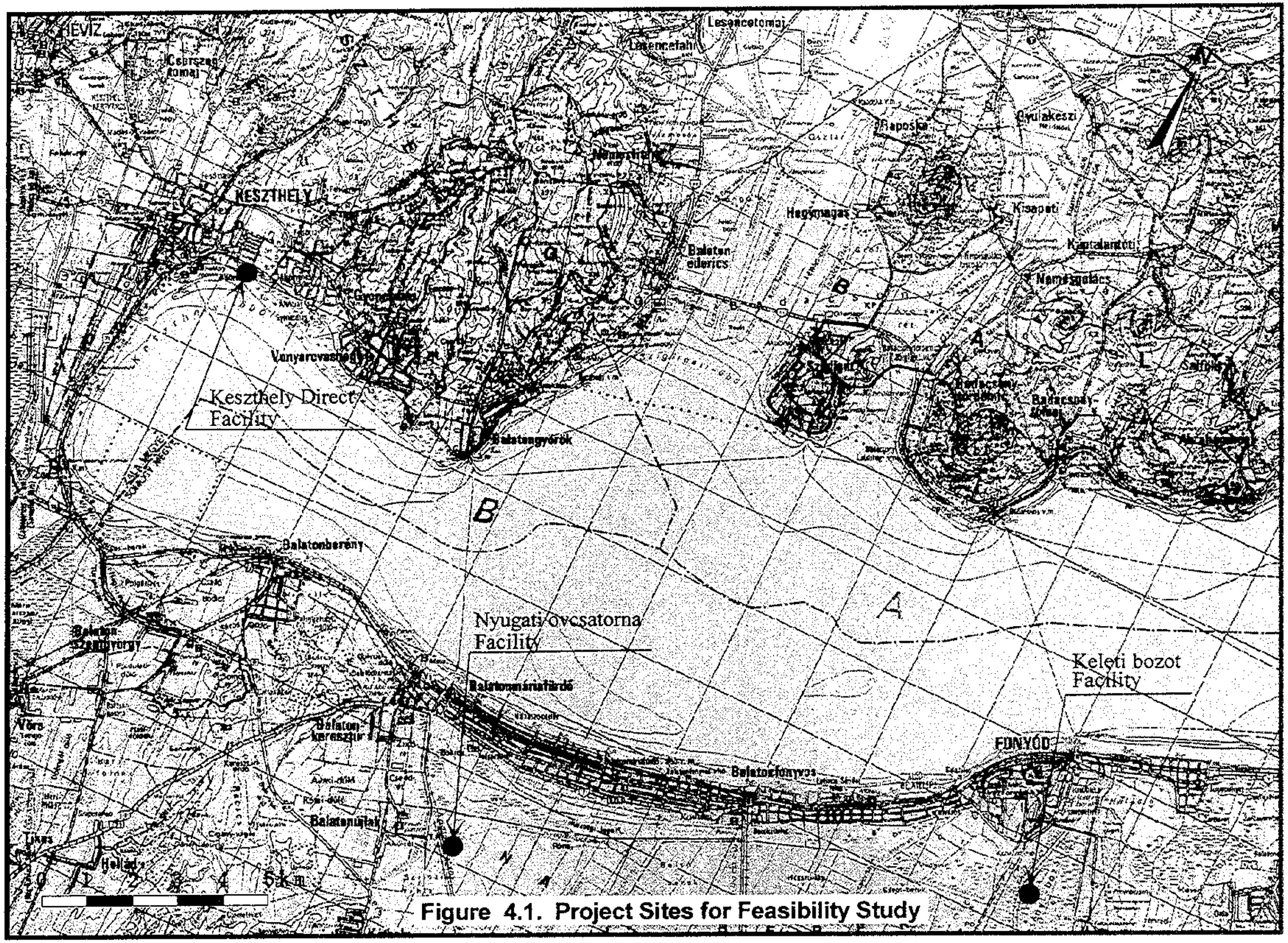


Figure 4.1. Project Sites for Feasibility Study

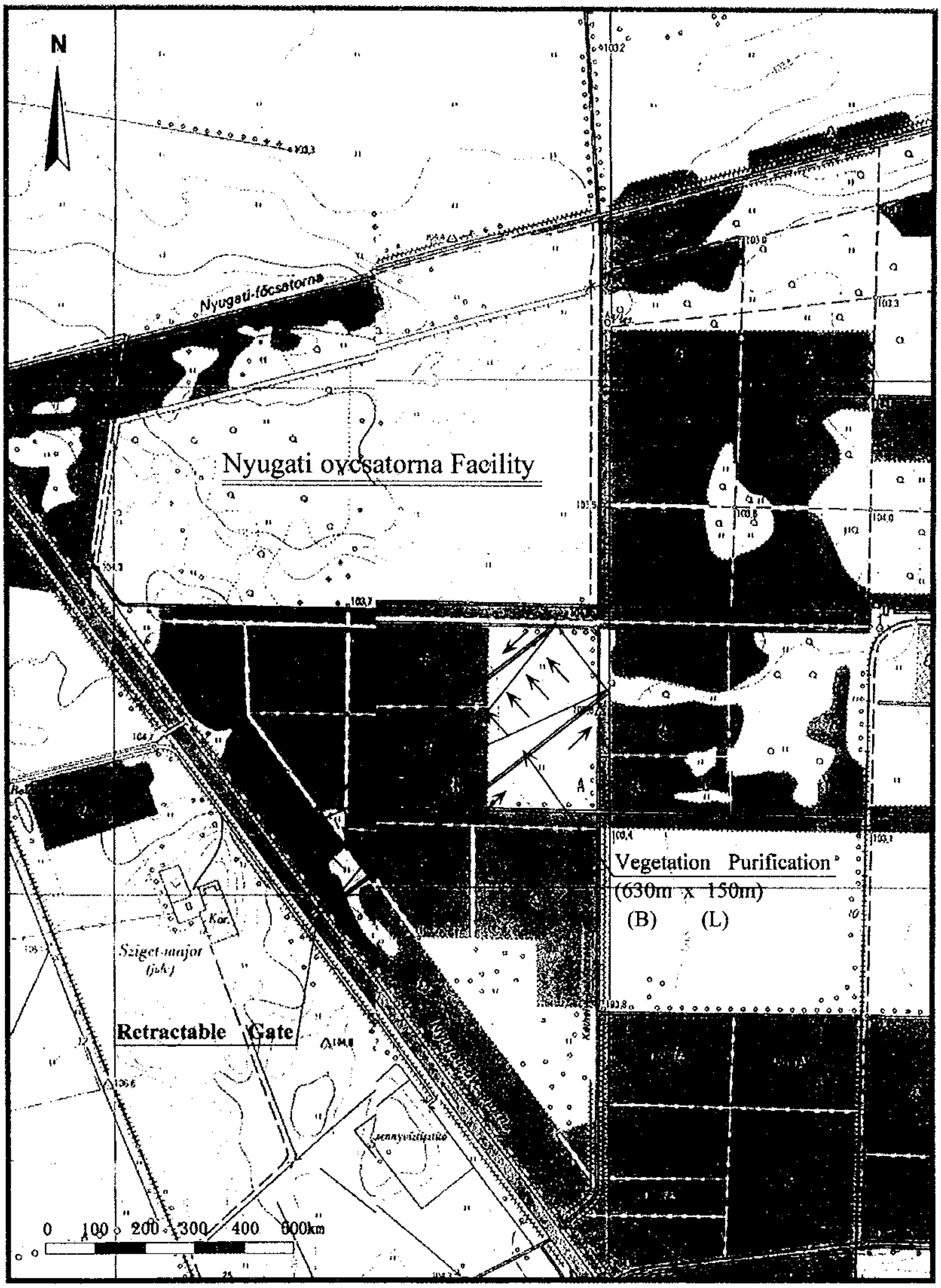


Figure 4.2 Location of Nyugati-ovcsatorna Facility

Nyugati Ovcsatorna Facility

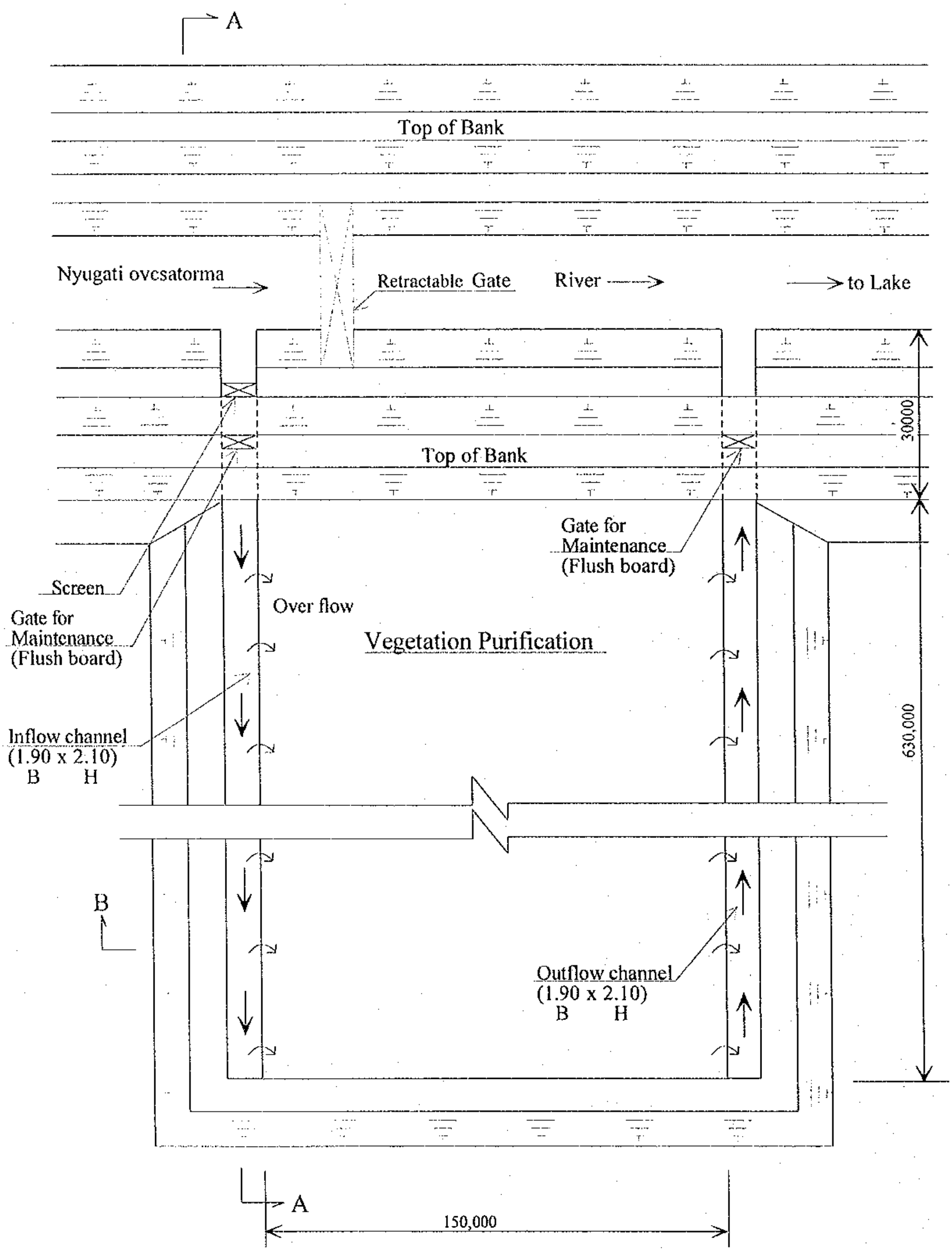


Figure 4.3 General Layout of Nyugati-ovcsatorna Facility

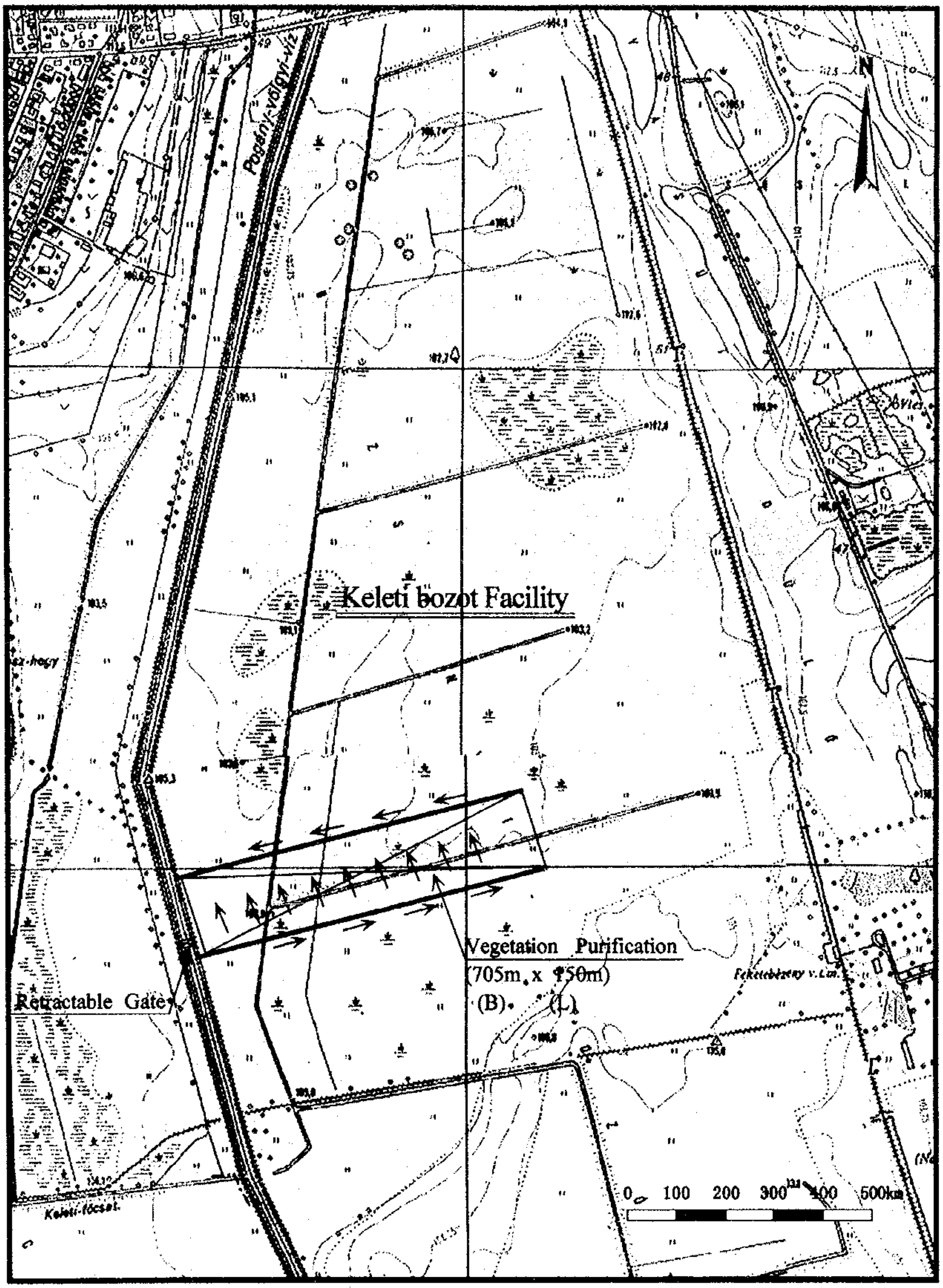


Figure 4.4 Location of Keleti-bozot Facility

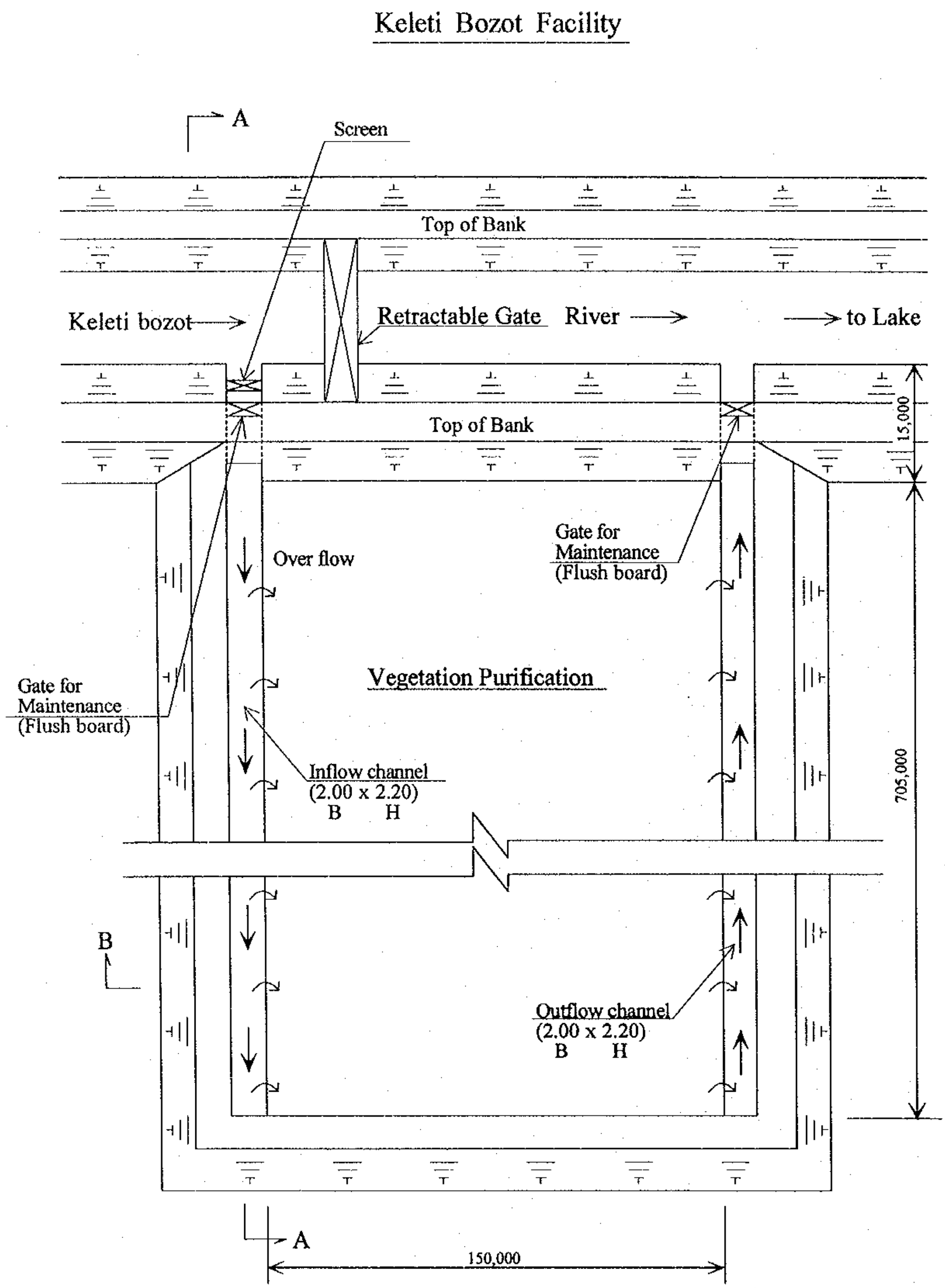


Figure 4.5 General Layout of Keleti-bozot Facility

4.3 Project Costs

The project costs consist of the construction cost and the operation and maintenance (O/M) cost.

The construction cost consists of the following items.

- Direct construction cost
- Engineering service cost
- Physical contingency

The O/M cost consists of the following items.

- Facility operation cost
- Facility maintenance cost
- Water quality monitoring cost
- Personnel expenditure

The estimated construction cost and operation cost are shown in *Table 4.1*

4.4 IMPLEMENTATION PROGRAM

The implementation schedule is shown in *Table 4.2.*

4.5. PROJECT EVALUATION

(1) Environmental Improvement

Quick effect may not be expected from external load reduction. However, external load is undoubtedly an origin of internal load and the effect of its control may be slow but steady like preventive medicine.

(2) Technical Aspect

It must be a great challenge to tackle the water quality improvement in Lake Balaton. The important thing is to start with acceptable one which is easy to operate and maintain, cheap to materialize, and harmless to the environment.

The vegetation purification method meets those requirement. This study prepares how to design the facility, how much it costs, and to what extent it contributes for phosphorous load reduction in Lake Balaton.

(3) Financial Aspect

It is concluded in this study that the vegetation purification method is the most cost-effective, and the total investment cost of the feasibility study projects is about 1,248 million HUF for six (6) years and annual O/M cost is 75.2 million HUF. The amount of cost falls within the central government's budget and the Central Environmental Fund allocated for Lake Balaton area.

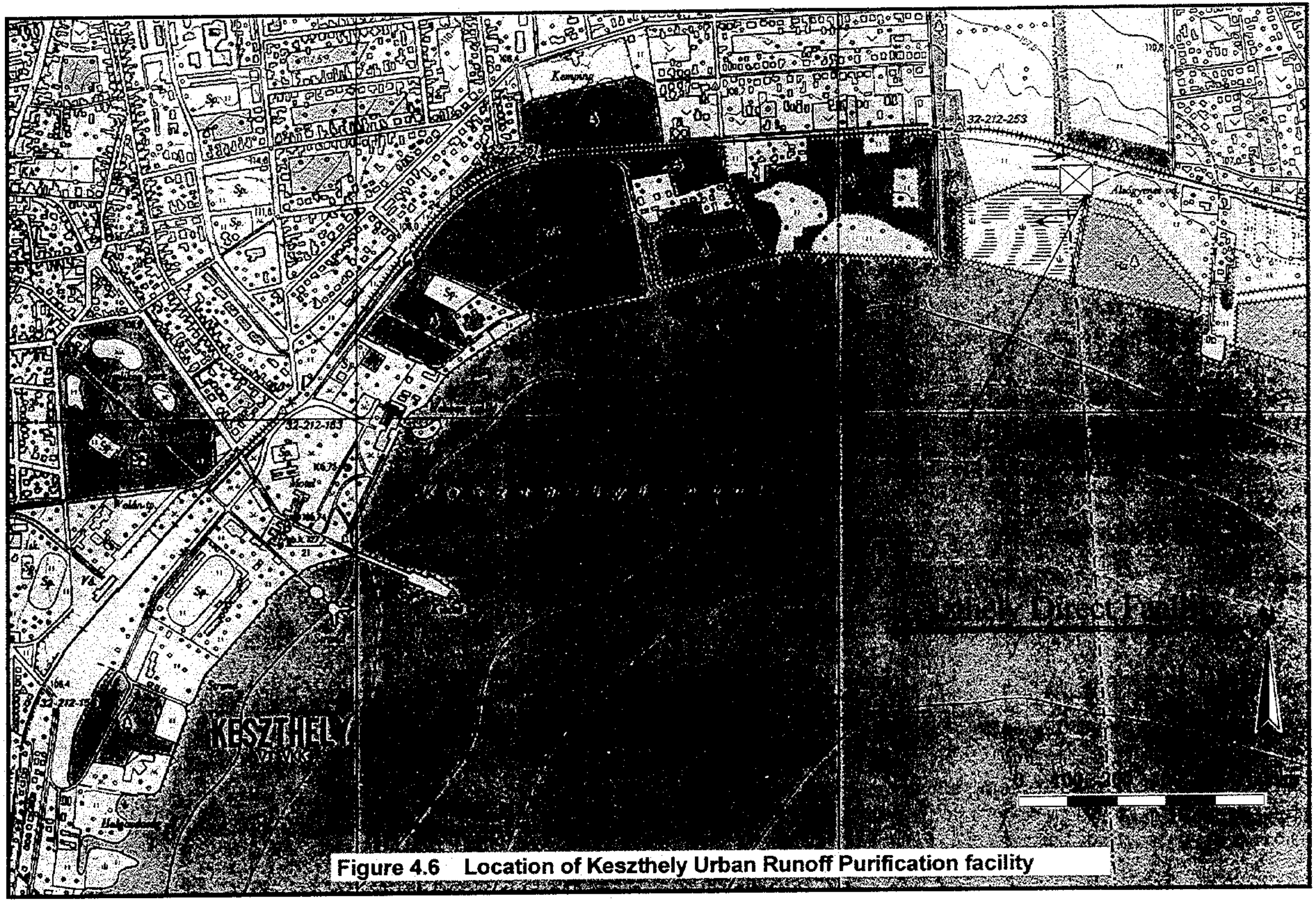


Figure 4.6 Location of Keszthely Urban Runoff Purification facility

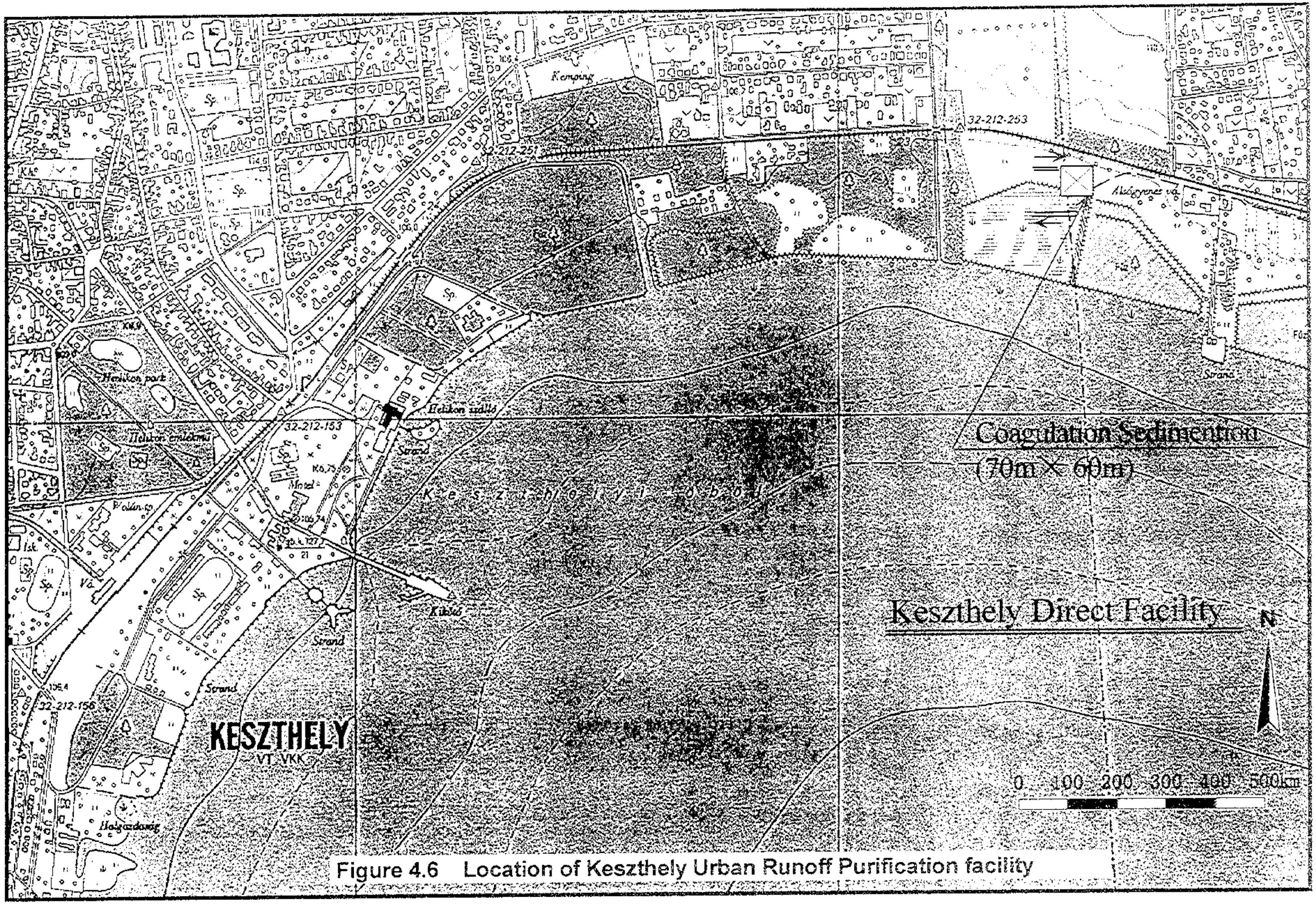
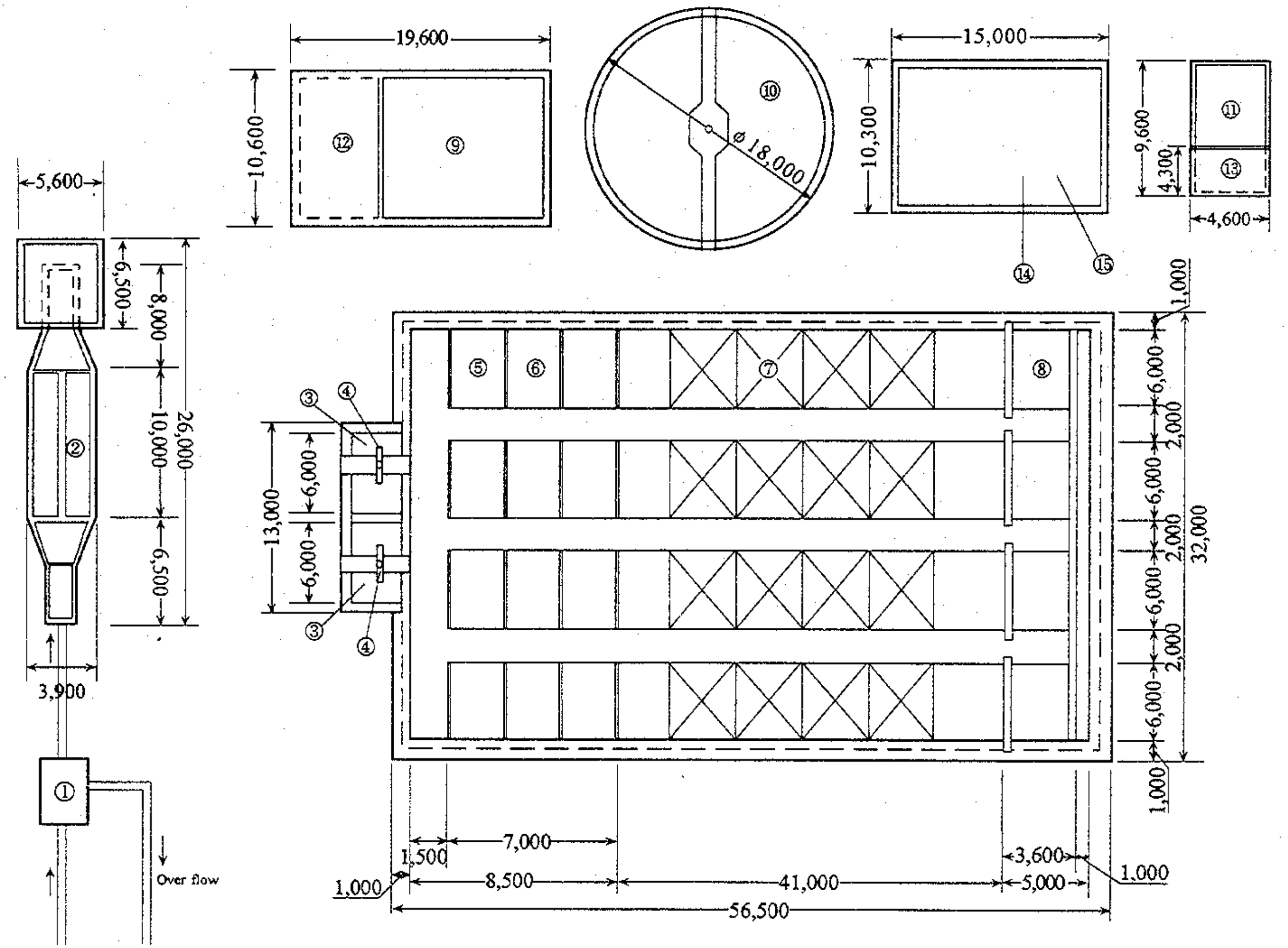


Figure 4.6 Location of Keszthely Urban Runoff Purification facility

Coagulation Sedimentation Facility



No	Name
1	Storm outfall
2	Sand basin
3	Mixing basin
4	Rapid mechanical aeration
5	Flocculator
6	Slow mechanical aeration
7	Settling pond
8	Overflow pond
9	Sludge tank
10	Sludge thickener
11	Sludge storage tank
12	Pumping station
13	Sludge pump
14	Coagulant storage tank
15	Dehydrator

Figure 4.7 General Layout of Coagulation Sedimentation Facility

Table 4.1 Construction Cost and Operation Cost

Name of Project (Water Purification Method)	Design Flow Rate (m^3/sec)	Construction Cost (1000 HUF)				Operation Cost (1000HUF/year)
		Direct Construction Cost	Engineering Service Cost *	Contingency**	Total	
Nyugati ovcsatorna (Vegetation purification method)	1.01	403,898	21,701	21,280	446,879	29,148
Keleti bozot (Vegetation purification method)	1.13	411,972	22,275	21,712	455,959	32,573
Keszthely Urban Runoff (Coagulation sedimentation method	0.47	312,621	15,766	16,419	344,806	13,500
Total	–	1,128,491	59,742	59,412	1,247,644	75,221

* : (5% of direct construction cost) + (survey cost)
** : 5% of (direct construction cost + engineering service cost)

Table 4.2 Implementation Schedule for Feasibility Study Projects

Name of River and Facilities	2001	2002	2003	2004	2005	2006	2007
Survey,Design	- - -						
Nyugati ovcsatorna							
1.Purification Facility		———	———				
2.Retractable Gate			———				
3.Gate and Screen			———				
4.Inflow,Outflow Channel			———				
5.Operation				- - -	- - -	- - -	- - -
Keleti bozot							
1.Purification Facility				———	———		
2.Retractable Gate					———		
3.Gate and Screen					———		
4.Inflow,Outflow Channel					———		
5.Operation						- - -	- - -
Keszthely urban runoff							
1.Purification Facility						———	
2.Inflow,Outflow Channel						———	
3.Operation							- - -

(4) Environmental Impact

The measure itself would contribute much to environmental improvement of Lake Balaton. Although the vegetation purification facility is in principle to be a sink of nutrients, it might be a source of nutrients if the facility is not well operated and maintained. Coagulation sedimentation method is to use chemicals as a coagulant. So an occasional water quality check would be necessary, though harmless coagulant is used.

During construction stage, it can not be denied that environmental impacts would be caused to some extent. However, most construction sites are located in wetlands or farmland. There would be no impacts on the residents.

5. CONCLUSION AND RECOMENDATION

5.1. GENERAL

The Study revealed that significant improvement of the trophic condition of Lake Balaton would not be expected by the reduction of external and internal pollution loads. However, it should be much stressed that the present lake conditions are a gift from every effort that has been made during these several decades by various organizations concerned to Lake Balaton. The eutrophication is an irreversible process of natural lakes. Although people may not be able to turn back or to stop the process, people could slow down the speed of the process. Therefore, it is necessary to continue the efforts, which have been made, to reduce the external and internal loads and outputs of the Study should be utilized to integrate the efforts efficiently and effectively.

5.2 INSTITUTIONAL APPROACH

The Study provided Policy Making Process (PMP), which includes the management of relevant data and information, preparation of scenarios for the improvement and coordination to materialize the scenarios, and proposed Balaton Policy Making Unit (BPMU) to implement PMP as a responsible organization for the improvement of Lake Balaton. It is recommended that an organization responsible for the Lake Balaton management be set up by incorporating the concepts of PMP and BPMU as much as possible.

5.3 STRUCTURAL APPROACH

Sewerage development and Kis-Balaton Project

The sewerage development and the implementation of Kis-Balaton Project Phase II are a basis of Comprehensive Plan. The future conditions in Comprehensive Plan are assumed on the conditions where both projects are to be implemented since they are considered to be an established policy. Therefore, these two projects should be implemented at the highest priority.

Dredging

Comprehensive Plan proposes two structural measures; dredging and non-point source control. The reduction of the internal load by dredging of the bottom sediments in the Keszthely and Szigliget sub-basins was indicated more effective than the reduction of external load by results of the water quality simulation model. While the effect is not enough to achieve the improvement targets completely, the reduction of internal load indicated to reduce the frequency of occurrence of algal blooming. Therefore, it is recommended the dredging projects by the on-going feasibility study by Hungarian side be implemented as early as possible, expecting mitigation of algal blooming in summer season.

Non-point source control

Comprehensive Plan proposes measures for controlling the external load from non-point sources. The measures investigated in the feasibility study are small in its scale and require a large number of facilities to achieve significant effects. Moreover, methods applied are technically less established compared to methods for the point sources, such as wastewater or sewage treatment. It will require further research works to establish practical methods for the non-point source control. Therefore, it would be advisable to start with a pilot plant scale within an available budget, to improve and modify the methods through actual operations, and to generalize them over the whole catchment.

5.4 NON-STRUCTURAL APPROACH

Environmental Education and Campaigns

Youth camp in Balaton organized by KDT-VIZIG and other youth camps Kis-Balaton by other VIZIGs would be a good example of the environmental education. These activities should be encouraged over the catchment area. Incorporating into school curriculum in schools around Lake Balaton would be a practical method to encourage the environmental education.

Legal Enforcement, Fines and Subsidy

Generally, wastewater quality, landuse, and development and construction in specified areas are well controlled under the current legislative framework. One thing the Study found to be considered is a legislative framework for the encouragement of a sewerage house connection and an on-site sewage treatment facility. It is recommended to consider legal enforcement, fines and subsidies or their combination to motivate citizens to install sewerage house connection or on-site sewage treatment facility.