CHAPTER 1 SCOPE OF THE STUDY

1.1 Background of the Study

Water resources in Vietnam are characterized by severe water shortage in the dry season and, on the contrary, serious flood damages in the rainy season.

The water shortage in the dry season causes not only irrigation domestic and industrial water supply problems but also serious water pollution and saline water intrusion. Flood damages in the rainy season including agricultural production loss, human lives and important assets in densely populated urban areas are being accelerated due to recent remarkable urbanization.

As such, solution of the problems is of keen necessity of Vietnam, and several water resources development projects comprising mainly multipurpose dam based projects have been proposed by each province. However, since the proposed projects are not integrated as a basin-wide water resources development, the Ministry of Agriculture and Rural Development (MARD) has difficulty to determine the implementation sequence for these water resources developments. In order to overcome these constraints, the Government of Vietnam has come to conclusion that an integrated approach to water resources development and management is unavoidable, and had a strong intention to carry out a study on nationwide water resources development and management.

In order to materialize the study, the Government of Vietnam requested to the Government of Japan the technical assistance of the Study on Nationwide Water Resources Development and Management Master Plan (the Study). In response to request of the Government of Vietnam, the Government of Japan decided to conduct the Study within the general framework of the technical cooperation between the Government of Japan and the Government of Vietnam signed on October 20, 1998.

1.2 Objectives of the Study

The objectives of the Study are:

(1) To formulate a master plan for nationwide water resources development and management,

(2) To conduct a feasibility study for selected priority projects, and

(3) To pursue technology transfer to counterpart personnel in the course of the Study.

1.3 Study Area

The Study covers the following 14 major river basins:

1) Bang Giang and Ky Cung River basin
2) Red and Thai Binh River basin
3) Ma River basin
4) Ca River basin
5) Thach Han River basin
6) Huong River basin
7) Vu Gia-Thu Bon River basin
8) Tra Khuc River basin
9) Kone River basin
10) Ba River basin
11) Sesan River basin
12) Srepok River basin
13) Dong Nai River basin
14) Cuu Long River basin

Location map of the above 14 major river basins is shown in Figure 1.1

1.4 Scope of the Study

The Study has been undertaken in the following manner in the two phases:

Phase I : [Basic Study and Formulation of Master Plan]

a) Formulation of a master plan for nationwide water resources development and management in 14 major river basins

Phase II : [Formulation of Integrated River Basin Management Plan(s) for the Selected River Basin(s) and Feasibility Study on Priority Projects]

a) Formulation of an integrated river basin management plan for the Huong River basin (Phase 2-1)
b) Formulation of an integrated river basin management plan for the priority river basin selected from 14 river basins (Kone River basin, Phase 2-2)
c) Feasibility study for the priority projects to be selected from the priority river basin (Phase 2-3)

1.5 Implementation Organization

Institute of Water Resources Planning, Ministry of Agriculture and Rural Development(MARD) act as the counterpart body to the JICA Study Team and also as the coordinating body in relation with other governmental and non-governmental organizations concerned in Vietnam for the smooth implementation of the Study.

The JICA Study Team is headed by the Team Leader who is responsible for maintaining a close liaison with the MARD, JICA and agencies concerned. He is also responsible for planning activities and monitoring the progress of the entire study for ensuring its timely and efficient completion. The members of the Study Team and the members of the Advisory Committee are presented in Table 1.1.

The Steering Committee was organized in February 2002, chaired by the Vice Minister of MARD. The Committee consists of MARD, Ministry of Planning and Investment (MPI), Vietnam National Mekong Committee(VNMC) and Peoples Committee(PC) r related to the Study. The Steering Committee members are shown is Table 1.2.

1.6 Study Schedule and Activities

(1) General Schedule

Phase I : Basic Study and Formulation of Master Plan during a period from September 2001 to July 2002,

Phase II-1 : Formulation of Integrated River Basin Management Plan for the Huong River Basin, during a period of October 2001 to July 2002, including

1) 1st Works in Vietnam

2) 1st Works in Japan

Phase II-2, II-3 :

Formulation of Integrated River Basin Management Plan for the Selected River Basin(Kone River basin) and Feasibility Study on Priority Projects during a period of August 2002 to September 2003, including

1) 2nd Works in Vietnam

2) 2nd Works in Japan

3) 3rd Works in Vietnam

4) 3rd Works in Japan

(2) Activities in the Works in Vietnam

In accordance with the objectives of the Study and schedule, the works in Vietnam were conducted in October 2001 through March 2002 for Phase I, and from August 2002 through March 2003 for the Phase II study. The third works in Vietnam was conducted from July to August 2003 for the discussion on the Final Report.

As a part of the works in Vietnam, the following field survey works have been carried out on sub-contract basis:

Phase I

(i) Inventory survey works

(ii) Hydro-meteorological observation

Phase II-1

(iii) Hydro-meteorological observation

Period : December 2001 to March 2002

Scope of Works : Installation of hydro-meteorological station and their observation in Huong River basin

(iv) Topographical survey

Period : December 2001 to February 2002

Scope of Works : River survey in the Huong River, Lagoon survey and Sea survey

(v) Environmental Impact Assessment (EIA)

Period : December 2001 to March 2002

Scope of Works : EIA study in the Huong River basin

Phase II-2

(vi) Hydro-meteorological observation

Period : August 2002 to March 2003

Scope of Works : Hydro-meteorological observation in Kone River basin

(vii) River survey

Period : September to November 2002

Scope of Works : River cross section survey along the Kone River

(viii) Initial Environmental Examination (IEE)

Period	:	August to November 2002
Scope of Works	:	IEE in the Kone and Ha Thanh River basins

<u>Phase II-3</u>

(ix) Topographic survey

Period	:	December 2002 to January 2003
Scope of Works	:	Topographic survey including mesh survey and digitizing topographic maps for Dinh Binh dam site and Van Phong weir site

(x) Environmental Impact Assessment (EIA)

Period	:	December 2002 to March 2003
Scope of Works	:	EIA on the priority projects in the Kone River basin

(xi) Geological investigation

Period	:	December 2002 to February 2003
Scope of Works	:	Geological investigation in Dinh Binh dam site, Van Phong weir site and river improvement area in the Kone River basin

(3) Workshop, Technical Transfer Seminar and Presentation Seminar

Workshops and Seminars were held in the course of the Study in the following manner:

(a) Workshop

	Workshop	Subject	Date
(i)	Inception Workshop	Inception Report	November 2001
(ii)	1st Workshop	Progress Report (2)	March 2002
(iii)	2nd Workshop	Progress Report (3)	December 2002
(iv)	3rd Workshop	Interim Report(2)	March 2003

(b) Technical transfer seminar

	Seminar	Subject	Date
(i)	1st T.T.Seminar	- Formulation of flood control plan in the study - Application of computer software in runoff analysis - Application of computer software in irrigation planning/management - Alternative study in Huong river basin	September 2002
(ii)	2nd T.T.Seminar	- Achievement of Water Resources Development in Japan - River Plans in Japan - Planning Concept and Methodology on Multi-purpose Dam - Planning Methodology of Flood Control - Irrigation Planning for Better Operation and Maintenance	August 2003

(c) Presentation seminar

	Seminar	Subject	Date
(i)	Presentation Seminar	- Achievement of Water Resources Development in Japan - Recommendation and Overall Outcome of the Study - Formulated Water Resources Development and Management Plan - Planning Methodology of Flood Control - Formulated Agricultural Development Plan in the Study	August 2003

(4) Reports

In the course of the study, the following reports have been prepared and submitted to MARD to date:

	Report	Main Subject	Submission
(i)	Inception Report	Scope of works, work plan and work schedule	October 2001
(ii)	Progress Report (1)	Work progress of Phase I and Phase II-1	January 2002
(iii)	Progress Report (2)	Work progress of the formulation of the master plan for nationwide water resources development and management in 14 major river basins as well as the formulation of the integrated river basin management plan for the Huong River basin (Phase 2-1)	March 2002
(iv)	Interim Report (1)	Master plan for nationwide water resources development and management in 14 major river basins as well as the integrated river basin management plan for the Huong River basin (Phase 2-1)	August 2002
(v)	Progress Report (3)	Work progress on the formulation of the integrated river basin management plan for the Kone River basin (Phase 2-2)	December 2002
(vi)	Interim Report (2)	The integrated river basin management plan for the Kone River basin (Phase 2-2) and the Feasibility study for the priority projects in the Kone River basin (Phase 2-3)	March 2003
(vii)	Draft Final Report	All results of the Study	July 2003
(viii)	Final Report	All results of the Study incorporating the comments for the Draft Final Report	September 2003

This is the Main Report, as a part of the Final Report, covering the Integrated River Basin Management Plan for the Huong River basin (Phase II-1).

1.7 Phase II-1 Study

Flood and inundation have caused serious damages in Hue city and downstream parts of the Huong River basin.

The reasons for flooding in Hue city are the low elevation of the city, long duration of rains and the fact that strong tides make drainage difficult.

The flood in November 1999 caused very severe casualties in which 89 people reportedly died and huge assets were damaged.

In view of high urgency for countermeasure, both Vietnam and Japanese governments agreed that a comprehensive Water Resources Development and Management Master Plan be formulated for the Huong River basin at the earliest.

The feasibility study for major water resources development projects in the Huong River basin was already conducted by the Government of Vietnam, and the Government of Vietnam has a strong intention to promote these projects to the implementation stage, after the formulation of the Comprehensive Water Resources Development and Management Master Plan for the Huong River basin.

CHAPTER 2 PRESENT SITUATION OF THE HUONG RIVER BASIN

2.1 Socio-economic Condition

(1) Local Administration

The Thua Thien Hue Province administratively consists of a capital city of Hue and eight districts. Under these districts and city, there are 122 communes and 28 towns, as listed in Table 2.1 and summarized below:

Area and Administrative Units in Thua Thien Hue Province

City & District	Area (sq. km)	Towns	Communes	Communes in the Project
1. City Hue	71	5	20	5
2. District. Phong Dien	954	15	1	6
3. District. Quang Dien	163	10	1	6
4. District. Huong Tra	521	15	1	15
5. District. Phu Vang	280	19	1	6
6. District. Huong Thuy	457	11	1	8
7. District. Phu Loc	728	17	1	2
8. District. A Luoi	1,229	20	1	0
9. District. Nam Dong	651	10	1	0
Total	5,054	122	28	48

*1: preliminary basis, subject to change after confirmation.
Source: Statistical Yearbook 2000, Hue Province

Two districts of A Luoi and Nam Dong are totally outside the project area. It is estimated that 48 communes of 1 city and 6 districts entirely or partially falls under the project area.

(2) Population

The total population of the province is 1,066,200 in 2000, consisting of 316,200 (29.7%) in urban area and 750,000 (70.3%) in rural area, as shown in Table 2.2. Population density is 211 person per km^2, ranging from the lowest density of 21 persons per km^2 in Nam Dong district and the highest of 4,201 in Hue City.

Average population growth rate during the period from 1995 to 2000 is estimated at 1.56% per annum in total, composed of 4.11% in the urban area, and 0.61% in the rural area.

The natural population growth rate is estimated based on the fertility and mortality rates. The result shows the growth rate (1.63% per annum) in urban area far lower than the actual, on the other hand, rural area is much higher. Based on the natural growth rate, the population is projected to calculate the balance population between the actual population and projected one. The result is shown in Table 2.3, and summarized below:

Balance of Population between Actual and Projected during 1996 to 2000

(unit: persons)

	Urban			Rural		
	Actual	Natural	Balance	Actual	Natural	Balance
Growth Rate	4.11%	1.63%	+2.48%	0.61%	2.17%	-1.56%
Population	288,400	281,600	+6,800	737,700	749,100	-11,400

Source: Projection by the JICA Study Team.

It is estimated that 6,800 persons have been annually flowing into urban area, and 11,400 have been out-migrating from rural area.

According to the Interim Report, population in the project area was estimated at 718,400, of which 472,000 are rural population. It seems that this figure includes large number of urban population in Hue city as well as district capitals. Based on the information, the present population is estimated at 733,800 consisting of 276,100 in urban area and 457,700 in rural area, as shown in Table 2.4 and summarized below:

Population in the Project Area

(unit: persons)

City & District	Total	Urban	Rural
City Hue	272,800	221,500	51,300
Dist. Phong Dien	31,800	1,900	29,900
Dist. Quang Dien	66,600	7,300	59,300
Dist. Huong Tra	90,800	6,200	84,600
Dist. Phu Vang	142,600	25,100	117,500
Dist. Huong Thuy	74,600	10,000	64,600
Dist. Phu Loc	54,600	4,100	50,500
Total	733,800	276,100	457,700

Source: Estimation by the JICA Study Team based on the Interim Report and Statistical Yearbook 2000, Hue Province.

(3) Labor Force and Employment

Workable population in 2000 in the province is 573,100 or 53.7% of total population. About 40% or 429,000 is engaged in employment, and 1.7% is unemployment status, as summarized below:

Balance of Population between Actual and Projected during 1996 to 2000

(unit: persons)

	Total Population	Workable Population	Employ -ment	School Enrollment	Housewives & Inactive	Unemploy -ment
Total	1,066,200	573,000	429,900	73,000	51,600	18,500
	100%	53.7%	40.3%	6.8%	4.8%	1.7%
Male	525,200	286,900	232,400	41,500	4,300	8,600
	100%	54.6%	44.2%	7.9%	0.8%	1.6%
Female	541,000	286,100	197,500	31,500	47,300	9,900
	100%	52.3%	36.5%	5.8%	8.7%	1.8%

Source: Statistical Yearbook 2000, Hue Province.

Out of total employment, 80.6% or 346,300 persons are engaged in agriculture sector, consisting of 300,100 (69.8%) in agriculture, 2,300 (0.5%) in forestry, and 43,900 (10.2%) in fishery, as shown in Table 2.5. Employment in industry sector is 30,200 persons representing 7.0% of total employment.

(4) Economic Activity

a) GRDP

The GRDP of the Huong River basins in 2000 was estimated at VND3,461 billion (approx. US$244 million), which account for 0.8% of the national GDP.

GRDP of the Huong River Basins in 2000

Province	GRDP (Billion VND)	Per capita GDP (D1,000)	Share (%)			Avg. ann. growth rate (%)
			Agri.	Industry	Service	
Thua Thien -Hue	3,461	3,251	24	31	45	6.3

Source: Socio-economic Statistical Data of 61 Provinces and Cities in Vietnam, GSO

The average annual growth rate of GRDP from 1995 to 2000 was 6.3%, which is slightly lower than national growth rate of 6.9% on a constant price basis.

The shares of agriculture, forestry and fishery are approximately 24%, while those of industry and service sector are 31% and 45%, respectively.

b) Agriculture, Forestry, and Fishery

The gross output of agriculture, forestry, and fishery of the province was VND1,158 billion and the share of each category was about 70%, 14%, and 16%, respectively in 1998. The major crops of the basin are rice, maize, sweet potatoes, cassava, sugar cane, peanut, tobacco, tea, pepper, etc. Animal husbandry is also practiced such as buffaloes, cattle, pigs, and poultry.

c) Industry and Construction

Industry and construction sector is rather weak comparing with other sectors in the Huong River basin. GRDP of industry and construction accounted for only

0.7% of the national GDP in the same sector, while those of agriculture, forestry and fishery, and service sector accounted for 0.8% and 0.9% respectively. Major products are cement, frozen products, lime, stone, beer, woolen carpet, etc.

d) Service Sector

Hue city, ancient capital of the Nguyen dynasty, is recognized as a world heritage by UNESCO, which is one of the most famous tourist attraction in central Vietnam. Therefore, tourism and its related commercial industry is active in the city. Other than tourism industry, the province directly exported 800 thousand pieces of garment and 1,000 tons of frozen marine products in 1998.

(5) Land Use

According to the statistics, the present land use of the province as of 2000 is presented in Table 2.7 and summarized below:

Present Land Use of the Province (2000)

Agricultural Land	Forest Land	Specially Used Land	Residential Land	Unused Land	Total
61,200 ha	216,800 ha	20,900 ha	4,300 ha	204,200 ha	505,400 ha
12%	43%	4%	1%	40%	100%

Source: Statistical Yearbook 2000, Hue Province.

2.2 Water Resources

2.2.1 General

Together with the rainfall the rivers are the most important source of fresh water. The available water has to be shared for domestic, industrial use and irrigation. Though the priority level of the irrigation water is becoming lower in these days in comparison with it of the domestic and industrial water, the irrigation sector is still the biggest consumer with about 85%. Treatment of wastewater and desalinization of brackish/ salt water are at present not existing.

The coastal plain (adjacent to the project area) northwest of Bo River is a sandy area, with some long shaped lakes/swamps parallel to the lagoon. Rainwater flows as groundwater partly to the lagoon and partly to the lakes/swamps. No data are available of the flow of water (overland or in the ground) to Bo River (low river water levels) or from Bo River (high river water levels).

After completion of dams in the upstream river tributaries fresh water storage reservoirs will be created. There are already a few minor reservoirs. Truoi dam is expected to be completed soon and Ta Trach dam possibly a decade from now.

Other dams planned for the 'unknown' future are on Bo and Huu Trach rivers. Thao Long Barrage (Chapter 2.9), under construction in the mouth of Huong River, will create a 'special' fresh water reservoir.

2.2.2 Irrigation Water

Most of the available fresh water is required for agriculture. The present major irrigation water resources are (a) rain and (b) rivers, including storage in rivers and canals. After construction of dams in the upstream river branches reservoirs will become important for storage.

The Vietnamese Government is planning to supply irrigation water by a modification of the existing irrigation drainage system and by the water resources of the Huong and Bo rivers to irrigate the farmlands of 25,900 ha in the downstream areas.

2.2.3 Ground Water

The present use of groundwater is limited. Hue City receives its water from treatment plants on the banks of the Huong River. Only in the rural areas tube wells are found. In the coastal plains the source of fresh water is often only rain and river water. Shallow tube wells give brackish or acid water, whereas deep tube wells are too expensive.

There are plans to extend the piped water supply to about 50% of the rural population in the coastal plains. In isolated rural areas (outside the piped water system) deep tube-wells may be installed, possibly with (local) piped water supply systems (deep tube-well with pump and pipes).

The use of groundwater for irrigation is negligible. An increased use of groundwater for irrigation should not be encouraged because of the risk of over-exploitation. Use of ground water for homestead gardens should be permitted.

2.2.4 Re-use of Irrigation Water

The main irrigation canals also function for navigation and drainage. Often they are old river branches. Part of the irrigation water will, via the drainage system, groundwater or adjacent fields, return in the watercourse. More downstream this water can be re-used for irrigation.

2.3 Rivers and Lagoon

2.3.1 Rivers

The river basins are relatively small and the rivers are short. The major tributaries of Huong River, Ta Trach and Huu Trach, cause flash floods during rainstorms (steep river slope, short runoff time) and water shortage in the dry seasons (no storage capacity in the river). Another tributary, Bo River, joins Huong River in the coastal plain. Truoi River and some other small rivers drain independently in the same lagoon.

Water levels in Huong River and lagoon are important for irrigation, drainage and flushing. Downstream of the confluence of Ta Trach and Huu Trach (32 km from the lagoon) tidal effects influence the discharges. The intruding saltwater wedge causes serious salinity intrusion problems during low river discharges. Water levels, river run-offs, velocities and sediment transport in the downstream sections of Huong River will soon be affected by Thao Long Barrage and Ta Trach Dam.

In general the bed and banks of the rivers are rather stable, although local bank slides and/or erosion takes place. Heavy bank erosion takes place just downstream of Hue, where locally bank protection has been carried out. The effects of Nov.'99 flood are unknown.

There are no sediment transport recordings for Huong river basin. The sediment load maximizes during peak discharges and is small during low discharges. With assumed average annual turbidity 100 g/m^3 and specific weight 0.5 t/m^3 the annual sediment transport amounts to (a) average suspended load: 331,000 m^3/year (for Q_0=52.4 m^3/s), (b) bed load: 66,200 m^3/year (20% of suspended load), resulting in (c) total sediment transport: 397,200 m^3/year.

Huong and Bo rivers transport sand and gravel in their middle reaches, where sand mining in the river (by local people) takes place. The relation between supply by the river, removal by the people and effects on erosion downstream is unknown. The authorities plan to prevent (unauthorized) sand mining. Sand mining should not have much effect on the downstream stretches of the river as long as it takes place in designated areas.

Most sediments are finally deposited in the lagoon. Through intakes and overflow part of the suspended load will enter and settle in the canals/drains, the remaining as alluvial layer on agricultural lands. The rate of sedimentation is unknown.

In Huong South the inflowing canal water with sediments is mixed with inflow from the hills. But the small rivers have dams and hardly bring sediments into the coastal plain. The concentration of suspended load decreases away from Huong River.

2.3.2 Lagoon

The Tam Giang - Cau Hai Lagoon stretches from about 20 km NW to 30 km SE of the mouth of Huong River. The width varies around 2 km with depth 5 -7 m in the NW and 1 km with depth 3-4 m in the SE. The 'sandbar' between the sea and the lagoon has only two openings: (1) in front of the mouth of Huong River, and (2) at the SE-end of the lagoon. The major village on the sandbar is Thuan An, with a fishing port, connected to the mainland by a bridge.

The sandbar protects the lagoon against wave action from sea and coastal currents. The funnel effect of the openings reduces the high tides and raises the low tide sea water levels in the lagoon. The lagoon has a complicated ecological system, sensitive and vulnerable to interacting dynamic processes.

The drainage capacity of gravity drainage outlets depends on the water levels in the lagoon. The areas adjacent to Thuan An have regular half-day tides. The levels of the high and low tides, with frequencies, have been given in the table below:

Frequency (%)	0.1	1	5	10	50	90	95	99	99.9
High tide (m+)	1.10	0.90	0.69	0.60	0.36	0.18	0.13	0.02	-0.14
Low tide (m+)	0.30	0.12	0.00	-0.06	-0.24	-0.41	-0.46	-0.53	-0.64

High and low tides, with frequencies

The water in the lagoon varies from fresh (river mouths and other fresh water outlets) via brackish to salt (openings in sandbars). The flow pattern through the openings in the sandbar (volume) and the conditions in the lagoon (wind, current) will influence the rate/speed of the mixing of fresh and salt water. High river discharges decrease the salinity considerably, and the very low dry season discharge will hardly reduce the seawater salinity. With the Thao Long Barrage (anti-salinity weir) and dams in the river (regulated river flow) the fluctuations of salinity in the lagoon will reduce.

2.4 Agriculture

Most of the population lives in the coastal plain of Huong River because it is the most promising area for agricultural development and settlement. Out of the about 40,000 ha coastal plain in Huong River Basin about 25,900 ha is cultivated.

The present natural disasters that limit agricultural productivity are droughts (shortage of irrigation water and salt water intrusion) early flooding (damage of crops) and insufficient/ not maintained facilities. Potential areas for agricultural development in the hilly area, with altitudes between 10 and 50 m^+ are small.

2.4.1 Agriculture Households

Total number of agriculture households engaged in crop sector in the province is about 108,800 as of 2000, composed of 5,700 in urban area and 103,100 in rural area, as shown in Table 2.6, and summarized below:

Features of Agriculture Households (as of 2000)

(unit: persons)

	Province	Urban Area	Rural Area
No. of Agriculture Households	108,800	5,700	103,100
Agriculture Population	566,400	30,600	535,800
Average Family Size	5.21	5.37	5.20
Agriculture Labor Force	300,100	16,200	283,908
Labor Force per Household	2.76	2.85	2.75

Source: Statistical Yearbook 2000, Hue Province.

Based on population, agriculture household in the project area is roughly estimated at 67,900 households with 353,900 of agriculture population. However this estimation seems to be rather large side, and need further confirmation.

2.4.2 Soil

According to the Interim Report on feasibility study, major soils in the province are, saline soils, white – yellow sandy soils, light yellowish soils, and alluvial soils. Saline soils are situated in the shoreline along the lagoon, and not suitable for crop cultivation due to effect of sea water. The coastal area is covered by white – yellow sandy soils, and this area is also not suitable for crop production. The mountains and hill area is mostly covered by the light yellowish soils developed from sand stones and laterite soils. Natural vegetation of this soils is forest, however, more than half of this area remains bare land due to removal of vegetation during the war time.

Alluvial soils are mainly extending over the flood plain in the downstream of rivers. These soils is principally suitable for crop cultivation, where the land is not suffered from the see water.

2.4.3 Agricultural Land Use

Agricultural land, including paddy field, upland crop field and grazing land, is 61,200 ha or 12% of total land. Forest land comprises of natural forest and planted forest. Specially used land is composed of construction, transportation, other facilities. Unused land is mainly located in the mountains, as denuded slopes.

Out of 61,200 ha of agricultural land, paddy field is roughly estimated at about 27,400 ha, of which 900 ha is located in the mountainous area. In this 900 ha, winter paddy crop is only planted under rain-fed condition. The remaining 26,500 ha of paddy field is mostly extending over the alluvial soils along the coastal plains.

According to the Interim Report, total agriculture land in 1994 was 47,047 ha in the province, of which 25,900 ha is located in the project area, as shown below:

Distribution of Agricultural Land (1994)

(unit: persons)

	City and District	Agriculture Land	Project Area	Proportion
1	City Hue	1,992	1,822	91.5%
2	Dist. Phong Dien	6,880	2,167	31.5%
3	Dist. Quang Dien	5,787	4,237	73.2%
4	Dist. Huong Tra	6,905	4,812	69.7%
5	Dist. Phu Vang	8,154	6,214	76.2%
6	Dist. Huong Thuy	5,570	4,647	83.4%
7	Dist. Phu Loc	5,331	2,001	37.5%
8	Dist. A Luoi	2,687	-	-
9	Dist. Nam Dong	4,742	-	-
	Total	48,048	25,900	53.9%

Source: Interim Report on Feasibility Study, December 1999.

Agricultural land in the project area is mostly situated in the flood plains along the lower reaches of the Huong River near the lagoon. In this area, the soils of agricultural land is alluvial soils, and mostly suitable for paddy cultivation.

The area is situated on the low ground level mostly lower than 1.0 m elevation. The cultivation is not allowed during the major flood season from September to November. The area have also been suffering from early flood in May to June as well as saline water intrusion in the summer season from March to August.

2.4.4 Cropping Calendar

The suitable lands are used for double cropping. The cropping calendar (with cropping pattern, intensity and planting area of the Agricultural and Rural Development Department of Thua Thien - Hue Province; 1997) shows:

Winter/spring paddy	mid Dec. - end May	18,000 ha
Summer/ autumn paddy	early May - end Aug.	15,200 ha
Subsidiary crop	early Dec. - mid April mid April - end June	5,600 ha 1,000 ha
Vegetables	early Feb. - mid Sep.	2,300 ha

2.4.5 Cropped Area and Production

The total cropped area in the province is about 80,000 ha on average during the period of 5 years from 1996 to 2000, as shown in Table 2.8 and summarized below:

Planted Area of Crops (average during 1996 to 2000)

Annual Crop				Perennial Crop		
Paddy	Other Food Crops	Vegetables & Beans	Industrial Crop	Industrial Tree Crops	Fruit Trees	Total
50,400 ha	12,500 ha	5,000 ha	7,900 ha	2,500 ha	1,500 ha	79,800 ha
63.2%	15.7%	6.2%	9.9%	3.1%	1.9%	100.0%

Source: Statistical Yearbook 2000, Hue Province.

The above table indicates that food crops, particularly paddy, are represents nearly 80% of total cropped area, however, the planted area has not been expanding. Planted area of vegetables as well as fruits trees has been recently expanding, though their area remains in small extent. Industrial crops like sugarcane, groundnuts, rubber are also expanding.

The average paddy production during the period from 1996 to 2000 is presented along with cropped area and unit yield in Table 2.9 and summarized below:

Production of Paddy (average during 1996 to 2000)

		Spring Crop	Autumn Crop	Winter Crop	Total
Planted Area	(ha)	26,500 ha	24,200 ha	700 ha	51,404 ha
Unit Yield	(ton/ha)	4.2 ton/ha	3.5 ton/ha	1.0 ton/ha	3.8 ton/ha
Production	(ton)	111,800 ton	83,800 ton	700 ton	196,300 ton

Source: Statistical Yearbook 2000, Hue Province.

The cropping season is categorized into three seasons, namely spring crop (winter to spring), autumn crop (summer to autumn) and winter crop (monsoon).

The paddy is mainly cultivated in spring and autumn crops in the lower flood plains near the coastal area. Spring paddy crop is started in December when monsoon season is over, and harvested in May. After harvesting spring paddy, autumn paddy crop is started in May to June, and harvested August to September. Due to severe inundation in the monsoon season during September to December, paddy field in the lowland is not cultivated.

Production of other crops is presented in Table 2.10 and summarized below:

Production of Other Crops (average during 1996 to 2000)

	Planted Area (ha)	Unit Yield (ton/ha)	Production (ton)	Remarks
Maize	1,000	1.9	1,900	Expanding planted area
Sweet Potato	5,500	4.3	23,700	Reducing planted area
Cassava	4,500	5.7	25,600	Reducing planted area
Vegetables	2,700	10.3	27,800	Expanding planted area
Beans	2,000	0.5	1,000	-
Groundnut	4,100	1.4	5,700	-
Sugarcane	4,600	16.2	74,300	Expanding planted area

Source: Statistical Yearbook 2000, Hue Province.

Sweet potato is prevailing the largest planted area, however, the area has been reducing from 7,000 ha in 1996 to 4,400 ha in 2000. Cassava, cultivated under rain-fed condition, has also been reducing. On the other hand, maize, vegetable and sugarcane have been expanding cropped area as well as production.

2.4.6 Conclusion of Present Agriculture Condition

(1) Total population in 2000 is 1,066,200 in the Thua Thien Hue Province. Rural population is About 750,000 or 70% of total population stays, of which about 71% (535,800 persons) is categorized as agriculture population, whose main income is generated from crop cultivation. It is estimated that about 11,400 of population has been out-migrated from rural area to urban area within the province as well as outside the province.

(2) Agriculture is the most important economic sector to sustain the rural population, though its position in the regional economy has been reducing from 30.5% in 1995 to 24.4% in terms of contribution to GRDP of Thua Thien Hue Province.

(3) Out of total gross output in agriculture, 71% has been produced by crop production sector during the period from 1996 to 2000. Particularly, paddy production accounts for 47% of agricultural gross output. Fruits and

industrial crops has been growing recently, however, contribution of these crops remains low in the rural economy.

(4) Total land of the province is 505,400 ha, of which 61,200 ha or 12% is agricultural land. Paddy field is 27,400 ha, producing 47% of agricultural gross output as well as 196,300 ton of paddy on average for 5 years from 1996 to 2000.

(5) About 25,900 ha including 18,000 ha of paddy field is located on gross area of 40,000 ha of the flood plain extending over the lower reaches of the Huong River. This area, equipped irrigation and drainage facilities, is the largest production center of agriculture in the province. This is also the project area prposed for irrigation rehabilitation and drainage improvement under the Ta Trach Reservoir Project.

(6) According to the past studies, the present crop production in the project area of 29,500 ha is shown below:

Production in the Project Area

Crop	Win – Spr	Sum – Aut	Total	Unit Yield	Production
Win – Spr Paddy	18,022 ha	-	18,022 ha	2.8 ton/ha	50,500 ton
Sum – Aut Paddy	-	15,197 ha	15,197 ha	3.0 ton/ha	45,600 ton
Subsidiary Crop	5,622 ha	1,033 ha	6,655 ha		25,400 ton
(Maize)	(79 ha)	(78 ha)	(157 ha)	1.2 ton/ha	200 ton
(Sweet Potatoes)	(4,838 ha)	(0 ha)	(4,838 ha)	4.8 ton/ha	23,200 ton
(Groundnuts)	(705 ha)	(955 ha)	(1,660 ha)	1.2 ton/ha	2,000 ton
Vegetables	2,256 ha	2,256	4,512 ha	6.0 ton/ha	27,100 ton
Total	25,900 ha	18,486 ha	44,386 ha	-	148,600 ton

Source: Interim Report of Feasibility Study, December 1999 with modification by the JICA Study Team.

(7) The crop production is presently constrained due to (i) early flood occur in May to June damaging summer – autumn crop, (ii) salt water intrusion suffering spring and autumn crops along the irrigation canal in the dry season , and (iii) short supply of irrigation water in the dry season.

(8) Without measures against the above constraints, agricultural production will not be able to increase. This situation will result in stagnation of rural economy as well as acceleration of population outflow from the area. In order to avoid this situation, it is required for measures to increase agriculture production as well as to improve income of rural population in the project area.

(9) In order to intensify crop production as well as to increase income of rural population in the project area, the fundamental infrastructure is to be developed for i) protection of early flood, ii) reduction of salt water intrusion, and iii) staple supply of irrigation water and sufficient drainage capacity.

(10) The project will enable to increase income of rural population of about 457,700. This will expand the rural economy, and finally result in reduction of the population outflow of population from the project area in the future.

2.5 Irrigation and Drainage

2.5.1 Irrigation and Drainage System

(1) Irrigation System

The coastal plain, 15 to 70 km wide, consists of river deposits and sea alluvium. This plain contains agricultural lands, lagoons and sand dunes. The area can be divided in a 'southern area' (SE of Huong River) and a 'northern area' (NW of Huong River). The present irrigation system is located in the flat, low coastal plains in the downstream reach of Huong River.

Huong River is the main source of irrigation water, with contribution by Bo River to the NW-part and Truoi River to the SE-part of the scheme. Various river branches, streams and creeks form a natural network of watercourses that is used for irrigation, drainage and local transport.

(2) Drainage System

Along the south-boundary are a number of small reservoirs, of which Truoi Reservoir in the SE-corner is the most important. Irrigation water is usually pumped from the rivers and watercourses (canals).

The drainage system is most important during the critical period of crop production (harvest in May and initial growth period in June).

The drainage possibility and the required capacity of drainage canals depend on water levels in the Huong River. The drainage system can only prevent crop damage during the early floods at the end of the dry season. Major floods during the rain season cannot be coped with. The capacity of drainage canals would be determined taking into account the above-mentioned condition on the flood water level to be considered for the design.

The canal/drain system has not been maintained well, and siltation has become a serious problem. There are over fifty drainage sluices along lagoons, a few major outlets but mostly simple timber gates structures facilitated with double stop logs grooves. The space between the stoplogs is filled with soil to seal the gate. This is a too cumbersome and labor-intensive system to ensure proper operation.

Inundation with sediment rich fresh water during the rain season is preferred for the eradication of weeds, rodents, etc. and the deposit of nutrient rich sediment as natural fertilizer (after the harvest September to November).

(3) Ground Levels

All ground levels and water levels have Vietnamese National Standard as reference level. The ground levels of the coastal plain vary from <0.0 m^+ to about 4.0 m^+, but most of the area is below 1.5 m^+. The various elevations for the different areas, with percentages of the total area, have been given in the table below.

Elevation (m+)	Southern area (ha)	(%)	Northern area (ha)	(%)	Total coastal area (ha)	(%)
< 0+	8,145	43.4	1,528	7	9,673	24.3
0 - 0.5+	2,800	14.9	1,133	5	3,933	9.9
0.5 - 1.0+	1,897	10.1	540	3	2,437	6.1
> 1.0+	5,926	31.6	17,788	85	23,714	59.6
total	18,768	100	20,989	100	39,757	100

Ground elevations, with areas and percentages

(4) Canals and Drains

Inventory of the existing canals and drains has not been completed yet, the following have been grasped through the field reconnaissance and interview to the authorities concerned.

The rivers and main canals/drains are unlined (old) river channels/branches, serving irrigation as well as drainage. Their condition is rather stable. Erosion occurs where sedimentation reduces the cross section. Secondary irrigation canals are lined, or planned to be lined. Farmers cut vegetation (reed, weed, water hyacinth) in canals and use them as fertilizer.

Tertiary canal and on-farm quaternary ditches have to be constructed, maintained, etc. locally. Canal structures such as turn-outs, culverts, siphons and check gates often need repairs. The alignments of the canals are shown on the maps, but particulars, like longitudinal and cross sections are unknown. Also details on locations, type, and condition of these structures are not available.

2.5.2 Flood Protection for Agriculture Lands

There are two types of flood protection as follows:

- Controlled flooding with protection: protection by embankments against 'early floods', so that farmers can harvest the winter/spring and plant the summer/autumn crops.
- Full flood protection: protection by embankments, sufficient high to prevent flooding. This enables farmers to cultivate throughout the year, in combination with irrigation and drainage.

Flooding in the wet season, when there are no crops on the fields is permitted. Inundation kills weeds, insects and rodents, and increases fertility by silt deposits, thus saving on agro-chemicals.

Farmers want measures against 'early floods' that damage their harvest or young plants.

2.5.3 Drainage Improvement

Drainage requirements depend on rainfall, inflow from small rivers and overland flow. Main irrigation canals also function as drains, so their dimensions need to cope with the much bigger drainage discharge. The present drainage capacity is insufficient in a number of areas, in particular the low lands in the downstream part of Huong South and between Huong and Bo rivers in Huong North. In these areas inundation is too deep and/or too long, although this is related to the growing stage of the crops.

The running cost of the pumps (electricity) is high so drainage by gravity should be used where possible, if necessary supported by pumps. High lands may be drained by gravity only, but lands that are low, compared to the lagoon water levels, can only be drained sufficiently with support of pumps.

CHAPTER 3 HYDROLOGICAL ANALYSIS

3.1 Low Flow Analysis

3.1.1 Methodology

Review of the available historic hydro-meteorological information has revealed a shortage of sufficiently long series for making straight statistical analysis for the assessment of probable runoffs and flood discharges for planning and design purposes. For a good understanding of the hydrological characteristics of the basin it is essential to generate runoff series on the basis of the sufficiently available rainfall data, using an adequate rainfall – runoff simulation model.

The Terms of Reference call for the use of the MIKE 11 mathematical model for the estimate of the Huong basin runoff. For this specific purpose, the MIKE 11 system disposes of the so-called NAM Hydrological Modelling system. In order not to depend fully on the results of the NAM model, it has been deemed appropriate to employ a second internationally accepted model for the rainfall - runoff simulation, i.e. the Sacramento model. The MIKE 11-NAM Hydrological Modelling system and the Sacramento model are introduced in Appendix C of Vol. VII Supporting Report.

The hydrological model of the Huong basin describes the runoff of the three major sub-basins i.e. Ta Trach, Huu Trach and Bo. The model is restricted to the upper and middle catchment area, that is to say, that the lower limit of the model is situated at Tuan, just downstream of the Ta Trach – Huu Trach confluence, and Co Bi in the Bo sub-basin.

Input requirements for the Huong basin rainfall – runoff simulation refer to:

- Model parameters
- Initial conditions
- Rainfall and Potential Evapo-transpiration
- Stream flow data for model calibration and verification.

Model parameters have been assessed in the process of model calibration, starting from realistic estimates of these parameters from the available information of the basin.

In calibrating the models for being used in the low flow analysis, emphasis was put on a good reproduction of the recession curve of discharges after the flood season. The slope of this recession curve, that is determined by the volume and rate of discharge of groundwater volumes, is indicative for the availability of water during the dry season. In both the models it appeared necessary to introduce two groundwater reservoirs, one with a slow and one with a fast emptying rate.

3.1.2 Mike11 - NAM Results

For the assessment of the model parameters for the Mike11 – NAM model, a detailed calibration has been carried out for the upper Ta Trach basin at Thuong Nhat. Following this calibration verification runs have been made for the three other stations for which discharge data were available, viz. Co Bi in the Bo sub-basin, Binh Dien in the Huu Trach sub-basin and Duong Hoa in the Ta Trach sub-basin. The results of these validation runs show especially during the high flow months substantial deviation from the observed discharges. This is partly due to an expected overestimate in the observed flood discharges, and partly to the fact that calibration efforts concentrated on the low flow conditions. Under low flow conditions the results of the Mike11 – NAM model are reasonable. Re-calibration of the model with the help of the auto-calibration facility of the model did not give better results. Therefore, the model parameters that were found in the manual calibration effort were accepted and used for the generation of the basin runoff in the years 1977 - 2000. The results are summarized as follows:

Dependable Monthly Runoff at Tuan in Mm^3

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
50%	210	109	71	52	68	69	53	57	148	589	726	498
75%	144	79	53	35	40	40	32	36	84	370	497	354
90%	102	59	40	24	26	24	20	23	51	243	353	260

Dependable Monthly Runoff at Co Bi in Mm^3

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
50%	95	48	33	32	45	41	32	32	85	298	363	251
75%	58	30	22	21	32	27	21	22	52	205	254	181
90%	38	20	16	14	23	18	15	15	33	147	185	135

3.1.3 Sacramento Results

The Sacramento model has been used for a further verification of the results of the Mike11-NAM model. A slightly different approach has been used, in which the model calibration has been carried out at sub-basin level, so that for each sub-basin separate model parameters were determined. It is noted that the parameters of the different sub-catchments appeared to be quite similar. This conclusion supports the approach used in the Mike11-NAM modeling in which one set of parameters was used for the entire basin.

The results of the Sacramento modeling are summarized as follows.

Dependable Monthly Runoff at Tuan in Mm^3

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
50%	222	146	117	85	86	83	68	62	195	609	797	490
75%	189	122	99	72	63	55	50	46	108	430	527	352
90%	172	106	85	62	55	47	39	40	78	209	306	230

Dependable Monthly Runoff at Co Bi in Mm^3

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
50%	119	66	46	31	44	40	37	40	78	295	415	254
75%	97	51	36	25	31	27	23	22	60	206	239	196
90%	76	43	30	20	24	21	16	16	27	139	196	153

3.1.4 Present Feasibility Study

In the 1999 –2000 Feasibility Study on the Ta Trach project HEC presented the following estimate of the average monthly discharges in the Huong basin with a dependability of 75%.

Average Monthly Volumes in Mm^3 with 75% Dependability

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept	Oct	Nov.	Dec.
Ta Trach	53	32	23	27	21	24	17	13	37	418	473	188
Huu Trach	41	24	17	20	16	18	21	22	28	321	360	143
Co Bi	49	29	21	24	19	22	16	12	34	381	433	172

3.1.5 Conclusion

The low flow results of both models are similar for the Bo sub-basin. For the Huu Trach – Ta Trach sub-basin, however, the Sacramento model gives substantially higher low flow volumes than the Mike11-NAM model. Based on these results it is decided to use the outcome of the Mike11-NAM model for the water balance simulation under low flow conditions. It is anticipated that this approach might be at the conservative side.

3.2 High Flow Analysis

3.2.1 Methodology

As for the analysis of the low flows in the Huong basin, it has been inevitable also for the estimate of peak flows and corresponding volumes to make use of an appropriate rainfall – runoff modelling. As called for in the Terms of Reference, use has been made of the Mike11-NAM model, while as second modelling tool the Sacramento model has been used.

In contrast with the low flow analysis that focuses on monthly runoff volumes, the high flow analysis relates to the much shorter hourly time base. The simulation of peak runoffs, therefore, required not only the preparation of a reliable simulation tool in the form of a calibrated and validated model, but also the assessment of the storms that are anticipated to generate the peak discharges.

For the estimate of the probable storms, use has been made of 24 years of daily rainfall series. The duration and hourly distribution of the probable storms was estimated on the basis of a limited number of historic storms for which hourly data were made available.

Probable storms have been compiled for both the main flood season (September – December) and for the early flood season. For the latter season, the probable peak rainfall intensities have been used that occur in the period January – August.

The calibration and validation of the flood runoff model was carried out for the three sub-basins Bo (at Co Bi), Huu Trach (at Binh Dien) and Ta Trach (at Thuong Nhat) separately with the help of, on the average, three historical storms per sub-basin.

3.2.2 Probable Storms

The estimated probable storms range from the 10 years storm of 400 mm in the Huu Trach – Ta Trach sub-basin and 440 mm in the Bo sub-basin to the 100-year storm of 525 mm in the Huu Trach – Ta Trach sub-basin and 665 mm in the Bo sub-basin. The duration of the storms has been taken at 12 hours, with hourly peak intensities ranging from 50 mm during the 10 years storm to 75 mm during the 100 years storm.

Probable storms during the early flood season are substantially lower, they range from 40% (Bo sub-basin) to 60% (Huu Trach – Ta Trach sub-basin) of the main storm intensities.

3.2.3 Mike11 – NAM Results

Calibration of the Mike11-NAM model was done with the help of the auto-calibration option. This calibration gave reasonable results for the three sub-basins. Subsequent simulations where carried out with the probable storms, with the following results.

Peak Discharges, Main Flood Season (m^3/s)

	10 years	20 years	50 years	100 years
Bo at Co Bi	5,100	6,200	7,400	8,800
Huu Trach at Binh Dien	4,700	5,500	6,400	7,300

Note: The above figures don't include the safety margin in consideration of the length of available data series.

3.2.4 Sacramento Results

Intensive calibration and validation efforts have been made to achieve an acceptable reproduction of the historical floods with the help of the Sacramento model. Both the land-phase (runoff generation) and the channel-phase (flood routing) were included in the calibration process. The following peak discharges were generated:

Peak Discharges Main Flood Season (m^3/s)

	10 years	20 years	50 years	100 years
Bo at Co Bi	3,900	5,100	6,700	7,800
Huu Trach at Binh Dien	3,600	4,200	5,000	5,800
Ta Trach at dam site	5,500	6,400	7,500	8,200

Note: The above figures don't include the safety margin in consideration of the length of available data series.

3.2.5 Previous Studies

In the 1999 –2000 Feasibility Study on the Ta Trach project HEC, the following flood discharges have been presented for the different sub-catchments:

Peak Discharges Main Flood Season (m^3/s)

	10 years	20 years	50 years	100 years
Bo at Co Bi 1)	4,100		6,400	7,200
Bo at Co Bi 2)	2,558	2,850		
Huu Trach at Binh Dien 2)	3,450	3,848		
Ta Trach at dam site 3)	4,240	5,570		9,400

1): Feasibility Study of Four Dams, WAPCOS, India, 1982
2): Feasibility Study on Ta Trach Project, Interim Report, HEC-1, 1999
3): Ta Trach Reservoir Project, Supplemental Report, HEC-1, 2000

3.2.6 Conclusions

It is observed that the peak discharges as generated with the help of the Sacramento model tend to be higher than peak discharges presented in previous studies. The peak discharges generated with the Mike11-NAM are again substantially higher than the Sacramento results. It is anticipated that the Mike11 results give an overestimate of the peak flows and that further detailed calibration of this model may give a more attenuated reproduction of the runoff of the basins.

For the present study the results of the Sacramento model have been selected for the formulation of flood mitigation measures in the Huong basin.

CHAPTER 4 WATER DEMAND FORECAST

4.1 Domestic and Industrial Water Demand

Domestic and industrial water demand for Huong River basin was examined in Phase 1 study and was presented in Chapter 6 of Main Report (Phase 1).

As referred to Tables 6.14 (1) and 6.16, Volume III Main Report for Phase1, domestic and industrial water demands are projected to increase as follows:

(Unit: m^3/day)

	Present (2001)	2010	2020
Domestic Water Demand	36,545	67,800	118,660
Industrial Water Demand	5,000	17,734	65,743
Total	41,545	85,534	184,403

4.2 Agricultural Water Demand

4.2.1 Forecast Demand for Irrigation

Gross unit water requirements (GIR) of the Huong River Basin estimated based on the present and future conditions of cropping patterns and irrigation areas are as follows:

Gross Unit Irrigation Water Requirement (GIR)

- Year with less than 1/4 of examined long period selected from Peak 10-day GIR -

River Basin	Present (2001)		Future (2010)		Future (2020)	
	Peak 10-day lit/sec/ha	Annual Total m^3/year/ha	Peak 10-day lit/sec/ha	Annual Total m^3/year/ha	Peak 10-day lit/sec/ha	Annual Total m^3/year/ha
06. Huong, 1991	1.24	12,200	1.22	11,800	1.48	13,500

Gross Unit Irrigation Water Requirement (GIR)

- Year with less than 1/4 of examined long period selected from Water Balance -

River Basin	Present (2001)		Future (2010)		Future (2020)	
	Peak 10-day lit/sec/ha	Annual Total m^3/year/ha	Peak 10-day lit/sec/ha	Annual Total m^3/year/ha	Peak 10-day lit/sec/ha	Annual Total m^3/year/ha
06. Huong, 1993	1.21	15,100	1.19	14,500	1.45	16,100

Gross Unit Irrigation Water Requirement (GIR)

- Average Rainfall Year -

River Basin	Present (2001)		Future (2010)		Future (2020)	
	Annual Average lit/sec/ha	Annual Total m^3/year/ha	Annual Average lit/sec/ha	Annual Total m^3/year/ha	Annual Average lit/sec/ha	Annual Total m^3/year/ha
06. Huong	0.38	12,100	0.37	11,700	0.41	13,100

Irrigation water demands (IWD) of the Huong River Basin estimated based on the present and future conditions of cropping patterns and irrigation areas are as follows:

Irrigation Water Demand (IWD)

- Year with less than 1/4 of examined long period selected from Water Balance -

River Basin		Present (2001)	Future (2010)	Future (2020)
06. Huong, 1993	Area (ha)	25,900	25,900	25,900
Water Demand	(m^3 / sec)	12.4	11.9	13.2
Water Demand	(10^6 m^3 / year)	390	380	420

Irrigation Water Demand (IWD)

- Average Rainfall Year -

River Basin		Present (2001)	Future (2010)	Future (2020)
06. Huong	Area (ha)	25,900	25,900	25,900
Water Demand	(m^3 / sec)	9.9	9.6	10.7
Water Demand	(10^6 m^3 / year)	310	300	340

Process and result of IWD estimation of the Huong River Basin are as follows:

(1) Cultivated Land Area and Planted Area

The present and future cultivation areas and planted areas are presented in Chapter 4, Phase 1- Main Report. Those of the Huong River Basin are as follows:

a) Present (2001)

Cultivated Land Area and Planted Area in Huong River Basin (Unit: ha)

Item	Cultivated Land Area	Planted Area
Paddy Field	25,000	48,500
Upland Crop Field	20,000	27,500
Total	45,000	76,000

b) Future (2010, 2020)

Cultivated Land Area and Planted Area in Kone River Basin (Unit: ha)

Item	Cultivated Land Area		Planted Area	
	2010	2020	2010	2020
Paddy Field	25,000	25,000	48,500	48,500
Upland Crop Field	19,000	24,000	29,000	34,000
Total	44,000	49,000	77,500	82,500

(2) Cropping Pattern

The present and future cropping patterns are presented also in Chapter 4, Phase 1 - Main Report. Those of the Huong River Basin are as shown below. The planted areas shown below are composed of the irrigation area and the rainfed area.

a) Present (2001)

Cropping Pattern covering both Irrigated and Rainfed Fields(Unit: ha)

Cropping Time	Paddy Rice	Upland Crops
Winter - Spring	25,000	9,500
Summer - Autumn	23,000	7,500
Rainy Season	500	-
Year Round	-	10,500
Total	48,500	27,500

b) Future (2010, 2020)

Cropping Pattern covering both Irrigated and Rainfed Fields (Unit: ha)

Cropping Time	Paddy Rice		Upland Crops	
	2010	2020	2010	2020
Winter - Spring	25,000	25,000	10,000	10,000
Summer - Autumn	23,000	23,000	8,000	10,000
Rainy Season	500	500	-	-
Year Round	-	-	11,000	14,000
Total	48,500	48,500	29,000	34,000

(3) Irrigation Area

Estimated irrigation areas at present and required irrigation areas in future are determined in Chapter 4, Phase 1 - Main Report in consideration of the crop production plan. Those of the Huong River Basin are as shown below:

a) Present (2001)

Irrigation Area in Huong River Basin (Unit: ha)

Item	Cultivated Land Area	Planted Area
Paddy Field	18,000	33,000
Upland Crop Field	7,900	11,100
Total	25,900	44,100

b) Future (2010, 2020)

Irrigation Area in Huong River Basin (Unit: ha)

Item	Cultivated Land Area		Planted Area	
	2010	2020	2010	2020
Paddy Field	18,400	19,900	34,300	39,800
Upland Crop Field	7,500	6,000	11,000	12,000
Total	25,900	25,900	45,300	51,800

(4) Cropping Pattern in Irrigated Field

The present and future cropping patterns in the irrigated field are determined in Chapter 4, Phase 1 - Main Report. Those of the Huong River Basin are as follows:

a) Present (2001)

Cropping Pattern in Irrigated Field (Unit: ha)

Cropping Time	Paddy Rice	Upland Crops
Winter - Spring	18,000	7,900
Summer - Autumn	15,000	3,200
Rainy Season	0	-
Year Round	-	0
Total	33,000	11,100

b) Future (2010, 2020)

Cropping Pattern in Irrigated Field (Unit: ha)

Cropping Time	Paddy Rice		Upland Crops	
	2010	2020	2010	2020
Winter - Spring	18,400	19,900	7,500	6,000
Summer - Autumn	15,900	19,900	3,500	6,000
Rainy Season	0	0	-	-
Year Round	-	-	0	0
Total	34,300	39,800	11,000	12,000

(5) Potential Evapo-transpiration (ETo)

River Basin	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Huong (mm)	68	68	82	116	150	176	189	163	116	96	75	61	1,360
(%)	5.0	5.0	6.0	8.5	11.0	13.0	14.0	12.0	8.5	7.0	5.5	4.5	100.0

(6) Crop Coefficient (Kc)

Kc values of the respective development stages determined are as follows:

Crop	Initial	Mid	Harvest
Rice	1.05	1.35	0.90
Upland Crops, Winter-Spring, Summer-Autumn, Rainy Season (Tomato)	0.35	1.05	0.25
Year Round Crops (Sugar Cane)	0.55	1.15	0.60

Crop coefficient curves drawn for the respective crops are shown in figures of Appendix – F for Phase 1. Value of Kc at each growing time has been read from the curve.

(7) Crop Water Requirement (CWR)

Crop water requirement (CWR) or crop evapotranspiration (ETc) of the crops concerned have been estimated based on the respective cropping patterns. It of the Huong River Basin for the present and the future is described below.

a) Present (2001)

Present crop water requirements (CWR) for the Huong River basin estimated for the average rainfall year are shown in Table 4.1.

b) Future (2010, 2020)

Future crop water requirements (CWR) of 2010 and 2020 estimated for the average rainfall year are shown in Tables 4.2 and 4.3, respectively.

(8) Consumptive Use of Water of Crops (CUW)

Consumptive uses of water of crops of the various crops concerned are shown also in Tables 4.1 to 4.3, respectively. For example, the peak values of CUW of the respective crops based on the present (2001) cropping pattern are shown below:

Peak Consumptive Use of Water (CUW), Huong, 2001 (Unit: mm/10-day)

Crop	Time	Peak CUW
Rice, Winter-Spring	Late Dec.	64
Rice, Summer-Autumn	Late May	125
Upland Crops, Winter-Spring (Tomato)	Early Mar.	28
Upland Crops, Summer-Autumn (Tomato)	Middle July	68

(9) Effective Rainfall (Peff)

The monthly effective rainfall (Peff mm/month) has been estimated with use of the monthly rainfall data (Ptot) in the Huong River Basin.

Peff (mm/month) of the 25 years from 1976 to 2000 has been estimated with use of the monthly rainfall data (Ptot) at the Hue Station collected during this study period.

Peff (mm/month) of the average rainfall has been estimated with use of the average monthly rainfall data (Ptot) at the Hue Station taken from the Vietnam Hydrometeorological ATLAS, 1994.

Peff (mm/month) of the Huong River Basin in the average year is as follows:

Rainfall (Ptot) and Effective Rainfall (Peff), Average Year (with ATLAS's Data), Huong(Unit: mm)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Ptot	158	57	43	57	86	115	100	115	459	789	574	315	2,868
Peff	118	52	40	52	74	94	84	94	171	204	182	157	1,322
(%)	75	91	93	91	86	82	84	82	37	26	32	50	46

Further, a balance calculation has been made between the above-mentioned CUW and Peff. In case Peff is larger than CUW, Peff has been adjusted to be equal to CUW. The balance calculation process is shown in Tables 4.1 to 4.3, respectively.

(10) Net Irrigation Water Requirement (NIR)

Net irrigation water requirements (NIR) of the respective crops concerned have been estimated based on the respective cropping patterns for the present (2001) and the future (2010, 2020) of the Huong River Basin are shown also in Tables 4.1 to 4.3, respectively.

(11) Gross Unit Irrigation Requirement (GIR)

Taking the irrigation efficiency (Ep) into the calculation, the gross unit irrigation water requirements GIR (mm/10-day) as well as GIR (l/sec/ha) have been estimated based on the respective cropping patterns for the present (2001) and the future (2010, 2020) in the average year rainfall condition of the Huong River Basin as shown in Tables 4.1 to 4.3, respectively.

The monthly gross irrigation water requirements GIR (l/sec/ha) based on the present (2001) and future (2010, 2020) cropping patterns and the average year rainfall condition in the Huong River Basin, which have been calculated with an average of the 10-day basis GIR (l/sec/ha), are as follows:

Monthly Gross Unit Irrigation Water Requirement (GIR), Average Year, Huong (Unit: l/sec/ha)

Condition	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
2001	0.09	0.49	0.62	0.39	0.90	0.71	0.92	0.30	0.00	0.00	0.00	0.18	0.38
2010	0.09	0.46	0.58	0.37	0.88	0.70	0.90	0.29	0.00	0.00	0.00	0.17	0.37
2020	0.09	0.45	0.57	0.37	1.03	0.83	1.09	0.35	0.00	0.00	0.00	0.17	0.41

The monthly gross unit irrigation water requirements GIR (l/sec/ha) with use of the data of 25 years from 1976 to 2000 were calculated for the present (2001) and future (2010, 2020) cropping patterns. Those GIR data have been used for the water balance calculation.

Monthly gross unit irrigation water requirement GIRs (l/sec/ha) in the 1/4 drought year (1993) with less than 1/4 of examined long period selected from the above water balance calculation are shown in Tables 4.4 to 4.6, respectively.

On the other hand, the peak value of 10-day basis GIR (l/sec/ha) for irrigation schemes in the Huong River Basin based on the future (2020) cropping pattern and in the condition of the drought year with less than 1/4 of examined long period is shown below:

Peak Gross Unit Irrigation Water Requirement (GIR)
Year with less than 1/4 of examined long period selected from Peak 10-day GIR(Unit: l/sec/ha)

River Basin	Time	Peak GIR
Huong, 1991	Middle July	1.48

(12) Irrigation Water Demand (IWD)

Taking the irrigation area into the calculation, the irrigation water demands IWD (m^3/sec) have been estimated for the present (2001) and the future (2010, 2020).

The irrigation water demands IWD (m^3/sec) in the Huong River Basin based on the present (2001) and future (2010, 2020) cropping patterns and the average year rainfall condition are shown as follows:

Monthly Irrigation Water Demand (IWD), Average Year, Huong (Unit: m^3/sec)

Condition Irri. Area	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
2001 25,900 ha	2.3	12.7	16.1	10.1	23.3	18.4	23.8	7.8	0.0	0.0	0.0	4.7	9.9
2010 25,900 ha	2.3	11.9	15.0	9.6	22.8	18.1	23.3	7.5	0.0	0.0	0.0	4.4	9.6
2020 25,900 ha	2.3	11.7	14.8	9.6	26.7	21.5	28.2	9.1	0.0	0.0	0.0	4.4	10.7

4.2.2 Forecast Demand for Livestock

(1) Present Water Demand for Livestock

With reference to the Agriculture in Vietnam - 61 Provinces and Cities, MARD, NIAAP, 2001, numbers of various kinds of livestock are taken for estimation of water demands for the present (2001).

Present Water Demand for Livestock (2001)

River Basin	Pig (10^3 heads)	Ox (10^3 heads)	Buffalo (10^3 heads)	Poultry (10^3 heads)	Goat (10^3 heads)	Daily Consumption (m^3/day)	Required Intake Discharge (m^3/sec)
Huong	227	33	35	1,790	-	6,200	0.07

(2) Future Water Demand for Livestock

With reference to the Agriculture in Vietnam - 61 Provinces and Cities, MARD, NIAAP, 2001, numbers of various kinds of livestock are taken or estimated for livestock water demands of the future (2010, 2020).

Future Water Demand for Livestock (2010)

River Basin	Pig (10^3 heads)	Ox (10^3 heads)	Buffalo (10^3 heads)	Poultry (10^3 heads)	Goat (10^3 heads)	Daily Consumption (m^3/day)	Required Intake Discharge (m^3/sec)
Huong	305	49	38	2,261	-	8,200	0.10

Future Water Demand for Livestock (2020)

River Basin	Pig (10^3 heads)	Ox (10^3 heads)	Buffalo (10^3 heads)	Poultry (10^3 heads)	Goat (10^3 heads)	Daily Consumption (m^3/day)	Required Intake Discharge (m^3/sec)
Huong	666	68	42	2,872	-	14,600	0.17

4.2.3 Forecast Demand for Aquaculture

(1) Present Water Demand for Aquaculture

With use of the unit water requirement, which is expressed in the water depth (m/year), and the estimated aquaculture pond area (ha), the present water demand has been estimated as follows:

Present Water Demand for Aquaculture (2001)

River Basin	Coastal Shrimp Culture		Inland Fish Culture		Total	
	Pond Area (ha)	Fresh Water Demand (10^3 m^3)	Pond Area (ha)	Fresh Water Demand (10^3 m^3)	Fresh Water Demand (10^3 m^3)	Average Intake Discharge (m^3/sec)
Huong	1,010	4,646	920	31,280	35,926	1.1

(2) Future Water Demand for Aquaculture

With use of the unit water requirement, which is expressed in the water depth (m/year), and the estimated aquaculture pond area (ha), the future water demands have been estimated as follows:

Future Water Demand for Aquaculture (2010)

River Basin	Coastal Shrimp Culture		Inland Fish Culture		Total	
	Pond Area (ha)	Fresh Water Demand (10^3 m^3)	Pond Area (ha)	Fresh Water Demand (10^3 m^3)	Fresh Water Demand (10^3 m^3)	Average Intake Discharge (m^3/sec)
Huong	3,290	15,147	2,730	92,643	107,790	3.4

Future Water Demand for Aquaculture (2020)

River Basin	Coastal Shrimp Culture		Inland Fish Culture		Total	
	Pond Area (ha)	Fresh Water Demand (10^3 m^3)	Pond Area (ha)	Fresh Water Demand (10^3 m^3)	Fresh Water Demand (10^3 m^3)	Average Intake Discharge (m^3/sec)
Huong	4,510	20,762	3,690	125,545	146,307	4.6

4.3 Water Demand for Power Generation

Power supply in Vietnam is made under the nationwide power supply grid. Thus, the multipurpose reservoir projects are to contribute to power supply under this national power supply system.

The Master Plan which was prepared by EVN (Electricity of Vietnam) and approved by the Government conducted power demand forecast and formulated power development plan to meet the power demand growth. As discussed in Section 6.5, Phase 1 – Main Report, power demand in Vietnam is forecast to increase as follows:

Demand	2001	2020
Peak Load	5,800 MW	32,500 MW
Energy Demand	30,000 GWh/yr.	202,000 GWh/yr.

To meet the said power demand growth, the Master Plan considers to additionally provide various power plants including hydropower plants of multipurpose reservoir projects.

However, relatively small scale of power generation like the multipurpose reservoir projects in the Huong River basin was not considered in the national power supply plan. Therefore, it is assumed that the multipurpose reservoirs in the Huong River basin will primarily serve the water supply such as the domestic and industrial water supply, agricultural water supply and river maintenance flow, etc. and that the power generation will utilize the water to be used for the said water supply purpose and any surplus water.

Thus, the multipurpose reservoirs projects in the Huong River basin will have no particular water demand for power generation.

CHAPTER 5 EXAMINATION OF MAINTENANCE FLOW

5.1 Examined Items on River Maintenance Discharge

River maintenance discharge, which is needed for preventing saline water intrusion, water quality degradation, river mouth clogging, maintaining fluvial navigation, and ecological conservation is to be studied from the following view points:

1) Saline water intrusion: necessary discharge for allowable salinity at objective area is to be examined from correlation between discharge of the objective area from river mouth and salinity. Effect of the proposed river mouth barrage is to be taken into consideration.
2) Water pollution: necessary discharge is to be examined from correlation between river flow and allowable water quality standard.
3) River mouth clogging: necessary discharge is to be estimated from past clogging conditions.
4) Fluvial navigation: necessary discharge is to be examined from correlation among draft of ships, discharge and depth.
5) Ecological conservation: necessary discharge is to be examined from the viewpoint of ecological conservation in the river system.

Comparing these 5 discharge figures obtained as a result of the examination, the maximum figure should be adopted as the river maintenance discharge of Huong river.

5.2 Maintenance Discharge Proposed in EIA Study

In the report on the EIA for the Ta Trach Reservoir Project in Thua Thien Hue Province, a couple of examinations were undertaken. Firstly, it was examined and calculated from the stand point of the water use for irrigation.

Salinity depends on various factors such as discharges from upstream and tributaries, tidal level, and distance from the sea. In general, the further from the sea, the less salinity contents in river water. Based on the actual data on salinity at several points on the Huong River, the relationship of the salinity level and the distance from East Sea were identified.

Currently, there is an intake for irrigation to South Huong River irrigation area at Phu Cam, at a distance of 14.2 km from the East Sea. Taking into consideration the water use as irrigation water, the salinity of the Huong River at the intake must meet the condition of less than 1 ‰ as maximum salinity content for crops, and it was concluded that the discharge must be more than 61 m^3/s at Phu Cam. Excluding the inflow from tributaries of approximately 16.9 m^3/s, the maintenance discharge from upstream must be more than 45 m^3/s.

5.3 Various Aspects to be Required for Maintenance Flow

5.3.1 Water Quality

Water quality of the river depends on such conditions as discharge volume, pollution loads, water temperature and runoff velocity, etc. The discharge volume will determine the function of dilution, and temperature and runoff velocity will do the effectiveness of the capacity of self purification. Pollution loads include wastewater from domestic, industrial and agricultural use as well as the flush water from city ground. In the dry season, in general, water quality of river water is degraded as the dilution capacity is low as far as the other conditions are the same.

The water pollution analysis on BOD is generally employed as quantitative examination for determination of river maintenance flow. However the data and information prerequisite for analysis, such as original unit of pollutant load, pollution runoff ratio, and attenuation rate of the river, are not available in the Huong River Basin. Therefore, the examination of maintenance flow was carried out based on the existing data of water quality condition in the river and other relevant information.

Some water quality data measured in February to April, 1997, show that the water quality of Huong river is good condition even in most of dry season, meeting the Surface Water Quality Standard (TCVN 5942-1995) except for coliform bacteria.

The table below shows the water quality (BOD) measured in June to December, 1998, at 6 locations in the section between river mouth to confluence of Ta Trach and Huu Trach rivers. This also indicates that the water pollution in Huong River, even in the drought season, is insignificant.

Water Quality (BOD) in Huong River (measured Jun-Dec, 1998) Unit: mg/l

Location of Measurement	Average	Minimum Value	Maximum Value
River Mouth (Thao Long Barrage)	0.8	0.4	1.1
Sinh (Confluence of Bo and Huong Rivers)	0.9	0.5	1.6
Downstream of Hue City	0.9	0.3	1.7
Upstream of Hue City	0.6	0.2	3.4
Van Nien	0.5	0.2	0.7
Tuan (Confluence of Huu Trach and Ta Trach Rivers)	0.5	0.2	1.1

Source: Report on Current Situationof Water Quality of Thua Thien Hue Lagoon System and Tentative Culture Ponds (Vietnam-French Lagoon Project, 1999)

Besides, according to the scientists of the Department of Environmental Science, Hue University of Sciences, when the discharge volume of the Huong river becomes less than 10 m^3/s at the confluence of Ta Trach and Huu Trach rivers, water quality of the Huong river degrades. However, they have no suggestion on the discharge volume at the river mouth.

Accordingly, it is recommended that, in order to ensure the existing good condition of water quality of the Huong river, the decrement of existing low discharge be avoided through maintaining the hydrological regime of low water. The hydrological analysis of monthly availability water at the river mouth shows 86 MCM as the minimum monthly discharge during the term of the above water quality measurement. This corresponds to approximate 30 m^3/s on a trial of calculation of the average.

5.3.2 River Mouth Clogging

According to the available information, any problems and constraints on river mouth clogging were not reported so far at the mouth of the Huong river. This suggests that, although the effectiveness of the flood for flushing the sediment at the mouth is unknown, the existing low discharge is almost enough for prevention of river mouth against clogging. Therefore, the river mouth clogging can be avoided by maintaining the existing hydrological regime of low water.

5.3.3 Fluvial Navigation

Usage of inland waterways in the Huong River Basin is a relatively small scale. The freight transport of waterways accounts for less than 5 % of the total transport in the region.

The small boats for sightseeing, fishery, and transportation of gravel and local passengers were observed in the field reconnaissance. According to the People's Committee of Hue province, in addition, the fluvial navigation in the Huong river is only locally important, and most of the transport of the freight and passengers can be substituted for the other transport such as roads in case of insufficiency of the depth and surface width of water. Therefore, it is considered that the condition for the fluvial navigation can be mostly ensured by maintaining the existing hydrological regime of low water.

5.4 Minimum Discharge for Ecological Conservation Proposed in EIA Study

In the EIA study for the Ta Trach Reservoir Project in Thua Thien Hue Province, the minimum discharge for ecological conservation was also examined and proposed. The ecologically minimum discharge of the Huong river was determined as equal to minimum monthly discharge at the inlet of river mouth corresponding to P =90%. Data on monthly and annual flow were calculated and restored based on rain intensity data using TANK model. As a conclusion, river maintenance discharge for ecological conservation was obtained as 31.0 m^3/s at the river mouth.

5.5 Set up of River Maintenance Flow

Based on the above examination, the outcomes for determination of the maintenance flow of the Huong river are summarized below:

- 61 m^3/s at Phu Cam from the view point of prevention of the saline water intrusion,
- Ensuring the existing hydrological regime of low water from the view point of water quality, river mouth clogging and fluvial navigation, and
- 31 m^3/s at the river mouth from the ecological view point.

Among these, it is expected that the problem of the saline water intrusion will be solved apparently after completion of the new Thao Long barrage. Therefore, 31 m^3/s at the river mouth is obtained as the river maintenance flow of the Huong river.

CHAPTER 6 WATER BALANCE ANALYSIS

6.1 General

The analysis is made to evaluate water balance in the Huong River basin between available water resources (supply side) and respective water requirement (demand side) in present and future conditions. The evaluation incorporates the following components:

Water resources

1) River runoff(surface water) in natural flow condition
2) Reservoir storage water(as supplemental water resources during drought season and high irrigation demand period

Water demand

1) Agriculture including irrigation, aquaculture and livestock
2) Domestic use
3) Industry
4) Hydropower generation as minimum water release requirement

River maintenance flow

6.2 Methodology

6.2.1 Basic Condition

(1) Water Balance System

Water balance point is predetermined at each water demanding point and river mouth. Runoff at the water demanding point is evaluated if it is in surplus or in deficit incorporating agricultural uses, domestic use and industry water use. Balance point at the river mouth is to evaluate sufficiency of river maintenance flow in a whole basin basis.

Water balance analysis is made in monthly basis. Water resources and water demand data is given as monthly basis for duration of 24 years.

The water balance system of the Huong River basin is shown in Figures 6.1 as a schematic model.

(2) Natural Flow

River runoff worked out by the hydrological analysis precedingly described in Chapter 3 has been used. Those runoff is to be a natural runoff series since it has been directly estimated from observed rainfall.

(3) Return Flow of Irrigation Water

a) Return flow from irrigation area is assumed to be 10 % of demand, respectively.

b) Return flow of the irrigation water would not come back to the river in case that the flow goes directly to the sea.

(4) Return Flow of Domestic and Industrial Waters

Return flow from the domestic and industrial water uses is not incorporated in runoff at the balance point.

6.2.2 Available Water Resources in the Huong River Basin

(1) Natural Flow

Monthly natural runoff in the whole Huong River basin with a catchment area of 3,300 km^2 has been worked out for 24 years as monthly discharge basis as shown in Table 6.1. General feature of the natural runoff is presented below:

a) Long-term average runoff ; - Average for 24 years is 213 m^3/sec

- Annual average range from 114 m3/sec to 354 m3/sec

b) Drought year (annual) ; - Most severe among 24 years ; 1977 (annual mean=114.1 m3/sec)

c) Drought month ; - Most severe ; April (long-term mean=40.9 m3/sec)

- 2nd severe ; July (long-term mean=44.4 m3/sec)
- 3rd severe ; August (long-term mean=47.4 m3/sec)

In connection with the long-term average runoff of 213 m3/s which is different from the 50 % dependable discharge calculated in Phase 1 study, the following is noted:

In Phase 1 study, 50 % dependable discharge of the whole river basin was calculated to be 179 m3/s(or 5,673 MCM/year). On the other hand, the long-term average runoff is calculated at 213 m3/s(or 6,731 MCM/year) as mentioned above. The difference between the 50 % dependable discharge and the long-term average runoff can be explained as follows:

The 50 % dependable discharge in each month is derived from a regression line obtained through the statistic analysis on the basis of the monthly discharge data in each month. The 50 % dependable discharge to be obtained from the above regression line is not same as the average discharge in each month, from which the difference arises between the 50 % dependable discharge and the long- term average runoff.

(2) Reservoir

In the Huong River basin, no existing reservoir is available, while three planned reservoir are considered in the analysis model. The said dam reservoirs are as follows:

Planned reservoir

i) Ta Trach : Storage capacity ; 460 MCM (Effective)
Catchment area ; 717 km^2

ii) Huu Trach : Storage capacity ; 90 MCM (for flood control only)
Catchment area ; 570 km^2

iii) Co Bi : Storage capacity ; 455 MCM
Catchment area ; 712 km^2

In the analysis actually made, the only Ta Trach dam is included in the calculation.

6.2.3 Water Demand

(1) Irrigation Water Demand

Irrigation water demand is the most major water requirement in the Huong River basin. In the analysis, the irrigation area are divided into five(5) areas in the Huong River basin itself as shown in Figure 6.1. Present and future irrigation water demands have been worked out and are shown in Table 6.2 in terms of monthly unit requirement. Name and area of the irrigation areas are as follows:

	Present	**Future**	
	2000	2010	2020
North Huong Irrigation Area(1)	2,840 ha		
North Huong Irrigation Area(2)	4,845 ha		
North Huong Irrigation Area(3)	2,155 ha		
South Huong Irrigation Area	8,630 ha		
Bo Irrigation Area	2,720 ha		

(2) Water Demands for Aquaculture and Livestock

Water demands for aquaculture and livestock are estimated as described in

Sub-sections 4.2.2 and 4.2.3. Water demands by each irrigation area are presented below in terms of monthly volume:

(million m^3/month)

	Present Demand		Future Demand			
	2001		2010		2020	
	Aquaculture	Livestock	Aquaculture	Livestock	Aquaculture	Livestock
North Huong Irrigation Area(1)	0.282	0.020	0.835	0.027	1.132	0.048
North Huong Irrigation Area(2)	0.603	0.035	1.823	0.046	2.477	0.082
North Huong Irrigation Area(3)	0.279	0.016	0.845	0.020	1.149	0.036
South Huong Irrigation Area	0.979	0.062	2.936	0.082	3.985	0.146
Bo Irrigation Area	0.270	0.020	0.800	0.026	1.084	0.046

(3) Domestic and Industrial Water Demands

Water demands for domestic and industrial uses in Hue City and its vicinity are considered in the water balance analysis. Demand projection has been made for years 2010 and 2020 as shown in Figure 6.1 in terms of required monthly volume, and in terms of discharge as below:

		(unit)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Present	Disch.	cms	0.54	0.54	0.58	0.66	0.66	0.73	0.73	0.69	0.58	0.62	0.58	0.58
2010	Disch.	cms	0.73	0.73	0.81	0.93	0.93	0.96	0.96	0.93	0.77	0.85	0.77	0.77
2020	Disch.	cms	1.31	1.27	1.42	1.62	1.62	1.74	1.74	1.66	1.39	1.50	1.39	1.39

(4) Flood Control Space

To keep a flood control space in the reservoir during flood season is not water demand but restriction of water availability of the reservoir. According to the flood control plan, a flood control space will require 392 million m^3 to control the flood inflow to the Ta Trach reservoir in order to attain the predetermined flood control criteria. A 392 million m^3 is to be secured below the surcharge water level which corresponds to 610 million m^3 in terms of a gross storage. Therefore remaining available space for water supply purpose is 145 million m^3 above the dead space of 72 million m^3. This flood control space is to be considered in the analysis during September to November.

6.2.4 Reservoir Operation

(1) Reservoir Operation Rule Applied for the Analysis

In the present water balance analysis, preliminary reservoir operation procedure is predetermined to control reservoir storage volume in flood control aspect according to the two seasons a year, i.e.: no-flood season (December to August of the following year) and major flood season (September to November).

In addition to the above, a procedure on reservoir outflow control in the water supply aspect is predetermined as well. A concept of this rule is to discharge reservoir storage to meet water demand in the downstream reaches as long as storage water is available.

(a) Operation for Reservoir Storage Control

In annual operation for reservoir storage control, the highest priority is given to the following matter, respectively according to the flood seasons:

(i) Non-flood season : Securing effective storage capacity for water supply is prioritized provided that water supply demand is satisfied

(ii) Major flood season : Predetermined flood control space is to be secured

(b) Operation for Reservoir Outflow Control

Reservoir outflow control is to be made in the following manner that current reservoir storage will not exceed the respective effective storage capacities according to the flood seasons:

(i) Current Reservoir Storage = Max .Effective Storage Capacity

- Qout = Qin when Qin > Qdemand
- Qout = Qdemand when Qin < Qdemand

(ii) Current Reservoir Storage < Effective Storage Capacity

- Qout = Qdemand until Current Reservoir Storage reaches to the Effective Storage Capacity, when Qin > Qdemand
- Qout = Qdemand until Current Reservoir Storage become the lowest, when Qin < Qdemand

(iii) Current Reservoir Storage = the lowest

- Qout = Qin when Qin < Qdemand
- Qout = Qdemand when Qin > Qdemand

In the above,

Qout : Necessary outflow volume from the reservoir
Qin : Inflow volume to the reservoir
Qdemand : Water demand in downstream reaches

6.3 Evaluation of Water Balance Analysis

6.3.1 General

Water balance analyses have been made in the Huong River basin by applying monthly runoff series for 24 years, incorporating one planned reservoir (Ta Trach Dam for analyses at 2020 only) as well as water demands including irrigation, aquaculture, livestock, domestic and industrial uses. The water balance at present condition and future conditions in 2010 and 2020 are studied

Prior to examination of the water balance between supply and requirement at the balance point set at the river mouth as well as each water demand points, adjustment of reservoir operation have been made in order that ineffective discharge is to be minimized, and that reservoir storage should be utilized to eliminate water deficits at respective balance points as much as possible.

In the evaluation, a river maintenance flow is considered at the balance point. As discussed in Chapter 5, required maintenance flow is respectively presumed to be 61 m^3/sec against saline water intrusion in the present condition, and 31m^3/sec to maintain river ecology in the future condition incorporating effect of Thao Long barrage which will function to be against saline water intrusion.

6.3.2 Evaluation Criteria on Probable Drought Year

Water supply condition against the water demand is evaluated of its tightness in accordance with the criteria set out as follows:

	Water Demand		Drought Probable Year
(a)	Agriculture, River maintenance flow	:	Water demand shall be satisfied more than 3/4 period in years out of evaluated long period (24 years in the Huong River basin)
(b)	Domestic use, Industry	:	Water demand shall be satisfied more than 9/10 period in years out of evaluated long period (24 years in the Huong River basin)

6.3.3 Present Condition

Summary of water balance analysis in present condition is presented in Table 6.3. In the present condition, there is no available reservoir storage. Preliminary evaluation has been made according to results in Table 6.3, as follows:

(1) Water deficits are observed in both cases with / without consideration of the maintenance flow. In the case of maintenance flow considered, much deficits are found every year for analyzed 24 years.

(2) In case no maintenance flow is considered, water deficit at the river mouth point for whole basin are observed at 9 years among 24 year analysis. At each balance point at the intake site of each irrigation area, deficits are found for 13 years at the balance point along the Bo River and 9 years at the South Huong Irrigation area, while one-time deficit at balance point of the North Huong Irrigation Area taken from the Huong River.

(3) It is said that the present supply capacity by the natural river runoff without any regulating function, serious drought is caused almost every other year and serious saline water intrusion will be occurred, at the lower Huong as well as the Bo River.

6.3.4 Year 2010 Condition

In future condition of 2010, no available reservoir storage is assumed since completion of dam is not expected before a year 2010, while the Thao Long Barrage is assumed to be already functioned.

Preliminary evaluation has been made according to the results in Table 6.4, as follows:

(1) Water deficits are observed in both cases with / without consideration of the maintenance flow. In the case of maintenance flow considered, much deficits are similarly found every year for analyzed 24 years even though the maintenance flow is considered at 31 m^3/sec, which is a half of the present condition.

(2) In case no maintenance flow is considered, water deficit at the river mouth point for whole basin is observed at 9 years among 24 year analysis. At each balance point at the intake site of each irrigation area, deficits are found for 9 years at the balance point along the Bo River and 13 years at the South Huong Irrigation area, while one-time deficit at balance point of the North Huong Irrigation Area taken from the Huong River.

(3) The situation in 2010 is similar to the present one although slight improvement would be expected due to expected completion of the Thao Long Barrage.

6.3.5 Year 2020 Condition

In future condition of 2020, available reservoir storage is at 460 million m^3 in terms of effective storage capacity for water supply in the Ta Trach reservoir.

Evaluation based on the results shown in Table 6.5 and 6.6 has been made, as follows:

(1) In this stage, flood control space is considered in the month of September, October and November. A full capacity of 460 million m^3 is available during month except these three months, while only 145 million m^3 is expected during those months as the effective storage for water supply.

(2) In case that no maintenance flow is considered, water deficits at the river mouth balance-point are still observed in 1977 runoff series, which year correspond to the most serious drought year. Local deficits are found for about two-third out of 24 years at the some balance-points along the Bo River.

(3) Local deficit at the Bo River would be sharply eliminated by the construction of the Thao Long Barrage due to expected effects of the barrage as described in the preceding section.

(4) In case of maintenance flow of 31 m^3/sec taking into consideration, deficits are seen in five years. And storage water would be fully released to eliminate any water deficit in the whole basin in case of another year.

(5) It could be said that the expected supply capacity in 2020 would be just enough to the projected demand except when a serious drought condition is occurred by 5 times out of 24 years.

6.4 Result and Conclusion of Water Balance Analysis

Through the analysis made for year 2020, the following situation is found out:

(1) Water deficit would be caused for 5 years out of 24 years even after the Ta Trach Reservoir is available. The sixth drought year could be covered by the Ta Trach Dam with a storage capacity of 460 million m^3 for water supply.

(2) To examine usefulness of the Ta Trach reservoir, a study for 2020 demand without dam is carried out. Comparison of each case are summarized as follows in terms of number of years out of 24 years when deficits are

occurred:

	2020 without Dam	2020 with Dam
Whole basin with maintenance flow	23	5
Whole basin without maintenance flow	13	1
Bo River	16	5 (Thao Long Barrage considered)
South Huong Irrigation Area	12	1
North Huong Irrigation Area	1	0

(3) Water deficit to be occurred is estimated below according to the water balance analysis:

	(1)	(2)	(3)	(4)	(5)	(6)
Annual Deficit Volume (MCM)	275	199	185	164	149	0
(corresponding year)	1977	1990	1988	1980	1978	1983

No deficit is found in the sixth drought year, which corresponds to 1983, while reservoir storage will be fully used to solve drought condition.

(4) Based on the predetermined criteria that water supply capacity requires to satisfy water demand at the 1/4 drought probable year (6th year of the whole 24 years), the result shows that the water supply capacity with the Ta Trach reservoir will just satisfy water demands in 2020 by incorporating the Thao Long Barrage and the river maintenance flow.

CHAPTER 7 ENVIRONMENTAL IMPACT ASSESSMENT

7.1 Significant Environmental Aspects Based on Review of MARD's Investigation

Environmental Impact Assessment (EIA) for the Ta Trach Reservoir Project in Thua Thien Hue Province was conducted and the report on the EIA was prepared in May 2000 by MARD. The project proponent is MARD and the Ta Trach Reservoir Project is composed of the following (Sizes are the ones shown in F/S):

- Reservoir with a capacity corresponding to maximum storage elevation is 610,000,000 m^3.
- Dam with a crest elevation of 56m.
- Spillway with a flood flow of 11,400 m^3/s.
- Inlet sluice with a maximum flow of 100 m^3/s.
- Hydropower plant with a capacity of 19,500 kW.

The result of the EIA Study is briefly summarized hereinafter.

7.1.1 Present Situation

(1) Natural Environment

Water Quality: Water quality indicates that the river water is affected by coliform so the water sample must be treated before domestic use. However, the river water is not contaminated by heavy metal. In dry season, it shows high salinity due to tidal flow so it becomes non-suitable for domestic use.

Vegetation Cover: The vegetation cover of the project area can be divided corresponding to the two elevation belts: The elevation belt with the height of less than 900m is covered by thick tropical rain forest, and the elevation belt with the height of more than 900m is mainly the thick semi-tropical rain forest.

Flora and Fauna: There are 585 species of flora, and 45 species of mammals, 149 species of birds, 35 species of reptiles and 12 species of amphibians identified growing/inhabiting in and around the project site.

(2) Social Environment

The project area is basically located in Nam Dong and Huong Thuy districts of Thua Thien Hue province. The present situation of social environment is summarized as follows:

The land, in general, has relatively high potential, which is suitable for forestry development (afforestation), some industrial trees and fruit trees. The grazing area is relatively large, allowing the development of buffaloes and cows. Thus, the whole climate and natural condition is suitable for agriculture. There are, however, some difficulty, including insufficient capital for agricultural development, low education level of local people and the lack of marketability awareness, and poor condition of roads, etc.

(3) Issues on Land Acquisition and Resettlement

According to the EIA report prepared by HEC-1, Ta Trach reservoir project will cause the resettlement whose magnitude would be estimated at 815 households with about 5,000 of affected people. The loss of property such as land and agricultural production to be compensated amounts to approximately 55,000 million VND.

7.1.2 Environmental Impacts of the Ta Trach Reservoir Project

The environmental impacts caused by Ta Trach reservoir project and possible mitigation methods were analyzed and the levels of each impact was evaluated.

In the study conducted by MARD, the most significant negative impacts include the following components:

- Inundation, emigration away from reservoir bed and resettlement.
- Erosion and mud flow
- Diversion of downstream flow

The first item may have the impacts/issues such as inappropriate compensation, relocation(s) of affected (submerged) households and livelihood problems after emigration. The second item is the impacts of mud flow and turbid flow in the downstream area during construction stage when raining. The third item means the impacts caused by the change of water regime in operation stage, including the impacts on fluvial transport, irrigation, water quality and riverside and riverbed erosion. Other conceivable impacts are as listed in the table.

7.1.3 Review of the EIA Study Conducted by MARD

In the EIA Study, environmental impacts were examined, predicted and evaluated from ecological, physico-chemical and socio-economic points of view at the three stages: preparation stage (planning or designing stage), construction stage and operation stage. Conceivable impacts caused by the implementation of the Project was evaluated and described in detail, both qualitatively and quantitatively. In addition, mitigation measures are enumerated and environment management plan was described (but the environmental monitoring plan was not proposed).

However, considering the current conditions of the Project site that holds a wealthy biodiversity, and the magnitude of the project that has a submerged area of $23.5km^2$ (at average storage elevation), the following points should be studied more in detail and sufficiently:

- Impacts on terrestrial flora and fauna, including precious species
- Identification on social conditions especially in inland fishery, health condition and cultural/historical heritage

In addition, the environmental monitoring plan is to be prepared during both construction and operation stages. Taking into account these items to be studied and identified in detail, the Environmental Impact Assessment (EIA) study was undertaken under the Study, covering the scopes listed in the next section.

7.2 Scope of Environmental Impact Assessment

EIA research undertaken in subcontract bases. The environmental impacts on physical, natural and social environment were examined and evaluated based on the environmental standards in Vietnam, if applicable and appropriate to assess the proposed project. Otherwise, other adequate standards were introduced for the evaluation. The study report also includes the mitigation measures, environmental management and monitoring plans.

7.3 Overview of Results of the EIA Study

7.3.1 Introduction

The target development project for the EIA study is the Huong River Development Project, including the following components:

- Ta Trach Reservoir development, and
- Thao Long Barrage.

The approach and methodology for the EIA study are mainly i) collection of existing data or information, ii) literature review, iii) field measurement and laboratory analysis of water quality, and iv) interview to the informant including local people. The mitigation measures and monitoring plan was proposed in the final report.

Besides, prerequisite conditions such as the scale and dimension of the target projects for EIA study are obtained from the following reports:

- Feasibility Study for Ta Trach Dam prepared by HEC-I
- Feasibility Study for Thao Long Barrage prepared by SAFEGE

7.3.2 Current Status of Environment

(1) Physical Environment

a) Salinity intrusion

Current situation based on the existing data: The Huong river is affected by irregular semi-diurnal tidal regime, and the highest tidal amplitude may achieve up to 60 to 80 cm. Accordingly, salinity intrusion is measured in the river and it can rise over Gia Vien water factory which is located at approximately 19 km upstream from the estuary.

Salinity intrusion is alleviated by the existing Thao Long Barrage but it is old and its function is not enough at the moment. The new Thao Long Barrage is now under construction just below the existing one on the Huong river.

The results of on-site measurement in the course of this study: The Salinity measurement as well as the water level measurement was conducted for 24 hours on 21^{st} through 22^{nd}, February, 2002. The measurement was done at the 6 locations. Salinity samples were taken at vertical line in mid-stream, and on each vertical line, the salinity sample was taken at 3 points: surface point, middle point and bottom point. The samples were taken 12 times a day in odd hours. Salinity was identified by a salinity meter for each sample taken. The time to take samples was simultaneous with the time to measure the water level at the station.

The measurement results of the salinity concentration are summarized as follows: At Lai Y station, the average salinity only reached to 0.178 ‰, but when the tide was high, the salinity varied from 1-1.4 ‰, which indicates taking water for production and domestic use should be ensured its safety by the measurement and prediction of salinity concentration. From Phu Cam and upstream reach of the Huong river, the salinity is diluted this time of the year so it is possible to use the river water for domestic and production use.

b) Water quality

Current situation based on the existing data: According to the secondary data, the water quality of the Huong river is summarized as follows:

- Most of the parameters are consistent with the Limitation Value A of Surface Water Quality Standard of Vietnam, except for Coliform.
- Coliform concentration does not meet the Limitation Value A, or even Value B, which indicate the pollution caused by untreated municipal wastewater, direct defecation and other activities form residents living

along river banks and from "floating communities using boats" in the river.

- BOD_5 is lower than 2.0 mg/l and COD is lower than 9.0 mg/l, indicating the pollution caused by organic substances is quite slim. These concentrations, however, increase as river water flows to downstream, especially at downstream of Hue City. This shows that Hue city is the origin of water pollution by organic substances.
- The DO concentration is higher than 6.0 mg/l, mostly higher than 7.0 mg/l, which indicates the river water is suitable environment in terms of the habitat for aquatic organisms and, hence, of the aqua culture production.
- The concentrations of heavy metals such as Mercury, Arsenic, Cadmium, Lead, Copper, Nickel and Zinc are quite low. There is no problem on contamination by heavy metals at all.

In dry seasons, however, when discharge of the Huong river reduces remarkably, the phenomenon of "alga flower" is reported to occur in many sections. High concentration of phosphorus is considered to be one of its causes. This phenomenon makes the river water specific green, causing un-preferable condition in terms of scenery, aquatic organisms and so on.

Water Quality Analysis conducted in the course of this Study: Water quality analysis was conducted and its results were summarized as follows:

Comparing the results with the secondary data mentioned above, the concentration of BOD_5 and COD have changed to be polluted far beyond the Limitation Value A. Suspended Solid (SS) also showed the concentration not met the Limitation Value A. In addition, the average lead concentration has not met the Limitation Value A. On the contrary, there are similar tendency that high concentrations of Dissolved Oxygen (DO) and Coliform.

As for BOD_5 and COD, the cause of the relatively high concentrations is unclear at the moment. It is also not identified whether or not the high concentrations lasts from now on. The on-site ocular observation has not recognized such a high concentration of BOD_5 and COD.

Regarding the high average concentration of lead, this is brought about by the result of only one sampling point with very high lead concentration. The remaining points met the Limitation Value A.

In conclusion, water quality of the Huong river is characterized by high concentration of SS and is being affected by domestic effluent and direct defecation, reflecting the high concentration of Coliform and the tendency of high BOD_5 and COD. Additionally, it is featured of high DO value, which indicates the good condition for aquatic organisms and aquaculture production.

(2) Ecological Environment

a) Vegetation

According to 1998 statistics of Thua Thien Hue forestry resources, the vegetation and forest land cover the area of 347,653 ha and are divided into the following seven categories: 1) Evergreen closed trivially affected forests; 2) Evergreen closed considerably affected forests; 3) Rehabilitation sapling forests; 4) Scattered lumber plots mixed with secondary big-sized lumber bushes; 5) Perennial afforested and cash crop forests; 6) Bushes mixed with small-sized lumber trees and some secondary kinds; and 7) Grass-plot mixed with some light-favored fast growing species.

b) Flora

The present reservoir bed is covered with some area of forests including natural timber forest, bamboo forest, planted young forest and on-rock forest, of which the vegetation cover is mainly of bushes, grass and agricultural plants.

According to the document of Natural Conservation Division under Forest Management Department, MARD, the flora in and around the Ta Trach Dam Project Site has 585 species, 363 members, and 177 families belonging to 7 high-ranked plants. However, these numbers are supposed to be still smaller than the actual numbers in reality.

The flora is badly affected and there are 12 rare and precious species listed in Red Data Book of Vietnam. They are mostly seen in upstream area of Bo and Ta Trach rivers, especially, an area in Bach Ma National Park with elevation of 600 to 1,200 m.

c) Fauna

According to "Actual Environmental Situation Report of 5 years (1994 to 1998) in Thua Thien Hue province, 1998," the following numbers of terrestrial fauna inhabit in and around the Project Site. They include:

- 8 assemblages, 20 families and 45 species of mammals;
- 13 assemblages, 36 families and 146 species of birds;

- 2 assemblages, 11 families and 35 species of reptiles and 35 species of amphibians; and
- 1 assemblage, 4 families and 12 species of fishes.

The total number of species identified is 273, of which 25 species of rare and precious ones are listed in the Vietnam Red Data Book, Volume 2: Animals.

d) Bach Ma National Park

Bach Ma national Park is located 45 km far in the south of Hue city. Geographically, it occupies 16°05'- 16°06', north latitude and 107°43'-107°53', east longitude, with the total area of 22,030 ha. There are mainly two 2 types of forests in the park:

- Closed, year-round green, rain semi-tropical forest in the elevation of more than 900 m with the majority of *Podocarpaceae*, *Fagaceae*, and *Theaceae*; and
- Closed, year-round green, rain tropical forest in the elevation of less than 900 m with the majority of *Dipterocarpaceae* and *Fabacea*e.

A total of 1,286 plant species are recorded, of which the mostly seen are Euphorbiaceae: 22 species, Lauraceae: 18 species, Orchidaceae: 20 species, Palmae: 18 species, Moraceae: 16 species, Asteraceae: 16 species, Theaceae: 13 species. Among them, there are many endemic species and precious species identified.

A total of 459 animal species are recorded, of which 55 mammal species, 135 bird species, 31 reptile species, 20 amphibian species and 218 butterfly species are identified. Bach Ma national park has some endemic animal species representing for the animals in the south region of Vietnam.

(3) Social Environment

a) Population

In 2000 the Thua Thien Hue province has an estimated population of 1,066,200. The population is evenly distributed in the province with its densely-populated areas mostly in the city, towns and along rivers and coastal zones. The labor force in 2000 totals 576,000 persons, covering 54% of the total population.

Thua Thien Hue province is the home of 25 ethnic groups who live friendly in a harmonious community, comprised of Kinh, Ban Na, Ede, Ngai, Giao, Nung, Muong, Khome, Tay, Thai, Hoa, San Chay, Co Ho, Cham, Hore, Monong, Bru, Tho, Day, Ca Tu, Ta Oi, Lao, Chut and Van Kieu.

b) Major Economic Activities

Agriculture: According to the socio-economic development plan of the province, the agricultural produces are estimated at 683 billion VND in 2000 (in 1994 price). The average growth in 1996-2000 is slow as estimated about 1.6%. In the production value structure, the husbandry proportion accounts for 22-23%, and the contribution from the services varies from 6-7%.

Forestry: In 5 years of 1996-2000, through the mobilization of funds from various sources, a total of 19,267 ha of forests and 25.9 million trees have been planted in the province (Hai Van north area, Phu Loc district, Phong Dien district, etc.), according to .the socio-economic development plan of the province. The forest covering increases approximately from 34% in 1995 to 44% in 2000. The natural forest timber are exploited with the capacity of 5000 m^3 in 2000, substantially lower than the previous years due to the policy on exploitation restriction and closure of the forests in critical locations. The majority of timber capacity of 25.000 m^3 is mature trees of planted forests for wood pulps.

Fishery: According to the socio-economic development plan of the province, the fishery production gains approximately 182,3 billion VND in 2000 (in 1994 price), and the average annual growth rate in 1996-2000 is 12.9%. The internal structure of fishery has been rightly shifted; i.e. exploiting the fishery resources of lagoon and swamps, and increasing the proportion of aquaculture. The exploitation of fishery has a remarkable growth, especially offshore fishing. In addition, the aquaculture is developed rapidly in the lagoon and swamps in the coastal area recently, focusing on shrimp, crab, and fish in brackish water. Fresh water fish culture is somewhat popular in ponds, swamps, streams, rivers and reservoirs for local/household consumption.

Industries: The garment industry plays an important role in Thua Thien Hue. The production value of garment industry makes up 20% of the total industrial production in the basin, and it attracts 25% of total industrial labors. In addition, the construction materials production is one of industries that have a fast growth rate. Food and drinking processing, such as beer and frozen aquatic products, is also major industry in the province.

Tourism: Huong river basin has a lot of well-known places such as Ngu Mountain, Hai Van mountain pass, Bach Ma, lagoon and many beaches. Hue ancient capital city with many masterpieces of imperial palace architect, cultural structures and royal mausoleums was ranked by UNESCO as a world cultural heritage on December 11, 1993. The ancient Hue city is a key for the enhancement of tourism sector. And also, the province has hundreds of pagodas with unique traditional architectures such as Thien Mu, Bao Quoc, etc.

Targeting the tourism for key-economic sector, the physical infrastructures of the tourism increase notably from early 1990s. For example, the rooms of hotels totaled 509 in 1991 but in 2000 a total 2,153 rooms are accounted, responding to the increasing requirement and demand of customers. In the last 10 years, the international customers to Hue increase 29.8% per year in average, and the national customers increase to 12.8% annually. The incomes from tourism increase 7 times, and contribute to the GDP growth from 2% in 1990 to 7.7% in 1999.

c) Health and Sanitary Condition

The annual national health programs are always launched, including open vaccination program, cholera and typhoid preventive program, and other environmental sanitation and diseases preventive programs. These programs are effectively implemented and help eliminate a certain social diseases and cease the diseases spreading. However, the poor quality of domestic water affects negatively to the health of the people especially in the rural area. In recent 4 years, the out-patients of water-related diarrhea were annually recorded of about 10,000 or more in the province.

Besides, from the living environmental point of view, the air pollution caused by the large cement factories is considered to be somewhat significant, although the actual measured data is not available.

7.3.3 Impacts on Physical Environment

(1) Meteorology

The existence of Ta Trach reservoir may increase the humidity in the surrounding area due to the evaporation from it especially in dry season. In addition, the groundwater table would rise in the vicinity of the reservoir. The soil humidity would, therefore, increase remarkably, providing a good condition of the development of forests and vegetation cover around the reservoir.

Thao Long barrage will cause no impacts on the climate conditions because it will not produce a new water body or raise the groundwater level along the Huong river significantly.

(2) Saline Water Intrusion

After the construction of Thao Long barrage, the sea tide will not enter deeper than the barrage in the Huong river any longer, which will solve the problem on water use for paddy fields and domestic water caused by saline water intrusion along the Huong river.

(3) Geology

Based on the study results on earthquake aroused of big reservoirs, the necessary and sufficient conditions for an earthquake acceleration that can harm the reservoir and dams area are summarized as follows:

- Capacity of reservoir is over one billion m^3;
- Depth of reservoir exceeds 90 m; and
- Reservoir locates in a complex geological condition especially in a tectonic destroyable zone which is still active.

Given the size of Ta Trach Dam of the height of 56 m and a total volume of 610 million m^3, the possibility of seismic acceleration is considered to be quite slim.

(4) Impacts on Water Environment

In the reservoir, temperature stratification will be created after the water has been accumulated. Considering other case of reservoir in Vietnam, e.g. Hoa Binh Dam reservoir, the temperature difference between the surface and the bottom is estimated to be less than 6 ℃ even in dry season, and the water temperature at the bottom is estimated at around 20 ℃. This level of water temperature would not cause significant adverse effect on water use for irrigation, domestic, or industrial one in the downstream area.

As to Dissolved Oxygen (DO), the stratification, or the difference of DO between surface and the bottom, will also be created in the reservoir. DO concentration will temporality become less than 2 mg/l at the bottom layer since DO in the bottom layer will be consumed for biological decomposition of submerged organic matter such as trees and grasses formerly growing on the reservoir bed.

The circulation of the reservoir water would not fully occur because of the climate in Vietnam because due to the warm climate, water temperature of surface layer does not go down or last enough to boost the vertical circulation. With respect to this condition, the reservoir might have a possibility of occurrence of eutrophication. However, based on other cases of major dams in Vietnam, e.g. Hoa Binh Dam reservoir, the occurrence of eutrophication is considered to be rare. In addition, taking into account the water quality of the Huong river that water pollution of organic substance or high concentration of nitrogen or phosphorus is not recognized on an upstream reach, the possibility of eutrophication is considered to be slim.

After the construction of Ta Trach Dam, sediment contents from upstream will be stored in the reservoir. The reduction of sedimentation in the lagoon would contribute to prolong the life of the lagoon system taking into account the fact that its depth has been getting shallower historically.

When Thao Long barrage is completed, saline water intrusion shall be controlled at the barrage in the Huong river, thus the water quality shall be improved and suitable for the agricultural development and fresh water fishery development along the river.

In contrast to the improvement of water quality in the Huong river, Thao Long saline control barrage makes the water environment in Tam Giang lagoon more brackish or fully saline water in dry season unless discharge from Ta Trach Dam is adequately controlled.

(5) Erosion and Sedimentation

During the construction stage, mud flow and turbid flow from the construction site of Ta Trach Dam to downstream would be spawned, which in turn causes the sedimentation in the lower reach. In addition, concrete placement for the dam body would cause the alkaline water discharge, in case that gravity type dam by concrete would be applied to Ta Trach Dam although fill type was planned in F/S of Vietnam. During the operation stage, as a result of discharge from Ta Trach Dam and Thao Long barrage, erosion would occur especially at the foot of the dam and barrage.

7.3.4 Impacts on Ecological Environment

(1) Impacts on Vegetation and Flora

The present vegetation cover to be submerged by the Ta Trach reservoir is mainly comprised of grass, bushes and agricultural plants. Besides, majority of planted forests are eucalyptus and bamboo, where the natural degree of vegetation is considered to be low. Therefore, the impacts caused by Ta Trach reservoir on the vegetation cover and forest resources are not considered to be significant.

As mentioned in the previous section, there are 12 rare and precious plant species identified in the headwater area of the Huong river. The most of them are seen in the area in Bach Ma National park, especially that with elevation of 600 – 1,200 m. Impacts on these species, therefore, are not significant because even the maximum water level of Ta Trach reservoir, approximately 52.0 m, is far below the area where these species grow.

(2) Impacts on Wild Animals

According to the mobilization of large number of construction workers during construction period, wild animals would be affected in the form of the disturbance and/or the loss of their habitat, including illegal hunting.

As mentioned in the previous section, there are 25 rare and precious wild animals identified in and around the Project Site. Of which otters (*Lutra lutra*) and green peafowls (*Pavo muticus imperater*) would be affected because they are riparian species and their primary habitat would be lost. In addition, as for the other precious species, except for birds, there would be some adverse effects in terms of migration for foods, hiding or breeding. Therefore, it is quite important that the monitoring focusing on the changes of habitat, the population and the breeding grounds of precious species is carried out before and after the construction of the Ta Trach Dam.

(3) Impacts on Fishes in the Huong River

Due to the existence of Ta Trach reservoir, the sediment content shall reduce in downstream in the river, which would cause the reduction of the nutrition for the phytoplankton and results in affecting to its development. The decreased quantity of phytoplankton affects the food sources of fishes in the Huong river. The existence of the dam and reservoir also impedes the migration of fishes to upstream and vise verse.

On the other hand, the freshwater fish production in the reservoir and its upstream area is expected to increase due to the formation of the water body, i.e. Ta Trach reservoir, and the increase of phytoplankton, humus and residues in it, being combined with the increased potential of fishery development.

(4) Impacts on Lagoon Ecological System

a) Salinity condition and Nutrition

After the construction of Ta Trach Dam and Thao Long Barrage, the discharge from the dam is regulated and maintained at more than $25m^3/s$ even in dry season. During the flood season, all the valve gate of Thao Long Barrage will be open for a fast flush of floodwater. Thus, the constructions of the dam and barrage will form a stable discharge flowing into the lagoon and more stable salinity condition during non-flood season and yet will not reduce the nutrition supply excessively from the upstream because of the remaining of fast flush of floodwater.

b) Phytoplankton

The change of phytoplankton in Tam Giang lagoon is the alternate of the typical compositions of fresh water phytoplankton and sea water phytoplankton. With Ta Trach reservoir, floodwater shall be restored and then regulates the discharge to downstream and Tam Giang lagoon, thus the freshwater phytoplankton will be reduced in rainy season. On the contrary, the sea water phytoplankton will increase relatively even in rainy season.

c) Zooplankton and benthic macro-organism

The composition of the freshwater zooplankton and benthic macro-organisms usually appear in Thuan An estuary where receiving the Huong river water. However, it will gradually decrease and be replaced with brackish and sea water ones.

d) Fishes

A total of 163 species of fishes identified in Tam Giang – Cau Hai Lagoon can be divided into four groups:

- Fresh water fishes
- Brackish water fishes;
- Saline water fishes; and
- Migratory fishes.

The impacts of the construction of Ta Trach Dam and Thao Long Barrage on fishes will differ depending on these groups.

<u>Fresh water fishes</u>

During period of water shortage, the maintenance flow will contribute to improve the living conditions near the estuary of the Huong river for fresh water fishes. During flood season, the living conditions for fresh water fishes will be almost the same as present due to the full open for a fast flush of floodwater. The change of water regime caused by the project implementation, therefore, will not bring about a negative effect significantly on fresh water ecology in the lagoon.

<u>Brackish water fishes</u>

The brackish water fishes are able to live in a large amplitude of salinity varying from 5 ‰ to 18 ‰, and account for the largest number in the lagoon. Therefore, the impact on the brackish water fishes will be small, and the fish catch will be maintained.

Saline water fishes

Salinity in the lagoon water varies over time and space, depending on the river water supply and sea tides. But, all in all, the magnitude of salinity fluctuation will be reduced and stabilized due to the discharge regulation from the dam as mentioned above. Therefore, living conditions for saline water fishes will be improved, not be damaged, and fishery production will be estimated to increase than the present status.

Migratory fishes

The construction of Ta Trach Dam and Thao Long Barrage shall affect the migratory fishes migrating between the sea and river, including *Chupanodon* and *Marura* because they migrate deeply into river. The impacts may also fall on eels (*Anguilliformes*), *Lutianus*, *Stolenphorus* and *Theropn* because they migrate between the sea and river. Magnitude of the impacts, however, is not clear because the information on the number of these species is not available.

Necessity of further investigation and monitoring

Based on the existing data and information on current status of lagoon ecology, the impacts of the constructions of Ta Trach Dam and Thao Long Barrage were examined and described above. However, considering the complicated geographical feature of Tam Giang – Cau Hai Lagoon and the biological diversity in it, further investigation and monitoring on the ecology before and after the implementation of the projects are needed in order to better understanding of the ecosystem of the lagoon and to prevent the adverse effect on it.

7.3.5 Impacts on Bach Ma National Park

The normal water level and the high water level are 49 m and 52 m above sea level, respectively. The construction of Ta Trach Dam and the formation of reservoir will submerge a certain area of the park. However, the area to be submerged does not affect the natural forests even at the high water level. Accordingly, the ecosystem will be kept unchanged and the habitat of the precious species in good condition. It does not affect either the resort and tourism area where there exist hundreds of villas and road systems connecting such villas.

Thus, although the construction of Ta Trach reservoir shall submerge a part of forest in the transition area of Bach Ma National Park, the impact is not considered to be significant because the area to be submerged is not ecologically important forest lands.

7.3.6 Impacts on Social Environment

(1) Magnitude of Land Acquisition

Ta Trach reservoir responding to SWL of EL 52 m will submerge about 34 km2 including the agricultural land of 5 km2 and forest of 17 km2. Whereas Thao Long barrage will acquire about 2 ha for constructing of 2 ends of the bridge, and management area temporarily occupies about 5 ha for borrowing area such as material stockpiling and layout of the works. These impacts are negative and indispensable.

(2) Resettlement and Change of Social Issues

The construction of Ta Trach reservoir in the case of SWL of 52 m will directly affect 4,300 people (predicted to year 2003) in 855 households, of which 383 people are Van Kien ethnic minority in 73 households. In addition the host communities will be indirectly affected because they have to share the natural resources and will be suffered from the disorder of social and cultural activities.

Van Kieu group is almost civilized, and at present they live with Kinh in the reservoir bed. The structure of their houses is similar to Kinh's, and this might mean that it would be acceptable for Van Kieu group to resettle in the same manner of the Kinh.

It is expected that the resettlement will cause the significant change of living and social condition of affected households. Therefore, it is quite important that the monitoring focusing on the process of resettlement action and the status of self-sustenance of affected households including Van Kieu group is carried out before and after the construction of the Ta Trach Dam.

(3) Health and Sanitary Condition

Ta Trach reservoir and Thao Long barrage will reduce a probable infectious risk especially in urban area with the enhancement of distribution of domestic water, and will introduce a great positive effect on the water use in daily life of the people living along the river. This means that the people in Huong river basin have convenient conditions to take care of their health, and that the community health/sanitary condition will be significantly improved.

On the other hand, the due consideration should be paid on the following issues:

- Probable deterioration of health and sanitary condition caused by mobilization of large number of labor force, and
- Increment of potential risk of diseases such as malaria in the areas adjacent to the new water bodies.

(4) Cultural or Historical Heritage

Both Ta Trach reservoir and Thao Long barrage will not cause negative impacts on the historical monuments and cultural structures or landscapes.

(5) Noise and Dust

A huge amount of earthwork is planned for the construction both of Ta Trach reservoir and of Thao Long barrage. The construction sites and the vicinity will be affected by nuisance of noise and dust, and by chemical use if any.

(6) Impact on Forestry

Total forestland to be lost by Ta Trach reservoir will be about 1,300 ha of planted forest and about 400 ha of natural forest. The natural forest in reservoir bed mainly comprises of bamboo and timber with low capacity, and the vegetation cover mainly comprises of grasses and bushes. Thus the impact on the natural forest is minor.

According to the proposed land-use plan for production land in the resettlement area, the planted forestland of about 1,200 ha is planned. The scale of this reforestation plan will approximately meet the magnitude of loss by the reservoir.

(7) Impact on Fishery

Inland Fishery

Ta Trach reservoir would affect the migration of some fishes in Huong river to Ta Trach branch and vice verse. And also Thao Long barrage would affect the migration of some fishes in river and lagoon that go deeply to upstream for spawning. Although the change of condition for fish migration will probably reduce the productivity of fishery, the impact on annual fish production will not be significant because the migratory fish species are not considered to be economic ones.

Lagoon Fishery

The catch amount of lagoon fishery after 1999 flood increased remarkably, i.e. more than five times as much as that in 1980's and 1990's. It is considered that i) the appearance of the new lagoon estuaries by flood helped increase the migration species into the lagoon, and ii) the higher saline environment over the large area of the lagoon facilitates the development of the fish species in the lagoon. This suggests that the water exchange among river, lagoon, and sea plays an important role to the lagoon ecological environment, affects the catch amount of fishery in the lagoon.

Ta Trach reservoir has a function to regulate the river flow, and will, especially in dry season, contribute to stabilization of supplying the fresh water to the downstream and lagoon. From the experience mentioned above, this might have a tendency of decreasing the product of fish dependent on high saline water.

7.4 Environmental Management Plan

7.4.1 Mitigation and Enhancement Measures

The conceivable impacts by the constructions of the Ta Trach Dam and Tao Long Barrage on environment were predicted and described in detail in the previous section. The mitigation and/or enhancement measures to cope with the impacts are listed in Table 7.1.

7.4.2 Environmental Monitoring Plan

In the previous section, the impacts by the implementation of both Ta Trach dam and Tao Long Barrage construction projects were predicted, and its mitigation and/or enhancement measures were described in detail. In order to manage both natural and social environment and to keep them in favorable condition, the existing environment and its change is to be monitored properly before and after the project implementation.

Table 7.2 shows the necessary monitoring plan to follow-up the physical, ecological, and social environment in and around the project sites.

CHAPTER 8 FORMULATION OF INTEGRATED RIVER BASIN MANAGEMENT PLAN

8.1 Alternative Basin Development Plans

8.1.1 Water Supply Requirement

Water demand in the basin was analysed in the foregoing section Chapter 4. The water balance analysis conducted on the basis of the water demand in Chapter 6 found that reservoir to be planned should have a storage capacity of 460 million m^3 to meet the water supply requirement.

In the case of non-reservoir scheme, freshwater supply to meet the water supply requirement has to be considered. Necessary freshwater supply in the case of non-reservoir scheme is assessed to be 219 million m^3/annum as examined in Sub-section 8.1.3.

8.1.2 Flood Control Requirement

Flood control requirement of the Huong River Basin which is targeted by MARD is as follows:

a) Hue city should be protected from the same magnitude of flood as that in 1999. Flood water level at Kim Long due to 1999 flood with the peak discharge of 13,670m^3/s was EL. 5.84m which should be lowered to EL. 3.7m at Kim Long, corresponding to the river discharge of 2,000m^3/s. Flood hydrographs of 1999 flood are seen in Figure 8.1.

b) The agricultural lands extending in downstream reaches should be protected from 10-year (or 10%) probable early flood, of which flood hydrographs are seen in Figure 8.1.

c) Flood water level of the Bo River at Phu Oc due to 1999 year flood with the peak discharge of 3,050m^3/s was measured to be EL. 4.89m. This flood water level of EL. 4.89m should be lowered to EL. 4.50m, corresponding to the river discharge of 1,410m^3/s.

The target area is shown in Figure 8.2.

8.1.3 Study on Alternatives of Structural Measures for Water Supply and Flood Control

To find the optimum plan, the study was made on conceivable alternatives as discussed below.

(1) Discharge Carrying Capacity of River Channel

The Huong River has the following discharge carrying capacity in its downstream reaches:

a)	The reaches along the agricultural land (downstream of urban area)	:	1,400m^3/s
b)	The reaches along Hue City	:	2,000m^3/s

The above discharge carrying capacity of river channel is examined as seen in Figures 8.3 and 8.4.

(2) Necessary Reservoir Storage Capacity for Water Supply

Reservoir storage capacity necessary for meeting the plan is assessed to be 460 million m^3 through the water balance analysis in Chapter 6.

(3) Necessary Freshwater Production in Case of Non-Dam Plan

Assuming a plan without dam, freshwater will be required to be produced in order to meet the water demand for the domestic and industrial water supply and agricultural water supply.

A technically possible way to produce freshwater without dam construction is to provide facilities to produce freshwater from sea water. Necessary production of freshwater in this case is estimated at 219 million m^3/annum, assuming that freshwater should be produced for the incremental water demand from 2001 to 2020 for domestic and industrial water supply and agricultural water supply so that the present water supply condition be maintained at least. The above incremental water demand is estimated at about 600,000m^3/day, amounting to 219 million m^3 per year.

(4) Conceivable Facilities for Structural Measure

Facilities which were conceivable and taken up for examination of structural measure are as mentioned below. Location of each facility is shown in Figure 8.5. Storage-capacity curves of three (3) dams taken into consideration are presented in Figure 8.6 to 8.8.

a) Maximum Ta Trach Dam

This is nearly topographically maximum scale of the dam at the Ta Trach damsite, as shown below:

- Dam crest level	:	EL. 55.0 m
- Effective storage volume	:	460 million m^3

- Flood control volume : 392.6 million m^3

b) Minimum Ta Trach Dam

The minimum Ta Trach Dam is defined as the dam to be provided with the flood control volume necessary to fulfil the flood control target with the maximum Huu Trach Dam. The minimum Ta Trach Dam will have the following:

- Dam crest level : EL. 53.0 m
- Effective storage volume : 460 million m^3
- Flood control volume : 312 million m^3

c) Maximum Huu Trach Dam

This is the maximum scale of the dam at the Huu Trach damsite, having the following:

- Dam crest level : EL. 61.0 m
- Effective storage volume : 182 million m^3
- Flood control volume : 182 million m^3

d) Minimum Huu Trach Dam

The minimum Huu Trach Dam is defined as the dam to be provided with the flood control volume necessary to fulfil the flood control target with the maximum Ta Trach Dam.

The minimum Huu Trach Dam is provided with the following feature:

- Dam crest level : EL. 56.0 m
- Effective storage volume : 105 million m^3
- Flood control volume : 105 million m^3

e) Maximum Co Bi Dam

The maximum Co Bi Dam which is of the maximum scale at its damsite in Bo River is provided with the following feature,

- Dam crest level : EL. 46.0 m
- Effective storage volume : 167 million m^3
- Flood control volume : 167 million m^3(*)

f) Minimum Co Bi Dam

The minimum Co Bi Dam is provided with the flood control volume to meet the flood control criteria for Bo River as follows:

- Dam crest level : EL. 38.0m
- Effective storage volume : 45 million m^3
- Flood control volume : 45 million m^3(*)

(*): It is noted that the flood control volume of Co Bi Dam does not contribute to flood control for Hue City.

g) Non-dam Facilities

Non-dam facilities for water supply

Freshwater production plants from sea water with production capacity of 600,000m^3/day are considered as an alternative measure for necessary water supply without dam.

Necessary cost for freshwater production ranges approximately from US$ 1.5/m^3 to US$ 2.5/m^3. Assuming US$ 2.0/m^3 for the cost of freshwater production from sea water, the cost for necessary water supply in the basin will approximately be US$ 438 million/annum (219 million m^3/annum x US$ 2.0 /m^3 = US$ 438 million/annum)

Non-dam facilities for flood control

The following combination is considered as conceivable non-dam flood control facilities:

Non-dam Facilities for Flood Control	Flood Control Capacity
- Diversion Channel	3,000 m^3/s
- Parapet Wall	2,000 m^3/s (*)
- Retarding Basin	400 m^3/s (**)
- Diversion Tunnel	350 m^3/s

Note(*): Parapet wall capacity of 2,000means that Hue City to be enclosed with a parapet wall of 1.0 m in height can withstand further increase of flood discharge.

(**): Capacity of retarding basin of 400 m^3/sis determined by assuming the retarding basin area of 3 million m^3, its depth of 5.0 m and flood cutting of 10 hours(3 million m^3x 5.0 / 10 hours = approx. 400 m^3/s)

(5) Examination on Alternatives

To find the optimum basin plan, thirty-three (33) alternatives in total were taken up for examination as shown in Table 8.1.

The examination on the alternatives is made as follows:

a) There are four (4) requirements which the basin plan should satisfy as explained in the foregoing Sub-sections 8.1.1 and 8.1.2.

Those are summarised below:

i) Water supply requirement

Reservoir with effective storage capacity of 460 million m^3 is required for meeting the water supply requirement in the basin, or freshwater of 219 million m^3/annum has to be produced without reservoir.

ii) Flood control requirement for Hue City

For flood control for Hue City, flood peak discharge of 13,670 m^3/s (1999 flood) should be reduced to 2,000 m^3/s by cutting 11,670 m^3/s.

iii) Protection of agricultural lands from early flood

For protection of agricultural lands, 10-year (or 10%) probable flood should be controlled so that river discharge be limited to 1,400 m^3/s which is the river channel discharge carrying capacity in the downstream reaches where agricultural lands are extended.

iv) Bo River flood control

For Bo River flood control, flood peak discharge of 3,050 m^3/s in Bo River (1999 flood) should be reduced to 1,410 m^3/s which is the river channel discharge carrying capacity of Bo River.

Requirement of the above (i) to (iii) are considered to be essential requirements which have to be satisfied by the basin plan. On the other hand, requirement of the above (iv) is not considered to be requirement which have to be satisfied essentially in consideration that,

- Bo River flood control has no effective contribution to flood control for Hue City,
- Provided that Ta Trach and Huu Trach dams are constructed, the problem of damages on agricultural lands due to early flood can be solved without Bo River flood control, and
- Protection of agricultural lands from major floods is not important in view that the cropping pattern considers to avoid the damages due to major floods.

Thus, the Bo River flood control should duly consider its economic viability.

b) Therefore, in the first screening, alternatives which can not meet all three (3) essential requirements as mentioned are screened out, and further examination on these alternatives are omitted.

c) Alternatives which pass the first screening proceed to evaluation from environmental aspect consisting of natural environment and social environment as the second screening. Alternative which are not acceptable in the evaluation from environmental aspect are screened out in this second screening.

d) Economic viability is assessed on alternatives which pass the second screening, and the optimum basin plan is recommended through an overall evaluation on alternatives which pass the second screening.

(6) Result of Examination on Alternatives

The result of examination on alternatives is presented in Table 8.1. Major points of the result are summarized below:

a) Alternatives without dam require facilities such as diversion channel, parapet wall, retarding basin and diversion tunnel for flood control requirement, and freshwater production facilities from sea water for water supply requirement. Adverse impacts on environment due to flood control facilities such as diversion channel, parapet wall, retarding basin and diversion tunnel will be much more larger than those of dams. Especially, necessary resettlement by the diversion channel is estimated to be not less than 20,000 people which is much more than 4,000 to 5,000 people in the Ta Trach Dam. The diversion channel will also have large impacts on the infrastructures such as the railway and national road including replacement of bridges. Large adverse impacts as mentioned above are considered not acceptable from the environmental aspect.

In alternatives without dam, freshwater is forced to be produced from sea water to meet the water supply requirement. Freshwater production from sea water is very costly, requiring the cost of US$ 1.5 to 2.5 per m^3. Annual freshwater production cost to meet the water supply requirement is preliminarily estimated at US$ 438 million /annum., which will make the economic viability as low as about 0.1 in terms of Benefit/Cost ratio, meaning that necessary cost will be more by ten times than the benefit to be obtained. As such, alternatives without dam are considered unjustifiable economically and unrealistic.

b) Necessity of the Co Bi Dam in the Bo River is not high at present by the reasons as explained in the foregoing (5).

Besides that, the Co Bi Dam will make economic viability worse as seen in Table 8.1.

Thus, implementation of the Co Bi Dam is considered too early at the present stage, and the Co Bi Dam is proposed to be implemented when its necessity becomes higher due to development of areas along the Bo River.

c) Provision of Ta Trach Dam and/or Huu Trach Dam will be the most effective measure to attain the target of the basin plan in 2020.

In order to attain completely the flood control target, both Ta Trach Dam and Huu Trach Dam are required, although Ta Trach Dam will play a large part of role to attain the target.

d) As shown in Table 8.1, the combination of the maximum Ta Trach Dam and the maximum Huu Trach Dam (Case No. I-B.2) indicates the highest economic viability out of alternatives which can achieve the target of the basin plan in 2020.

The above two dams are also judged acceptable from the environmental aspects as evaluated in Table 8.1, and the overall evaluation recommends to select the above two dams (Case No.I-B.2) as the optimum basin plan towards the target in 2020.

8.1.4 Recommended Basin Development Plan

(1) Recommendation for Selection of Basin Development Plan

As discussed in the Sub-section 8.1.3, the basin development plan consisting of the maximum Ta Trach Dam and the maximum Huu Trach Dam, i.e. Alternative case No.I-B.2, was evaluated to be the most favourable scheme through the overall evaluation. Based on the above, the basin plan was recommended and proposed as follows:

Recommended Basin Plan

- Ta Trach Dam with,

Crest level	:	EL. 55.0m
Effective storage volume	:	460 million m^3
Flood control volume	:	392.6 million m^3

- Huu Trach Dam with

Crest level	:	EL. 61.0m
Effective storage volume	:	182 million m^3
Flood control volume	:	105 million m^3

(2) Recommendation for Implementation of Basin Development Plan

As examined and discussed above, two dams of Ta Trach Dam and Huu Trach Dam will be required to completely satisfy the flood control requirement as explained in Sub-section 8.1.2, while project effectiveness of Ta Trach Dam only is as follows:

- Without any project, the probable damage in terms of annual damage due to 1999 flood with peak discharge of 13,670 m^3/s is estimated at 595,200 million VND/annum.
- Thus, Ta Trach Dam will contribute to the flood damage mitigation as much as 546,200 million VND/annum (or about 90% of the total annual flood damage) with the flood control volume of 592.6 million m^3, while the that of Huu Trach Dam is 105 million m^3.
- With Ta Trach Dam only, the flood water level of EL. 5.85m at Kim Long which was caused by 1999 flood will be lowered to EL. 4.6m, resulting in water level reduction of 1.25m. Although the target water level to be lowered is EL. 3.71m, the above flood water level of EL. 4.6m, which corresponds to the flood water level due to about 1.5-year probable flood of 5,600 m^3/s in peak discharge, is considered to be within an acceptable range as follows:

  Under the discharge of 5,600 m^3/s from the upstream, the overflow from the river channel will be about 3,600 m^3/s since the river channel has the discharge carrying capacity of 2,000 m^3/s. In this case, the water level in the downstream urban area is assessed to be EL.4.38 m. Since the ground level of the urban area is about EL.3.85 m, the inundation depth is calculated at about 0.53 m, which will occur at the probability of about 1/17(the flood peak discharge of 1999 flood is estimated to be of about 17 year probability).
- Water supply requirement will be satisfied with Ta Trach Dam only.
- Economic viability of Ta Trach Dam only will be slightly higher than Ta Trach Dam plus Huu Trach Dam as follows:

	EIRR
· Ta Trach Dam only	16.6 %
· Ta Trach Dam + Huu Trach Dam	16.5 %

Effectiveness of Ta Trach Dam is as high as discussed above. Considering this high effectiveness as well as the financial constraints, implementation of only Ta Tach Dam is considered sufficient for the time being. It is considered possible that Huu Trach Dam can wait until the financial conditions allow its implementation.

8.1.5 Provisional Flood Control Measure until Construction of the Huu Trach Dam

The flood control plan of the Huong River basin has been proposed as the construction of the Ta Trach reservoir and the Huu Trach reservoir without river improvement plan in the downstream reaches. With the combination of the said two reservoirs, the flood peak discharge of the Huong River could be decreased from 13,670 m^3/s to 2,000 m^3/s at Kim Long site. The discharge of 2,000 m^3/s is estimated to be the safe discharge of the Huong River for the Hue City.

The construction of the Ta Trach reservoir is now on the stage of procedure of loan application for the construction with the government decision. Accordingly the realization of the Ta Trach reservoir is not a long way.

But it will take a long time to construct the Huu Trach reservoirs in this river basin since the available national resources are limited. In the whole nation, there still remain many river basins that need construction of big scale reservoirs for water resources development and management.

The Ta Trach reservoir could decrease the flood peak of the Huong River from 13,670 m^3/s to 5,600 m^3/s at Kim Long site. This flood peak reduction is very substantial and the Hue City can enjoy the full benefit of the Ta Trach reservoir. But the remaining flood peak discharge is still hazardous for the Hue City until the completion of the Huu Trach reservoir. To receive the full benefit of the Ta Trach reservoir for the Hue City, some provisional flood control measures are needed for the Hue City until the completion of the Huu Trach reservoir.

Presently the river reaches of the Huong River just upstream of the Hue City does not have the discharge carrying capacity of 5,600 m^3/s. Accordingly the substantial part of the flood even after flood peak reduction by the Ta Trach reservoir would overflow in the said reaches reducing the flood peak discharge at the Hue City site. This includes the flood diversion through a left side river branch located just upstream of the Hue City flowing to the north-western direction. Presently there are no discharge control facilities at the branch site. This situation is favorable one for the safety of the Hue City and is important as a provisional measure until the completion of the Huu Trach reservoir. Accordingly this situation should be left as it is now until the completion of the Huu Trach reservoir.

If the flow control is to be done at the said site of the branch, the flood peak at the Hue City site would become worse and accordingly the full benefit of Ta Trach reservoir could not be enjoyed. The positive impact of Ta Trach reservoir would be reduced by the flow control at the said branch site.

8.2 Examination on Effectiveness of Dams in Upstream Reaches of Ta Trach Dam

8.2.1 General

The optimum development plan of the Huong River basin has been examined and development scale of the Ta Trach Dam has been optimized in this Huong River basin development planning.

The proposed damsite of the Ta Trach Dam is considered most effective topographically for achieving both flood control and water supply targets of the basin. For confirming the above, effectiveness of possible dams in the upstream reaches of the proposed Ta Trach damsite is preliminarily examined herein.

Damsites are also conceivable in the upstream reaches of the Huu Trach River. However, the river basin conditions of the Huu Trach River are similar to those of the Ta Trach River. Thus, considering that the result in both the river basins will be same, the examination is limited to the Ta Trach River basin.

8.2.2 Possible Damsites in the Upstream Reaches

There are three conceivable damsites in the upstream reaches of the proposed Ta Trach damsites. The location map of the conceivable damsites is shown in the Figure 8.10. These three damsites are named as T-1, T-2 and T-3, respectively as seen in the figure. These three sites have V-shape river valley suitable for dam construction, and downstream of these sites, the topography of river valley becomes flatter remarkably which is evidently disadvantageous compared with these three sites. Thus, no other damsites are considered conceivable from the topographical aspect, and the examination is made on the said three damsites.

8.2.3 Methodology of Examination

The effectiveness of the dams in the upstream reaches was examined as follows:

1) It was confirmed whether or not, the flood control and water supply targets of the basin can be fulfilled with the upstream dams.

2) In the case that the targets of the basin cannot be attained only with the upstream dams, combination with the Ta Trach Dam was considered to attain the targets, and contribution of the upstream dams on cost reduction of the Ta Trach Dam was examined.

3) Cost comparison between the Ta Trach Dam only and combination of the Ta Trach Dam and upstream dams was conducted to verify effectiveness of upstream dams.

8.2.4 Flood Control with Upstream Dams

Flood control volume necessary for control of the objective flood is found to be 392.6 MCM as examined in the planning of Ta Trach Dam of which damsite has a catchment area of 717 km^2.

The catchment areas of upstream damsites are measured, respectively as follows:

Damsite T-1 : 76.8 km^2

Damsite T-2 : 114.6 km^2

Damsite T-3 : 166.1 km^2

Assuming that the flood runoff is proportional to the catchment area, flood volume of the objective flood at each upstream dam is calculated as follows:

Damsite T-1	:	392.6× 76.8 / 717	=	42.1	MCM
Damsite T-2	:	392.6×114.6 / 717	=	62.8	MCM
Damsite T-3	:	392.6×166.1 / 717	=	90.9	MCM
Total				195.7	MCM

Thus, three upstream dams of T-1, T-2 and T-3 are provided with the flood control volume of 42.05 MCM, 62.75 MCM and 90.90 MCM respectively to accommodate all objective flood at each damsite. As seen above, the flood control volume of three upstream dams will be 195.7 MCM in total against the necessary flood control volume of 392.6 MCM. The flood from the remaining catchment area of 395.5 km2 is forced to be controlled at the proposed Ta Trach damsite with the flood control volume of 196.9 MCM(392.6-195.7=196.9 MCM), since no other appropriate damsites for control of the flood from the catchment area of remaining 395.5 km^2 are found.

The flood control effect of the three upstream dams is as shown in Figure 8.11. As seen,the flood from the remaining catchment area of 395.5 km^2 will still have the flood peak discharge of 4,332 m^3/s and flood volume of 196.9 MCM at the Ta Trach damsite, although the peak discharge will be reduced from 8,070 m3/s to 4,332 m^3/s.

As discussed above, the flood control target of the basin will not be possible to be fulfilled without a dam at the proposed Ta Trach damsite.

8.2.5 Combination of Upstream Dams and Ta Trach Dam

Figure 8.12 indicates the storage capacity curve at each upstream damsite and dam size with which each dam should be provided for control of the objective flood. Figure 8.13 indicates dam volume curves of the three upstream dams and dam volume of each dam which will accommodate the flood volume of the objective flood at each damsite.

Principal features to show the size of each dam are summarized as follows:

Principal Features of Upstream Dams

Upstream Dams	Dead Storage Volume	Effective Storage		Flood Control Space		Dam		
		Volume	F.S.L	Volume	S.W.L	Height	Volume	Cost
	(MCM)	(MCM)	(El. m)	(MCM)	(El. m)	(m)	(10^3m^3)	(Mil. US.$)
T-1	7.7	37.3	102	42.1	105	60	2,870	31.6
T-2	11.5	55.5	141	62.8	144	61	2,700	29.7
T-3	16.7	83.3	134	90.9	137	55	1,950	21.5

Note: S.W.L: Surcharge Water Level F.S.L: Full Supply Level

As mentioned, the flood control target of the basin is not possible to be attained only with the upstream dams, requiring the combination with a dam at the proposed Ta Trach damsite to attain the target.

The development scale of the dam at the proposed Ta Trach damsite in combination with the upstream dams is shown in Figure 8.14. It should have the following development scale to attain both the flood control and water supply targets:

Principal Features of Dam at the Proposed Ta Trach Damsite

(in Combination with Upstream Dams)

Dead storage volume	:	72MCM×(717−357.5)km2/717km2	=	36.1	MCM
Flood control volume	:	392.6MCM−195.7MCM	=	196.9	MCM
Effective storage vol.	:	460MCM−176.1MCM	=	283.9	MCM
Dam crest level	:			E.L.45.5m	
S.W.L	:			E.L.42.5m	
F.S.L	:			E.L.39.5m	
Dam cost	:			82.5 Mil.US$	

8.2.6 Summary and Conclusion

(1) In order to confirm that the proposed Ta Trach damsite is most effective, effectiveness of upstream dams was examined.

(2) Topographically conceivable damsites for the upstream dams are three sites

of T-1, T-2 and T-3 as shown in Figure 8.10.

T-3 dam will seriously submerge the Bach Ma National Park, and its implementation will be accompanied with environmental issues. However, the study assumed the construction of T-1 dam.

(3) Planning of the three upstream dams were made so that each dam will have the flood control volume to accommodate the objective flood at respective damsite.

(4) The examination found that the upstream dams cannot achieve the flood control target of the basin without a dam at the proposed Ta Trach damsite due to the flood from the catchment basin which is not covered with the three upstream dams. The possible flood control effect with upstream dams will approximately be a half of that of the proposed Ta Trach Dam, while the cost of the three upstream dams amounts to about 80% of the cost of the proposed Ta Trach Dam.

(5) The cost of the Ta Trach dam to attain the flood control target of the basin with upstream dams will be lessened from 100.6 Mil.US$ to 82.5 Mil.US$. However, since the cost of upstream dams will amount to 82.72 Mil.US$, the combined total cost will result in 165.22 Mil.US$ which is much more expensive compared with the cost of 100.6 Mil.US$ in the plan of the Ta Trach Dam without upstream dams.

(6) As stated above, dams in upstream reaches of the Ta Trach river have been found much less effective.

(7) Besides that, adverse impacts on the natural environment due to upstream dams will become larger than those of the proposed Ta Trach Dam. Especially, the T-3 dam will largely submerge the Bach Ma National Park, and its implementation will encounter difficult environmental issues.

The area(about 18.3 km2) to be submerged by the upstream three dams will be larger than the area(about 11.5 km2) to be reduced by the smaller dam at the proposed Ta Trach damsite.

(8) The decrease of necessary resettlement by the smaller dam at the proposed Ta Trach damsite is estimated to be very small.

(9) Thus, the study confirmed that the dam planning of the Ta Trach river should be made at the proposed Ta Trach Damsite.

8.3 Water Resources Management Plan

8.3.1 Basic Concept of Water Resources Management Plan

The water resources management plan as a part of the integrated basin management plan of the Huong River basin is formulated on the basis of the following basic concept:

(a) Water resources management in the Huong River basin will be carried out by an unified river basin management organization (Board of Management) having been established that the Provincial Peoples Committee is in charge of the Board.

(b) Provincial government agencies and bodies presently related to the management of the Huong River basin will be the task force members of the organization as well as stakeholders of the basin water resources that will be the committee member.

(c) Main tasks of the organization will be enumerated as follows:

- Water use management,
- Flood control management, and
- River Environment management.

8.3.2 Water Use Management Plan

The water use management plan in the Huong River and Bo River basins is proposed that the priority activity is aiming at effective use of limited water resources taking priority of water use into account. For this purpose, the Water Use Management Committee will be established under the Board of Management.

(1) Proper Management of Water Demand

To make an updated estimate of water requirement every year at the beginning of dry season when water demand is to start increasing, the Board of Management/Committee will request the respective water users to submit expected monthly water requirement. The Board of Management/Committee will be authorized to coordinate each requirement when it is deemed necessary.

The Board of Management/Committee will have an authority to monitor the actual water intake amount by respective water users.

(2) Latest Information Management of Water Resources Including River Flow and Reservoirs' Storage

The Board of Management/Committee will monitor the current available water resources amount including river runoff and reservoir storage in future as well as actual water requirement. The Board of Management/Committee may allow providing additional water when actual river runoff is more than scheduled one and as far as increase of production be expected by such additional water allotment.

(3) Proper Water Allotment Under Severe Drought Condition

Not only at the beginning of high demand period, but also when drought situation is foreseen, which may be at the peak period of water demand, the Board of Management/Committee will coordinate all water users to cope with expected water deficit by adjusting water demands incorporating priority of water demands.

(4) Water Saving Measures

For the purpose of mitigation of water shortage, non-structural measures mentioned below will be useful and should be introduced positively:

1) Enhancement of public awareness for water saving,
2) Installation of water measuring devices for control of proper water intake/distribution,
3) Preparation of management rule and operation manual, establishment of organization, and education of management staff for control of proper water intake/distribution,
4) Water saving with measures such as decrease of water loss due to leakage, increase of return flow, arrangement for reuse of industrial water, and reduction of extra water use by installing faucet aerators, etc.

8.3.3 Flood Control Management Plan

(1) Non-structural Measures

The following non-structural flood control measures are considered appropriate for inclusion in the proposed flood control management plan for the Huong River Basin:

1) National & Provincial Disaster Warning Systems
2) Disaster Preparedness
3) Flood Inundation Mapping
4) Field Benchmark Network
5) Public Awareness Program
6) Reforestation

(2) National & Provincial Disaster Warning Systems

This component of the flood control plan considers the upgrading of the current national and provincial disaster warning systems, as it relates to the Huong River Basin. It is one of the non-structural disaster mitigation programs recommended for implementation by the Multi-donor Mission in 2000.

At the provincial level it is proposed to create a Disaster Mitigation Management Centre in Hue under the direct control of the already existing Provincial Flood and Storm Control (FSC) Committee. During the November 1999 floods local authorities had difficulties reacting to the floods. This was due mainly to the lack of information concerning the extent and severity of the floods; insufficient information concerning those areas most adversely effected by the floods and insufficient communication equipment to alert the districts and communes about the impending danger.

The proposed center would have the facilities to forecast and map areas at risk of natural disasters and issue radio-based warnings about the impending danger to government officials and the public, including farmers and fishermen. The center would contain a list of all water resources structures in Thua Thien-Hue Province at risk of failure or damage during flooding and proposed emergency response plans. In addition to these tasks the center would also be responsible to carry out the activities associated with the other non-structural measures proposed.

At the national level, the Law on Water Resources, ratified in January 1999 specifically designates the responsibility for the timely issuing of information relating to rain and floods to the Hydro-meteorological Service of Vietnam (HMS).

The lessons learnt from the 1999 flood indicated communication between the national HMS and regional and provincial centers including Thua Thien-Hue province was weak. The transmission of national-level satellite imagery to the provincial-level was too slow and unreliable to enable timely warnings given by the FSC to be effective. Most of the relevant data was received at the provincial level only after the disaster event had occurred.

To rectify this situation it is proposed under this present flood control plan to support the development and improvement of natural disaster hydro-meteorological forecasting and establish mechanisms to improve the exchange of information on impending dangers, between the national HMS and the newly created Disaster Mitigation Management Centre in Hue.

(3) Disaster Preparedness

This non-structural measure directly addresses the issues of disaster mitigation to those most vulnerable at the communal and village level.During natural disasters including floods and typhoons, the majority of life saving activities occurs at the village level. It is during the first critical hours when disaster strikes that these communities are virtually cut-off from the rest of the world and are left to their own devices. This lack of communication between the village and province results in the province receiving inadequate and unreliable information when it is most needed, making it difficult for additional resources for life saving and rescue operations to be allocated.

It is essential if loss of life and property is to be minimised the local community receives timely and realistic information and advice of impending natural disasters, to allow them to prepare for such events. It is clear the accuracy, timeliness and relevancy of the information received during the 1999 flood and the means by which this information and warning was passed onto the local community was inadequate.

It is envisaged the proposed measures, which will address these issues, will be carried out by the newly created Disaster Mitigation Management Centre in Hue and would include the following:

- To ensure the dissemination of accurate and timely information during natural disasters is made available at the grassroots level at all times.
- Establishment of a system to provide advanced warning to the local population at the grassroots level concerning the timing and nature of a disaster before it occurs, to allow preparation and appropriate action to be taken.
- To increase the number of safe havens in flood-prone areas by the construction of additional schools and clinics with two storeys in areas where they are still required.
- To increase the life saving capacity at the village level to save those unable to save themselves by the provision of training and rescue equipment including ropes, boats, life buoys, rafts and canoes.
- To facilitate local communities to request emergency assistance when their own life saving and rescue capacity is exceeded, by providing adequate and appropriate communication systems.

- To ensure the people living in villages and communes, being the most vulnerable population group, are included in the disaster mitigation process, by involving them through a participatory approach.

(4) Flood Inundation Mapping

Flood inundation maps provide an accurate record of past disasters and indicates those areas inundated by past floods. They reflect the location where people would be at risk of being inundated by future flooding, based on a series of predetermined levels of risk. They are one of the most effective tools available for flood mitigation decision making and public education. This fact was well recognised by the relevant authorities and as reported previously flood inundation maps to a scale of 1:10,000 have been prepared for the flood-affected areas downstream of the Huong River.

Under this present flood control plan it is proposed these maps be now upgraded and used as a basis for a more practical and detailed mapping exercise, as the current scale and presentation of maps is not appropriate for all parties involved in the process of flood mitigation. Final mapping would contain additional information relating to the strategic location of high storey shelter structures; areas of high elevation terrain where people would be safe during flooding; areas where not to build because of the dangers of being washed away; administrative boundaries for province, district and commune; location of stored emergency food supplies and rescue equipment; flood evacuation routes and location of dams and other hydraulic structures at risk due to flooding.

The final maps will be to a scale and in a format that presents the information in a way that is suitable for the purpose of flood mitigation and can be understood by all levels of disaster officials and decision makers, ranging from those in Central Government through to those living in the provinces, districts, communes and villages. The simplicity and practicality of the maps envisaged can best be illustrated by drawing an analogy to the schematic sketch found in most hotel rooms around the world, which indicates the fire escape route for that specific room. A similar sketch with corresponding instructions, indicating the community flood evacuation route, could possibly be made for each village located in flood-prone areas, giving clear and simple instructions on what to do and where to go during times of flooding. It could be foreseen the sketches being made available and displayed in a prominent position in each household in the village.

(5) Field Benchmark Network

As reported previously, following the floods of 1999 and as part of the program to produce flood inundation maps for Thua Thien-Hue province, a series of 20 primary and 18 secondary flood level warning monuments were installed in the flood-affected districts of the province.

Although these existing monuments served the purpose of providing a basis for the production of flood inundation maps, they failed in one of their major functions to assist in maintaining community preparedness for flood disasters. It is only the primary flood level warning monuments that are installed in public locations and with only 20 located in the flood-affected districts over the whole province, including Hue City, means that for many people they are not be visible and in turn not a daily reminder of the dangers of flooding.

To rectify the situation it is proposed, under this present flood control plan, to install a tertiary network consisting of substantially more flood level warning monuments, than what already exists in the primary and secondary networks. These tertiary monuments would be installed in highly visible public locations and to be effective will be considerably more in number than what already exists in the primary and secondary networks. The monuments would consist of simple concrete pillars and to be distinctive and visible, be brightly painted with previous flood levels clearly and simply marked in a manner for local people to understand. The installation of these monuments could also be coupled with an organised program to paint previous flood levels at highly visible locations on public buildings.

These permanent marks in public locations, both on buildings and in the form of monuments, showing previous flood levels, would be an effective way to raise people’s awareness about the dangers of flooding.

(6) Public Awareness Program

The original *Strategy and Action Plan for Mitigating Water Disasters in Vietnam* emphasised the need for a continual public relations campaign in order to heighten communal awareness of the hazards of water disasters. This fact is no less relevant today than it was in 1992 when it was originally proposed.

There is a need to keep reminding people, living in flood prone areas, of the dangers of floods and convincing them of the necessity to make preparations in case of emergency. Flood waters can be extremely dangerous. The force of only 15cm of swiftly moving water can knock people off their feet. The best protection during a flood is to leave the area and go to shelter on higher ground. Flash flood waters move at very fast speeds and can roll boulders over, tear out trees, destroy buildings and obliterate bridges. Walls of water can reach heights of up to 3 to 6 metres and generally are accompanied by a deadly cargo of debris. The best response to any sign of flash flooding is to move immediately and quickly to higher ground. These are all lessons learnt by others who have experienced the dangers of floods. Local people, particularly those living in flood-prone area should be made aware of these inherent dangers and efforts directed to overcoming their inert complacency.

It is proposed, under this current flood control plan, to directly address these issues by implementing a public awareness program. The program would be administered by the newly created Disaster Mitigation Management Centre in Hue, have as its main objective the maintenance of communal preparedness for floods disasters and include the following components:

- Permanent marks in public locations showing previous flood levels. This component would be covered by the field benchmark networks discussed in the previous section.
- Conduct a program of training and education for both primary and secondary schools including the supply of basic information concerning storms and floods to be added to the school curricula.
- Print and distribute information pamphlets addressed specifically to the general public living in flood-prone areas on what to do during the different phases of a flood, including the periods of the initial flood warning, the actual flood, evacuation and after the flood waters begin to recede. Some examples of items to be addressed would include learning what specific flood warning signs and community alert signals are relevant; plan and practice individual evacuation routes as part of the community flood evacuation plan; determine safest routes to shelters; what disaster supplies to have on hand; development of an emergency communication plan and ensure all family members know how to respond to flood warnings etc.
- Training Provincial Flood and Storm Control (FSC) operatives how to effectively run the Public Awareness Program and training these operatives in general public relations related to flood disaster mitigation.
- Regular local public FSC displays indicating the dangers of floods, flood disaster mitigation and photographs of previous floods.
- To use some of the lessons learnt from the public awareness program used so successfully in the implementation of the forest fire mitigation plan in

Phu Loc district as discussed previously.

(7) Reforestation

Forestation is said the one of the measures to control runoff. Generally forest has the following functions related disaster mitigation:

- to conserve the water
- to reduce soil yield by leaf or branch protecting from the impact of raindrop
- to prevent collapsing the slope of mountain by root expanding on the earth

In Hue province, forest area is increasing for these 9 years from 1991 to 1999 on the static data 2000. But forest density is changing from rich forest to medium or poor forest. So changes of forest were examined by using land use map or satellite image of current and past. As the result it was found that headwaters of Ta Trach river are developing during 12 years from 1989 to 2001.

In Vietnam some forest project which are Program 661, Program327 and foreign cooperation are executed before. Reforestation area is now on planning with referring to those experience within the Ta Trach river basin. Detailed reforest area is not fixed yet, but basically shrub land change to forest on land use map. Mainly protection forest to conserve the water for Ta Trach dam are planning. Connecting the forest with Bach Ma national park also contribute to environmental preservation as Bach Ma-Hai Green Corridor.

8.3.4 River Environment Management Plan

The river environment management plan is proposed to compose two issues on the river maintenance flow and the water quality control. It is recommended that the River Environment Management Committee will be established under the Board of Management to cope with the said issues.

(1) Management of the River Maintenance Flow:

It is recommended that the river environment management committee will collaborate with the proposed water use management committee to attain proper water distribution between the respective water demands and requirement of the river maintenance flow through well coordination with the related stakeholders.

(2) Water Quality Control

In order to cope with river water deterioration due to waste water discharge from domestic and industrial uses according to increasing water demand, the river water quality is to be maintained and/or improved by waste water control. It is recommended to establish regular monitoring activities of river water quality as well as proposed reservoirs including Ta Trach Dam and Thao Long Barrage.

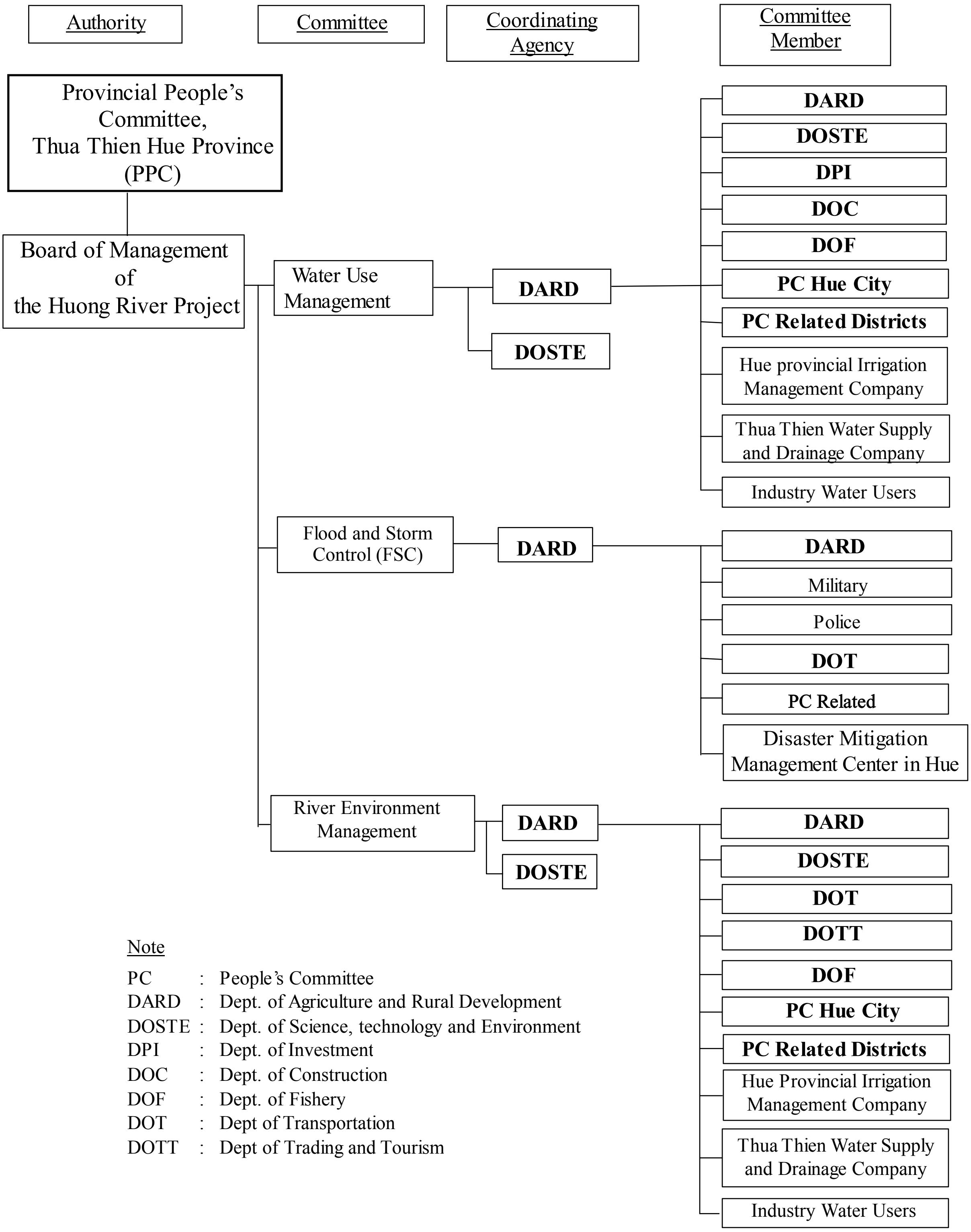
(3) Environmental Monitoring

As discussed in Sub-section 7.4.2, the existing environment and its change is to be monitored properly before and after the project implementation in order to manage both natural and social environment and to keep them in favourable condition.

8.3.5 Administrative Management Plan

To accomplish the proposed river basin management plan, the Board of Management of the Huong River Project with the water use management committee, flood control and warning committee and river environmental management committee is extended to be established as a river basin organization (RBO). Involvement of this organization will be local government agencies as task force member and related organizations as committee member. A proposed organization of the Board of Management is proposed and organization chart is presented below:

Proposed Organization of Huong River Basin Management



Note

PC : People's Committee
DARD : Dept. of Agriculture and Rural Development
DOSTE : Dept. of Science, technology and Environment
DPI : Dept. of Investment
DOC : Dept. of Construction
DOF : Dept. of Fishery
DOT : Dept of Transportation
DOTT : Dept of Trading and Tourism

8.4 Domestic and Industrial Water Supply Plan

8.4.1 Domestic Water Supply

The Thua Thien Water Supply and Drainage Company is responsible for all urban domestic water supplies in the Thua Thien province, which approximately coincides with the Huong River basin. The main urban centre is Hue town, but smaller centres like Phong Dien, Tu Ha, Phu Bai, Nam Dong and A Luoi also fall under the responsibility of the water supply company.

As far as Hue is concerned, it is one of the few towns in Vietnam having nearly 100% service coverage and with more than sufficient water production capacity. The total water production capacity for Hue town is more than 90,000 m^3/day, while the actual production is only 42,500 m^3/day. However, the old Quang Te-1 plant dates from the year 1926 and needs to be decommissioned some time in the future. Recently, a brand new treatment plant at Quang Te came on line, backing up this old plant, which produces under its original capacity of 40,000 m^3/day. The third plant in town is called Da Vien plant, which is located near the railway bridge. The intake of Da Vien is right next to the bridge and suffers from salt intrusion during the dry season. The old and new plant at Quang Te do not have this problem because its raw water is transported from a different intake site 8 km further up stream. The near to 100% service coverage in Hue is achieved with approximately 31,000 house connections. Most of these cover at least two separate households.

Smaller treatment plants for other urban centres in Phu Bai and A Luoi are presently under construction. The plan is to link the production capacity in Phu Bai to the Hue water system and in A Luoi a new independent system will be developed for the urban settlement there. Service coverage is much lower in these places.

The present situation can be summarised as follows:

Production Facility	Year	Capacity (m^3/day)	Actual Production (m^3/day)	Supply to	Remarks
Quang Te-1 (old)	1926	40,000	20,000	Hue City	To be decommissioned
Quang Te-2 (new)	1997	20,000	15,000	Hue City	Phase 1 project
Quang Te-2 (ph-2)	-	20,000	-	Hue City	Phase 2, planned
Da Vien	1952	12,000	10,000	Hue City	Salt intrusion problem
Tu ha	1968	4,000	350	Tu Ha & Hue	
Chan May dong	(2000)	6,000	300	Phuoc Hai	
Nam Dong	(2000)	1,000	300	Nam Dong	Under construction
A Luoi	-	4,000		A Luoi	Under construction
Phu Bai	-	5,000		Phu Bai, Hue	Under construction
Phong Dien	-	6,000		Phong Dien	planned

The future development plan for Hue and surrounding urban centres will have to focus on keeping up with the population growth in Hue and reaching full service coverage in the smaller towns. Apart from the present projects in Phu Bai and A Luoi, the future investments will probably concentrate on the following required facilities:

- Construction of Phase 2 of Quang Te 2, i.e. additional 20,000 m3/day treatment capacity
- Additional pipelines to connect new development areas in Hue, 50 to 100 km of primary and secondary pipelines
- Approximately 45,000 house connection to cover the population growth until 2020 and maintain full coverage
- Various projects in smaller urban centres in the province, such as Phong Dien and Nam Dong

8.4.2 Industrial Water Supply

The industrial activity in Thua Thien Province is very limited. Presently, the main industrial water users are a Beer factory, cement industry, glass and garment factories. The largest user by far is the Beer factory, producing 33 million litres per year, which amounts to a water demand of approximately 4,500 m^3/day.

Although the government's policy strongly supports industrial development, the future plans do not foresee any new large-scale industries for Thua Thien province. It can therefore be concluded that any industrial activity will receive its water from the Hue urban water supply scheme in limited quantities.

8.4.3 Investment Costs

The approximate investment costs of the works identified above can be estimated as follows:

- Construction of Phase 2 of Quang Te 2: US$.10 - 15 Million
- Additional pipelines, (50 – 100 km), @ US$.60 /metre: US$.3 - 6 Million
- 45,000 house connections, @ US$.150 /connection: US$.6.5 Million
- Booster stations and ancillaries: US$.1 - 2 Million
- Other projects: US$.10 Million

Depending on priorities and urgency of facilities, the investment costs required in the water supply sector of Thua Thien Province may vary from 30 to 40 Million US dollars over the next 20 years. It should be noted that these figures do not cover maintenance costs, rehabilitation works or replacement of old equipment at existing facilities.

8.5 Agricultural Water Supply Plan

Irrigation water supply plan is formulated based on the agricultural development plan, which determines the cropped area and seasons of future irrigation, as described below:

8.5.1 Agricultural Development Plan

In the Thua Thien Hue Province, agriculture sector has been producing 24% of total GRD, and directly sustains agricultural population corresponding to 50% of total population and indirectly rural population accounting for 70% of total population. The agriculture is the main stay of rural population.

The Huong River Basin extends over 65% of land area of the Thua Thien Hue Province. Out of total agriculture land in the province, 43,000 ha (70% of agriculture land) is located in the river basin, comprising 26,000 ha of paddy field, 13,500 ha of upland crop field and 3,500 ha of perennial crop land. Irrigated land is 25,300 ha, of which 18,000 ha is paddy field and 7,900 ha upland crop field.

(1) Agricultural Development Policy and Target

According to the agriculture development policy and strategy of the government, the direction given to the North Central Coast Region is i) acceleration of commodity-based production, ii) expansion of livestock and agro-processing, iii) improvement of rural living standard through increase of farmers' income and enhancement of rural services.

Along with this direction, the agricultural policy of the province put their emphasis on i) food security and poverty alleviation, ii) enhancement of living standard through income generation, iii) increase of export earning, and iv) expansion of vegetation cover on slopes for environmental conservation. The target in 2010 and its approach for development is presented in Table 8.2 and summarized below:

Agricultural Development in Thua Thien Hue Province

Sector & Focus	Target and Approach
Annual Crop (food security, export, domestic consumption)	Food crop: annual production of 25,000 ton equivalent to 200 kg per capita, other annual crops: expansion of groundnuts and tobacco, vegetables and beans. Development of infrastructure (irrigation and drainage, protection from flood, etc), improvement of farming practice, rural community development.
Perennial Crop (export, domestic consumption, environment)	Rubber: annual production of 3,300 ton from cropped area of 5,500 ha of plantation, horticulture: 5,000 ha of fruit plantation. Conversion of low productive land, development of infrastructure for production and marketing.
Livestock (domestic consumption)	Increase of raising and rearing of pig, cattle, buffalo, poultry.
Forest (environment)	190,000 ha of natural forest and 115,000 ha of forest plantation. Promotion of natural re-generation and plantation, development of infrastructure for production and forest community.
Fishery (export, domestic consumption)	Annual production of 17,600 ton by marine catch and 4,800 ton by aqua culture. Development of infrastructure for production and rural community for fishermen's households.

Source: 2010 target stated in "Agriculture of Vietnam, 61 Provinces and Cities, National Institute of Agriculture Planning and Projection, 2001" with modification by the JICA Study Team.

(2) Agricultural Development Situation

Based on the above target and approach, the agriculture development projects in the Huong River Basin are listed in terms of water resources development and management through review of existing data and information, and shown in Table 8.3 as summarized below:

Water Resource Related Agricultural Development Project

	Project	Description
1.	Projects related to Ta Trach Reservoir	
1.1	Protection of flood, irrigation rehabilitation and drainage Improvement related to Ta Trach Reservoir	40,000 ha in gross and 25,900 ha in net for paddy field and upland crops. Increasing cropping intensity from 178% to 200% for paddy and upland crops.
1.2	Thao Long Barrage (on going)	Prevention of salt water intrusion in the Huong and Bo Rivers and store fresh water in the river channel.
1.3	Settlement of households from the proposed Ta Trach Reservoir	Industrial crops as sugarcane, pineapple, coffee and rubber along with food crops. Rural infrastructure and agro-processing facilities.
1.4	Watershed conservation in the upper reaches and tributaries of Huong River Basin	45,000 ha for natural re-generation and 70,000 ha of forest plantation with forest community development.
2.	Truoi Reservoir (on going)	8,000 ha of irrigation from the Truoi River, supplemental irrigation water supply to the area irrigated by the Huong River
3.	Co Bi Irrigation Project	Irrigation development using water from the Bo River.
4.	Small scale irrigation development	Irrigation development in small spots sporadically located in the river basin.
5.	Inland Fishery in Reservoir	Fish catch in the reservoir through release of fish fries and nurseries without heavy input, in order to increase of income for local population of surrounding area.
6.	Aqua Culture of Shrimp and Fish	Aqua culture development in the coastal area through conversion of low productive agricultural land, in order to increase productivity as well as to conserve lagoon and aqua environment in the brackish zone.

Source: Information from the relevant agencies with modification by the JICA Study Team.

The present status of the above projects is examined regarding (i) relation with other projects, particularly the flood control, (ii) maturity of project, (iii) progress of relevant projects and agency, and summarized below:

Present Status of Projects

Project Group	Relation with Flood Control	Maturity of Project	Progress of Relevant Projects
1. Projects related to Ta Trach Reservoir			
1.1 Irrigation Rehabilitation and Drainage Improvement	To be protected by flood control	F/S completed	Thao Long Barrage under construction for salt water control
1.2 Thao Long Barrage	-	Under construction	-
1.3 Settlement from the Proposed Reservoir	Essential for reservoir	Consideration by province	Sugarcane mill under operation
1.4 Watershed Management and Forest Community Development	-	-	Regular work by province
2. Truoi Reservoir	-	Under construction	-
3. Co Bi Irrigation Project	-	Preliminary Plan	-
4. Small Scale Irrigation Development	-	Plan to be prepared	-
5. Fishery Development in the Existing Reservoirs	-	Plan to be prepared	-
6. Shrimp and Fish Culture Development in Brackish Water Zone	-	Plan to be prepared	-

Small scale irrigation development and fishery developments as well as Co Bi Irrigation Project are not matured for implementation, and require further study. Truoi Reservoir Project is under implementation and will be completed in 2002.

The primary objective of water resources development and management in the Huong River basin is to reduce the flood damage of the Hue City and surrounded populated area. In this regard, the Ta Trach Reservoir is selected in the flood control plan including protection of the existing agricultural land surrounding the Hue City. Such projects as Thao Long Barrage and Truoi Reservoir, supporting the agriculture development in this area, have been implemented and under construction.

Taking this situation into account, the first priority for agricultural development in the Huong River basin is given to the irrigation rehabilitation and drainage improvement of 25,900 ha surrounding the Hue City.

(3) Agricultural Development Plan

Irrigation rehabilitation and drainage improvement will provide i) irrigation water supply, ii) drainage improvement, iii) mitigation of the early flood during May to June, iv) prevention of salt water intrusion into irrigation water, v) protection from tidal wave during storm. Assuming these conditions, the future agricultural development plan is formulated as below:

a) Change in land use

The present irrigation condition of 25,900 ha of agriculture land will change in the following manner after completion of the project:

Change in Land Use

Land Use	Condition	Present	Future	Balance
Paddy Field	Irrigated	18,022 ha	19,912 ha	+1,890 ha
Upland Crop Filed	Irrigated	0 ha	5,988 ha	+5,988 ha
Upland Crop Filed	Rain-fed	7,878 ha	0 ha	-7,878 ha
Total		**25,900 ha**	**25,900 ha**	**0 ha**

b) Future cropping area and unit yield

Under the future condition, paddy field will increase by 1,890 ha and all the cultivated land will be irrigated. All the cropped land can be fully cultivated in both cropping season of winter – spring and summer – autumn. Accordingly, cropping intensity will increase to 200% from the present 171%. Cropped area of each crop is shown below:

Future Cropping Area of Each Crop

Crop	Season	Present	Future	Balance
Paddy	Winter – Spring	18,022 ha	19,912 ha	+1,890 ha
Paddy	Summer – Autumn	15,197 ha	19,912 ha	+4,715 ha
Sub-Total	5,622 ha	33,219ha	39,824 ha	+6,605 ha
Subsidiary Crop	-	6,655 ha	7,976 ha	1,321 ha
(Maize)	Winter – Spring	(79 ha)	(460ha)	(381 ha)
(Maize)	Summer – Autumn	(78 ha)	(460ha)	(382 ha)
(Sweet Potatoes)	Winter – Spring	(4,838 ha)	(3,456 ha)	(-1,382 ha)
(Groundnuts)	Winter – Spring	(705 ha)	(72 ha)	(-633 ha)
(Groundnuts)	Summer – Autumn	(955 ha)	(3,528 ha)	(2,606 ha)
Vegetables	Winter – Spring	2,256 ha	2,000 ha	-256 ha
Vegetables	Summer – Autumn	2,256 ha	2,000 ha	-256 ha
Total	25,900 ha	44,386 ha	51,800 ha	7,414 ha
	Cropping Intensity	171%	200%	+29%

Source: Interim Report of Feasibility Study, December 1999.

Crop yield will increase from the present level, resulted from i) staple irrigation water supply in the draft season, ii) drainage of excess water, iii) protection of early flood and tidal wave, and iv) avoidance of salt water contamination to irrigation water in dry season. Anticipated unit yield of each crop is given below:

Anticipated Unit Yield of Each Crop

Crop	Present	Future	Increment
Winter – Spring Paddy	2.8 ton/ha	5.0 ton/ha	2.2 ton/ha
Summer – Autumn Paddy	3.0 ton/ha	5.0 ton/ha	2.0 ton/ha
Maize	1.2 ton/ha	4.0 ton/ha	2.8 ton/ha
Sweet Potatoes	4.8 ton/ha	7.0 ton/ha	2.2 ton/ha
Groundnuts	1.2 ton/ha	1.5 ton/ha	0.3 ton/ha
Vegetables	6.0 ton/ha	10.0 ton/ha	4.0 ton/ha

Source: Interim Report of Feasibility Study, December 1999.

c) Future Agricultural Production

Based on cropped area and anticipated unit yield of each crop, agricultural production is estimated at about 200,000 ton of paddy, 3,700 ton of maize, 24,000 ton of sweet potatoes, 5,400 ton of groundnuts and 40,000 ton of vegetables, as shown below:

Production in the Project Area

Crop	Win – Spr	Sum – Aut	Total	Unit Yield	Production
Win – Spr Paddy	19,922 ha	-	19,022 ha	5.0 ton/ha	99,610 ton
Sum – Aut Paddy	-	19,922 ha	19,022 ha	5.0 ton/ha	99,610 ton
Sub-Total	19,922 ha	19,922 ha	39,844 ha		199,220 ton
Subsidiary Crop	3,988 ha	3,988 ha	6,655 ha		33,272 ton
(Maize)	(460ha)	(460 ha)	(920 ha)	4.0 ton/ha	3,680 ton
(Sweet Potatoes)	(3,456 ha)	(0 ha)	(3,456 ha)	7.0 ton/ha	24,192 ton
(Groundnuts)	(72 ha)	(3,528 ha)	(3,600 ha)	1.5 ton/ha	5,400 ton
Vegetables	2,000 ha	2,000 ha	4,000 ha	10.0 ton/ha	40,000 ton
Total	25,900 ha	18,486 ha	44,386 ha	-	272,492 ton

Source: Interim Report of Feasibility Study, December 1999.

8.5.2 Irrigation Water Supply and Drainage Plan

The irrigation water supply plan contains three related items that for a proper functioning of the scheme cannot be separated, i.e. irrigation, drainage and inundation protection. Better drainage facilities will decrease flooding in depth and duration. Better flood protection will reduce the required drainage capacity.

(1) Irrigation System

The present layout of the main irrigation system with canals, drains, intakes, outlets and pumping stations is shown in Figure 8.15, and schematic in Figure 8.16. It should basically remain unchanged in future. The Huong, Bo and Truoi Rivers will be the main sources of irrigation water. Main irrigation canals will also function as drains and pumping stations will serve secondary units. And the present intake and outlet locations seem all right and sufficient, but capacity of some outlets is insufficient.

For Huong North, the Bo River and its branches are the 'main canals' from where water is pumped into secondary canals, feeding more or less independent areas: 26 areas between 50 and 600 ha, 4 areas between 750 and 950 ha and 1 of 1,400 ha. Part of Huong North receives its irrigation water from the Huong River via Nham Bieu Intake. The area has, besides the Bo River itself, three main drainage outlets: Ha Do, An Xuan and Quan Cua.

For Huong South, irrigation water from the Huong and Truoi Rivers is conveyed through former river branches to 22 areas between 50 and 600 ha, 3 areas between 750 and 900 ha, 1 of 1,470 and 1 of 2,100 ha. There is a small upstream area with direct pumping from the Huong River. But the whole north and central part of Huong South receives its irrigation water via Phu Cam Intake, supported by the intake in La Y Spillway (when salinity low). The southern part receives its irrigation water from the Nong River (supplied from Truoi Reservoir).

In future agricultural and other developments will continue and when higher value crops are planted at bigger scale (usually in certain most suitable areas) better control of water levels with short variation between maximum and minimum will be needed. Then more strict, possibly automatic, operation of gates and pumps will be required. Even further increase of discharge capacity may be needed. At present too little is known to justify adjustments of (parts of) the irrigation system.

Nevertheless the present irrigation and drainage system needs rehabilitation and modernization to:

- Guarantee sufficient irrigation water in 3 out of 4 years
- Sufficient drainage capacity for excess rainfall and overland flow
- Prevent saltwater intrusion
- Protect against early flooding during the cropping seasons

But it should permit:

- Major flooding outside the cropping seasons.

Improvements are required on inundation protection and drainage, old civil works have to be rehabilitated and delayed maintenance has to be carried out. There are main works under construction (with planned year of completion): Truoi Dam (2002), Thao Long Barrage (2004), Phu Bai Dam (rehabilitation 2002), and planned: Ta Trach Dam, Cong Quan Outlet (additional), Khe Nuoc Dam. Recommendations on rehabilitation, etc. are described in Section 9.4.

(2) Irrigation Water Requirements

The efficiency of the use of irrigation water in an irrigation scheme is an important, but difficult to measure, parameter. The efficiency (for paddy) relates to losses from primary secondary and tertiary canals through seepage, evaporation, illegal off-takes, etc. and operational wastage (including over-application) of water.

For Huong River Irrigation Scheme the losses in the system are:

- In rivers and their branches are losses not applicable
- Primary canals/drains: negligible seepage and illegal off-take, evaporation losses and losses of unused irrigation water through outlets (due to the size of the scheme it is difficult to supply exactly the demand quantity of water at the intakes). Rivers and main irrigation canals also function as drains.
- Pumping stations: losses as result of inefficient pumping increase required power, but they are no efficiency losses of the irrigation system.
- Part of the irrigation water will flow back as drainage water into the main canal system.

Part of the losses in the secondary system will flow back into the primary canals/drains and can be re-used of water. This does not affect the efficiency since it is assumed that the losses are discharges through the outlets, caused by difficult adjustments to the supply to the system.

The following efficiency schedule is used:

Efficiency	0.95	0.90	0.90	0.90
river; intake; start main canal	pumping station; start sec. canal	end sec. canal; start tert. canal	end tert. canal; start field canal	end field canal; field; crop
1.48 l/s/ha	1.41 l/s/ha	1.27 l/s/ha	1.15 l/s/ha	1.04 l/s/ha

There are 79 major pumping stations, with their locations indicated in Figures 8.15 and 8.16:

Pumping station		Huong North	Huong South	Total
irrigation only	(IP)	31	22	53
irrigation and drainage	(IDP)	0	5	5
drainage only	(DP)	7	14	21

The names and command areas of the above pumping stations have been summarized in Table 8.4. With peak water demand at the fields of 1.04 l/s/ha the peak water supply at the pumping stations should be 1.41 l/s/ha for command areas smaller than 600 ha and 1.48 l/s/ha for command areas bigger than 600 ha and for the main intakes. For areas smaller than 600 ha the canal downstream of a pumping station is considered a secondary, for areas bigger than 600 ha a primary canal.

The general water demand for Huong North and Huong South is shown in Table 8.5, with details for different sub-areas, under command of the pumping stations in Table 8.6.

Huong North is for irrigation water dependent of the discharge of the Bo River, backwater of Huong River and Nham Bieu Intake on Huong River. Most of the irrigated area of Huong North, about 10,900 ha, is pumped directly from the Bo River and its branches. The remaining about 1,700 ha receives its irrigation water via Nham Bieu Intake. For details see Table 8.6. This corresponds with a peak supply, based on the maximum irrigation water demand, of:

Intake	Command area (ha)	Peak supply (m^3/s)
Bo River (pump)	10,883	1.56
Nham Bieu	1,676	2.42
Total Huong North	12,559	18.03

Huong South depends on Phu Cam Intake, with some support of La Y, both on Huong River. From (April/May) 2002 downstream parts will be irrigated from Truoi Reservoir. Irrigated areas will then be 168 ha (upland) plus 8,460 ha (Phu Cam) and 4,713 ha (Truoi). The contribution via La Y is uncertain (salinity) until Thao Long Barrage is completed. Thereafter it may supply 1,307 ha in the north-eastern part, reducing the supply via Phu Cam Intake to 7,153 ha. For details of calculation process of the peak supply, see Table 8.6.

This corresponds with a peak supply, based on the maximum irrigation water demand, of:

Intake	Command area (ha)	Peak supply (m^3/s)
Huong River (pump)	168	0.24
Phu Cam	8,460 - 7,153	12.24 – 10.35
La Y	0 - 1,307	0 - 1.84
Truoi	4,713	6.81
Total Huong South	13,341	19.23

The contribution of Phu Bai, Chau Son and other smaller reservoirs has not been taken into account.

The present capacity of the intakes at low river levels, coinciding with unsuitable (saline) water quality does not require measures. Thao Long Barrage will be completed soon solving problems caused by salinity and low natural river water levels.

The command areas of the different secondary units of the rivers, main intakes and outlets have been indicated on the schematic layout of Figure 8.16.

<u>Intake capacities</u>

The low water levels and design water levels in the main canal/drain system are unknown so the actual capacity of the intakes cannot be checked. After completion of Thao long barrage the minimum water levels in Huong and Bo River will be at least 0.50 m^+.

- Nham Bieu Intake will, with the supported pump facility, have sufficient capacity. This will further increase by Thao Long Barrage.

- Phu Cam Intake will have sufficient capacity. Thao Long Barrage will keep the intake levels above 0.50 m^+, and the intake of La Y Spillway and outlet of Truoi Reservoir will reduce the required capacity.
- The intake of La Y Spillway will mainly support Phu Cam Intake by taking over part of the inflow. It is not relevant to consider the sufficiency of its capacity.

(3) Improvement of Water Management Level

In order to improve the water management level, not only improvement of the facilities but also improvement of the operation skill should be achieved. Necessary projects so as to realize the improved water management skill of the year 2020 are considered as follows:

(a) Formulation of agricultural water use policy within the framework of water resources policy including all the other water-related sectors such as domestic water, industrial water, hydropower generation water, river maintenance flow

As FAO Irrigation and Drainage Paper No.52 “Performing Water Resources Policy - A guide to methods, processes and practices” presents the practical approach to the goal, it would be referred to as a guide in the course of the on-going water resources policy formulation in Vietnam.

(b) Capacity building and training, which are on-going in Vietnam, for (i) central, provincial and district governments’ water-related officials, (ii) irrigation management companies’ (IMCs’) staff, (iii) cooperatives’ water management staff and (iv) water users (farmers)

FAO Irrigation and Drainage Paper No.40 “Organization, Operation and Maintenance of Irrigation Schemes” would be used as a training material. No.40 presents also an important suggestion about the personnel training.

(c) Transfer of irrigation management services, which is on-going in Vietnam, from IMCs to cooperatives for efficient and effective operation and maintenance of irrigation schemes

FAO Irrigation and Drainage Paper No.58 “Transfer of irrigation management services - Guidelines” presents useful suggestions on all the steps from the mobilization to the implementation of the irrigation management transfer (IMT).

As projects related to the above are already on-going by the Provincial Government, the necessary measures to be taken from now on would be ones to improve the present methods so as to achieve the goal more efficiently and effectively in consideration of the Vietnam's or regional characteristics on the basis of the international standards mentioned above. To estimate the required period, staffing, and budget for the capacity building and training projects, the data of the on-going projects would be referred to. For example, according to the interview to the team leader of the AusAID Project made at the beginning of the Phase 1, the following were confirmed:

- Period : 32 months from October 2001
- Staffing : 3 foreign consultants with 124 M/M of local consultants

(4) Cropping during Early Flooding Time

The problems of early flooding in Huong North concerns mainly the areas adjacent to Bo and Huong rivers, near the lagoon, whereas in Huong South the whole south-eastern part, in particular the reclaimed lagoon lands, is affected.

These areas are, because of their low land levels, also longest and deepest inundated by the major floods. Major floods (if not too long and too deep) are widely accepted, whereas early floods, those cause most of the (agricultural) damage are not accepted.

a) Rainfall

Excess rainfall has to be discharged through an adequate drainage system. Part of the rainfall can temporary be stored in open water (canals, ponds), depressions, fallow land, fields, etc.

b) Lagoon water levels

High (tidal plus waves) lagoon water levels may hamper, or even prevent, drainage during some time. The tidal ranges in the dry season are in the order of 0.5 m, and in the rainy season, with high river discharges even less.

Of the lands in Huong North is 7.3% below 0.00 m^+ and 12.7% below 0.50 m^+ whereas in Huong South 40% is below 0.00 m^+ and almost 60% below 0.50 m^+. In comparison are 95% of the high tides above 0.69 m^+ and 5% below 0.13 m^+, whereas 95% of the low tides are above 0.46 m- and 5% above 0.00 m^+.

With so much low land near the lagoon it is obvious that gravity drainage is problematic.

(5) Drainage Capacity

Sufficient drainage capacity can be obtained by increase of drain cross sections (this also increases storage capacity), cleaning the drainage system and/or bigger pumping capacity.

Longitudinal and cross sections of the major drains could not be obtained from the authorities concerned, so the capacity of the drainage system could not be checked. Rainfall data are available, but no data on overflow from Huong or Bo rivers nor from inflow from the small rivers (with reservoirs with unknown flood regulating capacity). With the available data only a rough estimate of the required dimensions of drains and outlets could be made.

More drainage capacity results in quicker drainage with shorter inundation periods. The principle possibilities to cope with, or to reduce inundation periods and depths, are:

- Increased conveyance capacity of the drains (bigger/deeper cross section)
- Increased capacity of outlets (additional number and/or supporting pumps)
- Retarding areas
- Short-cut drain to the lagoon
- Polders

They can also be used in combination, as hereafter will be considered more detailed.

For Huong North the floods are (temporary) stored in the drainage system.

Possible increase of the capacities of the branches and their outlet structures is only required for their command area between Bo River and the lagoon. Only small areas could be found as suitable retention areas and compartments are no practical option, the area is already sufficiently divided by different branches. The required drainage flow can be handled by the existing (or enlarged) gravity outlets. It has to be investigated if future developments (agricultural and other) require enlargement or supporting pumping stations for emergency periods or better regulation of the canal/drain water levels.

For Huong South the situation is rather different. Rainfall and inflow from outside quickly rise the water levels in the main canals/drains till their banks overtop. An increase of gravity outlet, supported pumping, retention areas, compartmentalization, bypass of Nong River floods, or a combination of these measures is required.

(i) Increase capacity/ number of outlets and/or pumps

Cong Quan is the most important and effective outlet, because of its location at the end of the canal/drain that longitudinal crosses Huong South. There are also the lowest lands, to where the drain water flows. The drainage capacity of Cong Quan outlet should therefore be sufficient for design floods as will be considered in detail later in this chapter.

(ii) Retarding area

Storage of drainage (flood) water inside the area during periods that gravity discharge is hampered will reduce the pumping capacity. But storage of big water volumes means that retarding areas have to be found, i.e. areas that can be inundated. In fact extensive parts of the irrigation scheme are retarding areas during the major floods of the rainy season. But in the dry season retarding areas are to have to prevent early flooding damages in other areas.

For Huong South one apparently suitable area can be found. It is reclaimed land from the lagoon, i.e. about 400 ha northeast of Cong Quan Outlet. Because of this low land levels it is so long inundated, at the end of the rainy season and so early again at the start of the next wet season, that only one crop is possible. It could be used as retarding areas at the end of the main canal/drain, and store drainage water of upstream Huong South and Nong River.

(iii) Short-cut drain

Nong River flows directly into the south-eastern corner of Huong South irrigation scheme and it is the only small river without a dam. Its catchment is in the order of 80 km^2 against 60 km^2 of the other small rivers together. Its discharge flow into the main canal/drain and via Cong Quan Outlet into the lagoon. Heavy rainfall in the small, steep catchment will result in flash floods that directly discharge into the lowest part of the agricultural area, resulting in, or aggravating flooding.

A diversion of Nong early floods discharge directly to the lagoon will be relatively easy, because there already exists an outlet channel. The original distance to the lagoon was short (2-2.5 km), but since the construction of an embankment through the lagoon, reclaiming a corner of the lagoon for agriculture, the length is increased (4.5-5 km). The alignment passes uninhabited agricultural low lands.

However, such a diversion requires a number of works:

a) Re-alignment and reshaping of the existing channel

Where possible the alignment should be adjusted (shortened) to get the optimum way of discharge to the lagoon. The reshaping includes widening and deepening to the required design cross-section for design discharge.

b) Structure to prevent inflow of salt lagoon water and outflow of irrigation water

This structure should be an outlet similar to Cong Quan, allowing outflow to the lagoon and prevent return flow, and a lock provision to prevent unwanted outflow of (irrigation) water. The capacity should be sufficient to discharge design early floods. During the wet season (major) flooding is permitted. The structure should be close to the lagoon, so that fresh water in the upstream channel can be used for irrigation.

c) Structure to reduce drainage flow to the agricultural area

A structure in the branch that conveys irrigation water has to prevent that early floods discharge pass this branch. A structure with vertical lifting gates requires manual operation, but the gates can be put in different positions to manipulate the discharge.

d) Embankments along outlet branch

With the structure near the lagoon protective embankments have to prevent overflow of early flood discharge. Embankments at some distance from the channel need lower crest levels, and in combination with retarding area lower crest, erosion protected parts. The lagoon embankment has to be connected to the structure.

It is not obvious that a short-cut drain of Nong River, with its adjacent works is more feasible than an increase of the drainage outlet capacity, by additional gravity outlets or supporting pumping capacity. It has certain advantages to concentrate the discharge through one outlet (two structures) at Cong Quan.

(iv) Polders

Polders are 'isolated' areas with their own water level in the canals/ drains. In Huong River Irrigation Scheme the individual secondary units, under command of a pumping station, are already more or less polders.

In particular the SE-part of Huong South has low to very low land levels, even reclaimed lagoon. With open connections the 'higher' lands will drain via the 'lower lands'. The lower lands will be longer flooded and they have already problematic gravity discharge to the lagoon.

Here polders the situation could be improved. The main canal/ drain (Dai Giang River) from Phu Cam Intake to Cong Quan Outlet separates the higher lands on hilly sides from the lower lands on the sandy lands/ lagoon side.

Each should have its own design water level, decreasing from NW (upstream) to SE (downstream). Because the area is rather flat the differences in design levels will be small.

Areas with different land levels are separated by boundary canals/drains, and do not receive outside water and are when needed surrounded by embankments. A boundary canal/drain can have a higher water level and increase the possibility (duration) of gravity irrigation and drainage, reducing (supporting) pumping. Lower lands may have to be drained by pumping, but since there is no inflow from outside the water volume will be less.

The main canals/drains of the system will be boundary canals/drains. Embankments and control structures prevent drainage water to flow into a lower compartment. Also water from the hills and overflow of the small reservoirs will drain into the main canals/drains only. The compartments will receive irrigation water from the main canals/drains.

However, decrease of storage in lower areas will increase the storage on higher lands. For drainage the water level main canal/drain system should be low and for irrigation high. Since (early flooding) rainstorms occur in the irrigation period the operation schedule has to be sophisticated.

(6) Drainage Requirements

The drainage system has to have a capacity to discharge a design rainfall plus inflow from outside within a certain time. The capacity should be designed to:

- Prevent early flooding (dry, irrigation season)
- Timely discharge after major flooding (end of wet season)

The capacity can be reduced if (guaranteed) storage possibilities are available.

The permitted period for water on the fields depends on the type and stage of the crops.

Since early flooding occurs during the vulnerable periods of harvest and planting, the water should be drained off within three days (72 hrs).

(a) Rainfall and run-off

Design flood rainfalls of 150, 175 and 200 mm have been adopted for 1-day (24 hours), 2-days (24-48 hours) and 3-days (48-72 hours) respectively. Part of this rainfall will be intercepted or temporary stored (see Table 8.5). The remaining rainfall has to be drained: from agricultural lands 65% and from hilly uplands 60%. Sandy areas will have delayed runoff that does not contribute to the above design rainfall.

The delay in runoff from the hills will be short (only a few hours), because of the short distance and the steep slopes. Only the more than 2,000 ha Thuy Dong area, close to Hue is about 25 km from Cong Quan Outlet, so a delay of 0.5 day may be taken into account.

(b) Storage possibilities

During harvest no irrigation is required and the water levels in the canals/drains can be low, but (second) planting takes place in the same season and demands high water levels. During early floods high water levels prevent drainage to the rivers. The actual storage in the small reservoirs depends on recent rainfall. They may be empty after irrigation during a longer drought period, or full after recent rainfall.

Possible storage on fallow and/or low lands may also be small since in the harvest/planting period the land use will be maximum. Most rainfall on the sandy areas will infiltrate and flow with delay to the irrigated lands or the lagoon.

(c) Inflow from outside

Inflow from saline lagoon water will be prevented by embankments, except negligible overtopping by wave action. The inflow from early floods in Huong and Bo rivers (bank overtopping) is also negligible. Upstream the banks are high and downstream the roads parallel to the rivers serve as embankments. They may overtop during high floods, but these do not occur in the early flood season.

As a result the inflow from outside into Huong North is negligible. The relation with the sandy and marshy areas to the north (rainfall, groundwater flow, etc.) are unknown, but can be neglected for design drainage runoff.

The inflow from outside to Huong South will be the runoff from the hills through small rivers, of which Nong River is the biggest. In particular the low lands (reclaimed lagoon) will suffer. Because of the small, hilly catchments the runoff time is short.

Insufficient cross drainage capacity in the railway and highway may lower the peak and lengthen the time to discharge the runoff volume. When this results in flooding on the upstream side the capacity will in future be increased. Inflow from the sandy areas in the east is unknown, but contribution to the design runoff can be neglected.

(d) Outlet capacities

The quantities of drainage water, in volumes and in discharges, are found in Table 8.5. The 12,559 ha (Huong North) and 13,343 ha (Huong South) require drainage of 142 m^3/s and 296 m^3/s in 24 hours, or 63 m^3/s and 132 m^3/s in 72 hours. The drainage is divided over a number of outlets, of which Cong Quan is the most important (big drainage area, outside inflow and low lands). The figures in Table 8.7 show the required discharges capacities per main outlet, of which Cong Quan Outlet is by far the biggest.

From paddy cropping point of view the water should be discharged within 72 hours. This implies that the drainage capacity of Cong Quan Outlet has to be 105 m3/s of which Nhong River contributes 37 m^3/s.

Because no information is known on design water levels in the main canal/drain system the actual discharge capacity of the outlets cannot be checked. Besides a '72-hour' discharge to prevent early flooding the same outlet has to discharge the bigger major foods in a longer period, but timely for the start of the winter-spring planting.

A first impression of the required discharges shows:

i) Ha Do, An Xuan and Quan Cua have together sufficient capacity to drain that part of Huong North that is not drained via Bo River (see Figure 8.16). In practice, however, are An Xuan and Quan Cua just rehabilitated and appears that the discharge capacity of the present old Ha Do sluice is insufficient. Rough estimate show drainage requirements of 4, 9 and 5 m3/s for Ha Do, An Xuan and Quan Cua outlets, excluded possible discharges from Bo River.

ii) Two additional drain structures are recommended in the Bo River branches to the northeast (see Figure 8.16). They have to regulate the flow (water levels) to Huong North irrigation area between Bo River and the lagoon. Preventing the high water levels in the canals/drains, caused by early floods, the embankments can be lower, reducing construction and maintenance cost.

The gates of the structures can remain open most of the time of the year. Closure is only necessary during (flood) water levels in Bo River above a design level to prevent excessive inflow from Bo River during early floods and at the end of the major floods.

The capacity has to be sufficient for (future) irrigation supply, flushing, etc. and to discharge part of the Bo River floods, up to the capacity (say 10 m^3/s) of the canals/drains and the outlets. The relation and influence of the structures on the drainage of the areas and the capacity of the outlets should also be investigated. Undesired high water levels in the irrigation area (caused by rainstorms) should be drained via Bo River, when this river has lower water levels.

iii) Cau Long Outlet may have to drain more water as the roughly estimated 12 m3/s. In practice the discharge capacity appeared too small. The design of a new outlet should include a more detailed estimate the required capacity.

iv) Cong Quan Outlet has to drain by far the biggest area. The outlet has a width of 11x2.2+1x2.7=26.9 m and floor level 1.50 m^-. Assuming the upstream water level at 1.00 m^+ the wet area will be 67.25 m^2, so to discharge 105 m^3/s the velocity has to be 1.56 m/s. Actual discharge and velocity depend on the water levels in the approach canal and the tidal water levels in the lagoon. In practice the conditions are often less favourable and is the present capacity of Cong Quan insufficient. When design criteria become available the additional requirement can be determined.

8.6 Urban Drainage Plan

The urban drainage in Hue City would be planned so as to smoothly drain the inundation at depressions scattered in the city. The gravity drainage would be applied in consideration that the pump drainage would be ineffective without the dike system along the Hue River. Therefore, the drainage time of the inundation caused in the depressions would be limited to the time after the flood of the main drainage river courses such as the Hue and the Bo.

(1) Urban drainage system

The drainage system to be planned in the urban area would be the combination of street drain, the street inlet, and the underground storm drain to e connected to main drainage streams and rivers.

(2) Implementation method

The drainage system would be along the street network. Therefore, the urban drainage system project should be implemented at the same time as the urban street improvement project.

CHAPTER 9 BASIC DESIGN OF MAJOR FACILITIES

9.1 Multipurpose Dam and Appurtenant Facilities

9.1.1 Review on the Geology and Seismicity Studies Made in the Feasibility Study

A preliminary overview of geological conditions of the project area is made in the Study and thereby gives a geotechnical evaluation of the proposed dam project, on the basis of the existing geological investigation reports as well as reconnaissance and interpretation of topographic features.

Overview has been made for the following subjects of which some subjects (in italic characters) are available in detail in Appendix – E for Phase 2-1.

a) General geology oh the Huong river basin

b) Geology of Ta Trach reservoir area

c) Engineering geology

d) Geological evaluation at the planned project

e) Construction material

f) Seismicity

(1) Geological Evaluation at the Proposed Project

The proposed Ta Trach dam is designed as a multi-purposes dam. The outline of the dam proposed in the Feasibility Study is summarized as follows:

- Dam type: Mixed earth and rockfill dam
- Dam height: 55 m
- Dam crest elevation: 55 m
- Dam crest length: 1,112 m
- Full supply level: 45.0 m
- Spillway type: Overflow spillway with gate
- Spillway crest elevation: 35 m
- Spillway width: 60 m
- Length of Spillway slope: 123 m

(a) Selection of Dam Type

Earthfill dam has been proposed during the pre-feasibility study and the Feasibility Study stages of the project. The proposal is possible and appropriate technically and economically. In construction, however, the earthfill dam seems to be less reliable and less safe in handling floods during construction. Therefore, concrete facing rockfill dam (CFRD) and concrete gravity type dam, such as roller compacted concrete (RCC) dam are considered in the present study as alternative plan.

The bedrock of the damsite is classified into four weathering zones. Zones I to IV will be appropriate for the foundation of 50 to 60 m high RCC dam. The rock layer of Zone V is considered unsuitable for the RCC dam foundation because the zone V, which is formed by strongly weathered rocks, has insufficient shear strength.

Accordingly, in case of RCC dam, the excavation depth of the foundation will be about 35 m or more in depth up to zone IV for the RCC dam foundation.

In case of rockfill dam, the strongly weathered rock (zone V) can be used as a dam foundation. Excavation of the overlying river alluvium only will be thus necessary in general. Moreover, the river valley, U shape of about 1,000 m wide, sustains good efficiency for embankment work. A careful study on dam type in consideration of the merits and demerits of each dam type is considered necessary, although the Study has difficulty to examine and determine the dam type at this stage.

(b) Selection of Damsite

The damsite is selected mainly in consideration of the following conditions and factors:

- Two ranges of flat mountains and hills at an elevation of 80 to 500 m nearly parallel with the course of the Ta Trach river. At the proposed damsite these ranges lessen the river width to about 1,000 m, while the valley floor upstream widens as much as 3,000 m. Accordingly, the proposed damsite will result in the effective storage capacity of reservoir.
- Geology of the reservoir area is very similar, and therefore, the geological condition has little or no effect on the selection of damsite.
- The proposed damsite provides a great convenience of layout of appurtenant structures and an easy access for construction.

(c) Excavation Depth and Line

The alluvium in the riverbed generally ranges in thickness from 10.0 to 15.0 meters with the maximum of 20.0 m, while in both banks, it is 0.5 to 5.0 m thick.

The strongly weathered rock (zone V), estimated to have compressive strength of about 20,000 kN/m^2, will be appropriate as the foundation of the earthfill dam. Accordingly, the excavation depth of the dam foundation will be 0.5 to 5.0 m in depth from the ground surface at both abutments and 15.0 to 20.0 m from the riverbed at the river valley up to the top surface of zone V. In the upper part of the zone V, these rocks, which are completely weathered into gravelly or sandy soils, should be removed in the impervious core zone.

(d) Foundation Treatment

The rocks of the dam foundation are Paleozoic sandstone and shale, with granitic intrusions. Granitic rocks provide a better foundation than the shale, and the major portion of the dam is on the jointed shale, which has permeability of 1.08×10^{-4}cm/sec to 8.30×10^{-5} cm/sec. Therefore, curtain grouting below the impervious core of the earthfill dam is proposed to improve the permeability of the dam foundation. The depth of curtain grouting shall be determined according to dam height or passing time of waterhead.

Careful attention shall be paid to the distribution of the discontinuities between the metamorphic rocks and granitic rocks during construction; these discontinuities should be tightly backfilled with stone blocks and concrete.

Consequently, the following foundation treatment will be required for the purpose of reducing leakage through the foundation rocks and hardening the foundation rocks for the Ta Trach dam.

i) Curtain grouting

- Two rows at 1 m interval, hole spacing of 2 m on each row
- Hole arrangement to be made at zigzag
- 30 meters in depth for the section of dam height more than 30 meters, and 20 meters for the section of dam height of 10 to 30 meters.

ii) Consolidation grouting

The whole area of the foundation rock for the impervious core zone and the filter zone at about 5 m in depth.

iii) Concrete replacement, if necessary

Discontinuities or weak zones between metamorphic rocks and granitic rocks.

(e) Spillway

The proposed spillway is located at the saddle of the right bank ridge with crest elevation of EL.35.0 m, and will cater to the design flood of 11,400 m^3/sec flown into a reservoir.

According to the draft design, the moderately weathered rocks (zone IV) will be used for the spillway foundation. The rocks of zone IV, having compressive strength of 20,000 to 30,000 kN/m^2, are sufficient for the spillway foundation. However, the consolidation grouting should be carried out for the spillway foundation.

(f) Inlet Sluice and Diversion Structures

In the feasibility study, two inlet sluice structures (6×8 m in diameter) were proposed to discharge flood during construction and to supply water into hydropower plant after completion of the project. The proposal seems unsafe in view of the unusual flood and the construction plan.

Therefore, diversion tunnels in the left bank are proposed as an alternative diversion structure. Although further geological investigation is necessary, the preliminary investigation shows that the thin ridge of the left bank formed along monoclinal structure has benefit to the layout of the tunnels since that:

- The proposed tunnel axis intersects the rock strata with large angle, this provides a favourable situation for the stability of the tunnel;
- The rock strata at upstream portals dip into the mountain and the overlying loose deposits are very thin. The outlet portal slopes of the tunnels are thus stable during excavation.

However, because of the monoclinic structure to catch water, during the tunnel excavation seepage from jointed shale layers may be encountered especially at their contact with underlying sandstone layers. Dewatering measures are needed.

(g) Others

i) Water leakage due to fracture zones

Three faults (F1, F2, and F3) run across the reservoir area with fracture zone, of 20 to 50 thick. Field reconnaissance shows that these fracture zones are tightly filled with impervious materials. The possibility of water leakage to the adjacent catchment through these fracture zones is considered very low or less even if the reservoir is impounded. However, geological investigation or insitu tests related to the permeability and continuity of these fracture zones should be carried out at the detailed design stage.

ii) Dam foundation (Left abutment)

The left abutment will be placed on the steep opposite-dip slope covered by alluvial deposit of 2 to 5 meters thick. Although no rock outcrop is found to observe the stability and joint condition of rock slope, small unstable rock mass due to creep may be usually confronted. Unstable rocks shall all be removed from the dam foundation.

(2) Construction Material

The Ta Trach dam is planned as an earthfill dam in the feasibility study, and the construction materials required for the project are given in the table below:

Required quantity of main construction materials (m^3)

Item	Earthfill dam	Spillway	Auxiliary dam	others	Total
1. Earth material	9,417,820	349,000	1,037,030	571,380	11,375,230
2. Sand and gravel filter	242,440	1,250	17,910	1,050	262,650
3. Riprap	219,500		38,210	420	258,130

According to this requirement, several quarry sites and borrow areas have been initially investigated within the range of 5 km upstream the damsite. The quantities and engineering properties of various kinds of natural construction materials investigated is outlined herein.

(a) Earth Material

Boring investigation and laboratory tests show that two types of earth materials can be used as earth material for the dam embankment, namely, river terraces alluvial (2b) and (3b). The two layers are both distributed mostly within 0.5 km to 3 km from the damsite. The reserves of the layers 2b and 3b are estimated to be $7{,}247 \times 10^6$ m^3 and $9{,}347 \times 10^6$ m^3, respectively. Table 9.1 summarizes the laboratory test results of the materials from the two layers.

As shown in Table 9.1, the materials of layer 2b can be classified as Silty CLAY (CM) by the Unified Soil Classification System of ASTM. The permeability coefficient of the layer 2b is in range of 10^{-5} to 10^{-6} cm/s, indicating that the layer 2b is suitable for impervious core materials for the earthfill dam. Moreover, on the basis of one dimensional consolidation test results, total settlement of the dam embankment is roughly estimated to be a maximum of 5 % of the dam height (50 to 60 m high), and more than 80% of the total settlement will occur during the construction period.

The layer 3b has the same index properties as those of the layer 2b. Similarly, the layer is considered suitable for the fill material of the earthfill dam.

(b) Sand and Gravel Filter

A sand and gravel filter needs to be provided between the impervious core zone and the shell zone. In the river valley near the damsite, underlies the river gravel layer that mainly consists of course sand, gravel, pebble and cobble of granite and sandstone. The gravel layer, having an exploitable volume of about 400,000 m^3, is considered suitable for the filter materials. The index properties of the layer are given in the table below:

Index properties of the river gravel layer

Component	Gs	BD	D60	D10	Cu	Proportion
Sand	2.67-2.68	13.1-13.7	0.4-0.6	0.2-0.3	2	20-30 %
Gravel	2.60-2.65	15.6-16.0				70-80 %
Mixture	2.65	18.0-19.0	30-48	0.6-1.0	48-50	

Note: Gs = Specific gravity, BD = Bulk density (kN/m3), Cu = Coefficient of uniformity, D60 = Grain diameter (in mm) corresponding to 60% passing by mass and, D10 = Grain diameter (in mm) corresponding to 100% passing by mass.

(c) Rock Material

Geological investigation shows that the riverbed gravel (Layer 1) and river terrace gravel (Layer 2a, refer to Section B Geology of Ta Trach reservoir area) can be used as riprap, toe rock and concrete aggregate materials. These layers are, however, of limited quantity and among these layers, gravel and boulder (grain size bigger than 4.75 mm) make up only 30 to 60%.

An alternative quarry site of granitic rocks is being considered in this study, which is located at the Tuan intersection, about 18 km far from the proposed damsite. The granitic rocks, having an exploitable volume of about 1,000,000 m^3, are slightly weathered and jointed with a compressive strength of 50 to 80 Mpa. The rock quarry site is thus considered, in terms of exploitable quantity and strength, to basically satisfy the design requirements. However, the crusher test of the rock should be carried out at the detailed design stage.

(3) Seismicity

(a) Characteristics of earthquake activity

The Ta Trach reservoir is located at the central Vietnam that is seismically stable and characterized by occurrence of less and smaller earthquakes. Moreover, no major faults attributed presumably to earthquake are reported in the Ta Trach reservoir and its surrounding areas.

The following table gives the list of earthquakes occurred in the Ta Trach reservoir and its surrounding areas, within the latitude of 15°00' - 17°20' and the longitude of 106°-109°, from 1666 through 1992. The earthquake records were obtained mainly from the International Seismological Center (ISC), Berkshire UK and Vietnamese Seismological Stations.

Earthquakes at the Ta Trach Reservoir and its Surrounding Areas

No.	Year	Lat.	Long.	Depth(km)	M	I	Location
1	1666	17.05	107.05	15	4.1	5	Ho xa
2	1685	16.50	106.60	15	4.1	5	Ta xing
3	1715	15.53	108.15	15	4.7	5	Tan an
4	1821	17.63	106.35	17	6.0	8	Dong hoi
5	1829	16.48	107.41	15	4.8	6	Hue
6	1919	15.00	109.00	33	4	-	North Lyson island
7	1947	16.55	107.43	10	4	-	Hue
8	1947	16.09	108.09	15	4.8	6	Da Nang
9	1954	16.09	108.09	15	3.0	-	Da Nang
10	1966	16.94	107.07	15	3.8	5	Gio linh
11	1966	16.22	108.27	15	2.7	-	Son tra
12	1968	17.30	105.50	15	5.0	6	Trung lao
13	1992	15.68	108.87	15	3.8	-	Dung quat

Note: Lat. = Latitude, Long. = Longitude, M = Magnitude in Richter scale, I = Intensity.

Around the Ta Trach reservoir area, the earthquake recorded first occurred in 1666 at Gio Linh, 115 km away from Ho Xa. The earthquake had a seismic intensity of 5 and magnitude of 4.1 in Richter scale. In 1829, a destructive earthquake with seismic intensity of 6 and magnitude of 4.8 in Richter scale occurred in Hue City and caused considerable damage to the old Hue Castle. During more than 100 years since that, only 2 small earthquakes occurred at Hue and Da Nang areas. These recorded earthquake events showed that the project area has low susceptibility to earthquake but probably suffers seismic influence.

(b) Estimation of Probable Maximum Acceleration

The probable maximum acceleration in the return period of 100 and 200 years was evaluated in this study on the basis of the earthquake record (13 records / 326 years) of the years from 1666 to 1992 for the area within a distance of about 200 km from the Ta Trach damsite.

The study was made for two cases as follows.

Case 1: the return period of 100 years by Cornell formula

Case 2: the return period of 200 years by Cornell formula

The estimation of the maximum intensity and the maximum acceleration at the damsite for each earthquake is made according to Cornell formula as mentioned above.

The estimated probable maximum acceleration at the damsite for the return period of 100 and 200 years are summarized as follows:

100 years : 0.01 g

200 years : 0.04 g

Accordingly, the estimated probable maximum acceleration at the damsite is in a range of 0.01g to 0.04g for the return period of 100 and 200 years.

(c) Determination of design seismic coefficient

i) Estimation

The following table presents a determination of seismic coefficient in connection with dam type and seismic intensity in Japan.

Determination of Seismic Coefficient in Japan

Seismic Zoning	Dam Foundation	Type of Dam			
		Concrete gravity	Concrete arch	Zone fill	Homogeneous fill
Strong	Rock	0.12 – 0.15	0.24 – 0.30	0.15	0.15 – 0.18
	Soil			0.18	0.20
Moderate	Rock	0.12	0.24	0.12 – 0.15	0.15
	Soil			0.15 – 0.18	0.18 – 0.20
Weak	Rock	0.10 – 0.12	0.20 – 0.24	**0.10 – 0.12**	0.12
	Soil			0.15	0.18

Source: Rock or soil: Type of foundation, Ministry of Construction, Japan, 1997

The Ta Trach reservoir area, which is seismologically stable, is considered to correspond to the weak zone of Japan. From the table above, the design seismic coefficient of the Ta Trach dam is estimated to be 0.10 to 0.12.

According to the seismic hazard analysis of the Global Seismic Hazard Assessment Program (GSHAP) made by ISC, the center Vietnam belongs to Low zone. The peak ground acceleration for the return period of 475 years on the zone of GSHAP is estimated to be as follows:

Low zone: Less than 0.8 m/s^2 (0.08g)

The Ta Trach dam is located in the Low zone. Therefore, the design seismic coefficient of the damsite will be 0.08g.

ii) Determination of design seismic coefficient at the Ta Trach reservoir

The estimated design seismic coefficient for the Ta Trach damsite in the Study is summarized as follows:

- Cornell's formula (Cases 2)	0.01 - 0.04g
- A standard in Japan	0.10 - 0.12g
- GSHAP (ISC)	0.08g

Accordingly, the design seismic coefficient will be probably in the range of 0.04 - 0.12 for the Ta Trach dam. The estimated values are mostly less than 0.10.

The general region of the Ta Trach dam is a low seismic area and in the 100-year record available no great earthquakes have been experienced within 50 km of the damsite. For the preliminary designs of the dam, it is, therefore, recommended to use the seismic coefficients in the range of 0.08 to 0.10. The values correspond to a seismic intensity of 5 to 7.5 on the Richter scale, and are regarded as sufficiently conservative in view of the historic record of earthquake and geological conditions in the area as well as the planned design specification.

9.1.2 Dam Design

(1) Left Abutment of Damsite

Thickness of the mountain at the left abutment of presently designed dam does not seem to be sufficient. A careful examination is required in the next design stage.

(2) Dam Type

The alternative studies in the feasibility report are only made by the earthfill type dam. It is recommended that a concrete facing rockfill dam(CFRD) and a roller compacted concrete (RCC) dam, which are a suitable dam type in this site conditions are included in the alternative studies.

In examination of CFRD, availability of rock materials for dam should be investigated. According to a geological map of the project site, a mountain consisting of granite is seen in the left bank from about 5 km to 10 km upstream of the Ta Trach damsite. This mountain composed of granite on the map is considered as a possible quarry site for the rock materials of the dam. However, any investigation has not been conducted yet due to difficult accessibility, and therefore, the investigation on possibility of quarry site for rock materials should be conducted, starting with reconnaissance and if the reconnaissance can confirm a possibility as the quarry site, the investigation for confirming quality and available quantity should be executed.

(3) Sluice Structure

Sluice structure is designed in the dam foundation. However, water seepage is probably caused by differentially settled embankment, poor contact between embankment and concrete, inadequate compaction about collar portions and different earthquake response between embankment material and concrete. Taking into consideration these phenomena, it is recommended to re-examine the location of sluice.

(4) Intake Tower

Intake tower is designed in the dam embankment. It is also disagreeable taking into consideration the different earthquake response between embankment material and concrete.

(5) Consolidation Grouting

To assure the consolidation and prevention of the water seepage for the dam foundation, it is recommended that the consolidation (blanket) grouting for the dam foundation is made.

(6) Reservoir Sedimentation

There is a discrepancy on the annual volume of sedimentation between 464,184 m3 (Feasibility Study, main report, IV-17) and 618,800 m3 (F/S, main report, VIII-3).

(7) Test

Rock abrasive test is recommended in addition to the rock properties test (main report, page IV-9).

9.1.3 Construction Plan and Schedule

(1) Working Schedule

In the working schedule of the supplemental report, the earthworks such as excavation and embankment are performed even in rainy season (Sep.- Dec.). However it seems to be difficult. The workable day for the earthworks and concrete works is estimated as follows on the basis of rainfall record during past ten (10) years (1991-2000):

Works	Dry Season (Jan.- Aug.)	Rainy Season (Sep.- Dec.)
Earthworks	18 days / month	3 days / month
Concrete Works	22 days / month	13 days / month

(2) Construction Equipment

The construction equipment to be employed for the dam works is planned by a combination of 1.6-2.3 m3 class excavator, 10-12 ton class dump truck, 140-180 ps class bulldozer and 9-16 ton class compactor. It seems those are too small, considering the scale of project.

Taking into consideration the work volume, hauling distance, limited working space and limited construction period, it is recommended to use a large size construction equipment such as 5.4-10.3 m3 class wheel loader, 32-46 ton class dump truck, 32- 44 ton (310-410 ps) class bulldozer, 10 ton class vibration roller and 20 ton class tamping roller.

(3) Embankment

In the 4th year, the embankment of riverbed and left side is planned at EL 25 m (from Jan. to Apr.) and EL 37 m (from May to Aug.). It seems to be the critical works in this project. Artificial calamity will happen, if the 5 % probable flood occurs under the condition of 2 nos. of sluice in the course of the embankment of main dam in the riverbed and left side before reaching at the elevation of 37 m in 4th year.

(4) Conclusion

So far as the collected data and information and examination of technical aspects are based, Ta Trach reservoir project is not found any negative problems except location of sluice and 4^{th} year embankment. In this connection, the roller concrete facing rockfill dam (CFRD) and compacted concrete (RCC) dam, which are reliable against flood should be included in the alternative studies. Therefore, It is recommended that the possibility of CFRD and RCC dams as well as problems identified herein should be clarified in the further study for the Ta Trach reservoir project. In examination of CFRD, it is most important to confirm the availability of rock materials. Thus, prior to the examination of CFRD, the investigation as mentioned in Sub-section 9.1.2 is strongly recommended to be conducted.

9.1.4 Proposed Basic Design

The alternative study in the plan formulation recommended the construction of the following two dams:

i) Ta Trach Dam with an effective storage capacity of 460 million m^3 and flood control volume of 392.6 million m^3.

ii) Huu Trach Dam with an effective storage of 182 million m^3, and flood control volume of 105 million m^3.

A preliminary design of these dams is presented in Figure 9.1 and 9.2.

Based on the result of the plan formulation study, crest levels of both dams are same as those of the design of the feasibility study.

As discussed in the review on the design conducted in the Feasibility Study (Sub-section 9.1.1, this report), an overall review including dam type is required for the present design of Ta Trach Dam. However, since the Study has difficulty to examine and propose the final design, the design similar to that of the feasibility study is tentatively provided.

9.2 Basic Design of Flood Control Facilities

In the study on flood control plan of the Huong River basin, some heightening of the present road running along the present channel of the Huong River in the downstream reaches may be needed as flood protection measures. Howeever, basic flood control measures are proposed as Ta Trach reservoir and Huu Trach reservoir. Neither new construction of the dike system along the Huong River nor the new construction of flood retarding basin is proposed in the present study.

9.3 Basic Design of Domestic and Industrial Water Supply Facilities

Based on the plan formulation mentioned in Subsection 8.3, a layout design of domestic and industrial water supply facilities was prepared as shown in Figure 9.3.

9.4 Basic Design of Irrigation Water Supply Facilities

Improvements of the irrigation system have to be achieved by rehabilitation of deteriorated works and additional works for irrigation and drainage. The present main system should in general remain unchanged, but further developments may demand better water level control, for which water level or discharge control structures may be more useful.

Parts of the actual irrigation and drainage systems are old, with delayed and outstanding maintenance. The main structures are functioning, but some canals and drains are silted up, small structures (outlets along the lagoon) need new gates, pumping stations require new, more efficient pumps. Details of the conditions of the different parts of the system are unknown.

Based on recent past, present situation and expected development it is recommended to rehabilitate and modernize parts of the existing irrigation and drainage system to:

- Provide irrigation water (3:4 year)
- Improve drainage of excess rainfall and overland flow
- Protect the irrigated coastal areas against early flooding in May/and June
- Allow controlled inundattion of agricultural lands from September to November
- Accept uncontrolled inundation of agricultural lands (1/10 year)
- Support flushing of the canal/drain system
- Minimize use of chemicals.

It is clear that all recommended improvements should be discussed with the responsible authorities, and where necessary the local population should be consulted. Their opinions have to be taken into account otherwise an optimum functioning of the system will become very difficult.

The necessary improvements for better functioning of the irrigation/ drainage system (rehabilitation and new works) have been estimated. The estimates are based on the information gathered during this study period and on field trips in 2001/'02, and summarized in Table 9.2. However, the table shows only a preliminary estimate of major works needed to improve the irrigation and drainage system. A more detailed investigation and estimate is under preparation by the authorities in Hue. The above estimate has to be updated as soon as new data become available. The improvements concern the present irrigation scheme of 25,900 ha. Additional works for a possible extension to 29,400 ha have not been taken into account.

The main intakes and outlets and other major structures have concrete footbridges for inspection etc., except over the shipping opening. Overtopping by waves is allowed. The structures are provided with one of the following gates:

- Flapgates
- Counter-lever flap gates
- Lifting gates
- Swing doors

Table 9.3 contains an example (1994) list of pumping stations. It shows that 82% is at least 10 years old, and the actual capacity of 60% of the stations is lower than 70% of the theoretical capacity (overall capacity is 68%). It is estimated that about 60% of the 79 major pumping station (av. 2 pumps with engines per station) need some improvement in the near future. Most pumping station buildings are in good condition, but they are housing old pumps and engines. The actual condition of pumps and engines should be determined by an electro-mechanical engineer. The number to be renovated, replaced and additionally required is estimated at 10 pump houses, 100 pumps and 100 engines. Additional measures to ensure sufficient power supply, and replacement or new power lines, are not considered.

Existing designs should be used as examples for new designs. But they should be adjusted and where possible be improved for the new conditions, in order to minimize the cost of operation (pumps, gates), running (pumps) and maintenance.

9.5 Recommendation on Operation of Flood Control Facilities

9.5.1 Ta Trach Dam

Reviewing the Ta Trach reservoir operation conducted by HEC-1, the following recommendation is made:

In order to duly cope with various magnitudes of flood which are not known in advance, flood control operation rule should be established. The operation rule will consist of determination of speed of gate opening and establishment of timing of spillway gate opening. Those should be prepared with the following consideration:

(1) Determination of Speed of Spillway Gate Opening

The spillway gate operation should be simple and the gate will be opened at a constant speed. The speed of gate opening should be determined so that the outflow discharge or river water level rise in the downstream reaches will be limited to an allowable extent. Generally accepted river water level rise in the downstream is around 1.0 m/hour not to endanger the downstream reaches . Thus, the speed of spillway gate opening should be determined so that the water level rise in the downstream is limited within around 1.0 m/hour.

(2) Establishment of Timing of Spillway Gate Opening

All floods less than the objective flood for flood control, for which the reservoir has the flood control volume to accommodate the flood volume, should be fully controlled by accommodating the flood volume in the reservoir.

For floods bigger than the objective flood, the spillway gate has to be opened at a proper timing.

Timing of gate opening should be determined with the following consideration:

a) Simulations of flood control will be conducted for various floods with the determined speed of spillway gate opening.

b) Timing of gate opening at which the maximum water level rise of reservoir will be controlled below the Surcharge Water Level will be found through the simulations for various floods.

c) Through the above simulations, a relationship between the speed of reservoir water level rise at flooding and the timing of spillway gate operation for opening will be obtained.

The operation rule should be established with the above speed of spillway gate opening and the relationship between the speed of reservoir water level rise at floodings and timing of spillway gate opening. Then, in the occurrence of floods, the reservoir water level rise and its speed will be observed, and the spillway gate will be operated based on the established operation rule.

9.5.2 Downstream Facilities

(1) General

In the downstream reaches of the Huong River basin, there are several facilities for flood control and/or irrigation water supply. Basic consideration for operation of these facilities is presented below.

(2) Major Facilities

Major facilities are the Nham Bieu Intake Gate, Phu Cam Intake Gate, Dap Da Weir, La Y Spillway and Thao Long Barrage. Location of these facilities is schematically shown in Figure 9.4.

General features of each facility are given below.

a) Nham Bieu Intake Gate

Nham Bieu Intake Gate located in a branch of the Huong River is the intake for Huong North. It has 4 gated discharge openings (2.5 m wide each, Floor EL.-1.1 m), and a supporting pumping station with 2 pumps.

b) Phu Cam Intake Gate

Phu Cam Intake Gate is the intake for Huong South, located just downstream of the railway bridge over the Huong River. It has 5 discharge openings (4.0 m wide each, Floor EL.-1.5 m) and 1 shipping opening, all with electrical operated flap gates, hinged on the floor.

c) Dap Da Weir

Dap Da Weir is a fixed cross dam, with a road on top at EL.1.5 m, overtopping during higher floods.

d) La Y Spillway

La Y Spillway has 22 openings, each having 2.5 m wide. Its apron and crest are set at EL.0.6 m and EL.2.0 m, respectively. The openings are provided with composite steel doors, blocking the flow from the Nuong River, but allowing drainage to the river. At high river water levels, the gates will be overtopped. A 2-opening inlet, with vertical lifting gates, allows intake of irrigation water.

e) Thao Long Barrage

Thao Long Barrage is of the length of 571.25 m between the dykes on both river banks. It will be provided with 15 overflow gates, each having 31.5 m in width, hinged on the floor. The sill level of 9 gates is EL.-2.5 m, and that of 6 gates is EL.-1.5 m. The top of the gates is at EL.1.2 m in the closed position. An additional navigation lock of 8 m wide and 52 m long with two-way swing doors, allows the passage of 4-5 m wide boats. The Thao Long Barrage will solve the problem of salt water intrusion.

These facilities will be operated with the following consideration:

a) The facilities will be closed to protect the agricultural lands from the early floods.

b) Inundation of agricultural lands due to major floods will be allowed, and thus, the facilities will be opened at the occurrence of major floods so that the inundation of urban areas be reduced.

c) During the non-flood seasons, the facilities will be operated to intake the water necessary for irrigation.

With the above consideration, operation of each facility is summarized below.

Facilities	Type of Facilities	Operation of Facilities		
		For Major Flood	For Early Flood	For Non-Flood
Nham Bieu Intake	4-gated discharge openings(4×2.5 m wide, Floor EL.-1.1 m) with a supporting pumping station	Fully opened	Closed	Closed(irrigation water supply with pumping up)
Phu Cam Intake	5 overflow gates (5×4.0 m wide, Floor EL.-1.5 m) hinged on the floor	Fully opened	Closed	Partially opened (To supply the required irrigation water)
Dap Da Weir	A crossing dam with the crest level at EL.1.5 m Note: No operation is necessary.	No operation (Large floods will overtop the weir)	No operation (Most of early floods will be protected)	No operation
La Y Spillway	22-gated discharge openings (22×2.5 m wide, Apron EL.0.6 m, Crest EL.2.0 m) Note: The gates are self-operational.	No operation (Large floods will overtop the crest of the gates)	No operation (Agricultural lands will be protected from most of the early floods)	No operation (The vertical shaft gates will be opened for necessary irrigation water intake)
Thao Long Barrage	15 overflow gates hinged on the floor(15×31.5m wide)	Fully opened	Fully opened	Partially opened to discharge the river maintenance flow of 31 m3/s

CHAPTER 10 PRELIMINARY IMPLEMENTATION PROGRAM AND COST ESTIMATE OF PROPOSED MAJOR FACILITIES

10.1 Basic Conditions for Construction Program

Basic conditions and consideration for implementation program are prepared on the basis of following conditions:

(1) Workable Days

The average annual rainfall is 2,858mm in Hue city to 3,529mm at Nam Dong, 70 to 75 % of it concentrates in the rainy season from September to December and Typhoon visits the area in this season. The dry season extends from January to August with a hot dry and rainfall is scarce amounting to 25 to 30 % of the annual rainfall. The average annual air temperature ranges between 41 deg.C to 4 deg.C. The mean annual humidity is 86 %.

Workable days for such earthworks as embankment, excavation and hauling, and concrete works are considered to be dominated by the weather conditions, especially rainfall. Therefore, the rainy days in the study area are examined by using the rainfall record at Nam Dong Observation from 1991 to 2000.

The annual workable days are estimated assuming that the works are to suspend on Sundays, National holidays and rainy days.

(a) Earthworks

Suspended days due to rainfall	:	153.6 days
Sunday	:	52.0 days
Holiday	:	8.0 days
Workable day	:	151.4 days
Total	:	365.0 days
Annual average workable day	:	13.0 days per month
Rainy season (Sep.-Dec.)	:	3.1 days per month
Dry season (Jan.-Aug.)	:	18.1 days per month

(b) Concrete Works

Suspended days due to rainfall	:	79.2 days
Sunday	:	52.0 days
Holiday	:	8.0 days
Workable day	:	225.8 days
Total	:	365.0 days
Annual average workable day	:	19.0 days per month
Rainy season (Sep.-Dec.)	:	12.6 days per month
Dry season (Jan.-Aug.)	:	22.4 days per month

Detailed workable day analysis is shown in Tables 10.1 and 10.2.

(2) Working Hours

Working hours of 8 hours/shift are assumed, and 2 shifts works are applied for the major works such as the dam and tunnel for expediting the completion of the project. 1 shift work will be applied for other works which are not critical for completion of the project.

(3) Labor Forces

Skilled and common labors for the works of proposed facilities will be required from the project area and surrounding area of the project, Hue, Danang, Hochi Minh and Hanoi cities. Especially, major works are erathmoving, dredging, concrete works, tunnel, dam, hydropower plant, pipeline, pumps, mechanical and electrical works and other related works. Number of foremen, operators, drivers, maintenance mechanics, skill labors, installation mechanics, electricians, plumbers, etc. will be required. Also some foreign foremen and instructors will be necessary for the construction works of proposed facilities.

(4) Construction Materials

Major construction materials required for the proposed facilities are earth, sand, concrete aggregate, rubble stone, cement, reinforcement steel bar, steel sheet piles, water stop, steel materials, reinforced concrete pipes, steel pipes, fuel and lubricant, etc. and these materials are available in Hue, Danang, Hochi Minh and Hanoi cities.

Some construction materials such as floaters, rockbolt, admixture, steel rib, valves and fittings, rods and bits, steel forms, spare parts and electrical and mechanical materials are imported from the overseas market.

(5) Construction Equipment

Major construction equipment for the proposed facilities such as backhoe, crawler loader, wheel loader, dump truck, bulldozer, tire roller, road roller, truck crane, vibration hammer, concrete pump car, truck mixer, etc. are available in Hochi Minh and Hanoi cities.

Special equipment for the proposed facilities comprising dredging equipment, drill jumbo, low bed dump truck, muck loader, shotcrete equipment, heavy dump truck, large capacity wheel loader, tower crane, vibrator, soil compactor, concrete plant, cement silo, aggregate plant, etc. will be imported and re-exported after the completion of the proposed facilities.

(6) Spoil Area

The spoil area to accommodate the surplus materials from the various excavation sites of the proposed facilities is taken into account. Especially the improvement of river / creek network, diversion channel from the upstream of Hue city to the lagoon, diversion tunnel from Ta Trach reservoir to Nong river and Ta Trach reservoir project anticipate to produce a large amount of surplus materials. Thus the planning of spoil area is indispensable.

10.2 Implementation Program of the Proposed Facilities

(1) Execution Body

The Huong River Basin Development in Thua Thien Hue Province will be implemented by the Department of Agriculture and Rural Development (DARD) and other Government Agencies under the Peoples Committee of Thua Thien Hue Province and Ministry of Agriculture and Rural Development (MARD).

(2) Project Execution Method

All the project works will be executed on a contract basis. Proposed permanent facilities and the temporary construction facilities including construction equipment, materials and labors required for the works will be made by the contractors to be selected through the international or local competitive bidding.

(3) Construction Schedule

(i) Pre- construction program

Pre-construction activities consisting of preparation of bidding document, the financial arrangement and the land acquisition are necessitated before the commencement of construction for the proposed facilities, and it is assumed that 2.0 years for the financial arrangement, 1.0-1.5 years for the detailed design for all sectors and 4.0 years for the land acquisition.

(ii) Construction period

The construction period for the proposed facilities is presumed as follows:

Multipurpose Dam

- Ta Trach Reservoir Project	:	7.0 years

Irrigation and Drainage Facilities

- Improvement of Canal / Drain Network	:	11.5 years
- Construction and Rehabilitation of Main Inlet and Outlet	:	11.5 years
- Rehabilitation of Pumping Stations	:	11.5 years
- Embankment of Dikes	:	11.5 years
- Improvement of Secondary System	:	11.5 years
- Improvement of Tertiary System / On-farm Works	:	11.5 years

Domestic and Industrial Water Supply

- Phase 2 of Quang Te 2 Water Treatment Plant	:	2.5 years
- Additional Pipeline	:	9.0 years
- 45,000 House Connection	:	16.0 years
- Booster Stations and Ancillaries	:	1.0 year
- Small Projects	:	3.0 years

The construction periods include mobilization, preparatory works, preparation of shop drawings, civil and building works, fabrication, installation, test run and training.

(4) Overall Implementation Schedule

The overall implementation schedule including financial arrangement, employment of consultants, land acquisition and compensation including resettlement, survey and investigation, detailed design works, prequalification of bidders, bidding and construction of all facilities is shown in Figures 10.1 and 10.2, respectively.

(5) Operation and Maintenance Organization

The operation and maintenance (O&M) of the Ta Trach reservoir project shall be undertaken by MARD. The Ta Trach Reservoir Management Office (TTRMO) will be established at the reservoir site to carry out actual operation and maintenance works. The most essential functions required are reservoir operation for flood control, irrigation, domestic and industrial water supply, hydropower generation and pushing back of saline water.

As of the irrigation and drainage facilities in the project area, the O&M shall be carried out by the following agencies and organizations depending on the type of facilities:

O&M Body	Type of Facilities
• Thua Thien Hue Provincial Irrigation Management Company	- Major river / creek network including intakes along Huong River - Irrigation canals and appurtenant structures - Pumping stations (large scale) - Drainage sluices (large scale)
• Cooperatives / farmers groups	- Pumping stations (small scale) - On-farm irrigation ditches
• Communes	- Drainage sluice (small scale) - Drainage dikes - Tidal wave protection dikes

The Provincial Water Resources Department shall supervise the O&M activities of the Irrigation Management Company.

10.3 Preliminary Project Cost Estimate

10.3.1 Basic Conditions

(1) Price Level and Exchange Rate

The construction cost is estimated based on the price level of December, 2001 and the applied foreign exchange rates are as shown below:

US$ 1.00 = VND 15,068

J. Yen 100 = VND 12,212, as of December 3, 2001

(2) Physical Contingency

The physical contingency is provided to cope with the unforeseen physical conditions. The physical contingency is assumed to be 10 % for the sum of construction cost, resettlement cost, engineering service cost and administration cost.

(3) Price Contingency

The price escalation is given with the rate of 4.9 % per annum in an average considering of the consumer price index in Vietnam from 1995 to 2000.

(4) Value Added Tax

Value Added Tax (VAT) is estimated at 5 % of total construction cost, engineering cost, administration cost and price escalation.

10.3.2 Direct Construction Cost

(1) General Items

General items consist of insurance and contractor's preparatory works. Insurance include insurance of works and contractor's equipment, third party insurance and insurance for accident or injury to workmen. Contractor's preparatory works comprise providing engineer's temporary offices, first-aid station, providing accommodations and vehicles for engineer, contractor's temporary buildings, water supply system, electric power supply system, telecommunication system, sewerage and drainage system, temporary access roads and contractor's testing laboratory.

General cost is estimated at 10 % of total construction cost.

(2) Unit Prices

The unit prices for the major work items are prepared referring to the collected cost data from the completed project or on-going project or feasibility study interim report on Ta Trach Project.

The unit prices for each work item consist of labor cost, material cost, equipment cost and contractor's overhead expenses and profit.

10.3.3 Indirect Construction Cost

(1) Resettlement Cost

Resettlement cost for Ta Trach reservoir project is reported in the feasibility report.

Total number of affected household is 805 households with 4,058 people of which inside reservoir area: 581 households, 2,819 people and outside reservoir area: 224 household, 1,239 people.

Total resettlement cost is estimated at 162,242.9 million VND of which:

- Compensation cost	64,339.0	million VND
- Investment cost for construction of resettlement area	62,198.0	million VND
- Cost for resettlement support	16,276.0	million VND
- Other cost	4,680.5	million VND
- Physical contingency cost	14,479.4	million VND

Unit average investment cost per household is 186 million VND.

(2) Engineering Service Cost

The engineering service cost is estimated to be 10 % of total construction cost comprising 5 % of detailed design and 5 % of construction supervision.

(3) Administration Cost

The cost for the project administration by the Government office is assumed to be 3 % of total construction and resettlement cost.

10.3.4 Project Cost

The project cost consists of direct cost and indirect cost. The direct construction cost comprises the general items, civil works, building works, mechanical and electrical works. The indirect cost includes the resettlement, engineering service, administration, price contingency and physical contingency. The total project cost without Huu Trach is estimated at 5,490,227 million VND, equivalent to 364.4 million US$. Then, the project cost with Huu Trach is estimated at 6,258,681 million VND, equivalent to 415.4 million US$.

10.3.5 Disbursement Schedule

The disbursement schedule of the project cost is estimated taking into account of the construction time schedule. The annual disbursement schedule of the project cost is shown in Tables 10.3 through 10.7.

CHAPTER 11 PROJECT EVALUATION

11.1 Technical Evaluation

Review on the present Ta Trach dam design made in the feasibility study points out the following:

(1) Two concrete culverts are installed within the dam body of fill type dam. The usual dam design criteria do not allow this design, since piping may occur through insufficient contact between concrete structure and dam embankment material will easily be caused due to differential settlement of concrete structures and dam embankment materials, or due to earthquake if it will happen, thus requiring a careful design review.

(2) The present dam construction schedule considers the river diversion system by using the two concrete culverts to be embedded in the dam body, and the schedule is too tight. In the event that dam embankment can not reach necessary level before the rainy season, artifical calamity may happened. Careful review of the construction schedule as well as the dam design will be required.

(3) Based on the design criteria has the fill type dam, river diversion system having a capacity to discharge 20 – years probable flood should be introduced. However, in the case of the Ta Trach river, 20 – years probable flood magnitude is estimated at 6.410m^3/s, requiring several diversion tunnels of 10m in its diameter, which are considered unrealistic. Therefore, the concrete dam (RCC dam) which allows overtopping during construction should be taken into consideration in the review of dam design and construction schedule. As such, detailed investigation far strength of the foundation rock will be important.

(4) The feasibility report notes that an active fault passes the damsite. Based on the investigation so far, it seems that the fault is ancient and inactive. However, further investigation such as test trench is required to confirm whether or not the fault cuts into the Quaternary deposits.

(5) The thickness of mountain at the left abutment in the present dam design does not seem sufficient, requiring a careful examination.

11.2 Economic Evaluation

Economic analysis has been examined for the following ten alternatives for the water resources development and management of the Huong River Basin:

Project Features of the Alternatives

Alter-native	Project Component	Flood Control	Hydro-power (GWh)	Irrigation (improve-ment, ha)	Water supply (mil. m3)
I-B.1	Max. Ta. Trach Reservoir only	Farmland: 10-year EF Urban area: 20-year MF	70	51,800	43.61 (in 2020)
I-B.2	Max. Ta Trach + Max. Huu Trach Reservoirs	- ditto -	70 80.6	- ditto -	- ditto -
I-B.3	Max. Ta Trach + Min. Huu Trach Reservoirs	- ditto -	70 68	- ditto -	- ditto -
I-B.6	Max. Ta Trach + Max. Huu Trach + Max. Co Bi Reservoirs	- ditto -	70 80.6	- ditto -	- ditto -
I-B.7	Max. Ta Trach + Max. Huu Trach + Min. Co Bi Reservoirs	- ditto -	70 80.6	- ditto -	- ditto -
I-B.8	Max. Ta Trach + Min. Huu Trach + Max. Co Bi Reservoirs	- ditto -	70 68	- ditto -	- ditto -
I-B.9	Max. Ta Trach + Min. Huu Trach + Min. Co Bi Reservoirs	- ditto -	70 68	- ditto -	- ditto -
I-C.2	Min. Ta Trach + Max. Huu Trach Reservoirs	- ditto -	70 71	- ditto -	- ditto -
I-C.6	Min. Ta Trach + Max. Huu Trach + Max. Co Bi Reservoirs	- ditto -	70 71	- ditto -	- ditto -
I-C.7	Min. Ta Trach + Max. Huu Trach + Min. Co Bi Reservoirs	- ditto -	70 71	- ditto -	- ditto -

Note: Max: Maximum, Min: Minimum, EF: early flood, MF: major flood

Economic analysis has been conducted devising into two steps, 1) comparison of alternatives and 2) evaluation of optimum plan. In a discounted cash flow analysis, the effects of costs and benefits come out in later year have very small influence to the results of the analysis. Therefore, for the comparison of the alternatives, simultaneous construction is assumed for all the alternatives in order to see the difference of economic efficiency of the project components. Then, for evaluation of an optimum alternative, stage construction will be considered. As for the irrigation improvement and water supply, a practical schedule has been applied for both the steps of the analyses.

11.2.1 Results of Economic Analysis

The results of the economic analyses showed all the alternatives have sufficient economic efficiency with EIRRs of more than 16%, which are far higher than the opportunity cost of capital in Vietnam (12%). The results did not show significant difference among the alternatives from the viewpoint of economic efficiency. All the alternatives can be rated as being economically feasible. However, the alternative I-B.2 showed the largest NPV and EIRR of 17.3%, which is slightly higher than others except the alternative I-B.1. Economic indicators are calculated and summarized below:

Economic Indicators (simultaneous construction)

Alternative	EIRR (%)	B/C Ratio	NPV (Million US$)
I-B.1	17.5	1.73	57.6
I-B.2	17.3	1.68	61.5
I-B.3	17.3	1.68	60.8
I-B.6	16.6	1.58	55.6
I-B.7	16.8	1.61	57.3
I-B.8	16.6	1.58	55.1
I-B.9	16.8	1.61	56.8
I-C.2	17.3	1.68	60.6
I-C.6	16.6	1.58	54.6
I-C.7	16.8	1.61	56.3

Note: B/C and NPV are calculated with a discount rate of 12%.

The economic analyses based on practical implementation schedule (stage construction) have been examined for the alternative I-B.2. The results also indicated the alternative has sufficient economic efficiency with EIRRs of 17.4%, which is higher than the opportunity cost of capital. The alternative can be rated as being economically feasible. The cash flow table of the analysis is shown in Table 11.1 and the results are summarized below:

Economic Indicators (stage construction)

Alternative	EIRR (%)	B/C Ratio	NPV (Million US$)
I-B.2	17.4	1.70	59.9

Note: B/C and NPV are calculated with a discount rate of 12%.

11.2.2 Methodology of Economic Analysis

The economic analyses of the alternatives are conducted by the methodologies discussed below:

(1) Assumptions

The economic analyses are examined based on the following assumptions:

(a) Price Level and Exchange Rate

Foreign exchange rate of one U.S. dollar equivalent to VND15,068 and 100 Japanese Yen equivalent to VND12,212 are applied at the price level of December 2001.

(b) Project Life

The project life of 50 years after construction is assumed for the economic analysis. Average lifetime of the electrical and mechanical facilities is assumed 25 years after installation. Replacement costs cover the cost for replacement of such facilities after the lifetime within project life.

(c) Discount Rate

A discount rate of 12% is applied to reflect the opportunity cost of capital in Vietnam.

(d) Standard Conversion Factor (SCF)

The standard conversion factor (SCF) of 0.9 with reference to recent similar studies is applied to adjust the effects of trade distortion, foreign exchange premiums, the local costs for non-traded goods and services.

(e) Transfer Payment

From the viewpoint of national economy, the transfer payment such as taxes, duty, subsidy and interest is merely a domestic monetary movement without direct productivity. Therefore, it is excluded from the costs of goods and services.

(f) Economic Prices of Agricultural Outputs

The prices of agricultural outputs are adjusted by SCF on assumption that most of the incremental outputs are for domestic consumption.

(g) Economic Price of Electricity

The economic price of electricity is assumed at 5 US Cents/kWh, which is generally used as a price of electricity in economic analyses.

(h) Economic Price of Domestic and Industrial Water Supply

The economic price of domestic and industrial water is assumed at VND 1,800/m^3, the long-term marginal cost of production adjusted by SCF.

(i) Economic Project Cost

The economic project cost has been estimated from the financial project cost adjusting by SCF after deducting the direct transfer payment.

(j) Operation and Maintenance Cost

The following annual operation and maintenance costs are assumed:

- Civil construction including dam and irrigation facilities: 0.5% of construction cost
- Mechanical and electrical facilities including hydropower facility: 1.5% of facility cost

- Domestic and industrial water supply: 5% of the construction cost

(k) Replacement Cost

The following replacement costs are assumed for replacement of facilities 25 years after installation:

- Mechanical and electrical facility for dam and hydropower generation
- Pumps and gates for irrigation and water supply facilities

(2) Project Benefits

(a) Flood Control Benefit

i) Definition of flood control effect

Flood control effects are measured from difference of flood damages between those with and without project conditions. In other words, they are flood damage mitigation benefit.

ii) Annual Mean Flood Damage and Flood Mitigation Benefit

Annual mean flood damage is estimated as accumulation of flood damage segments derived from various magnitude of probable flood damage multiplied by the corresponding probability of occurrence, from non-damageable flood up to design protection level of flood. Table 11.2 shows the annual mean flood damage under the conditions without project and with various alternatives.

Difference of the annual mean flood damage between those with and without project is considered as annual flood reduction benefit. The results of calculation is summarized below:

Annual Mean Flood Damage and Flood Mitigation Benefit (VND billion)

Alternative	2001		2020	
	Annual mean flood damage	Flood mitigation benefit	Annual mean flood damage	Flood mitigation benefit
Without project	479.0	-	595.2	-
I-B.1	42.6	436.4	49.0	546.2
I-B.2	6.6	472.4	7.6	587.6
I-B.3	6.6	472.4	7.6	587.6
I-B.6	6.6	472.4	7.6	587.6
I-B.7	6.6	472.4	7.6	587.6
I-B.8	6.6	472.4	7.6	587.6
I-B.9	6.6	472.4	7.6	587.6
I-C.2	13.1	465.9	15.0	580.2
I-C.6	13.1	465.9	15.0	580.2
I-C.7	13.1	465.9	15.0	580.2

(b) Incremental Agricultural Benefit

Agricultural benefits of the projects have been estimated for production of crop, livestock, and aquaculture.

According to the agronomic study, using model crops and cropping patterns based on the characteristics of the project area, after implementation of the projects, improvement in crop yields and production of higher value crops are expected. The benefits of incremental crop production are estimated as presented in Table 11.3 (1) and summarized below:

Incremental Crop Benefit

	Planted Area (ha)	Net Income (US$1,000)
Without Project	44,386	7,949
With Project (all the alternatives)	51,800	22,376
Incremental Crop Benefit	7,414	14,427

Unit values of livestock and aquaculture have been estimated by the study referring to "Statistical Data of Vietnam, Agriculture, Forestry, and Fishery 1995 - 2000, GSO". The process of estimation is shown in Table 11.3 (2).

The benefits from livestock and aquaculture production have been estimated as shown in Tables 11.3 (1) and (2). The results of the estimation are summarized below:

Incremental Livestock and Aquaculture Benefits

	Livestock (US$ million)	Aquaculture (US$ million)
Without Project	2.5	0.9
With Project (all the alternatives)	6.0	3.7
Incremental Benefit (2020)	3.5	2.8

(c) Hydropower Generation Benefit

Electricity production in Vietnam by mid-2000 was 350kWh per capita, about the half the level of Indonesia and one-fifth of that of Thailand. Although electricity output rose by 111% between 1993 and 1999, it has had difficulty in keeping up with demand.

The government has a master plan to increase power generation double by 2010 and five times from present level by 2020. Especially the government gives priority to develop hydropower plants, which bring about combined benefits such as flood control, water supply, irrigation, and electricity generation. The plan also mentions that exchange of electricity with neighboring countries will necessary in order to meet power demand in each region and whole country.

The economic price of electricity is assumed at 5 US Cents/kWh, which is generally used as a price of electricity in economic analyses. Annual mean energy produced by the projects is calculated as shown in Table 11.4:

(d) Water Supply Benefit

Future demand increase of domestic and industrial water supply in the Huong River Basin has been estimated at 14.50 million m^3/year in the year 2010, 27.29 million m^3/year in 2015, and 43.61 million m^3/year in 2020. The economic value of water is estimated at VND1,800/m^3. Therefore, annual benefits of the water supply are estimated as summarized below:

Water Supply Benefit (Million US$)

	2013 (Completion of Dam)	2015	2020
Water supply benefit	2.85	3.26	5.21

(e) Other Intangible Benefits

Other than benefits discussed above, various effects are expected by the implementation of the projects as listed below:

- Contribution to national food security,
- Reduction of food import and saving foreign exchange holdings,
- Creation of new job opportunity,
- Improvement of self-sufficiency and nutritional level of rural farmers,
- To narrow the earnings differentials among regions,
- Convenience of rural population by improvement of access roads to the dam sites and the roads may reduce the cost of moving produce from the farm to the consumer,
- Improvement of public health and quality-of-life by supplying better quality water including decrease of water-related disease,
- To ease the water carrying works,
- Groundwater recharge and improvement of vegetation, and
- Stabilization of rural farmers' livelihood and prevention of influx of rural population into urban areas.

The benefits listed above are very valuable, they are nevertheless virtually impossible to value satisfactory in monetary terms.

(f) Indirect Benefit

During construction period, the construction works may fuel various demand for other industries. Meanwhile, after construction works, incremental agricultural production will also arouse various demands for many different industries such as chemical industries, transportation services, trade services, etc. Flood control effect may prevent inundation of highway or railway and paralysis of economic activity may be prevented or mitigated. Such ripple effects must be enormous. However, such benefits are also very hard to value in money terms without more detailed study.

(3) Economic Project Cost

Annual project cost of the optimum plan (alternative I-B.2) based on stage construction is shown in Table 11.5.

(4) Cost-Benefit Analysis

Based on the benefits and costs discussed above, economic viabilities of the projects are examined by cost-benefit analysis. The analysis is conducted by the discounted cash flow analysis. The cash flow of the optimum alternative I-B.2 is shown in Table 11.1. The results of the economic analysis are summarized in Subsection 11.2.1.

(5) Sensitivity Analysis

Sensitivity analysis of the economic evaluation has been examined for the optimum plan I-B.2 by increase in cost and decrease in benefit. The results of the analysis are shown below:

Sensitivity Analysis (EIRR %)

Case	Alternative I-B.2
a) Base estimate	17.4
b) Cost increase of 10%	16.4
c) Cost increase of 20%	15.5
d) Benefit decrease of 10%	16.3
e) Benefit decrease of 20%	15.0
f) Combination of c) and e)	13.2

Even under the most downbeat case, the combination of cost increase of 20 % and benefit decrease of 20%, the alternative has sufficient economic efficiency (EIRR more than 12%).

11.3 Financial Evaluation

11.3.1 Financial Cash Statement

The financial evaluation has been conducted for the optimum alternative, I-B.2: Maximum Ta Trach + Maximum Huu Trach Reservoirs.

The financial feasibility of the projects is evaluated by examining the repayment capability of the capital cost for the projects. For the examination, a financial cash flow statement for the proposed development plan using the anticipated project revenue and fund requirement is prepared based on the following assumptions:

(1) Price Escalation

The price escalation of 4.9% (an average of CPI from 1995 to 2000) has been assumed for capital cost, O & M cost, replacement cost, and revenue from irrigation water, hydropower generation, and water supply (domestic and industrial).

(2) Condition of Foreign Loan

In the examination of repayment capability, it is assumed that the capital required for the project implementation will be arranged under the following conditions:

- 75% of the capital costs are financed by bilateral or international institution as far as the costs are eligible items. The non-eligible items are costs for land acquisition, house compensation, administration, and any type of taxes and duties.
- The assumed condition of finance is with an interest rate of 1.8% per annum for a repayment period of 30 years including a grace period of 10 years.
- The balance of the capital cost is financed by the budget allocation of the Government without interest and repayment.

(3) O & M Cost

The following annual operation and maintenance costs are assumed:

- Civil construction including dam and irrigation facilities: 0.5% of construction cost
- Mechanical and electrical facilities including hydropower facility: 1.5% of facility cost
- Domestic and industrial water supply: 5% of the construction cost

(4) Replacement Cost

The following replacement costs are assumed for replacement of facilities 25 years after installation:

- Mechanical and electrical facility for hydropower generation
- Pumps and gates for reservoir, irrigation and water supply facilities

(5) Irrigation Water Charge

Irrigation water charge has been estimated at an equivalent value of 270kg of paddy per hectare. According to "Vietnam Water Resources Sector Review", when water charge is paid in kind, the value of paddy is determined 10 to 20% below market level. The estimation is shown below:

Estimation of Unit Irrigation Water Charge (2001 price level)

	Market price of paddy in TT. Hue (VND/kg)	Adjustment of value when paid in kind	Rate of irrig. water charge (kg/ha)	Estimated irrig. water charge (VND/ha)
Irrigation water charge	1,555	80%	270	335,880

The total improvement cropping area is 51,800ha, and the total water charge is estimated to be VND17,399 million (equivalent to US$1.15 million) per year.

Since the reservoir will be completed in the middle of 2013, the water charge is assumed to be collected from that year and to be increase according to progress of the irrigation improvement works as shown below:

Estimation of Future Irrigation Water Charge

Year / Progress of agricultural improvement according to improvement of irrigation facilities	Irrigation water charge (US$ million)
Estimated irrig. water charge in 2001 price for 51,800 ha	1.15
Price in 2013	2.05
At middle of 2013 (completion of the reservoir) / 15%	0.31
In 2014 price / 65%	1.40
In 2015 price / 75%	1.69
In 2016 price / 85%	2.01
In 2017 price / 95%	2.36
In 2018 price / 100%	2.60
In 2019 price / 100%	2.73
:	:

(6) Electric Charge

Annual mean energy production by the project (both Max. Ta Trach + Max. Huu Trach) is calculated at 150.6GWh. EVN's electric charge for domestic firm is 5.2 US Cents/KWh at present. The future electric charge to be produced by the project is estimated as follows:

Estimation of Future Electricity Charge

Year	Max. Ta Trach	Max. Huu Trach	Total
Average annual power generation (GWh)	70	80.6	150.6
Estimated revenue from electric charge (US$ m)			
- In 2013 (Completion of Ta Trach, 1/2 year only)	3.11	-	3.11
- In 2014 (Ta Trach full operation)	6.52	-	6.52
- In 2019 (Completion of Huu Trach)	8.28	9.53	17.81
- In 2020	8.69	10.00	18.69
:	:	:	:

(7) Domestic and Industrial Water Charge

As discussed in Subsection 11.2, the future demand increase of domestic and industrial water in the Huong River Basin has been estimated by the study team. The present tariff of water supply is assumed at VND1,500/m^3. The future revenue from the water supply is estimated as shown below:

Estimation of Future Irrigation Water Charge

Year	Water demand ($10^6 m^3$/year)	Water charge (US$ million)
2013	21.19	3.75
2013 (half a year service)	10.60	1.87
2014	24.05	4.45
2015	27.29	5.31
2020	43.61	10.77
:	:	:

The financial cash flow statement of the project is as shown in Table 11.6.

11.3.2 Conclusion of Financial Analysis

From the financial cash flow statement, the following matter became evident:

- Irrigation water charge cannot fully cover O & M cost of irrigation but shortage is very small and can be covered by small adjustment of water charge.
- Hydropower produces large benefit for the project.
- Water supply revenue can cover O & M cost of the water supply.
- In 2019 and afterward, government subsidy will not become necessary except during the replacement work of major mechanical and electrical facilities.

If soft loan that assumed in this study is available, implementation of the projects will be financially possible. However, it should be noted that the results are largely depending on the setting of the future tariff of water and electricity.

11.4 Environmental Evaluation

This section preliminarily examines the likely negative impacts on environment caused by the projects composing the Master Plan, and proposes the approach to cope with the impacts. The environmental evaluation was carried out in accordance with the JICA Environmental Consideration Guideline.

Among the components of the Master Plan, the following projects were selected as those necessary for discussion in this section, in due consideration of characteristics of each project:

- Ta Trach Dam (Structural Flood Control Plan)
- Huu Trach Dam (Structural Flood Control Plan)
- Domestic/industrial Water Supply (Water Utilization Plan)

The components of the Master Plan such as i) Non-structural Flood Control Plan, ii) Agricultural Development and Irrigation Water Supply (Water Utilization Plan), iii) Other Management Plan, were screened out from the discussion, because it is expected that the negative impacts on environment will be insignificant.

The matrix on the results of environmental evaluation is shown in Table 11.7.

11.4.1 Social Environmental Aspect

(1) Land Acquisition and Resettlement

Land acquisition and resettlement are considered as one of the major negative impacts caused by Ta Trach Dam project. According to the existing studies in case of SWL of about EL 52 m, it is expected that more than 800 households will be compelled to resettle, of which about 600 are located within the proposed reservoir area and others are located at the dam site or stockpile. Out of the total affected households, approximate 5 % is Van Kieu group (one of the ethnic minorities in Vietnam). The existing studies also estimate the affected land to be approximate 35 km^2 including the agricultural land of 6 km^2.

Implementing Ta Trach Dam project, the above impact is inevitable. Therefore, it is, firstly, recommended that the program prepared for compensation and resettlement be carried out securely. Secondly, the consultation with the stakeholders, including the recipient communities of resettlers, should be done during all the stages not only of preparation and implementation of the program, but also of stabilization of living condition after program completion.

Although the construction of Huu Trach Dam would cause the land acquisition and resettlement, the concrete and actual magnitude is unclear due to no availability of the existing data and information. The proposed site and reservoir area of the dam is located at the steep valley, and, therefore, the magnitude of impact does not seem to be serious due to the limited inundated area of approximate 11 km^2. However, the more survey is necessary, in order i) to identify the magnitude of impact on land acquisition and resettlement, and ii) to prepare the proper program for resettlement action if the significant impact is expected. In addition, it should be also clarified, whether or not i) the ethnic minorities exist, and ii) impact on them is expected.

Regarding the domestic/industrial water supply plant, the magnitude of land acquisition and resettlement is not considered so significant since the required area for plant will be considerably small. However, the plan for compensation and resettlement should be prepared and implemented.

(2) Change or Split of Communities

According to the existing studies in case of SWL of about EL 52 m of Ta Trach Dam, approximate 60 % of the affected households will be compelled to resettle to other communes/districts, whereas on-site resettlement will be done for remaining affected households. This would cause the change or split of the existing communities. In addition, some conflict between new and old villagers would be introduced especially in the recipient communities. Thus, the close consultation with stakeholders is recommendable for mitigating the communal society as much as possible, and additional support should be given if necessary.

It is unclear whether or not the change or split of the existing communities will be caused by the construction of Huu Trach Dam. As well as the issues on land acquisition and resettlement, the more survey is necessary.

(3) Traffic and Public Facilities

Especially on the fluvial navigation, the transportation by small boats for gravel is observed at Ta Trach Dam site, although the frequency of passing through the dam site is unknown. The proper support, such as preparation of small port connecting alternate roads, should be given against the inconvenience during and after dam construction. Regarding Huu Trach Dam, the same consideration as Ta Trach will be preferable.

(4) Health and Sanitary Condition

Large number of labor forces will be mobilized for the construction of Ta Trach Dam and Huu Trach Dam. In order to avoid deterioration of health and sanitary status in and around the project areas of 2 dams, it is recommended that construction workers be given basic education and preliminary aid, and also that public medical services be improved.

The risk of water-borne diseases might increase due to the appearance of new water bodies by Ta Trach Dam and Huu Trach Dam. According to the Ministry of Health, malaria and dengue fever are not so common in T. T. Hue province at present. However, the ministry also suggests that the new dam reservoirs might make a potential risk of malaria high in the areas adjacent to the new water bodies. Therefore, monitoring of indicators such as out-patients will be required around the new reservoirs' area.

(5) Noise and Dust

Although the detail of construction plan and schedule of Ta Trach Dam and Huu Trach Dam is unknown, the construction activities are likely to increase the nuisance of dust and noise. Since these affect will be inevitable, the following measures is to be planned and implemented to the extent possible, namely i) the construction road and operation of heavy equipment should be away from settlement area, ii) the work hours should be restricted to the daytime hours, and iii) water spraying should be done on the construction road.

11.4.2 Natural Environmental Aspect

(1) Topography

The construction of Ta Trach Dam and Huu Trach Dam will cause the topographic change. However, there are no precious topography nor tourism spots relied on the unique topography. Thus the topographic change due to the dams construction will be acceptable.

After completion of Ta Trach Dam and Huu Trach Dam, the change of lagoon topography might occur due to the reduction of the sediment load from the upstream. The preliminary examination shows that the reduction of sedimentation rate in lagoon is estimated at about 26 cm/100years (average depth of lagoons is 1.5 – 2.0 m). According to the Study on Restoration and Stabilization of Thuan An - Tu Hien Estuary (May, 2001), the history of the lagoon system indicates that bed siltation on lagoon occurred together with the contraction of water surface. It is, therefore, considered that the reduction of sediment load to lagoon would make the progress of bed siltation slow somewhat.

Ta Trach Dam and Huu Trach Dam will improve the hydrological regime of the Huong river than the current status. Simultaneously, the composition of sediment, sediment transport pattern, and the tractive force will be also changed in the downstream. At present, it is unclear whether degradation/aggradation of river bed will occur or not.

(2) Water Quality

During the construction stage of Ta Trach Dam and Huu Trach Dam, there will be a risk of pollution to their downstream by blasting or earthwork that will increase sediment load. In addition, the concrete placement of 2 dams' bodies would adversely affect the river water quality due to the alkaline discharge, in case that gravity type dams by concrete would be applied to Ta Trach and Huu Trach dams although fill type was planned in F/S of Vietnam. It is therefore necessary, i) to provide the silting/sedimentation basin for reduction of sediment load, ii) to develop sediment control measures against soil erosion of exposed area, and iii) to provide treatment facilities of alkaline discharge if necessary.

Large number of labor forces will be employed for construction work of Ta Trach Dam and Huu Trach Dam. In order to avoid organic pollution to their downstream, the wastewater from campsites should be treated on sites. Moreover, emergency measures should be developed in the event of an accidental spillage of oil and other chemicals from the construction sites.

The proposed gross storage of Ta Trach Dam is 610 MCM, whereas the average annual inflow to the dam is estimated at 1,626 MCM by the hydrological analysis. The annual turn-over rate of the reservoir is obtained as about 2.7 times on an average. This means that there would be a possibility of occurrence of water temperature stratification in the reservoir. However, the difference of water temperature between surface and bottom will be 5 ℃ according to the experience of the existing dams in Vietnam. Therefore, the problem of cold water will be insignificant. In case of Huu Trach Dam, The annual turn-over rate of the reservoir is obtained as about 5.0 times on an average (gross storage of 230 MCM, average annual inflow of 1,154 MCM). This means that a possibility of occurrence of water temperature stratification in the reservoir would be small. And in the same manner as Ta Trach Dam, the problem of cold water will be insignificant.

Regarding eutrophication of the reservoir of Ta Trach Dam, the nutrient load to the reservoir will not be significant, since, i) the agricultural land as the major source of nutrient occupies less than 10 % of the catchment area of the dam based on the available information on land use, and ii) there are no developed urban area in the catchment area of the dam. And eutrophication phenomena is not so common according to the experience of the existing dams in Vietnam. Therefore, it is enough to check continuously whether or not the water bloom appears in the reservoir during the dam operation stage. In case of Huu Trach Dam, the problem of eutrophication will be insignificant in the same manner as Ta Trach Dam.

The storage and operation of Ta Trach Dam and Huu Trach Dam will ensure the discharge of the maintenance flow in Huong river. Therefore, the degradation of water quality of the downstream will be insignificant on the whole in the condition that new other pollutant load in the watershed will be adequately managed.

(3) Flora, Fauna, and Ecology

A part of the Bach Ma National Park will be included within the reservoir area of Ta Trach Dam. However, the area to be submerged does not affect the forest zone which is strictly protected in order to keep the ecosystem unchanged and the habitat of the precious species in good condition. Therefore, from the ecological view point, the negative impact on the national park is considered slim. For the ecological conservation of the park, it is enough to check whether or not the negative impacts occur by Ta Trach Dam through the ordinary inspection result of MARD that is responsible for the management of the park.

The existing studies so far reported that some of flora/fauna listed in the red book as endangered or rare species were found in the upstream area of Ta Trach Dam. However, the impacts, such as whether or not the habitats of endangered/rare species would be damaged by the dam, are unclear in the existing studies. Therefore, it is recommended that the magnitude of impacts be clarified, and that mitigation measures be developed if practical.

Huu Trach Dam will not directly affect any designated areas such as national park and nature reserve. However, the existing condition on distribution and habits of endangered/rare species of flora/fauna is unclear. It is, therefore, recommendable that the more survey be carried out to grasp the existing condition, and that adequate consideration be given if the impact on endangered/rare species is expected significant.

According to the existing studies, the major species of fresh-water fish in the Huong river are carp, catfish, and eel. Since the eel is a migratory fish species, obstruction of migration might be caused by the dam structures. Therefore, adequate consideration such as fishway should be considered in case that the eel is catadromous for spawning in the sea by passing through the dam sites.

Any components of the Master plan of Huong river basin will not directly change or affect the existing conditions of the lagoons. However, the lagoons have an ecologically fragile system. So the ecological system of lagoons might be affected indirectly due to the change of river hydrology and reduction of sediment load by Ta Trach Dam and Huu Trach Dam, although the magnitude and positive/negative direction are unclear. In the case that the change of ecological condition in the lagoons would be significant, economic activities especially on lagoon fishery would be also affected considerably. The change of fishery condition in lagoon can be considered as one of the most important indicators of ecological deterioration/enhancement of lagoon. It is, therefore, recommendable that the monitoring of fishery activities in lagoon, such as the change and trend of catch amount and fish/shellfish kinds, be carried out continuously and frequently.

(4) Landscape

The existing landscape will be changed drastically due to the construction of Ta Trach Dam and Huu Trach Dam. After the completion of the dams, however, appearance of vast water areas will also create the new landscape spot and have a potential for enhancement of regional economic activities such as tourism.

In the case that the domestic/industrial water supply plant would be constructed near the Hue city, the consideration in harmony with the existing landscape nearby is preferable because of the designation of the city as World Heritage.

11.5 Undertakings of Vietnamese Side

The project evaluation pointed out that the following undertakings or attentions of Vietnamese side are important.

(1) The provisional flood control measure as mentioned in Sub-section 8.3.8 should be kept in mind: that is, the present condition of the left side river branch located just upstream of the Hue City should be maintained until the completion of the Huu Trach Dam.

(2) The non-structural measures for flood damage mitigation or water saving as discussed in Section 8.3 which will be efficient both before and after the completion of upstream dam(s). The non-structural measures which can be implemented at a less cost should be put into execution at the earliest.