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The Study on Nationwide Water Resources Development and Management in the Socialist Republic of Vietnam

Final Report

Volume VI

Supporting Report

Phase 2-1: Integrated River Basin Management Plan for the Huong River Basin

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COMPOSITION OF FINAL REPORT

Volume I	**Executive Summary**
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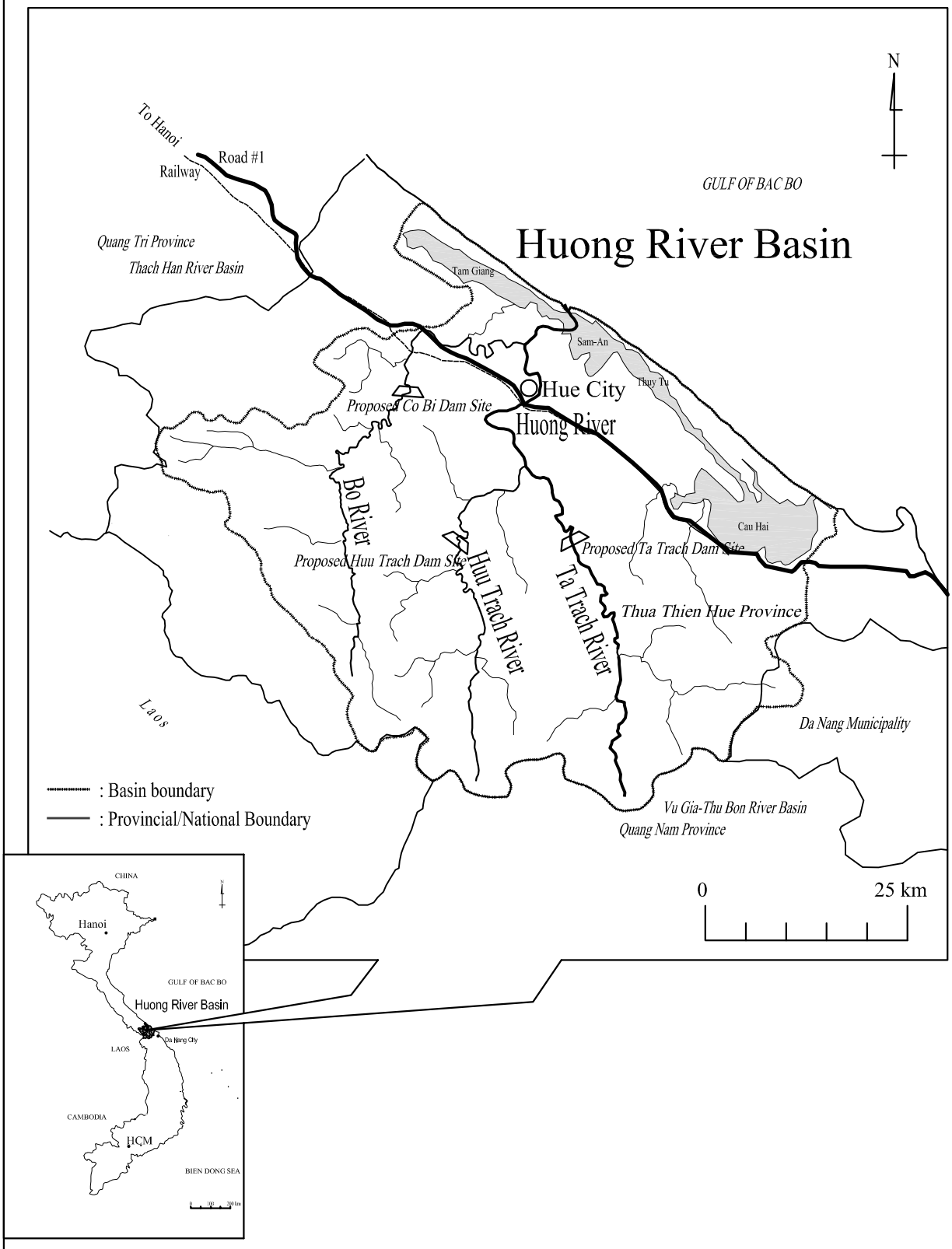
Volume VIII	**Data Book**

Exchange Rates

US$ 1 = Vietnamese Dong 15,068
Yen 100 = Vietnamese Dong 12,212

As of December 3, 2001



Location Map of Study Area

THE STUDY
ON
NATIONWIDE WATER RESOURCES DEVELOPMENT AND MANAGEMENT
IN
THE SOCIALIST REPUBLIC OF VIETNAM

FINAL REPORT

Phase 2-1: Supporting Report

Composition

Abbreviations

1. Organization

ADB	:	Asian Development Bank
AFD	:	Agence Française de Développement
AusAID	:	Australian Agency for International Development
BARD	:	Bank of Agriculture and Rural Development
CWRET	:	Center of Water Resources and Environment Technology
DANIDA	:	Danish International Development Assistance
DARD	:	Department of Agriculture and Rural Development
DOSTE	:	Department of Science, Technology and Environment
DSI	:	Development Strategy Institute
EPRI	:	Electric Power Research Institute
EVN	:	Electricity of Vietnam
ESCAP	:	United Nations Economic and Social Commission for Asia and the Pacific
FAO	:	Food and Agriculture Organization
FPD	:	Forest Protection Department
GSO	:	General Statistical Office
HEC 1	:	Hydraulic Engineering Consultants Corp. No.1
HMS	:	Hydro Meteorological Service
IBRD	:	International Bank for Reconstruction and Development
ICD	:	International Cooperation Department
IUCN	:	International Union for Conservation of Nature and National Resources/ World Conservation Union
ISG	:	International Support Group
IFEP	:	Institute of Fishery Economics and Planning
IWRP	:	Institute of Water Resources Planning
IWRR	:	Institute of Water Resources Research
JBIC	:	Japan Bank for International Cooperation
JICA	:	Japan International Cooperation Agency
MABR	:	Man and the Biosphere Reserve
MARD	:	Ministry of Agriculture and Rural Development
MOF	:	Ministry of Fishery
MOH	:	Ministry of Health
MONRE	:	Ministry of Natural Resources and Environment
MOSTE	:	Ministry of Science, Technology and Environment
MOTC	:	Ministry of Transport and Communication
MPI	:	Ministry of Planning and Investment
NEA	:	National Environmental Agency
NGO	:	Non-governmental Organization
NIAPP	:	National Institute of Agricultural Planning and Projection
NWRC	:	National Water Resources Council
PC	:	People's Committee

PECC2	:	Power Engineering and Consulting Company No.2
SBV	:	State Bank of Vietnam
UN	:	United Nations
UNDP	:	United Nations Development Programme
UNESCO	:	United Nation Educational, Scientific and Cultural Organization
USDA	:	United States Department of Agriculture
VNMC	:	Vietnam National Mekong Committee
WB	:	World Bank (International Bank for Reconstruction and Development)
WHO	:	World Health Organization
WWF	:	World Wide Fund for Nature

2. Unit

MW	:	mega-watt	km	:	kilometer
kW	:	kilo-watt	km^2	:	square kilometer
MWh	:	mega-watt hour	ha	:	hectare
kWh	:	kilo-watt hour	$mile^2$	:	square mile
GWh	:	giga-watt hour	m^3	:	cubic meter
GWh/yr	:	giga-watt hour per year	m^3/year	:	cubic meter per year
kV	:	kilo volt	m^3/sec, m^3/s	:	cubic meter per second
MVA	:	mega-volt ampere	m^3/sec/km^2	:	cubic meter per second per square kikometer
mm	:	millimeter	$feet^3$/sec/$miles^2$	:	cubic feet per second per square mile
mm/day	:	millimeter per day	g	:	gram
mm/year	:	millimeter per year	mg/l	:	milligram per liter
m	:	meter	Mm^3	:	million cubic meter
m/s or m/sec	:	meter per second	MCM	:	million cubic meters
m/sec^2	:	meter per square second			

3. Currency

VND	:	Vietnamese Dong
US$	:	US Dollar
JPY	:	Japanese Yen

4. Others

AC	:	Alternating Current
BOD	:	Biochemical Oxygen Demand
C.A.	:	Catchment Area
C-Cycle	:	Combined Cycle
CHES	:	Cultural and Historical Environmental Site
COD	:	Chemical Oxygen Demand
CPI	:	Consumer Price Index
DO	:	Dissolved Oxygen
DP	:	Dynamic Programming
EGEAS	:	Electric Generation Expansion Analysis System
EIA	:	Environmental Impact Assessment

EIRR	:	Economic Internal Rate of Return
FC	:	Foreign Currency
FDI	:	Foreign Direct Investment
F.M.	:	Finess Modulus
FIRR	:	Financial Internal Rate of Return
FSL	:	Full Supply Level
FWL	:	Flood Water Level
GDP	:	Gross Domestic Products
GNP	:	Gross National Products
GRDP	:	Gross Regional Domestic Products
HCM	:	Ho Chi Minh
HCMC	:	Ho Chi Minh City
HPP	:	Hydropower Project
ICB	:	International Competitive Bid
IEE	:	Initial Environmental Examination
IPP	:	Independent Power Producer
LC	:	Local Currency
LCB	:	Local Competitive Bid
LEP	:	Law on Environmental Protection
LOLP	:	Loss of Load Probability
LRMC	:	Long Run Marginal Cost
MDD	:	Maximum Dry Density
MIT	:	Massachusetts Institute of Technology
MOL	:	Minimum Operation Level
NGO	:	Non-Governmental Organization
ODA	:	Official Development Aid
OMC	:	Optimum Moisture Content
PMP	:	Probable Maximum Precipitation
RAC	:	Resettlement Action Committee
RAP	:	Resettlement Action Plan
RBO	:	River Basin Organization
ROE	:	Return on Equity
SCF	:	Standard Conversion Factor
SGS	:	Streamflow Gauging Station
SME	:	Small and Medium Enterprises
SRMC	:	Short-Run Marginal Cost
SS	:	Suspended Solids
UFW	:	Unaccounted For Water
VAT	:	Value Added Tax
WASP	:	Wien Automatic System Planning Package

Appendix A

Water Resources Facilities

Appendix A
Water Resources Facilities

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Appendix A Water Resources Facilities

1 DAMS AND RESERVOIRS

Truoi Dam and the irrigation canal are nearly completed. Operation is planned to start next irrigation season (Apr.'02). Truoi Reservoir will be for irrigation and water supply only. It has a storage capacity to irrigate about 6,000 ha. Via an outlet structure and main canal about 1,100 ha on the right bank of Truoi River will be irrigated. Then the canal crosses Truoi River and discharges into Nong River to support the irrigation of about 4,900 ha in the coastal plain. The total length of the main canal is 13.5 km.

The reservoir has no capacity provided for flood control. Floods will be discharged 'directly' over the spillway and via the present river to the lagoon. In the dry season a small flow (about 1.5 m^3/s) will be discharged through the river against salinity intrusion.

Phu Bai Dam (1981) was damaged during Nov.'99 flood. Before damage the theoretical capacity was 460 ha, but practical 300 ha. Its rehabilitation is almost completed (Jan.'02), including a diversion weir downstream of the dam and lined irrigation canals. The works will be ready for next irrigation season.

Chau Son Dam (1976) was designed to irrigate 150 ha, but covered in practice 100 ha. The site could not be inspected.

Khe Nuoc Dam (catchment 24 km2) is planned in the small tributary that joins Huong River at Nam Bieu intake channel. It should supply irrigation water for 1,100 ha (upland and Huong North), of which 710 ha by gravity and the remaining 390 ha by pumping.

Minor dams to create reservoirs for irrigation dams have been constructed on the other streams that originate in the hills south of the project area. Each of them is designed to serves less than 120 ha, but in practice it is in the order of 60 ha. The reservoirs are too small for flood control, so peak discharges of these streams contribute to the flooding problems.

2 IRRIGATION INTAKES, CROSS-DAMS AND DRAINAGE OUTLETS

2.1 Irrigation Intakes and Cross-dams

The two main irrigation intakes, both gravity inlets, on the Huong River are Nham Bieu and Phu Cam intakes. Further downstream the inflow from the Huong River to Huong South is prevented, except during flood discharges, by the Dap Da Dam and La Y spillway.

Nham Bieu Intake (1996), located in a branch of Huong River, is the intake for Huong North. It has 4 gated discharge openings (2.50 m wide; floor 1.10 m^-), and a supporting pumping station with 2 pumps. From the three downstream channels, one flows along Hue Old City. The structure is expected to be in good condition could not be visited because of a damaged section in the approach road.

Phu Cam Intake (1977) is the intake for Huong South, located just downstream, of the railway bridge over Huong River. It has 5 discharge openings (4.00 m wide; floor 1.50 m^-) and 1 shipping opening (4.00 m wide; floor 2.00 m^-), all with electrical operated flap gates, hinged on the floor. The structure has an additional shipping ramp for the passing of ships when the gates are closed, and extra set-up for higher river levels at the gate openings (only reduces the total opening; water can bypass at both ends). The inlet capacity is 15 m^3/s, for 12,000 ha (i.e. 1.25 l/s/ha). The facility is old, but well maintained and the operation of the gates is working properly. Major maintenance or replacement is at present not recommended.

Dap Da Dam is a cross-dam, with a road on top at 1.5 m^+, overtopping during higher floods. It is in good condition and no rehabilitation or improvement is recommended.

La Y spillway has 22 openings, 2.50 m wide, its apron at 0.60 m^+ and crest at 2.00 m^+. It has been rehabilitated recently. The openings are provided with composite steel doors, blocking the flow inflow from Huong River, but allowing drainage to the river. At high river water levels the gates will overtop. A 2-opening inlet work, with vertical lifting gates, allows inlet of irrigation water. The spillway is in good operational condition and no further works are recommended.

2.2 Drainage Outlets

The main outlet of Huong River will be controlled by Thao Long Barrage. There are over one hundred small drainage sluices along the lagoon, which allow drainage and prevent salinity intrusion. Quite a number require new gates. Some main outlets, but not all, have been inspected during field visits.

(1) Drainage outlets for Huong North

For Huong North (including Bo) the main drainage outlets to the lagoon are, from east to west, Quan Cua, An Xuan and Ha Do, all with 2 discharge openings with vertical lifting gates.

Quan Cua has 3 openings 2.20 m wide and floor 1.56 m⁻. It is a rather new concrete structure with stoplog grooves, but no closure facilities. Both embankments of the approach channel, adjacent to the structure, have lower crest with side slope and crest protections, allowing major floods to overtop. This outlet should be provided with closure facilities, preferably one-way swing doors, to allow outflow of drainage water and prevent inflow of lagoon water, with the possibility to lock them in closed position for storage of irrigation water.

Along the lagoon the embankment has recently been rehabilitated (reported 7.7 km) with side slope and crest protection.

An Xuan with 2 openings 2.50 m wide and floor 0.91 m⁻, and Ha Do with 2 openings 2.00 m wide, shipping opening 2.50 m wide and floors 1.00 m⁻ could not be inspected. It was learned that An Xuan has recently be rehabilitated, and Ha Do requires a new structure with bigger drainage capacity (more openings).

(2) Drainage Outlets for Huong South

For Huong South the main drainage outlets to the lagoon are Cong Quan, in the far south-east and Cau Long, in the north, south-east of Huong River. Their construction date could not be found.

Cong Quan has 11 discharge openings (2.20 m wide; floor 1.50 m⁻) and 1 shipping opening (2.70 m wide; floor 1.80 m⁻), provided with swing doors in all openings. The swing doors are in practice only used one way, i.e. towards the lagoon. The outlet is in proper condition and need no repairs. The two-way swing door principle is working properly. It is a more or less standard solution all over Vietnam. However, in this case one-way swing doors would be sufficient. An inflow of (brackish/salt) water from the lagoon will never be required.

The capacity of the existing sluice is too small for proper drainage. An additional outlet sluice is considered necessary, and can be located adjacent to the existing sluice. A feasibility study has not yet been carried out to determine the capacity, etc. The status of planning, design, etc. of the additional work could be found.

Cau Long Outlet (6 openings) is an old outdated structure with wooden vertical lifting gates and counter-lever concrete flap gates. The wooden gates seemed to be in operational condition, but the flap gates (hinges) are damaged. It is recommended to replace the structure. The type with (one-way) swing doors, like Cong Quan Outlet, may be suitable.

In the lagoon, in front of the outlet, are numerous fishing nets placed. On the right side of the approach channel to the structure are quite a number of shrimp/ fishponds under construction.

Vung Cau Hai outlet, close to the main land, is a 3-opening drainage sluice without closure facilities, next to a low, but protected overflow dike section. Both are in proper condition, but the outlet requires closure facilities, preferably one-way swing doors.

3 PUMPING STATIONS

There are about 140 pumping stations for irrigation, drainage or both. They are concrete/brick structures, equipped with electrically driven pumps. The capacities vary from 270 to 2,500 m^3/hr (0.07 to 0.7 m^3/s). For irrigation the pumps are in operation up to 20 hrs/day and for drainage they run up to 15 days continuous.

Irrigation pump capacity seems to be sufficient, but old pumps need major repair and/or replacement. Electric power is rather reliable, but costly. Power cuts usually do not last more than one day, and in periods of low electricity supply priority is given to agriculture and industry. Reliability and capacity is at present sufficient for irrigation and drainage pumps.

3.1 Pumping Stations in Huong North (irrigation)

Pumping station (2-pumps) for Phong Son area, on the left bank of Bo River, just downstream Co Bi (former hydrological) station, is old but in running condition. Only the short intake channel has to be re-excavated after every flood (sand deposits). An extension of the suction pipes may solve the problem, or at least reduce the re-excavation work.

Pumping station (3-pumps) for Lai Bang area on the opposite (inner) bank has no such problems.

Pumping station (2-pumps) for Phong Hien area, on the high left bank of Bo River, just downstream of the bridge in Highway No.1 is also old but in running condition. Connecting channels have to be maintained before the start of the irrigation season.

Pumping station (2-pumps; originally 4-pumps?) for Vinh Phu, located on the left bank of Bo River behind the river dike, has a gated inlet structure with culvert under the dike. The station and pumps are old but in running condition.

3.2 Pumping Stations in Huong South

Phu Da pumping stations, i.e. two drainage pumping stations (2-pumps), alongside a main irrigation/ drainage channel. Pump houses, pumps and engines are old but at the visit running for drainage. One of the stations has 2 out of order old screw pumps, and running newer pumps (one inside, one outside the pump house).

Vung Cau Hai pumping station, at the downstream end of Thieu Hoa River, is an old station with 4 pumps. At the time of visit they were running for drainage.

New pumping station under construction, close to Vung Cau Hai, with house for 2 pumps has been completed, but still without pumps and engines. Near the pumping stations starts an embankment empoldering part of the lagoon.

The pumping stations inspected (end of Jan.'02) seemed ready for operation. The pump

houses were in good condition. The concrete quality may not be of a high standard, but cracks in the buildings (from settlements or vibrating pumps/engines) were not observed. Most pump houses have provisions (higher level floor in part of the building) to store engines when the station is flooded. Each station should be equipped with an overhead crane/hoist rail and hoist equipment.

Drainage pumps were actually running. The pumps and the engines were usually old but well maintained. The efficiency of the pumps could not be checked. Newer pumps will certainly have a more efficient relation between pumped water quantity and power consumption.

It has been regularly reported that power supply is reliable but costly and total available power is hardly sufficient. There is a tendency to more, but smaller pumping units that will become under responsibility of local communes/ farmers groups.

The quality of the access and discharge channels varies. The condition of the a few secondary canals could be inspected differed. Some require maintenance/cleaning before next irrigation starts. Others appeared just re-sectioned (earthen canals with steep side slopes) or were lined (rectangular cross-section). Structures in the secondary system, tertiary canals, etc. have not been inspected.

More and more farmers are using small diesel powered pump-units to conduct water to their fields, in particular where supply by the bigger (electrical) pumping stations is insufficiently available.

4 EMBANKMENTS, ROADS, WATERWAYS, ETC.

4.1 Embankments

Earthen embankments eventually partly constructed as elevated roads can protect rural settlements. Design flood levels (with frequency of occurrence) have not yet been determined. Leakage and overtopping should not be allowed. Pumped discharge may be combined with gravity drainage (after the flooding).

Agricultural lands need protective embankments against inundation caused by:

- Fresh water flooding by river and canal system, i.e. during early floods (May/ June). Big floods (Sep.- Nov.) are allowed to flood the lands.
- Brackish/ saline water flooding from the lagoon, i.e. full year flood protection to prevent saline water inundation of the fields during high tides.

Long stretches along the lagoon have already been protected by a 'sea dike embankment', with crest level at 1.50 m^+. The embankments are physical boundaries between land and lagoon. The landside should be developed for agriculture, the seaside for fishery. Protective low bunds around (a group of) farmlands with low elevations have to be made and maintained by (a group of) farmers. Mangrove planting (or fishponds) is recommended on the lagoon side.

Where embankments have to function as road the crest width and the crest level should be increased, depending on the road type, additional safety and settlements of embankment body and subsoil. The embankments need sufficient (gated) drainage openings.

The river embankments, with roads on top, from Hue City towards the lagoon run more or less parallel to Huong River. They provide together with Phu Cam Intake Structure, Dap Da Dam and La Y spillway a proper early flood protection for Huong North and Huong South. In 2001 flooding season the road was reported flooded during a short period of high river levels during the wet season (high floods) only.

Inundation by early flooding is therefore most likely caused by improper drainage of rainfall and inflow from the high lands. The capacity of the (small) reservoirs hardly contributes to storage of early floods.

All inspected embankments along the lagoon had (rubble stone) slope and (placed concrete blocks) crest protection. The crests can be used for inspection by motorbike. Minor repairs are needed. It concerns unequal settled crest blocks. During repairs also the cause of settlement should be checked.

4.2 Roads

The highest density of roads is found in urban and plain areas and the lowest density in

coastal and mountainous areas. The main road (National Highway No.1) from Hanoi to Ho Chi Minh City passes Hue. Road connections to Laos and Thailand are continuously improved.

Most of the roads in the coastal lowlands are in reasonable to good condition. They are often combined with embankments, or are embankments themselves. Some stretches are damaged, and should be repaired. Regular inspection, proper maintenance and quick repair of damages will save on O&M. Small damages will increase rapidly in the rainy season (traffic over potholes filled with water).

After Nov. 1999 flood a number of 'improvements' have been made:

- Slope protection (rubble stone masonry) of the railway embankment (not inspected, but seen during driving on Highway No.1) will protect the embankment during overtopping of floodwaters.
- Increase of crest level of Highway No.1 will prevent overtopping during 'normal' flooding. However, the number of discharge openings (culverts) in railway and highway embankments seems to be rather low, so the flooding depth on the upstream (hilly) side may increase.

The following new main roads are under construction:

- Bypass of Hue City by new Highway No.1B (existing will be no.1A) is under construction. The alignment is through the southwestern hills, between Phu Bai airport and Bo River, with a new bridge over Huong River under construction just downstream of the confluence of Ta Trach and Huu Trach rivers. The bypass follows more or less the watershed and will not noticeable influence the river- and overland flows.
- Road, starting just south of Phu Bai airport, on high embankment connecting Highway No.1 to the lagoon. Bridges over the canals/drains (old river branches) Ha Ta and Thieu-Hoa are completed. Construction of a bridge over the lagoon has not yet been started.

This road has to stimulate development and provide the 'sandbar' with a second connection to the mainland. The road embankment may hamper the overland flow in the irrigated area.

On the stretch of the embankment (east of Thieu-Hoa) the cross drainage seemed to be very small. Although no data on discharge and cross drainage openings are available it is not clear how much the new embankment will act as a dam, preventing overland flow from NW to SE.

There are two more bridges under construction over Huong River, one just downstream of Hue City, and the other as part of Thao Long Barrage.

Connections to the bridge on top of Thao Long Barrage must be high (underside bridge 5.50m+). The barrage itself has a somewhat lower discharge capacity than the original river. Embankments of access roads will block the overland flow in the mouth of Huong River and cause a rise in backwater during bigger floods. Overflow of (low sections of) the road will be unattractive since it disrupt the traffic. An extended bridge will allow overland flow underneath.

Present and new roads (equivalent to district roads) within the irrigation and drainage system, vital for connections, should in future be paved roads. Connections, like bridges, culverts, ferries, etc. over rivers, canals and drains are part of the road system. Minor roads should remain the responsibility of local communities.

4.3 Waterways

Navigation takes place on the downstream part of Huong River and all main canals/drains. Present and future navigation in the region will remain only locally important for farmers, fishermen and tourists. Because of the improving road system and short distance to Hue the road transport increasingly takes over for agricultural needs and products. But navigation is considered sufficient important, also in future, to include facilities in the main inlet/ outlets structures, bridges, cross-dams, etc. There are only a few ferries at the main rivers, and only basic local landing stages. Regular removal of sediments is required, but aquatic vegetation control (water hyacinth, weed, reed) is apparently no big problem. Growth is stemmed by farmers who harvest the plants, at sufficient rate, for use as fertilizer.

5 FISHERY

Fishery takes place in all open water, i.e. reservoirs, natural (seasonal) lakes, river (branches), creeks, canals, drains, inundated (rice) fields, lagoon and sea (Thuan Anh fishing port). Fishery can be fresh water, brackish water and marine, and in open water, ponds or cages. Fish culture in rice fields has several obstacles, like pesticides, rats, snakes, while water management is mainly focused on rice growing. Salt ponds do not exist in the area.

Many fishing nets are found in the shallow areas of the lagoon, and also boat fishing takes place, but details are unknown. The area on the south side adjacent to Cau Long Outlet and the lagoon is at present transferred into fishponds. Locations like this have ample fresh water from the drain and brackish/salt water from the lagoon. Fishponds are constructed by private enterprises. They get some support from the government, but this will not be considered more detailed.

At present there are about 3,000 ha shrimp ponds, for export, and 800 ha fishponds, for local use. Extension on the land will be mostly in the sandy areas that are unsuitable for agriculture. Extension in the lagoon is limited because of environmental protection. The threats to the ecological system of the lagoon are aquaculture overexploitation and water pollution.

The salinity in brackish water fishponds should be 1.5-2.5% (normal seawater 3.5%). In the dry season it may rise to 4-6% and in the wet season lower to 1%. The salt balance determines the water requirements of brackish water ponds. The peak requirements may reach 2.5 l/s/ha in the dry season, with normal values 1.0-1.5 l/s/ha in the wet season.

Fish farmers generally renew part of the water once/twice a month, depending on quality and transparency. The contribution of infiltrated rainfall on the sandy ridges (quantity and duration) to decrease salinity of the brackish water is unknown.

Flooding, which is the biggest problem for aquaculture, causes loss of fish crop and siltation of the ponds. Turbid and silty water is unsuitable for raising brackish-water fish or shrimp. Full flood protection or other measures, i.e. harvest before the floods, is required.

Appendix B

Review on Present Survey, Facility and Plan

Appendix B
Review on Present Survey, Facility and Plan

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Appendix B Review on Present Survey, Facility and Plan

1 REVIEW OF LAGOON ECOLOGY SURVEY

1.1 General

Tam Giang-Cau Hai lagoon covers a surface water area of 22,000 ha, the largest one in Southeast Asia, extending along Thua Thien Hue coastline with the total length of 60 km (Refer to Figure B.1). The lagoon system consists of Tam Giang-Cau Hai lagoon system and Lang Co swamp. Tam Giang-Cau Hai lagoon system is often divided into 3 main areas: Tam Giang lagoon in the north, Sam- An Truyen swamp and Thuy Tu swamp in the middle, and Cau Hai swamp in the south.

The Tam Giang-Cau Hai lagoon has two mouths at the moment: Thuan An mouth and Tu Hien mouth. These mouths have been repeatedly closed and opened over the past years. During the flood in November 1999, Hoa Duan mouth was newly opened as the result of the destruction of the sandbar located between the East Sea and the Sam- An Truyen swamp.

The Vietnamese Government conducted "the Study on Restoration and Stabilization of Thuan An - Tu Hien Estuary (RSTATHE Study)." The study was conducted from May 2000 through May 2001. The objective of the study was to predict the positive and negative impacts of the closure of the Hoa Duan mouth, and to formulate the countermeasures for the negative impacts brought about by the closure. However, MOSTE had decided to close the Hoa Duan mouth in August 2000 before the study has completed. The objective of the study, therefore, was changed to obtain a scientific foundation of comprehensive solution for this area where there is a sequence of river, lagoon/swamp and the sea, including such natural condition/phenomenon as flooding, the development of lagoon and marine hydro-dynamics, aquatic ecosystem and socio-economic conditions.

1.2 Lagoon Environment

In order to figure out proper measures for conservation and stabilization of Tam Giang - Cau Hai lagoon system, impacts of unstable estuaries on the lagoon environment and natural resources have been researched and analyzed as one of RSTATHE Study. A thematic report, "Impacts of the Destabilization of Lagoon Estuary on Tam Giang – Cau Hai Environment and Resources", was prepared in April, 2000.

(1) Environmental and Nutrient Factors

Temperature

The average water temperature in the cold season and the rainy season is 20.5 ^{0}C with the fluctuation ranging from 15.1^{0}C to 24.1^{0}C, and 29.1^{0}C with the fluctuation ranging from 26.2^{0}C to 30.0^{0}C. Temperature differences in the lagoon were observed at boundaries of the currents, namely, at the conjunction of river flows and tides with the maximum differences up to 3-4 ^{0}C, specifically at the areas from O Lau river estuary to Thuan An estuary, from Hoa Duan estuary to Vinh Hung and adjacent to Tu Hien estuary.

pH and DO

Lower pH is often observed in the area from O Lau river estuary to An Gia with the range from 6.5 to 7.5, whereas other areas have the pH value ranging from 7.6 to 8.2. This indicates that the lagoon has fairly strong interactions of tides from the sea except for the area from O Lau river estuary to An Gia (The value of pH of seawater is noticed as 8.1± 0.2 globally).

DO in the lagoon in 1999 and 2000 ranged from 5.3 to 8.4 mg/l and 4.9 to 8.0 mg/l, respectively. This DO concentration, on the whole, satisfies the requirement of aquaculture breeding.

COD and BOD_5

The average COD in the whole region varies from 6-12 mg/l, whereas the average BOD_5 about 0.5-1.0 mg/l. Because of the low COD and BOD_5 in the whole lagoon, environmental pollution by organic matter is not worth worrying. However, there are some locations with high COD concentration up to 25 mg/l.

Salinity

Before the 1999 flood, Tam Giang – Cau Hai lagoon system was able to be divided into sub-regions on the basis of salinity as follows:

- Sub-region I: the part near O Lau river mouth where the environment shifted from fresh brackish (salinity less than 0.5 ‰) to moderately brackish (salinity from 5 to 18 ‰),
- Sub-region II: the part from Dam market to An Gia where the environment shifted from fresh brackish to softly brackish (salinity from 0.5 to 5 ‰), moderately brackish, and
- Sub-region III: the part from Tu An Xuan to Thuan An estuary, from Sam-An Truyen to Tu Hien estuary where the environment shifted from fresh brackish to softly brackish, moderately brackish, heavily brackish (salinity from 18 to 30 ‰).

Tam Giang – Cau Hai lagoon environment changed in the rainy and dry seasons, showing

the two corresponding periods: de-salinity (dilution) and salinity intrusion. De-salinity period lasted longer than the salinity intrusion. The lagoon was drastically affected by freshwater intrusion in October and November and then the seawater began to intrude and affected on the lagoon in January and February, resulting in the highest level of salinity from April to August or September.

During the 1999 flood, Hoa Duan mouth was newly opened. The appearance of Hoa Duan mouth, however, has not converted Tam Giang – Cau Hai lagoon into a heavy brackish water body in whole, but it has brought about some changes. On the basis of salinity change affected by Hoa Duan and Tu Hien lagoon mouth, the lagoon can be divided into the following three sub-regions:

- The area with nearly unchanged salinity despite the appearance of newly opened Hoa Duan mouth: stretching from An Gia to O Lau river mouth.
- The area of slightly changed salinity to be affected by Hoa Duan mouth: stretching from the north of Thuan An estuary to An Xuan.
- The area of greatly changed salinity as a result of Hoa Duan and Tu Hien mouths: the large area including Sam-An Truyen, Thuy Tu and the whole Cau Hai area.

(2) Biological Inventory

After the Tu Hien estuary was silted up in 1979, the whole Cau Hai environment was strongly desalinated, causing a rapid change of inventories of flora and fauna. Creatures of sea origin have vanished and have been substituted by fresh water and by some softly brackish ones. In this respect, the most dominant phenomenon was the fast growth of *Cyrimus centralus* and aquatic grasses. The aquatic grasses with fresh and brackish water origin became abundant throughout Cau Hai area. They had grown to such big size that was an obstacle to navigation.

Consequently, a string of *Penaeus monodon* and *gracilaria* breeding ponds at Vinh Hien and Vinh Giang had become not to be suitable for aquaculture, which resulted in a stop of the operation of some aquatic activities. This indicate that if the sea influence on the lagoon was weakened and the salinity dropped below 12 ‰, it would make a water body poor in biodiversity, rich in the living mass of high-class aquatic grasses and unsuitable for *Penaeus monodon*, *gracilaria* and crab breeding.

The 1999 flood and the formation of new estuaries has triggered the increase in the average lagoon salinity. Under the newly created environment by the estuaries, biological composition has undergone many changes as summarized below:

Phytoplankton: Before the flood, Cau Hai area was considered poor in phytoplankton in terms of species and density, except a limited area at Tu Hien estuary. After the creation of Hoa Duan and expanded Tu Hien estuary, its density soared up largely due to the

dominant growth of *Prorocetrum*, a kind of *Dinophyceae*.

To conclude, the change in the lagoon environment brought about by the 1999 flood has affected to the growth and distribution of phytoplankton: *Dinophyceae*, especially *Chaetoceros* at Thuy Tu and *Prorocentrum* at Cau Hai have expanded its distribution area and have higher average density.

Aquatic Grasses: Dominant species observed by the area and its characteristics are as follows:

- Even after the 1999 flood, there remained those species: *Valisneria spiralis, Potamogeton malaianus, Hydrilla verticula* and *Ceratophyllum demresum* from O Lau to An Gia, and *Cymmodocea rotundata* from An Xuan to Thuan An estuary.
- Thuy Tu has similar characteristics, but *Halophylla beccari, Najas indica, Valisneria spiralis* are prevailing in the north area from Vien Trinh to Vinh Hung. However, these species have vanished due to the higher salinity.
- Cau Hai area has almost no aquatic grass cover but *Valisneria, Najas, Halophila* and *Potamogeton* are seen. Currently, they survive only in the form of limited bands near Truoi and Cong Quan river mouths.

Meanwhile, the noticeable changes in the sea grasses are recognized at Cau Hai area, reflecting the higher salinity brought about by the appearance of new lagoon mouths.

Zooplankton: No significant changes in the species composition have been found before and after the 1999 flood. Its density and distribution areas have experienced some changes: the most densely populated area was formerly stretching from An Gia to Thuan An, but now it tends to move to the south, from An Xuan to Thuan An. The remaining areas, from Hoa Duan to Cau Hai swamp, have lower density.

Copepoda is the dominant species in the lagoon, accounting for a large ratio after the formation of the new estuaries.

Benthic Macrofauna: Thirteen species identified are in annelid group, six in crustacean, and two in mollusk group. *Dendronereis arborifera, Ceratonereis mirabilis* are recognized to appear at Thuan An in the new environment after the 1999 flood. Besides, *Anomura* was seen for several times at Thuan An and Hoa Duan estuaries. *Dendronereis arborifera, Caratonereis mirabilis* are widely distributed over the whole Cau Hai swamp.

With the formation of the estuaries, the density of benthic macrofauna has multiplied from hundreds of individuals/m^3 to thousands of individuals/m^3, i.e. 30 to 50 times higher.

(3) Fisheries

Fish Catch

According to an expert of Department of Fishery, Thua Tien Hue province, current fish catch is on the increase compared to that before the 1999 flood, particularly that of *Metapenaeus ensis, Mugil spp., Scylla serrata, Penaeus semisulcatus, Siganus spp., Penaeus monodon, Epinepelus spp., Meretrix meretrix, Mactra quadragularis*. However, there are some species of which fish catch has fallen, including *Cyprinus centralus* and *Caridina sp.*

Aquaculture

With the appearance of Hoa Duan and Tu Hien estuaries, the salinity stage in the lagoon system has been lifted up on an extensive scale although its values did not rise up to the sea level. Additionally, the time for the restoration of salinity values after the rainy season has been significantly shortened. In light of aquaculture, therefore, the new environment characteristics have provided for great positive impacts even though there are some adverse effects raised, including direct impacts of waves, wind and tides through the Hoa Duan estuaries on aquaculture activities and its production loss.

(4) Summary of the Impacts of Unstable Estuaries on the Lagoon Ecology.

As results of the study on the impacts of unstable estuaries on Tam Giang – Cau Hai lagoon system, the following conclusions were obtained:

- Although the presence of Hoa Duan and Tu Hien estuaries does not lead to a higher peak in the lagoon, the salinity stage of 15 ‰ or more over an extensive scale and shorter periods for restoration of salinity after the rainy season have been brought about, which have resulted in more favorable condition for fisheries, particularly aquaculture activities.
- The southern part of Thuan An estuary, including Sam-An Truyen and north of Thuy Tu area are clearly affected by Hoa Duan estuary whereas Cau Hai area is strongly dominated by Tu Hien estuary. Areas to the north of Thuan An estuary is almost stable in the face of the newly formed Hoa Duan estuary.
- The southern part of the lagoon tends to shift from a system characterized by the production of aquatic grasses to that of marine phytoplankton and small-sized benthic macrofauna, and from a system characterized by creature preferring soft brackish water to that completely composed of moderately or heavily brackish water ones.

1.3 Fishery Activities in Lagoon Area

The socio-economic survey and research were conducted as one of RSTATHE Study. A

thematic report, "Some Issues on Socio-economic Development in Thuan-An – Tu Hien Estuarine Area and Tam Giang – Cau Hai Lagoon (the lagoon socio-economic report)", was prepared in April, 2001. The survey and research focused mainly on the fishery activities in lagoon area, and the outline of results is presented herein.

(1) Fishery Activities in Lagoon Area

Due to the difficulties, such as saline intruded water/land, in agriculture, fishery sector has been promoted and is the mainstay of economy at present in the coastal and lagoon area. The total households engaged in fishery in lagoon and coastal area amount to approximate 12,000, of which 10,000 - 11,000 are working within the lagoons.

There are three main types of fishery activities, namely fishing within the lagoons, aquaculture within or around the lagoons, and fishing in the coastal/offshore area.

i) Fishing within the lagoons

The following table shows the trend of catch amount of fishing within the lagoons. The considerable increment of fishing catch amount cannot be recognized in spite of a rise of fishing capability, and the catch per boat seems to decline.

Amount of Fishing Catch within the Lagoons

Unit: ton, ton/boat

Year	1966	1973	1979	1985	1990	1991	1992	1993	1995	1996	1997	1998	1999
Amount	4,042	4,517	2,575	2,937	2,100	2,650	2,830	2,500	2,600	2,927	2,700	2,500	2,500
Catch per boat	-	-	0.99[1)]	1.08[2)]	0.68	0.75	0.74	0.57	0.55	-	-	-	0.44

Source: Some Issues on Socio-economic Development in Thuan-An – Tu Hien Estuarine Area and Tam Giang - Cau Hai Lagoon, April 2001. ("Catch per boat" is calculated by JICA Study Team.)
1): The number of boats for calculation is as of 1975.
2): The number of boats for calculation is as of 1986.

The fishing in the lagoon was being enhanced for more than 10 years under the motivation of market economy, although total catch stagnated or followed a decrease trend. According to the lagoon socio-economic report, the followings are reasons why the investment is increasing in spite of decreasing the productivity (catch per boat) within the lagoons:

- The unit price of fishing product has been boosted up due to the open-door policy of the country.
- The economic activities in other sectors are less effective than that in fishing, as the survey of RSTATHE study shows that the households working in fishery sector gain higher income than those working in agricultural sector.
- It is considered that a re-distribution of benefits among fishermen is in progress, and that investment for fishing still brings about higher benefit.

The number of the households who live on the boats within the lagoons is about 1,400 or more, equivalent to more than 10,000 people. They are engaged mainly in

the fishing within lagoon, and their living standard and literacy level remain considerably low.

2) Aquaculture within/around the Lagoons

Aquaculture within/around the lagoons has been started with planting seaweed since 1977. And at present, shrimp breeding becomes flourishing in addition to seaweed planting. The situation of aquaculture is shown in the table below:

Situation of Aquaculture in Tam Giang- Cau Hai lagoon

Year	1993	1995	1996	1997	1998	1999
Shrimp/fish breeding area (ha)	437	830	1,102	1,162	1,298	1,628
Seaweed area (ha)	357	396	437	437	437	437
Total product of aquaculture (ton)	800	1,043	1,208	1,248	1,239	1,400

Source: Some Issues on Socio-economic Development in Thuan-An – Tu Hien Estuarine Area and Tam Giang - Cau Hai Lagoon, April 2001.

The increase rate of the total product is approximate 8 % annually from 1993 to 1999, and 2,700 – 3,000 households are engaged in the aquaculture within/around the lagoons.

3) Fishing in Coastal/offshore Area

The following table shows the trend of the number of boats and catch amount regarding the coastal/offshore fishing.

Number of Boats (w/ engine) for Coastal/offshore Fishing

Year	1995	1996	1997	1998	1999
Total boats (nos.)	1,884	1,924	2,003	2,208	2,250
Total catch amount (ton)	9,117	9,907	11,110	12,800	14,000
Catch per boat (ton/boat)	4.8	5.2	5.6	5.8	6.2

Source: Some Issues on Socio-economic Development in Thuan-An – Tu Hien Estuarine Area and Tam Giang - Cau Hai Lagoon, April 2001. ("Catch per boat" is calculated by JICA Study Team.)

The increase rate of the total catch amount is approximate 11 % annually from 1995 to 1999. The rapid development is mainly brought about by the enhancement and promotion of offshore fishing. And the offshore fishing is also lessening the coastal fishing density and is expanding the employment.

(2) Processing Sector on Fishery

In line with fishery development, processing is also following increased tendency as shown in the table below.

Trend of Processing Sector on Fishery

Unit: ton

Year	1995	1996	1997	1998	1999	2000
Total processing product	1,328	1,376	1,959	1,550	1,956	2,000
(Frozen products)	(1,159)	(1,045)	(1,636)	(1,200)	(1,529)	(1,550)
(Dried products)	(169)	(331)	(322)	(350)	(427)	(450)

Source: Some Issues on Socio-economic Development in Thuan-An – Tu Hien Estuarine Area and Tam Giang - Cau Hai Lagoon, April 2001.

The increase rate of the total product is more than 8 % annually from 1995 to 1999.

(3) Conclusion of the Lagoon Socio-economic Report

The main conclusion of the report is summarized as follows from the viewpoint of socio-economic development with sustainability.

- The scale and magnitude of existing fishing activities within the lagoons should be reduced drastically, since the exploitation of natural resources has reached or exceeded the maximum re-productivity of the lagoons. About 50 % of the current fishing load on the resources within the lagoons is to be released for restoration of lagoon re-productivity.
- The aquaculture within the lagoons does not contribute to the common economic growth on the whole fishery sector, since it only redistributes the benefit among the fishermen generated from the potential of natural resources in the lagoons. And the conflict will be introduced between monopolistic fishermen (aquaculture) and free fishermen (fishing). Thus, enhancement of aquaculture within the lagoons is not much prospective.
- It is preferable and acceptable to convert saline intruded paddy field near the lagoons into aquaculture/breeding area, since much higher productivity and advantage is expected. This direction will also contribute to releasing the fishing load on the lagoons.
- The processing/services sector should be enhanced, both through the transformed aquaculture/breeding mentioned above, and through the promotion of coastal/offshore fishing.

1.4 Interview Result

An interview to Professor Tran Dinh Hoi, Deputy Director of Vietnam Institute for Water Resources Research, MARD, and at the same time one of the members of the said study, was also carried out in Hanoi on December, 27th, 2001. The key issues of the interview are as follows:

The biggest difference between before and after the 1999 flood is that the formation of the new mouth, Hoa Duan mouth, has brought about the salinity increase. The existence of

Hoa Duan mouth is considered to have the following advantages: flood mitigation, good condition for aquaculture and ecological environment.

The Ministry of Fisheries is against to close the mouth for the reason of aquaculture. The Ministry of Transport, on the contrary, agreed with the closure of the mouth, because there was a road over the Hoa Duan mouth formerly, which is essential for local people and economic activity. People's Committee of Thur Tien Hue Province also agreed with the closure of the mouth, because if the Hoa Duan was remained open, Thuan An, a important port for local transportation, and other mouths might be closed naturally. As a consequence, it is likely to cause a serious damage to local transportation activities.

Current problems of the lagoon system comprise of the two: salinity variation and environmental degradation caused by human activities. Regarding the salinity variation, during the dry season in particular, sea water intrudes the lagoon, which makes the salinity higher. On the other hand, during the rainy season or after a heavy storm, flooding spawns the low salinity in the lagoon. This low salinity and the higher variation discourages the potential of aquaculture and constraints its products.

The content of nitrogen and/or phosphorous is increasing gradually although it has not reached a critical range nor the eutrophication has not been recognized yet at this moment. The phenomenon of red tide has been recognized recently.

1.5 Evaluation and Recommendations

(1) Evaluation of Lagoon Ecology

Tam-Giang – Cau Hai lagoon covers a surface water area of 22,000 ha, the largest one in Southeast Asia, extending along Thua Thien Hue coastline with the total length of 60 km. The lagoon can be divided into three areas: Tam – Giang Lagoon in the north, Sam – An Truyen swamp and Thuy Tu swamp in the middle and Cau Hai swamp in the south. Reflecting its variety of natural environment, the ecosystem in the lagoon is rather wealthy in the number of species recorded in comparison with other lagoon system in Vietnam.

The lagoon is currently open to the sea through two mouths: Thuan An and Tu Hien. Both of them are unstable and have been repeatedly incurring the shrinkage, occlusion or transformation. In addition, during the destructive flood in November in 1999, Tu Hien mouth was extended and the new mouth was created at Hoa Duan located south of Tuan An estuary, although the Hoa Duan estuary is closed again currently.

The lagoon system has the characteristics that the water quality varies with location and is easily affected by the fluctuation of river discharge and tide. Water quality in the lagoon is suitable for aquatic organisms at present and satisfies the requirements of aquaculture

breeding in terms of such indicators as pH, DO, COD and BOD. According to the interview to local fishermen, however, water quality has been degraded caused by human activities and there was the presence of red tides in 2000, which shows a sign of threatening the aquatic ecology and reducing the fish catch.

Salinity is one of the determinants of the distribution and growth of salty water flora and fauna in the lagoon where the environment constantly changes under the process of river and sea interaction. On the basis of the salinity data, the lagoon can be divided into the following three sub-regions: 1) the area with almost unchanged salinity (the area from An Gia to O Lau river mouth), 2) the area of slightly changed salinity (the area from the north of Thuan An estuary to An Xuan) and 3) the area of greatly changed salinity (the area including Sam-An Truyen, Thuy Tu and the whole Cau Hai swamp).

The appearance of Hoa Duan mouth and expanded Tu Hien mouth has not converted the whole Tam Giang – Cau Hai lagoon into a heavily brackish water body. However, the impacts on salinity were observed in some area, e.g. the salinity of Cau Hai swamp was partly raised by Tu Hien mouth.

With respect to the impacts on fisheries, due to the newly created mouth of Hoa Duan and expanded Tu Hien, most of the aquaculture production has increased. This fact indicates that the presence of the lagoon mouth/estuary, or intrusion of sea water, provide positive impacts on the aquatic production and tend to increase the biodiversity in the lagoon.

As for the socio-economic aspect, fishery is the mainstay of economy in the lagoon area. There are three main types of fishery in the area; i.e. fishing within the lagoons, aquaculture within the lagoons, and fishing in the coastal/offshore area. Fishing and aquaculture in the lagoon and coastal/offshore area have been increasing remarkably over the past years.

The scale and magnitude of existing fishing activities are considered to have reached or exceeded the maximum re-productivity of the lagoon system as pointed out by MOSTE. For the sustainable development of socio-economy in the area, it was recommended that the reduction of fishing and aquaculture activities, conversion of saline intruded paddy fields near the lagoon into aquaculture / breeding area.

(2) Recommendations

As described above, the major problems in the lagoon are enumerated as below:

- There is a symptom of degradation of water quality caused by human activities, which has reached the level on which the red tide is identified.
- Salinity in the lagoon is unstable which is largely due to the fragile estuaries, especially Tu Hien mouth.
- Fishing and/or aquaculture activities are considered to have reached to or exceeded

the re-productive capacity in the lagoon system including the adjacent coastal area.

In order to cope with these problems, the following actions/measures should be taken:

1) Environmental monitoring should be conducted in order to obtain benchmark data/information and to evaluate the change of lagoon environment. Parameters and/or indicators of the monitoring include 1) physico-chemical parameter; temperatures, pH, DO, BOD, COD, Salinity, Nitrogen and Phosphorous, 2) biological inventories; not only aquatic organisms including phytoplankton, zooplankton, aquatic grasses, benthic organisms but also fishes (not limited edible fishes) and waterfowl. The monitoring should be done regularly, preferably yearly at the same points as those made by MOSTE for the comparison. In addition, the data on fish catch and aquaculture production by breeding should be monitored monthly or at least yearly, because the fish catch amount is strongly reflecting the lagoon ecology.
2) Salinity is the most important and influential factor for the lagoon ecology and for the fisheries. Salinity is affected by the shrinkage or expansion of lagoon estuaries, especially by unstable Tu Hien at present. Therefore, adaptive management of Tu Hien mouth is essential as pointed out by MOSTE in the research report. Specifically, the maintaining of Tu Hien mouth in proper size should be required.
3) As indicated in the research report prepared by MOSTE, some control of fishing and aquaculture activities is needed. The excessive fishing activities will cause not only the exhaustion of aquatic resources but also the environmental load to the lagoon water quality. Considering the fact that red tide has observed in recent year, water quality in the lagoon is to be evaluated as at the entrance stage of eutrophication, although the current water quality is satisfactory level for aquaculture.

Thus, the environmental monitoring and the proper management of the Tam Giang – Cau Hai lagoon system are the most essential for the sustainability of lagoon ecology as well as the socio-economy of the surrounding area.

2. REVIEW ON THAO LONG BARRAGE

2.1 Issues Resulting from Salt-water Intrusion

The salinity in the coastal lowlands is affected by the fresh water flow of the rivers and the tidal influenced water levels in the lagoon.

Salt intrusion may take place through (a) Huong/Bo River mouth, (b) drainage outlets along the lagoon, and (c) saline/ brackish ground water flow from the lagoon.

During high river discharges in the rainy season the salt water intrusion is pushed back into the lagoon. In the dry season from January to August, however, salinity levels increase far inland. The confluence of Huong and Bo rivers is rather close to the lagoon so both rivers face salt water intrusion far inland. Droughts in July and August result very low river discharges with saline water intruding far upstream. Salinity may even pass the railway line that runs more or less on the high land side of the coastal lowlands. In very dry years even further upstream.

The low discharges limit the available irrigation water, and hampers the agricultural production and livelihood. Some farmlands are left fallow due to shortage of water. In these months intensive, short duration showers may bring early floods over farmland and damage harvest and young crops.

When water levels in Huong River become (very) low the irrigation intakes have to be closed to prevent saline river water to flow into the canal system. The main intake Phu Cam was closed 70 days in 1993 and 59 days in 1994, and farmers had to take water from any watercourse by small movable diesel pumps. This shows that the waterway system also has an important storage function.

At present salt intrusion is one of the major problems that hamper further development of irrigated agriculture in the low areas. There were even plans considered to replace the intake more upstream.

2.2 Effect of the Barrage to Prevent Salt-water Intrusion

In 1978 the 'old' Thao Long Anti Salinity Weir was constructed in the mouth of Huong River. It worked in some way, but had too many openings whereas closing and opening had to be carried out by placing 'gates' by hand. This was too inconvenient and time consuming. As a result the structure could not be operated adequately when river discharges changed too quickly. Such rapid changes often coincided with rainstorms in the mountains, and the quick runoff (6 hours). At present the weir is partly damaged and hardly functions anymore.

In the meantime a new Thao Long Barrage has been designed and the construction has

already started, about 50 m downstream of the old weir. The design principle looks alright. It contains a dam, a gated weir, a shipping lock and a bridge. The construction period is planned at 3 years. So with its actual start in Aug.'01 it is expected to be become effective in 2004.

The objectives of the new Thao Long Barrage are:

(1) to prevent salt water intrusion from the lagoon into Huong River.

(2) to store fresh water in the river channel upstream of the barrage for domestic, industrial and agricultural use.

Photo 1 shows the 'artist impression' of the barrage, including a cross section with the principle method of opening/closing of the gates. Photo 2 shows the state of the work on 9 Nov.'01. Nearby the old barrage is visible, and further away the construction crane at the site of one of the piers. Because of the (too) high water there were no activities ongoing.

The length of Thao Long Barrage is determined at 571.25 m, the distance between the dikes on both riverbanks. It will get 15 overflow gates (w=31.5m) hinged on the floor. The sill level of 9 gates is 2.50 m^-, and of 6 gates 1.50 m^-. In closed position the top of the gates is at 1.20 m^+. An additional navigation lock (8m wide and 52m long) with two-way swing-doors, allows the passage of 4-5 m wide boats. The total width of gate/lock openings is 480.50 m. A 7 m wide bridge (H.13 loads) over the weir will get a length of 571.25 m. The bridge underside is at 5.50 m^+.

Thao Long Barrage prevents the salt water to enter and, through operation of the gates, keep the upstream water level at 0.50 m+. This is usually above the (tidal) water levels in the lagoon, preventing seepage of saline water through the dam and/or subsoil. The discharge of the river can be used for brackish water of the fish cultures, for irrigation and for flushing of the main canal/drains.

With the new barrage and (later) Ta Trach Dam the salinity intrusion can be fully controlled and minimum water levels in the downstream reaches of Huong and Bo rivers rise to 0.50 m^+, which means that:

- The whole downstream Huong and Bo rivers will become a fresh water reservoir.
- Higher minimum water levels increase the capacity of the main intakes Nham Bieu, Phu Cam and La Y increase
- Higher minimum water levels reduce the static head of the pumping stations along Huong and Bo Rivers and connected branches.

During low river discharges water can be stored in the river branches and in the irrigation

system (in principle at 0.50 m^+). However, a high storage level reduces the storage capacity for heavy rainstorms and early floods.

Saltwater intrusion via the drainage outlets is negligible, as long as they are in good condition and properly operated. Limited leakage water will have negligible effect on the water quality.

Infiltrated rainwater on the sandy ridges infiltrates and flows partly to the lagoon and partly to the land. The infiltrated ground water forms a fresh water lens that obstructs the saltwater intrusion via ground water.

Regular adjustments of the opening position of the gates is needed to keep the upstream water level in the river as long as possible at the design level of 0.50 m^+. An operation schedule has to be developed for the present upstream situation. But since it is expected that Ta Trach Dam will be constructed it has to be adjusted in a few years. Although the upstream water level will in principle be maintained at 0.50 m+ it will fluctuate just upstream of the barrage because the discharge through gates fluctuates with tidal water levels in lagoon. Further the operation of gates is related to the river discharges.

The opening/closure time of the gates will be a few minutes per gate, depending on the installed lifting capacity and available power. Provisions for lifting the gates during general power failure are not known.

The (average) gradients of the water levels depend on the discharges and have been calculated by the River Engineer. For some major locations the values, with sea level at 0.00 m^+, are:

		Thao Long barrage	Conflu-ence Bo R.	La Y spill-way	Dap Da dam	Moi bridge	Phu Cam intake	Nham Bieu intake
Chainage (km)		2.8	9.1	14.2	17.3	18.6	19.8	24.8
Discharge (m^3/s)	Gradient (m/km)	Water levels (m+)						
200	0.01	0.01	0.05	0.09	0.11	0.12	0.12	0.15
1,000	0.07	0.18	0.86	1.33	1.51	1.55	1.59	1.81
3,000	*0.18*	*1.06*	*3.07*	*4.11*	*4.44*	*4.51*	*4.60*	*4.96*
5,000	*0.23*	*2.02*	*4.67*	*6.07*	*6.45*	*6.53*	*6.64*	*7.00*

Floods over 3,000 m^3/s will cause overland flow that reduces the gradient (italic figures in above table are for confined flow only). The water levels are affected by both the discharges of Huong and Bo Rivers. In the coastal lowlands, i.e. roughly downstream of the railway, both river courses are rather flat (forming more or less one basin). Any rise in water level in one of the rivers will cause a water level rise in the other river too. However, the discharges are mainly related to the rainfall, and that is usually rather

equally distributed over the (combined) catchment.

Fluctuating discharge will require manipulation of the gates. In case of depressions with heavy rainfall gates may have to be opened in advance to create storage. Even when rainfall is less than expected, river discharge will be sufficient to bring the level back to 0.50 m^+ soon. There is a simulation model under development, but details are not available.

Other effects of the Barrage are considered hereinafter.

Flooding

The operation of the barrage will only properly function as long as the discharges are not too high. During floods the capacity of the outlets is insufficient and the structure cannot discharge all the water. The total 'wet opening' of the barrage is less than the 'wet cross section' of the river. Only part of the floodwaters will pass the weir, the remaining discharge has to find other outlets, or pass as overland flow (over the agricultural lands).

Although the overland flow will increase, it is expected that the increase in water levels will be insignificant.

Sedimentation

During full and partly closures the flow velocities upstream of the barrage will decrease and in principle more sediments will settle. However, during low discharges, when the barrage is (partly) closed there is hardly any sediment transport.

Pollution

During longer periods of (nearly) closure the river water will be almost stagnant. So polluted water will not move and diluted or be replaced. In particular near outlets of untreated wastewater (around Hue City and other densely populated areas) the conditions can become unacceptable.

Flushing of the irrigation system

Without Thao Long Barrage the water level in the mouth of Huong River would, during low river discharges, be about the water level in the lagoon. With the operation of the barrage it is the intention to keep the water levels upstream at 0.50 m^+. So in general there will be additional head available for better flushing of the main irrigation system.

Fish breeding and migration

The barrage will influence the discharges and water levels in the mouth of Huong River (in particular the minimum). There will be a minimum discharge (for ecological, etc. needs). Fish could pass through the gates, but the overflow type gates may be difficult to pass. The actual influence of the barrage on the movement of fish in the mouth of the

river and the effects on breeding places are unknown. The operation program of the gates should take into account if fish like open gates in the center of the river, or near the banks.

Area development

The 7 m wide, two-lane bridge provides an extra road connection south of the lagoon. It will stimulate the regional development. However, the benefiting area is small, and (too) close to Hue. Most transport will be to/from the town.

Bridge and Road System

Details about the future connecting road system are not known. It needs special attention because the road embankment will block the overland flow. During extreme river discharges about 50% may pass the barrage and the other 50% as overland flow. This means that during a 'Nov.'99-flood' with about 12,000 m3/s the overland flow will be about 6,000 m3/s. This requires a big cross drainage capacity through the road embankment.

Lagoon exit

With Thao Long Barrage the river discharges will be regulated, but the effect on the lagoon and its exit is unknown, complicated and beyond the scope of irrigation and drainage.

2.3 Required Minimum Discharge from Upstream Dam

Thao Long Barrage creates a fresh water reservoir in the lower parts of Huong and Bo rivers. Part of this water can be used to support irrigation, and another part is needed to improve water quality.

The maintenance flow in Huong River is examined in Main Report Chapter 5. Therefore, A required minimum river discharge is discussed in this section focusing on a viewpoint of irrigation and/or agriculture, i.e.: (a) salt water exclusion, (b) fisheries, and (c) water quality.

With the barrage the present required river discharge to cope with salt water intrusion, etc. can be reduced.

(1) Salt Water Intrusion

Important locations for salinity are Huong River mouth (km 0.00), Thao Long Barrage (km 2.80) confluence of Bo River (km 9.10), La Y Spillway (km 14.20), Moi Bridge (km 18.6) and Phu Cam Intake (km 19.8).

The Feasibility Study on Ta Trach Project; May '00, and the Environmental Impact Assessment; Ta Trach Reservoir Project: May '00, show salinity (%0) measured at La Y Spillway, collected on 25-27 Apr.'86 (Thao Long Barrage open) and on 19-21 Jul.'86

(Thao Long Barrage closed). The river discharges, salinity and time of these measurements have been presented in the graph. The reported required 'anti salinity discharge' of Q=61 m3/s is based on the few data of 25-26 April, '86.

The irrigation supply through Nham Bieu and Phu Cam intakes is taken from the river discharge and 'lost' for salinity decrease. It is not clear how a (low) discharge of Bo River, with its confluence 17 km downstream of Phu Cam Intake, will contribute to the salinity reduction.

The salinity criteria of S=1.0^{TM} (mean value) is general accepted. However the salinity at La Y Spillway is used as design. But the intake of irrigation water at La Y can (temporary) be taken over by Phu Cam Intake, about 5.6 km more upstream. For irrigation higher salinity downstream Phu Cam could be accepted since there are no fresh water off-takes. Domestic/ industrial water intake is upstream of Phu Cam. Therefore also a maximum salinity of S=1‰ at Phu Cam Intake could be the design criteria.

In a cross section the salinity decreases from bottom (salt wedge) to surface, and from the (deeper) middle of the flow to the banks. Irrigation water is taken at the bank, at a level well above the riverbed, so the mean salinity is in general be higher than the irrigation water salinity.

(2) Water Pollution

There is a certain flow necessary to decrease the polluted water to quality standard. This depends on the type and concentration of pollution. Although at present there are no water treatment plants in Hue (except for the hospital and some industries), the existing condition of water quality in the river is almost acceptable. However, during further development of a country discharge of polluted water on open water (rivers, canals, drains and lakes, but also lagoons and even the sea/ocean) becomes less acceptable. Water with chemical and/or other pollution has to be treated before discharge into open water in order to keep the water quality and also to keep the acceptability for the purpose of irrigation use.

3. REVIEW ON THE HUONG RIVER MOUTH IMPROVEMENT PLAN

3.1 Background

There exists the biggest lagoon in Vietnam around the river-mouth of the Huong River. This lagoon is called as the Tam Giang - Cau Hai lagoon. The general location is shown in Figure B.2.

The surface area of the lagoon is some 22,000 ha, the length of the lagoon in the direction of north to south is some 68 km, the width ranges from 11 km to 700 m, and the volume is some 300 - 400 million m^3. The lagoon is intensively utilized for fishery, shrimp raising, sea weed cultivation, and water transport.

There exists a Thuan An port close to the river-mouth of the Huong River. This lagoon has the estuary to the sea at two locations, namely Thuan An estuary and Tu Hien estuary on the north and the south.

The boundary between the lagoon and the sea is a huge sand dune forming residential area as satellite town of Hue City and agricultural land. There exist dense road networks in the area.

The lagoon, in its long history, has changed the location of the mouths to the sea. Every time the mouth of the lagoon changed its location, the natural conditions in and around the lagoon and the living conditions of the local people changed. Accordingly the government of Vietnam has conducted the study on the hydrodynamic mechanism of the lagoon.

In November 1999, a big flood occurred in the Huong River basin, and the water level of the lagoon rose very high and as a result the sand dune collapsed at three locations, forming new estuaries of the lagoon to the sea..

A study was to be started to decide whether or not to close the newly created estuaries. But soon after that, two of three new mouths were closed by natural littoral drift and the remaining estuary called as Hoa Duan estuary, was closed artificially for restoration of local traffic. But on this occasion, the Government of Vietnam decided to conduct the study on the various functions of the lagoon including the functions of the estuaries of the lagoon.

3.2 Study on the Lagoon

The said study is called as the Study on Alternative Measures for Restoration and Stabilization of, Thuan An–Tu Hien Estuaries and Tam Giang-Cau Hai Lagoon.

The study was conducted for the period from May 2000 to May 2001. The study was

conducted under the chief researcher Professor Dr. Tran Dinh Hoi, Deputy Director of Institute of Water Resources Research under the superintendence of MOSTE. The involved researchers were 19 researchers of 6 Ministries and Research Institutes of the central government, universities, and the People's Committee of Thua Thien Hue Province.

The said study prepared the following reports:

(1) Main Report

(2) Specific Report

1) Geology-Geochemistry of Thuan An – Tu Hien Estuaries and Tam Giang - Cau Hai Lagoon
2) Frequent Monitoring of Thuan An - Tu Hien Estuaries and Hoa Duan Area
3) Geographical Rules of Natural Components Concerning Flood Disaster, Erosion, Sedimentation, and Overall Solutions to Thuan An – Tu Hien estuaries and Tam Giang - Cau Hai Lagoon
4) Impacts of the Destabilization of Lagoon Estuary on Tam Giang - Cau Hai Environment and Resources
5) History of Changes in Tam Giang and Cau Hai Lagoon Environment
6) Observation at Hue Coastal Line Development via Ariel Materials and Geographical Information Technology
7) Lagoon Development and Hydrodynamics
8) Marine Hydrodynamics
9) Urgent measures for the coastline of 2 villages of Hai Duong commune, Huong Tra district, Thua Thien Hue Province
10) Socio – Economic Development Issues of Thuan An – Tu Hien Estuaries and Tam Giang – Cau Hai Lagoon
11) Flood and Mathematical Models

(3) Study on Solutions for Thuan An – Hoa Duan Coastal Line Conservation

(4) Topography of Coastal Estuaries and Lagoon from Thuan An to Hoa Duan

(5) Draft Drawings of Coastal Line Conservation from Thuan An to Hoa Duan

(6) Cross Section Drawings of Coastal Estuaries and Lagoon from Thuan An to Hoa Duan

The main report concludes as follows:

- Solutions to minimize flood damages by the following:
  - To construct upstream reservoirs
  - To lower flood water level in Hue City by expansion of sea mouth

- To plant trees for protective forest
- To reduce the difference of water level between the upstream and downstream of the national highway No.1A and the North-South Railway.

- Solutions for coastline protection by the following alternatives:
  - To conduct artificial replenishment at Thuan An area
  - To construct groin system
  - To construct wave-resistant dike away from the coastline
  - To construct multi-purpose structures for sand retention and wave mitigation
- Solutions on settlement area by:
  - To evacuate people from erosion prone area and areas with the risk of forming the new sea mouth, and to arrange resettlement area for the people
  - To settle people ashore who are living in boat houses
- Solutions on production structure shift
  - To convert low productive farming area along the lagoon into area for aquaculture breeding
  - To decrease exploitation in the lagoon and change from fishing in the lagoon to offshore fishing
- Solutions of sea mouth stabilization
- Solutions of infrastructure investment

3.3 Review of the Study

The structural measures to mitigate flood damage in the Huon River basin including the Hue City concluded in the said reports are basically as follows:

- To expand the mouth of the lagoon
- To improve the bridges of the national highway No.1A and the North-South Railway

The report says that the expansion of the lagoon mouths to the sea at Thuan An and Hoa Duan is reasonable measures for reduction of flood damage of the flood in November 1999. The report says that the expansion of lagoon mouth would also substantially shorten the inundation period, not only lowering the peak flood water level. The present lagoon mouth to the sea at Thuan An mouth is not enough for draining the flood water in a case of November 1999 flood. The report also points out that the Tua Hien lagoon mouth is not effective for draining the flood water in such a case of November 1999 flood,

since the lagoon between the Cau Hay lagoon and Tam Giang Lagoon is very shallow and narrow.

In the report, it is discussed that flood flyover bridge can be built at Hoa Duan mouth when the Hoa Duan mouth is kept open as flood mitigation method.

Besides, the report refers to the assessment by Department of Fishery of the Thua Thien Hue Province that the opening of the Hoa Duan mouth will bring more benefit for fishery and contribute more to the economic development of the area than closing, and it is necessary to stabilize and expand the lagoon mouth to the sea to enrich and prolong the lagoon's life span as well as to reduce the flood damage.

On the other hand, the costal line from Thuan An to Hoa Duan area has been suffering from the serious seacoast erosion since the 1999 November flood. Even after the breach at Hoa Duan was closed for restoring the local traffic, the erosion is still on-going. Accordingly the report suggests some measures to protect the seacoast from erosion. The report recommends some structural alternatives as mentioned in the previous section.

But it is also discussed in the report that the concave pool created at Hoa Duan by the closure of the breach is causing great regional erosion to the north bank of Hoa Duan mouth and Thuan An beach area. (Refer to Figure B.2.)

Accordingly to keep the Hoa Duan mouth open to the sea for the mitigation of flood damage in the Huong River basin means that one of the reasons of the seacoast serious erosion would be left as it is. This can not be recommended since the serious discussion and the effort are being made to protect the seacoast from erosion in the area.

On the other hand, to expand the present lagoon mouth to the sea at Thuan An can be one of the effective measures to mitigate the flood damage in the Huong River basin in such a case of 1999 November flood since the Hoa Duan mouth is already closed. But the expansion of the Thuan An lagoon mouth may lead to the acceleration of aggradations of the mouth causing the difficulties of navigation for the Thuan An seaport. The central government and the local government of Thua Thien Hue province may suffer from the heavy load of maintenance of the lagoon mouth for not only keeping the navigation but also for bypassing the littoral drift to the south to avoid the more serious seacoast erosion.

As clearly mentioned in the report, the said study is a very limited one in the study period, the input and the objective area. Accordingly the report declares that the report result is not a master plan but the scientific conclusion for the very limited objective area from Hai Duong to Hoa Duan area.

Accordingly the report recommends further study for the comprehensive solution for the economic development of the overall lagoon system and the province.

Accordingly it is also not clear if some structural measures for the seacoast erosion protection at the Thuan An and Hoa Duan area are constructed, what would happen for the adjacent area regarding the seacoast erosion.

Concisely it can be said as follows:

- It is favorable to make more lagoon mouths or to expand the present lagoon mouth in the width and depth in the area of Thuan An to Hoa Duan for the mitigation of flood damage in the Huong River basin and for the more benefit for the aquaculture of the lagoon. The salinity intrusion to the Huong River can be controlled by the construction of Thao Long barrage and accordingly the adverse effect to the salinity intrusion due to more or wider mouths of the lagoon to the sea would not be expected.
- The favorable measures above-mentioned would worsen the situation of seacoast erosion in the said area or heavy load of maintenance of the lagoon mouths and endless effort for seacoast protection from erosion would be expected.
- The said report left some alternatives of seacoast protection measures. But those alternatives should be studied not only for the selection of the alternatives but also from the viewpoint if the implementation of those measures would cause further seacoast erosion in the adjacent areas.
- The conclusions of the said report are limited scientific conclusions due to the limitation of the study period, the input to the study, and the objective area. Accordingly the study recommends further study for the comprehensive development of the lagoon system and the surrounding area in Thua Thien Hue province.

3.4 Summary

(1) Relation between Sandbar Collapse and Flood Flow

The reason of sandbar collapse at Hoa Duan due to 1999 November flood is reported that the flood flow of the Huon River did not widely spread over the whole lagoon area but was concentrated to the limited area near the Thuan An and Hoa Duan area since the lagoon to the other area is narrow and shallow and accordingly the water level of the lagoon in the area became very high and due to the geological weakness of the sand bar around there and the pressure of the water level, the sandbar was collapsed.

(2) Restoration Alternatives of Lagoon

The following alternatives of restoration of collapse of sandbar are conceivable:

(a) To keep the openings as they are and construct bridges over the openings to keep

the local traffic, and construct facilities as measures for seacoast protection from erosion, since keeping the openings as they are may lead to more serious seacoast erosion near the area, but may lead better effect to the lagoon environment including the aquaculture.

(b) To close the openings with the height lower than the present closure at Hoa Duan but with the same with to that of the present sandbar to avoid the seacoast erosion as much as possible.

(3) Selection of Realistic Restoration Plan

The basic point is to close or not to close the openings of the lagoon to the sea. The point depends on the aquaculture in the lagoon, the seacoast erosion, and the flood control. If the openings are left as they are, the better situation can be expected for aquaculture and flood control, but adverse effect to the seacoast protection from erosion will be expected. If the opening should be closed, the worse situation for aquaculture and flood control and better effect to the seacoast protection can be expected. Presently the structural measures for seacoast protection from erosion may need the huge cost and the result is not always definite. Accordingly the option should be selected from the viewpoint that the option which may threaten the seacoast erosion should be avoided.

The alternative (A) in the above is a desirable one for aquaculture in the lagoon and also a good one from flood control viewpoint since the high water level in the lagoon can be avoided. But that alternative may cause the serious seacoast erosion around the area. Accordingly the alternative (B) may be the better selection of the restoration plan. The closure of the openings should be as low as possible for flood control viewpoint so long as the closure measures would not cause some adverse effect to seacoast erosion. The present elevation of the closure at Hoa Duan is +2.5 m. This seems to be rather high from the viewpoint of flood control of the Huong River. Some people suggest +1.5 m as the elevation of the closure at Hoa Duan since the ground elevation around the river-mouth of the Huong River is approximately +1.5 m. The width of closure should be as same as possible with the present width of the sandbar to avoid the seacoast erosion since the present closure at Hoa Duan forms the concave at the site and causes the seacoast erosion around the area. Regarding the aquaculture, the closure may not worsen the former situation of the lagoon before the openings are made.

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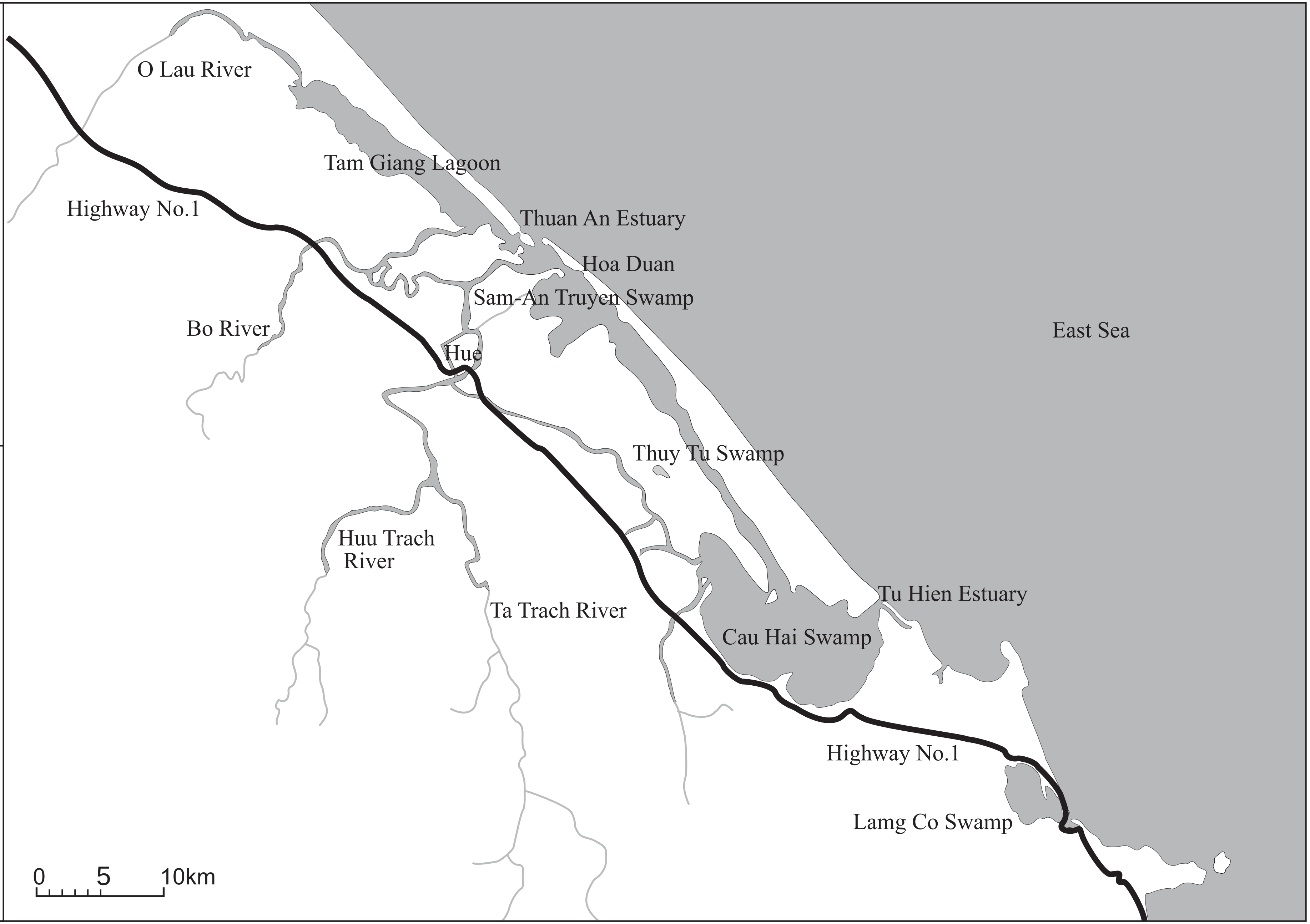
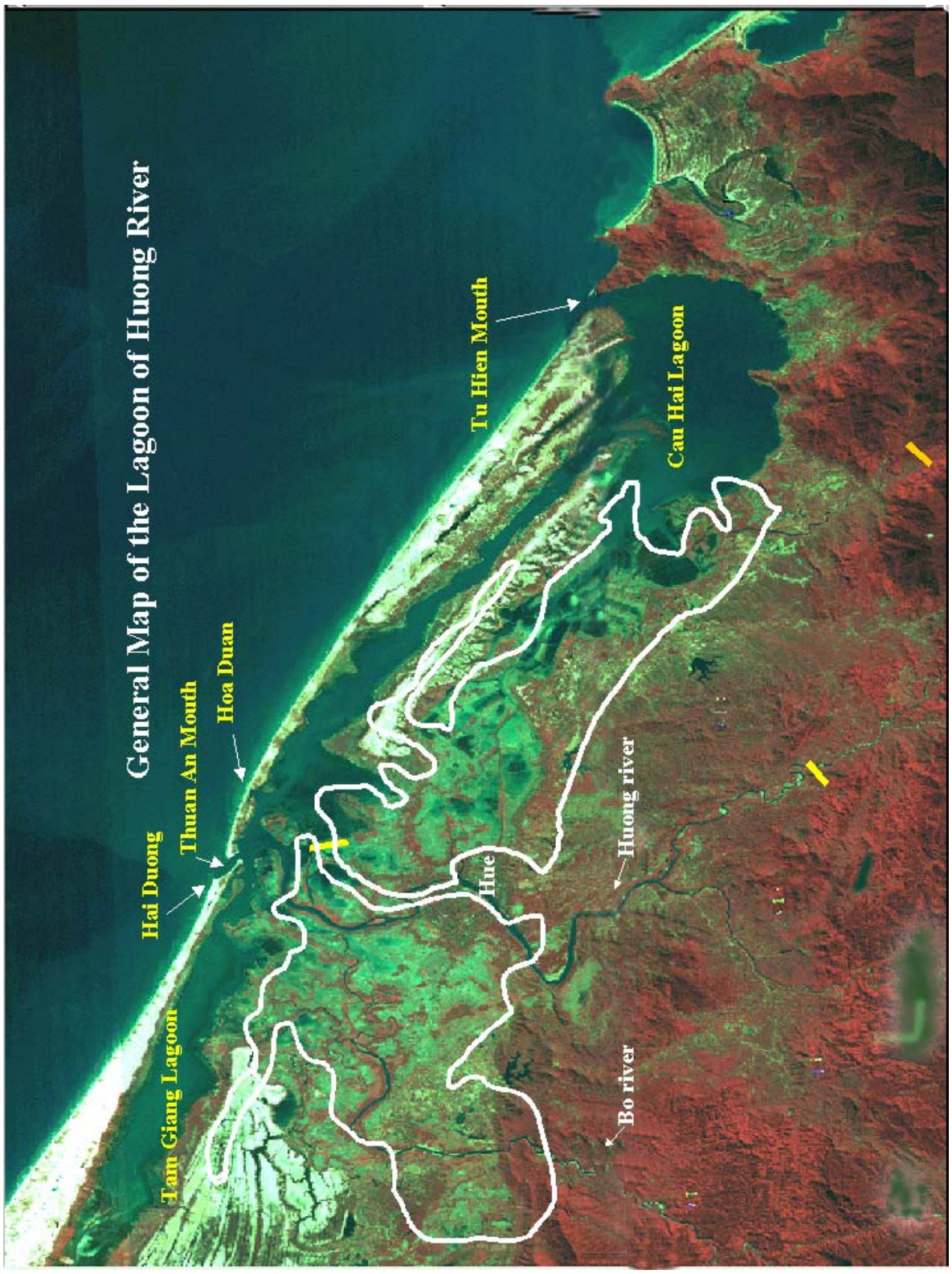
Figure B.1 Geographical Extent of Tam Giang - Cau Hai Lagoon





The Study on Nationwide Water Resources Development and Management in the Socialist Republic of Vietnam	**Figure B.2** General Location Map of Tam Giang - Cau Hai Lagoon
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