JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
STATE OCEANIC ADMINISTRATION (SOA)
PEOPLE'S REPUBLIC OF CHINA

THE STUDY ON IMPROVEMENT OF MARINE ENVIRONMENTAL MONITORING SYSTEM FOR THE PEARL RIVER ESTUARY IN THE PEOPLE'S REPUBLIC OF CHINA

FINAL REPORT

SUMMARY

September 2001

METOCEAN ENVIRONMENT INC.
UNICO INTERNATIONAL CORPORATION

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PREFACE

In response to a request from the Government of the People's Republic of China, the Government of Japan decided to conduct a study on Improvement of Marine Environmental Monitoring System for the Pearl River Estuary and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Noboru Sakuma of Metocean Environment Inc. (and consist of Metocean Environment Inc. and Unico International Corporation) to China, four times between March, 2000 and August, 2001. In addition, JICA set up an advisory committee headed by Mr. Masami Mizuguchi, Senior Advisor, Institute for International Cooperation, JICA between April, 2000 and August, 2001, which examined the study from technical point of view.

The team held discussions with the officials concerned of the Government of China 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 China for their close cooperation extended to the Team.

September, 2001

Takao Kawakami
President
Japan International Cooperation Agency

September 2001

Mr. Takao Kawakami
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

LETTER OF TRANSMITTAL

We are pleased to submit to you the Final Report entitled "The Study on Improvement of Marine Environmental Monitoring System for the Pearl River Estuary in the People's Republic of China." This report presents the results of all works conducted in both China and Japan during the period of April 2000 through August 2001.

The study: 1) consolidated baselines for the current state of the pollution load and marine water quality in the Pearl River Estuary, 2) developed a water quality simulation model for the estuary, 3) presented a blueprint for a comprehensive water quality monitoring program, and 4) implemented a technology transfer to the Chinese counterpart during the course of the joint study.

The study results, we believe, will contribute to the improvement of marine environmental monitoring system for the Pearl River Estuary that is indispensable for the sustainable development of the estuary.

We wish to express grateful acknowledgements to your Agency, Advisory Committee, Ministry of Foreign Affairs, and Ministry of Environment of Japan, Embay of Japan in China, and JICA China Office for courtesies and cooperation extended to our team. We also wish to express our sincere appreciation to our counterpart, State Oceanic Administration (SOA) of People's Republic of China for close cooperation and assistance extended to us during our study in China.

Very truly yours,

Noboru Sakuma
Team Leader

Figure 1. The Pearl River Delta

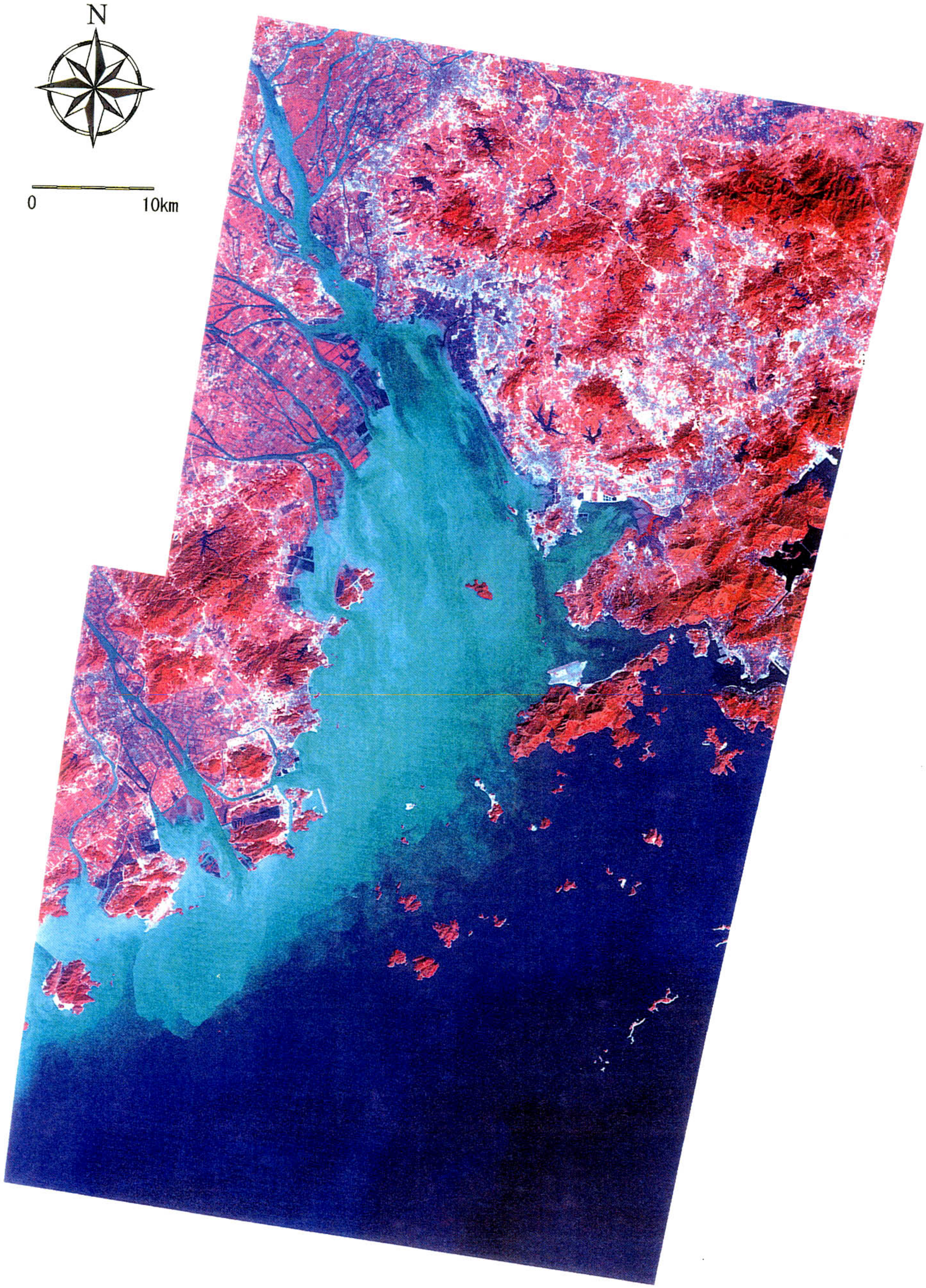

Figure 2. **Landsat TM Image (RGB:4,3,2)**
Date : 1999/12/25

Executive Summary

Background

The Pearl River is the largest river system in south China. Rising in Yunnan Province and flowing eastward for almost 2,200 km through Guangxi Zhuang Autonomous Region and Guangdong Provinces, it enters the South China Sea via an extensive deltaic region south of Guangzhou and west of Hong Kong. The river system has a drainage area of 452,600 km^2 and annual runoff of approximately 330 billion m^3. Some 80% of annual runoff occurs during the rainy season of April to September. Annual sediment loads total approximately 71 million tons.

The Pearl River system enters the South China Sea through eight outlets. Four are located to the east and drain into what is referred to as the Pearl River Estuary with approximately 60% of the annual runoff of the entire river system. These four outlets also collect the runoff from the North, East, Shui, and Liuxihe Rivers, and part of the runoff from the West River. The Hong Kong Special Administrative Region (SAR) is located on the eastern side and Macau; another SAR is on the western side.

The Pearl River Delta Region surrounds the estuary with the provincial capital of Guangzhou at its northern apex, the Special Economic Zone (SEZ) of Shenzhen at its southeast corner, and the Zhuhai SEZ at its southwest corner. The part of the region that forms the direct drainage basin to the estuary, with a population of 17.6 million (1999), is the economic and cultural core of south China. The region's rapid urbanization and industrialization were reflected in a significant population increase by the end of 1999. GDP in the region amounted to RMB 570 billion (approximately US$ 69 billion), 67% of Guangdong Province's GDP (Statistical Year Books of Guangdong, Guangzhou, Shenzhen, Zuhai, and Dongguan, 1998-2000, China Statistical Year Book, 1996-2000).

The rapid economic development has had major impact on the local environment. Extensive tracts of land have been converted from agricultural to urban and industrial uses. In the zone between Hong Kong and Guangzhou, 25% of arable land was lost between 1980 and 1990 (Roberts & Chan, 1997). Major new industrial centers such as Dongguan and Foshan emerged. Much of the development has been speculative, and inadequately planned and coordinated. Fierce competition among urban centers to attract investment in industrial and residential sectors aggravated the situation (Hills et al., 1998). The result is increasingly serious pollution problems. In particular, under-treated sewage discharges have increased significantly with the rapid population growth and many of these find their way into the Pearl River Estuary. Between 1989 to 1999, wastewater discharge in Guangdong Province increased from approximately 2.4 billion tons/year to 4.3 billion tons/year, of which 75% is of domestic origin (Guangdong Statistical Year Book, 1990-2000).

Agricultural activity, still a significant 12% of the delta region's economy, contributes to pollution by fertilizers and pesticides, as well as animal waste. An increase in intensive livestock production and an increasing dependence on chemical fertilizers, pesticides, and herbicides in the delta region have been reported. Between 1986 to 1989, chemical fertilizer consumption increased by 40% (Neller & Lam, 1994).

Although China has an extensive array of environmental legislation and a well-established organizational structure for environmental protection, the scale and rapidity of development in the delta region have caused particularly serious problems (Hills et al., 1998). Moreover, water pollution is an especially critical concern, with water quality both in the Pearl River system and the estuary threatened by a variety of urban-industrial and agricultural sources (Xu,1997).

The Government of China (GOC) therefore recognized an urgent need to control marine pollution and requested assistance from the Government of Japan (GOJ) to conduct a joint scientific study to establish a comprehensive water quality monitoring program in the estuary. GOJ responded by offering technical assistance through the Japan International Cooperation Agency (JICA) to conduct a Sino-Japanese joint study with the experts of the South China Sea Branch of the State Oceanic Administration as the counterpart, thus initiating the present study.

Details of objectives, approach, and organization of the study are presented in the Main Report version of this report.

Survey Results

- **Hydrodynamics**

Hydrodynamics of the Pearl River Estuary can be characterized by its shallowness, averaging only 5 m in depth, and strong tidal influence as well as by a large quantity of river water inflow. Annual runoff exceeds 1.8×10^{11} m^3 through the four major outlets of the Pearl River system. Some 80% of the runoff is concentrated during the rainy season. As a result, nearly the entire estuary is dominated by the river water during the rainy season, while during the dry season the influence of the outer seawater becomes stronger. Salinity of the estuary is, therefore, unstable through the passage of seasons, and even through tidal cycles. Salinity/temperature stratification is conspicuous in the rainy season despite the strong mixing and it persists even during spring tide. In the dry season, however, the stratification is nearly nonexistent during spring tide and is very weak during neap tide. Basically, the water currents in the estuary vary in both direction and magnitude in a regular diurnal cycle following the tide. During flood tide, water moves northward, and during ebb tide, southward. The largest current magnitude occurs during ebb tide in the rainy season accelerated by the strong river discharge, exceeding 190 cm/s in the upper layer.

Tidal residual current patterns, inferred from the field survey results, indicate that the outer-sea water enters the estuary through the middle and bottom layers at the southeastern corner of the estuary. A portion of the seawater travels north while the remaining portion turns the direction southward near Nielingding Island and exits to the outer sea through the southwestern corner of the estuary. In the upper layer, southerly residual currents persist in the entire estuary.

- Water Quality

  The river water also carries an enormous quantity of suspended solids (SS): more than $3x10^7$ tons/year of which nearly 90% is concentrated during the rainy season. The large SS load combined with re-suspension from the bottom, induced by strong tidal current, results in exceptionally high SS and turbidity levels in the estuary, exceeding 300 mg/L and 200 FTU in some locations during spring tide in the dry season. During neap tide, SS levels are lower in all seasons, indicating the significance of re-suspension by the tidal currents. Seasonal dependence is less conspicuous with spatially-averaged values ranging 80 to 10 mg/L. Spatially, the highest SS occurs in the southwestern and central parts of the estuary where currents are strong. The lowest SS occurs in the southeastern zone of the estuary. In Shenzhen Bay, SS levels are comparatively low, uninfluenced by tidal cycle.

  In addition, the river water carries approximately $4x10^5$, $4x10^5$, and $1x10^4$ tons/year respectively of COD_{Mn}, T-N, and T-P into the shallow estuary along with other pollutants concentrated in the rainy season according to the runoff quantity.

  Comparison of survey results in three seasons with the "Chinese Environmental Standard for Sea Water" indicates some potential water quality issues with respect to pH, DO, COD, SS, I-N, PO_4-P, Oils, Pb, and Zn. I-N and PO_4P, in particular, are critical near the river mouths and in Shenzhen Bay. The highest PO_4-P level, exceeding 0.4 mg/L, occurs in Shenzhen Bay during the dry season without significant dependence on tidal cycle. The highest I-N level, reaching 1.6 mg/L, is found near the river mouths in the upper bay area during the rainy season without dependence on tidal cycle. COD level is also high near the bay mouths and in Shenzhen Bay during the rainy season throughout the tidal cycle. The highest COD level, 4.8 mg/L, found in Shenzhen Bay is particularly conspicuous.

  DO levels in the estuary are much higher than would be expected from a large organic load without discernible vertical gradient. During the dry season, DO is nearly at saturation level in the entire estuary, except for Shenzhen Bay where it is slightly low. No significant DO depletion was found in the estuary throughout the survey periods.

  Oil concentration is considerably and consistently higher in Shenzhen Bay than elsewhere in the estuary. The highest level, 0.08 mg/L, found during spring tide in the dry season far exceeds the Class 4 Chinese Standard that applies to port/harbor and development zones.

  Distribution patterns of Pb and Zn have no definable characteristics except along the southwestern coast where the Class 1 Standards (Pb: 1 μg/L, Zn: 20 μ g/L) are occasionally exceeded.

- Bottom Sediment Quality

  Silt and clay are the main components of grain composition in the bottom sediment except along the eastern navigation channel where gravel and sand dominate. Organic content is consistently below 3 % at all the survey points except in Shenzhen Bay, with 3.2 % in the rainy season. Oil content is also low with the exception of Shenzhen Bay where it reaches 2,500 mg/kg in the dry season. In Shenzhen Bay in the dry season, a tendency toward 'reduction' is seen as indicated by high sulfide content and negative Eh level. Heavy metals, except Hg, consistently but slightly exceed the standard of coastal bottom sediment quality at all the survey points both in the rainy and dry seasons. Horizontal distribution pattern of heavy metals is indefinable except for Zn and As whose levels are somewhat higher in the southwestern and the upper bay zones.

- Low-level Aquatic Biota

In the rainy and dry seasons, chlorophyll-a (chl-a) concentration is generally higher toward the outer sea, and in the transient (spring) season the opposite occurs. Within the estuary, chl-a levels are consistently higher in Shenzhen Bay and the Hongqimen river mouth. It appears that the chl-a distribution pattern in the estuary follows the balance between the inflow quantities of freshwater phytoplankton in the upper estuary and marine phytoplankton in the outer sea.

Throughout the seasonal cycle, the most dominant zooplankton species in the estuary belong to the *Copepoda* class of *ARTHROPODA* phylum, all of which favor brackish water. The highest individuals-count occurs in the rainy season, followed by the dry and transient (spring) seasons. In the rainy season, individuals-count of zooplankton is highest in the center of the estuary where the salinity is midway between freshwater and seawater. In the transient season, the *Noctiluca scintillans* of *Dinoflagellate* class appear in large quantity with an individuals-count of 10^3 to 10^5 *ind/m³*, exceeding all other zooplankton species in nearly the entire estuary.

Phytoplankton species in the estuary are dominated by *Diatom* species throughout the seasonal cycle. Species of freshwater origin coexist with marine- origin species. In the rainy season, freshwater species are dominant in the northern half of the estuary, reflecting the large quantity of river inflow. In both the rainy and dry seasons, the density of phytoplankton cells, including marine species, is low at only 10^1 to 10^2 cells/mL. During neap tide in the transient (spring) season, the *Skeletonema costatum* of *Diatom* class blooms and cell-density increases to 10^3 to 10^5 cells/mL. Environmental conditions, including optimum temperature, stable salinity, and lower *SS* of the transient (spring) season, appear to have favored the temporary bloom of the species commonly found in semi-enclosed coastal basins.

In view of eutrophication potential, however, the current level of primary production in the estuary is not a cause for critical concern. By comparison, in typical eutrophic semi-enclosed embayments in Japan, cell-densities persistently exceed 10^3 cells/mL.

Benthos species found in the estuary are mostly of marine origin with a few brackish species. Benthos productivity in the estuary is generally low, and is particularly poor in the northern and western basins, likely as a result of unstable salinity and strong currents.

Water Pollution Mechanism

With the exception of Shenzhen Bay, the Pearl River Estuary is exemplified by its shallowness and strong tidal influence as well as by a large quantity of freshwater inflow through the four major outlets of the Pearl River system. The majority of the pollutant load is attributable to the river inflow covering the vast expanse of a densely populated and industrialized drainage basin carrying approximately $4x10^5$, $4x10^5$, and $1x10^4$ tons/year respectively for COD_{MN} , T-N, and T-P as well as over $3x10^7$ tons/year of sediment into the shallow estuary. At the same time, the tidal water exchange magnified by the shallow depth is very significant in shaping the estuarine water quality.

As a combined result of high tidal flushing rate and strong river through-flow, the detention time of the water in the Estuary is very short: on the order of few days. Consequently, the pollutant load does not accumulate in the basin and DO levels in the estuary remain higher than would normally be expected from the extent of the organic load. Similarly, no significant oxygen depletion takes place in the bottom sediment as evidenced by the positive red-ox potentials observed throughout the basin except in Shenzhen Bay.

The unusually low level of primary production found in the estuary is evidently attributable to the short detention time resulting from the enhanced tidal exchange and river through-flow. In addition, the huge quantity of freshwater inflow combined with the strong tidal exchange produces an unstable salinity level in the estuary, and phytoplankton species in the basin are constantly alternating from freshwater origin to seawater origin, further impeding the in-situ primary production despite the abundance of dissolved nutrients. The exceptionally high turbidity in the basin is also unfavorable to planktonic growth.

Overall, these factors jointly indicate that the estuary is biologically unproductive and its water quality is primarily governed by transport phenomena. Enhanced biochemical reactions, so commonly associated with typical estuarine bays elsewhere in the world, do not flourish in this estuary. The fate of conservative pollutants such as heavy metals can be inferred analogously: flushed off to the outer sea without significant accumulation which, in turn, indicates that the water quality of the Pearl River Estuary would immediately and almost linearly respond to load-reduction measures taken in the Pearl River drainage basin.

Shenzhen Bay is an anomaly within the Pearl River Estuary. In contrast to elsewhere in the estuary, it has an entirely different water mass exhibiting every sign of a semi-enclosed stagnant coastal basin receiving high nutrient load. Currents in the bay are weak and its water quality is exemplified by the high levels of phosphorous, nearly 20 times the values found elsewhere in the estuary, as well as by the high chl-a concentration levels. Despite the moderate level of DO, a likely result of photosynthesis, the red-ox potential of the bottom sediment is significantly lower than that observed elsewhere in the estuary, suggesting the occurrence of DO depletion in the low-level bay waters. A separately performed Principal Component Analysis, one of the multivariate statistical methods, suggests that the water quality of Shenzhen Bay is mainly affected by anthropogenic effluent as well as by in situ primary production.

Simulation Model Development

- **Pollutant Loads**

  Major pollutant loads were assessed by the results of field survey near the river mouths as well as by the unit-load method. Estimated annual loads into the estuary are 5.3 $x10^5$, 4.4 $x10^5$, and 1.4 $x10^4$ tons/year respectively for COD, T-N, and T-P.

- **Model Development**

  Two separate models, a hydrodynamics model and a water quality model, were developed.

  The hydrodynamics model, a 15-vertical level three-dimensional model, has been developed to investigate the complex hydrodynamics of the Pearl River Estuary frequently influenced by density stratification. By applying seasonal average river discharge data, extending the computational domain into the South China Sea, and also applying the "level-2.0 turbulence closure sub-model", the model is capable of reproducing satisfactorily the hydrodynamics of the estuary, including the transition of density stratification throughout the low- to high-tide cycle. SS simulation results, however, are less than satisfactory. There is a room for improvement in input data accuracy as well as in quantifying the re-suspension process of bottom sediments. Better temporal resolution in river discharge, both in terms of flow rate and SS load, would also benefit the simulation accuracy.

  The water quality model, a three-dimensional transport model combined with a standard form of low-level ecosystem sub-model, is driven by flow field generated by the hydrodynamics model. Overall, the model satisfactorily reproduced concentration levels for the majority of water quality constituents that are governed by the transport phenomena, but was insufficient in replicating the patterns of fluctuation and distribution for chl-a and related components, COD and PO_4-P. In addition to the scarcity of dependable load data as well as the complexity of water quality formation in the estuary that has not been grasped with sufficient detail, the aforementioned inadequacy in SS simulation is likely a significant contributing factor. Nonetheless, the fundamentals of the model are sound and ready for further refinements and calibration.

Comprehensive Monitoring Plan

The South China Sea Branch of the State Oceanic Administration (SCSB) has been engaged in marine environmental monitoring in the Pearl River Estuary since 1984. By analyzing the field survey results and by conducting inquiries to the related agencies and institutions, the present study formulated a comprehensive monitoring plan that would improve the ongoing SCSB monitoring program in the areas of effectiveness, sustainability, and economic efficiency.

- **Monitoring Locations**

  Reflecting the water quality characteristics as well as the proximity to common source load, the estuary basin is to be divided into six sub-basins, including Shenzhen Bay, that had been excluded in the ongoing SCSB monitoring program. A total of 14 strategically selected monitoring locations, including four points at the major river mouths, are recommended; two fewer than the ongoing monitoring program.

- Water Quality Parameters and Analysis

  A total of 43 water quality parameters, including the standard 35 parameters established in the "Environmental Standards for Sea Water in China", four human health-related items, and four eutrophication-related items are recommended for periodic monitoring. Analytical methods are to follow "GB17378.4-1988, The specification for marine monitoring Part 4: Seawater Analysis."

  A total of eleven parameters, analyzed in the present study, are recommended for bottom sediment quality monitoring. Analytical methods are to follow "GB17378.4-1988, The specification for marine monitoring Part 5: Sediment Analysis."

  Monitoring of aquatic biota is to include pytoplankton, zooplankton, and benthos.

- Monitoring Frequency

  Water quality monitoring is to take place thrice a year: the rainy, dry, and transient (spring) seasons.

  As the bottom sediment quality is uncritical at present, monitoring frequency may be reduced to a biennial or longer basis with the exception of Shenzhen Bay which is to be monitored annually.

  While it is preferable to monitor the aquatic biota thrice a year, as with the water quality monitoring, it may be necessary to reduce the frequency in consideration of resources requirements.

- Data Management

  Promotion of better quality control of monitoring data would involve improvements in certification procedures for technical staff and institutions, and methods of handling the numerical values obtained.

- Facility Development

  While the current monitoring facilities available in the subordinate units of SCSB are barely adequate for the purpose, some equipment and instruments are severely outdated and in need of upgrading. In addition, acquisition of some high-precision instruments is strongly recommended for analyzing dioxins and endocrine disruptors, substances currently under increasing attention worldwide.

  The current data management and utilization scheme, in which the units of SCSB collect monitoring data individually and compile and summarize manually in monthly reports to SCSB, is inefficient. Establishment of a centralized data control network is recommended, preferably involving external academic and public organizations for effective data sharing.

- Organizational Development

  Although SCSB is well established and experienced in marine administration and monitoring, it may become necessary to cooperate with external related organizations, as the regional development continues. An example of a successful cooperative system of marine environmental protection at administrative levels, "SETONAIKAI Marine Environmental Association", established for an inland-sea area of Japan, is presented for reference.

- Regulatory Development

  The current regulatory system of marine environmental protection is implemented in accordance with laws, ordinances, regulations, etc., solidly established at the national level. While there is no urgent need to introduce new regulations at the national level, issuance of local ordinance specifically targeted for the Pearl River Estuary might be considered, similar to the "Guangdong Ordinance for Water Quality Protection in Pearl River Delta." An example of such localized regulation, "Special Measures for SETONAIKAI Environmental Protection," enacted for the aforementioned inland-sea area in Japan, is suggested.

- Monitoring Scheme

  The current marine monitoring scheme has also been solidly established through substantial experience. Other than replacement of obsolete equipment needed for effective monitoring, no alarming shortcomings are found. In order to further advance the efficiency and the effectiveness of marine monitoring system, the following areas of improvement are suggested:

  1) Establishment of Master plan and Action Plan for solidifying the administrative functions of the marine environmental monitoring system.
  2) Reinforcement of monitoring and surveillance scheme including pollutant source management by database development, establishment of prioritized monitoring targets, and promotion of cooperation and information sharing among the parties involved.
  3) Reinforcement of data and information management and dissemination by establishing a centralized marine environmental information center in cooperation with external institutions and organization.
  4) Promotion of research and development involving local, national, and international scientists and engineers.
  5) Promotion of human resources development by systematic education and training and establishment of a sciences and engineering library specialized for the related fields of discipline.

- Cost Estimate

  Full implementation of the recommended comprehensive monitoring plan is estimated to cost RMB 57million (approximately US$ 6.7million), on a mostly local procurement basis. As possible funding sources, the World Bank, Asian Development Bank (ADB), and Japan Bank of International Cooperation (JBIC) are suggested. Terms and conditions for long-term loans from each potential source are also summarized.

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List of Abbreviations

GOJ	the Government of Japan
JICA	the Japan International Cooperation Agency
GOC	the Government of People's Republic of China
SOA	State Oceanic Administration
SCSB	South China Sea Branch of SOA
SCSEMC	South China Sea Environmental Monitoring Center
GMO	Guangzhou Marine Observatory
SCSEEC	South China Sea Exploitation Engineering Center
SCSIO	South China Sea Institute of Oceanology, Chinese Academy of Science
CORC	Coastal Ocean Research Center, Zhongshan University
SCSFI	South China Sea Fisheries Research Institute, Chinese Academy of Fishery Science
PRWRC	Pearl River Water Resources Commission
PRWRPB	Pearl River Basin Water Resources Protection Bureau of PRWRC
GEPB	Guangdong Environment Protection Bureau
GEPMC	Guangdong Environment Protection Monitoring Center
GIG	Guangzhou Institute of Geography
GDRGC	Guangdong Remote Sensing and GIS Center
SCM	South China National Center of Metrology
GIM	Guangdong Institute of Metrology

Chapter I. Introduction

1. Background

The inner bay of the Pearl River Estuary covers approximately 4,000 km^2. Its drainage basin, the so-called 'Pearl River Delta Economic Development Zone', encompasses many highly industrialized and densely populated cities, including Guangzhou, Shenzhen, Zhuhai, and Dongguang.

Since the 1970s, accelerating population and industrial growths in the Pearl River Delta have brought large-scale exploitation without adequate environmental consideration, which have caused various environmental pollution problems. In particular, water quality in the estuary has degraded considerably as a result of the increased quantity of under-treated wastewater drainage from cities, industries and agricultural land.

As a result, marine pollution and eutrophication in the Pearl River Estuary are reported to have advanced to such an extent that frequent occurrences of 'red tides', the depression of fisheries and aquaculture industries, and a decrease in biodiversity have become evident.

The Government of China (hereafter referred to as GOC) recognized an urgent need to control the advancing marine pollution. As a first step, GOC decided that water quality should be monitored in the estuary to scientifically establish the relationship between pollution load and water quality. Consequently, GOC extended a request to the Government of Japan (hereafter referred to as GOJ) for assistance in conducting a joint study to establish a comprehensive water quality monitoring program in the estuary.

GOJ responded to the request by offering technical assistance through the Japan International Cooperation Agency (hereafter referred to as JICA), the official agency responsible for undertaking technical cooperation programs, to conduct such a joint study, in close cooperation with a relevant counterpart organization of China.

2. Objectives

The objectives of this study were to:

- consolidate baselines for the current state of the pollution load and marine water quality in the Pearl River Estuary by (1) the collection and analyses of existing data; (2) a land-based field survey and (3) an offshore pilot water quality monitoring program;
- develop a water quality simulation model for the estuary, based on the results of the baseline study;
- present a blueprint for a comprehensive water quality monitoring program that can be realistically implemented by the GOC;

- implement a technology transfer to the Chinese counterpart during the course of the joint study.

3. Study Area

The study area is shown in Figures 1 and 2. The main area of this study was the inner bay area that is the northern part of a line connecting Macau to Lantau Island, Hong Kong.

4. Schedule

The study commenced in March 2000 and was completed in August 2001 (about 18 months in total). The study period was divided into two phases: the first phase was from March 2000 to December 2000 and the second phase was from January 2001 to August 2001.

5. Organization

The study was carried out by the study team, dispatched by JICA, in close collaboration with the counterpart agency i.e., State Oceanic Administration (hereafter referred to as SOA). On commencement of the study, JICA organized an advisory committee composed of experts and Japanese Government officials to advise and supervise the progress of the study.

The study was carried out by the JICA study team. The team was composed of nine specialists.

An advisory committee for the study, organized by JICA, was composed of three members.

The counterpart team was composed of ten specialists of South China Sea Branch (hereafter referred to as SCSB) of SOA.

The Chinese side also organized a steering committee composed of seven scientific experts, familiar with the transitional state of the Pearl River Estuary and the delta region.