cSUR-UT Series: Library for Sustainable Urban Regeneration
Volume 3

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cSUR-UT Series: Library for Sustainable Urban Regeneration

By the process of urban development in the 20th century, characterized by suburban expansion and urban redevelopment, many huge and sophisticated complexes of urban structures have been erected in developed countries. However, with conventional technologies focused on the construction of structures, it has become difficult to keep urban spaces adaptable to environmental constraints and economic, social and cultural changes. In other words, it has become difficult for conventional technologies to meet social demands for the upgrading of social capital in a sustainable manner and for the regeneration of attractive urban space that is not only safe and highly efficient but also conscious of historical, cultural and local identities to guarantee a high quality of life for all. Therefore, what is needed now is the creation of a new discipline that is able to reorganize the existing social capital and the technologies to implement it.

For this purpose, there is a need to go beyond the boundaries of conventional technologies of construction and structural design and to integrate the following technologies:

(1) Technology concerned with environmental and risk management
(2) Technology of conservation and regeneration with due consideration to the local characteristics of existing structures including historical and cultural resources
(3) Technologies of communication, consensus building, plan making and space management to coordinate and integrate the individual activities initiated by various actors of society

Up to now, architecture, civil engineering, and urban engineering in their respective fields have, while dealing with different time-space scales and structures, accumulated cutting-edge knowledge and contributed to the formation of favorable urban spaces. In the past, when emphasis was put on developing new residential areas and constructing new structures, development and advancement of such specialized disciplines were found to be the most effective.

However, current problems confronting urban development can be highlighted by the fact that a set of optimum solutions drawn from the best practices of each discipline is not necessarily the best solution. This is especially true where there are relationships of trade-offs among such issues as human risk and environmental load. In this way, the integration of the above three disciplines is strongly called for.

In order to create new integrated knowledge for sustainable urban regeneration, the Center for Sustainable Urban Regeneration (cSUR), The University of Tokyo, was established in 2003 as a core organization of one of the 21st Century Centers of Excellence Programs funded by the Ministry of Education and Science, Japan, and cSUR has coordinated international research alliances and collaboratively engages with common issues of sustainable urban regeneration.

The cSUR series are edited and published to present the achievements of our collaborative research and new integrated approaches toward sustainable urban regeneration.

H. Furumai • S. Sato • M. Kamata
K. Yamamoto (Eds.)

Advanced Monitoring and Numerical Analysis of Coastal Water and Urban Air Environment

Springer

Editors
Hiroaki Furumai
Professor
Research Center for Water Environment Technology
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku
Tokyo 113-8656, Japan
furumai@env.t.u-tokyo.ac.jp

Shinji Sato
Professor
Department of Civil Engineering
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku
Tokyo 113-8656, Japan
sato@coastal.t.u-tokyo.ac.jp

Motoyasu Kamata
Professor Emeritus
Department of Architecture
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku
Tokyo 113-8656, Japan
and
Professor
Department of Architecture
Kanagawa University
3-27-1 Rokkakubashi
Kanagawa-ku, Yokohama
Kanagawa 221-8686, Japan
kamat@kanagawa-u.ac.jp

Kazuo Yamamoto
Professor
Environmental Science Center
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku
Tokyo 113-8656, Japan
yamamoto@esc.u-tokyo.ac.jp

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Preface

Various environmental issues are related to urban activities. Through the growing recognition of the necessity to develop sustainable urban management, the University of Tokyo established the Center for Sustainable Urban Regeneration (cSUR) in July 2003. A research program at the cSUR was designed to create an integrated approach and to provide knowledge for sustainable urban regeneration with the aid of a global network of researchers and professionals, and to coordinate the international research alliance made up of leading academic institutions worldwide.

As part of the program, several studies have been conducted focusing on urban environmental problems in Asian megacities such as Tokyo, Taipei, Guangzhou, Shenzhen, and Bangkok. The following topics in particular were selected for integrated and strategic research supported by researchers from the fields of architecture, civil engineering, and environmental engineering:

–Integrated analysis of the urban atmospheric environment and its relationship with control of indoor air conditions in East and Southeast Asian countries

–Dynamic behavior of urban non-point pollutants in coastal environments

The research contains interesting intensive field-monitoring data on the coastal environment and the urban air environment. Topics also include state-of-the-art environmental monitoring and simulation analysis in urban areas. Key aspects of the research in advanced monitoring and the application of environmental numerical simulation were selected for inclusion in this book.

Integrating the monitoring and modeling of urban environments is essential for engineers to identify and investigate environmental problems and their solutions. In addition, advanced understanding of environmental phenomena is necessary to manage contemporary environmental issues. Environmental monitoring provides information about the processes and activities that characterize environmental quality. Model development cannot proceed without scientific data on environmental phenomena and the kinetics of associated processes. To understand the phenomena and processes, monitoring and modeling are fundamental.

The academic sector should update and add to the information on urban environments by discovering novel pollution phenomena and clarifying critical process mechanisms for pollution control. I hope that this book will be useful to undergraduate and graduate students and to experts and policymakers to improve their understanding of the field of environmental monitoring and model simulation.

Hiroaki Furumai

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List of Contributors

Yoshihiko Akamine
Project Assistant Professor
Department of Architecture
Graduate School of Engineering
The University of Tokyo
Tokyo, Japan
akamine@arch.t.u-tokyo.ac.jp

Kensuke Fukushi
Associate Professor
Integrated Research System for
Sustainability Science (IR3S)
The University of Tokyo
Tokyo, Japan
fukushi@ir3s.u-tokyo.ac.jp

Hiroaki Furumai
Professor
Research Center for Water
Environment Technology
The University of Tokyo
Tokyo, Japan
furumai@env.t.u-tokyo.ac.jp

Hideaki Hoshino
Nihon Sekkei Inc.
Tokyo, Japan
hp_shellfish@hotmail.com

Masashi Imano
Assistant Professor
Department of Architecture
Graduate School of Engineering
The University of Tokyo
Tokyo, Japan
imano@arch.t.u-tokyo.ac.jp

Motoyasu Kamata
Professor Emeritus
Department of Architecture
The University of Tokyo
Tokyo, Japan
and
Professor
Department of Architecture
Kanagawa University
Kanagawa, Japan
kamat@kanagawa-u.ac.jp

Hiroyuki Katayama
Associate Professor
Department of Urban Engineering
The University of Tokyo
Tokyo, Japan
katayama@env.t.u-tokyo.ac.jp

Yukio Koibuchi
Associate Professor
Department of Socio-Cultural Environmental Studies
Division of Environmental Studies
Graduate School of Frontier Sciences
The University of Tokyo
Tokyo, Japan
koi@k.u-tokyo.ac.jp

Fumiyuki Nakajima
Associate Professor
Environmental Science Center (ESC)
The University of Tokyo
Tokyo, Japan
nakajima@esc.u-tokyo.ac.jp

Tassanee Prueksasit
Lecturer
Department of General Science
Chulalongkorn University
Bangkok, Thailand
Tassanee.C@Chula.ac.th

Shinji Sato
Professor
Department of Civil Engineering
The University of Tokyo
Tokyo, Japan
sato@civil.t.u-tokyo.ac.jp

Yu-Feng Tu
Cydea Incorporated
zacktu@gmail.com

Kazuo Yamamoto
Professor
Environmental Science Center (ESC)
The University of Tokyo
Tokyo, Japan
yamamoto@esc.u-tokyo.ac.jp

Yunchan Zheng
Nikken Act Design
Tokyo, Japan
zheng.yunchan@nikken.co.jp

1. Significance of Advanced Monitoring and Application of Environmental Numerical Simulation

Hiroaki Furumai

1.1 Introduction

In the fields of civil engineering, architecture, and environmental engineering, environmental monitoring and model simulation are essential component in setting up the strategy of environmental research from the aspect of urban sustainability. Advanced knowledge of monitoring and numerical simulation is required for graduate students to conduct their research dealing with the identification of environmental problems and investigations toward their solution. When dealing with increasing environmental concerns associated with water, air and soil pollution, as well as climate change induced by human activities, the accurate assessment of the state of the environment is a prerequisite for undertaking any course of action towards improvement.

In the twenty-first century COE research project, several studies have been conducted that focus on urban environmental problems in mega cities in Asian countries such as Tokyo, Taipei, and Bangkok. The research works contain interesting and intensive field monitoring data on coastal environmental and urban air environments. Topics also included state-of-the-art of environmental monitoring and simulation analyses in urban areas: of hazardous substances, atmospheric movement, coastal hydrology, biological tests, and wastewater.

Before the representation of the COE research projects, this chapter will first discuss the significance of environmental monitoring and numerical simulations. Environmental monitoring provides information to describe the processes and activities, which characterize the environmental quality. Monitoring data is used in the preparation of environmental impact assessments, as well as in many circumstances in which urban activities carry a risk of adverse effects on the natural environment. In addition, monitoring

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data is required to construct environmental models and to calibrate and validate models.

Environmental models seek to reproduce that occurs in a certain area during certain events. It is much easier and more practical to create mathematical models and run certain experiments than to go out and do the same experiment in an actual environment. All models have a specific target area and should be developed in accordance with their purpose of modeling. This means that it is crucial to determine the target area and to formulate the target phenomena with involved processes. In addition, the purpose of modeling should be clearly defined, considering the required accuracy of reproduction by the model.

Model development cannot proceed without scientific information and knowledge on environmental phenomena and the kinetics of associated processes. Monitoring and experiment are fundamental steps to understand these phenomena and processes. Such as planning and strategy must be well-designed in order to establish the current status of the environment and to understand trends in environmental quality parameters. The basic steps of and the cyclic process for model development and simulation are illustrated in Fig. 1-1.

Models have three basic parts, starting with the science, moving towards a mathematical representation of that science, and ending in the solution of

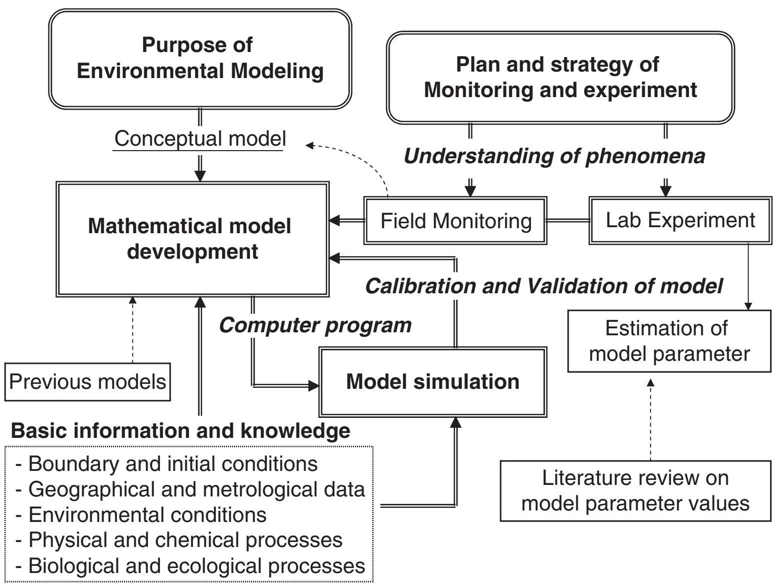

Fig. 1-1. Basic steps of and cyclic process for model development and simulation

the mathematics as a simulation. The overall process is actually a cyclical system: the answer that emerges from the simulation is used to refine the science, which leads to a new set of mathematics, which is expressed by a new computer program. One of the tasks we face in modeling is deciding when we think the answer is "right" enough.

Before the model application, the environmental models need to be calibrated and validated using monitoring and experimental data. Then the model can output the simulation results with given boundaries and initial conditions. A well-validated model can be used for future predictions within different scenarios, which are given considering future urban environmental planning. The simulation results are usually represented into a graphic form so as to depict their essential meanings. It is notable that graphic expression is also an important process in the entire of simulation research.

1.2 Water Quality Monitoring and Simulation for Sustainable Water Management

Since the author's specialty is water environment technology, the significance of monitoring and model simulation will be discussed with sustainable urban water management as an example. Many possible pathways to sustainable water management should be considered and relevant factors should be interrelated from the various aspects.

In order to explore sustainable water management, it would be necessary to evaluate and diagnose the water environment including water flow and quality. It is essential to know how to conduct the monitoring and how to construct models which can contribute to pollution control and management.

1.2.1 Evaluation of Water Cycle and Water Environment

First of all, we have to recognize the water cycle and water balance in the target watershed, since any water environment is deeply dependent on the characteristics of its related watershed. Rainwater falls on the ground and is stored in forests, soil, and groundwater. It then flows through rivers down to coastal waters and evaporates from lakes and seas to return as rainfall. This is the natural hydrological water cycle. The evaporation process contributes to the recovery of water quality, while the precipitation in mountainous areas provides the gravitational potential energy of water.

In urban regions, artificial water flow in water supplies and sewer systems coexists with the natural water flow as shown in Fig. 1-2 (Tambo 1976).

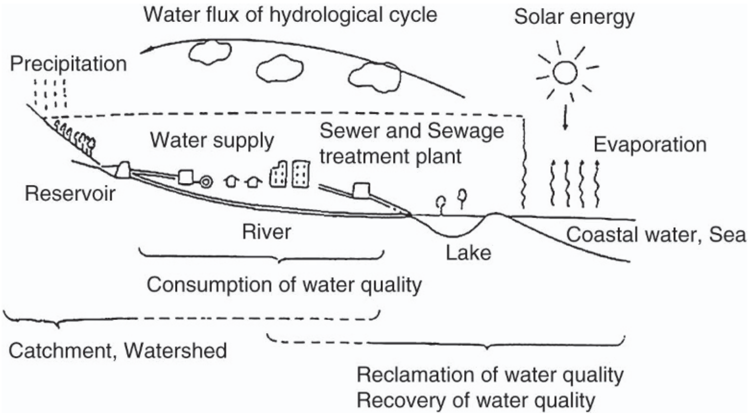

Fig. 1-2. Water environment and urban water systems in the entire water cycle

Dams and reservoirs have been artificially constructed to secure stable water resources. After the introduced water has been used in urban areas, the resulting wastewater or treated wastewater is discharged to receiving water. Urban water use has a high potential to impact the natural water cycle, even while we reap the benefits of various water usages. This impact can bring quite a lot of change in the water flow, in water quality and in the biological community which consists of the aquatic environment.

In order to understand the changes brought about by this impacts, it is necessary to quantify environmental components through monitoring. Additionally, it is desirable to evaluate them quantitatively using calibrated models. Figure 1-3 shows the important components of water environment and the interrelationships between the components and beneficial water use. Although the Figure is not sufficient to integrate all factors of influence, the afore-mentioned concepts and viewpoints are included. First, we have to evaluate the quality characteristics of available water resources and to discuss acceptable water use with appropriate management. In addition, we also must pay attention to the ecological impact made on the biological community as well as on the water flow and chemical quality.

Temporal and spatial changes in water resources and the water environment should both be considered in order to establish a stable water supply and to support safe water use. Since the required water quality depends on the types of beneficial water use, water resource distribution should be designed and planned in consideration of quantity, quality and their seasonal change. In other words, water resources and the environment should be monitored and modeled in consideration of water demands.

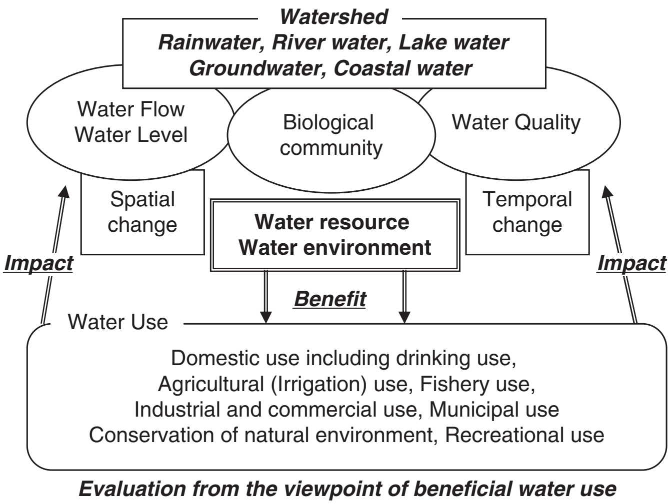

Fig. 1-3. Water environment components and beneficial water use

1.2.2 Environmental Quality Standard and Monitoring for Pollution Control

For water pollution control, environmental quality standards (EQS) are established as target levels for water quality that are to be achieved and maintained in public water bodies under the Basic Environment Law. The standards have two major goals: protection of human health and conservation of the living environment (Okada and Peterson 2000). The second goal is set for classified water bodies such as rivers, lakes, reservoirs, and coastal waters. The standard values for the living environment have been established for biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), and other variables based on water usage. Table 1-1 lists the classified standard values related to the conservation of the living environment in rivers (Ministry of the Environment 1997). Each class corresponds to type of water use. Therefore, both the water quality of water resources is considered as well as their amounts. In this sense, the rapid growth of the urban population raises serious concerns about water availability from the two viewpoints of the rapid demand for high quality water and of water pollution after water use in urban area.

Water quality monitoring has been officially conducted and the monitoring data is commonly used for evaluating the water environment. Figure 1-4 shows the changes in the attainment rate in terms of BOD and COD as the

Table 1-1. Ambient water quality standards for river related to the conservation of the living environment

Rivers class	Item	Standard value				
	Water use	***p*H**	**OD**	**SS**	**DO**	**Total oliform**
AA	Water supply class 1, conservation of natural environment and uses listed in A–E	6.5–8.5	1 mg l^{-1} or less	25 mg l^{-1} or less	7.5 mg l^{-1} or more	50 MPN/100 ml or less
A	Water supply class 2, fishery class 1, bathing and uses listed in B–E	6.5–8.5	2 mg l^{-1} or less	25 mg l^{-1} or less	7.5 mg l^{-1} or more	1,000 MPN/100 ml or less
B	Water supply class 3, fishery class 2. and uses listed in C–E	6.5–8.5	3 mg l^{-1} or less	25 mg l^{-1} or less	5 mg l^{-1} or more	5,000 MPN/100 ml or less
C	Fishery class 3, Industrial water class 1 and uses listed in D–E	6.5–8.5	5 mg l^{-1} or less	50 mg l^{-1} or less	5 mg l^{-1} or more	–
D	Industrial water class 2, agricultural water and uses listed in E	6.0–8.5	8 mg l^{-1} or less	100 mg l^{-1} or less	2 mg l^{-1} or more	–
E	Industry water class 3, and conservation of environment	6.0–8.5	10 mg l^{-1} or less	Floating matter such as garbage should not be observed	2 mg l^{-1} or more	–

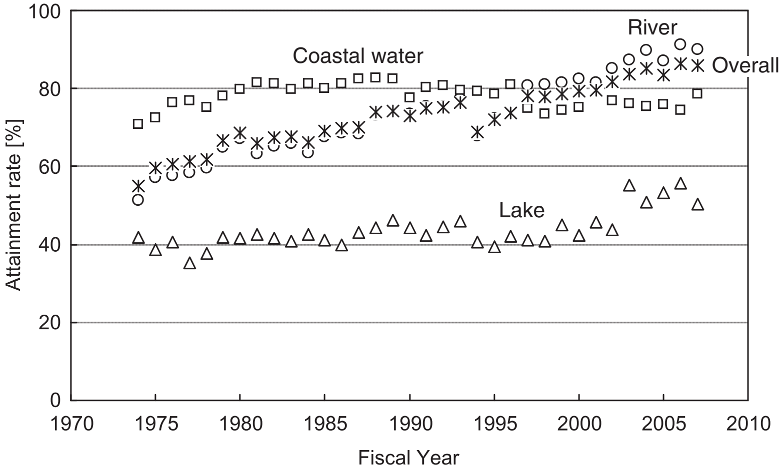

Fig. 1-4. Change in the attainment rate of water quality standards in public waters (River: BOD, Lake and Coastal water: COD)

organic pollution indicators since the year in which data was first collected on water quality management by the use of EQS. During the two decades of high economic growth from 1955 to 1975, the rapid spread of pollution in rivers and other water bodies was clearly evident in urban areas. After this period, river water quality has been improved around the country thanks to effective effluent regulation and the construction of sewerage systems with wastewater treatment plants. While the attainment rate of BOD in rivers was increased by mitigating organic pollution, the level of attainment of COD for water pollution remains low in enclosed water bodies such as bays, inland seas, and lakes with major pollution sources in their surrounding regions.

Efforts must be focused on effectively reducing pollutant loads in populated and industrialized areas around enclosed water bodies to improve their water quality. Additionally, specific regions contributing to water pollution are identified within each specified body of water. Every five years, the Minister of the Environment sets target on COD pollutant load reduction for each specified water area, as well as the target year by which they are to be met. These regulations, in accordance with the total pollutant load control standards, are the core of load-reducing measures based on the Areawide Total Pollutant Load Reduction Plan. These pollution control countermeasures have been implemented based on water quality monitoring data and water quality predictions by models. Combinations of monitoring data and model predictions are essential approach to manage water quality control effectively.

1.2.3 Significance of Advanced Monitoring and Modeling Research

Official water quality monitoring is designed so that the government can accurately evaluate the effectiveness of current countermeasures for pollution control. If there are no improvements in water quality, the government can deliberate the amendments as necessary and work to improve control measures. At the same time, the government also has to try to monitor any defects in the water environment as well as of water use impairment.

As mentioned in the last section, enclosed water bodies continue to suffer from pollution and are in need of long-term countermeasures. In order to maintain, conserve, and improve the functioning of lakes and coastal waters area, it is vital to ascertain and assess not only water quality, but also the aquatic environment of the area as a whole, including fish, bottom sediment, and benthic organisms. From this perspective, academic and administrative sectors have worked together to establish well-qualified methods to assess the water purification and other functions of enclosed water bodies, and quantitatively assess the aquatic environment as a whole.

Academic sectors must play a role in discovering newly relevant environmental phenomena and clarifying the pollution mechanism. It means that we have to conduct advanced environmental monitoring as well as officially monitored environmental indicators. Such advanced monitoring can provide new ideas and hints to capture unknown phenomena and processes. Then, a conceptual model can be built to express these mechanisms in the target water environment. This research process is the first step in developing a mathematical model, as shown in Fig. 1-1.

1.3 Monitoring and Modeling for Management and Research

1.3.1 Necessity of Water Environment Information on a Watershed Basis

The first version of the Basic Environment Plan was drawn up in December 1994 based on the Basic Environment Law, which outlines the general direction of Japan's environmental policies. The Basic Environment Plan is designed to engage all sectors of society in a concerted effort to protect the environment. The Plan maps out the basic approach of environmental policies with the mid-twenty-first century in view, and identifies four long-term objectives.

The Basic Environment Plan places "Conserving the Water Environment" among those policies under which we need to build a socioeconomic system which fosters a sound material/resource cycle. This system is closely