MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT (MARD)

PROJECT PREPARATION UNIT (PPU)

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ENVIRONMENTAL IMPACT ASSESSMENT

FOR NATURAL DISASTER MITIGATION PROJECT (WB4)

WORLD BANK PROJECT

VOLUME 4

MEKONG RIVER DELTA FLOOD WARNING AND MONITORING SYSTEM SUB-PROJECT

(Final Report)

PREPARED BY

ENVIRONMENTAL RESEARCH CENTER

June 01, 2005

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Investor
Project Preparation Unit

EIA Consulting Agency
Environmental Research Center
Director

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June 01, 2005

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CHAPTER 1. INTRODUCTION

1.1. Introduction

The Mekong River Delta is an area of special importance for the socio-economic development of the country in the sustainable direction. Firstly, this is a large and fertile area, and the biggest rice barn of our country, plays an important role not only for food safety, but also makes our country become one of the three biggest rice exporters in the world. The Mekong River Delta is an area of great potential in fishing and aquaculture, shrimp culture and fish culture in cages which have been strongly developed recently. Moreover, this area has great output of perennial fruit trees, enough to supply for provinces in the South and partly for whole country, and has the potential industry of processing fruit for export.

The Mekong River Delta is a rather flat area and the final part of the Mekong River downstream. Although the flood in the Mekong River Delta has the great effect in compensating the fertility for the soil, increasing the natural aquatic products, and promoting the alluvial deposit to the sea, it is also the most dangerous natural disaster affecting strongly the economic development and the life of the people in the area. Other natural disasters such as drought, typhoon and tropical depression, tsunami, collapse of river bank, salinity intrusion and other disasters also cause many damages for the area. This project only addresses flood and inundation in the Mekong River Delta. As a frequent phenomenon every year, the flood in the Mekong River Delta, in the one hand, brings many benefits for the environment, biodiversity, rich aquatic products, promotes the fertility of the soil in the catchment, maintains the ecosystem of the basin. But in every year, flood and inundation on a large area cause many damages in property and life, in agriculture and infrastructure, stagnation in socio-economic activities of the people living in the Delta. The depth of inundation is often from 0.5 to 4.0m. In big flood years, the architectural structures, infrastructure, and crops are heavily damaged by flood, particularly in big floods of the years 2000 and 2001. The most seriously damaged provinces are the ones in upstream of the Mekong River such as An Giang, Dong Thap and Long An. For instance, the flood of the year 2000 caused the loss of about US$ 250 million. Obviously, the future of socio-economic development in the Mekong River Delta depends much on measures to prevent and mitigate the damages caused by natural disaster. Experience shows that good flood warning and forecast can decrease 30% damages caused by flood and typhoon. Flood in the

Mekong River Delta is one of dangerous natural disasters, difficult to predict and without limit. Therefore, the flood monitoring strategy should be specified as a dynamic one but with limit. The facts of recent years have demonstrated the slogan "Living together with flood" is the most correct and effective direction. To realize that, apart from implementing structural projects, there must be non-structural projects, in which the project "Mekong Delta flood warning and motoring system" to raise the capability of warning and forecasting flood and inundation to serve the prevention and mitigation of natural disasters in the Mekong River Delta.

1.2. Objectives of ER

To provide information on present status of natural environment and social condition of project area; to predict impacts of project on environment in projected area; to specify issues concerning project; to forecast possible impacts on environment of the area during implementation of project and after completion; to suggest measures to mitigate environment impacts during the construction and operation to comply with the regulations on environment protection of the Socialist Republic of Vietnam as well as the environment policy of WB.

1.3. Documents and data as the basis for ER

1.3.1. Process, regulations, database, technical documents for ER

Information sources for making ER

- Results of investigation and survey on environment of projected area of the Environment Research Center, Institute of Meteorology and Hydrology.
- FS of "Mekong Delta flood warning and motoring system project"
- Data and documents on projected area.
- Summary of comments from the National Hydro-Meteorological Center, Department of Natural Resources and Environment, Hydro-Meteorological Regional Centers, Department of Agriculture and Rural Development.
- Reports on present status of environment of provinces in the Mekong River Delta
- Technical documents of project.
- Other concerned documents on topography, geology, socio-economy etc.

1.3.2. Legal documents for ER

This ER has been prepared on the basis of compliance with national laws and regulations of Vietnam on environmental and social impacts of project including:

- Law on Environment Protection of Vietnam 1993;
- Decision 175/CP 1994. Guidance on the implementation of Law on Environment Protection;
- Decision 26/CP 1996. Regulations on penalties to violations on Law on Environment Protection;
- Decision 12/CP in February 1997. Detailed regulations to implements Law on Foreign Investment in Vietnam;
- Decision 490/1998/TT-BKHCN &MT, Guidelines on verification of ER for investment projects;
- Decision 22/1998/ND - CP dated 24/4/1998 on compensation when the Government takes the land for national defense, national and public interest;
- Criteria of Vietnam Government on air quality, noise, vibration, soil, water,...
- Project on resettlement policy of Vietnam, final report. Decision on compensation and resettlement, Ministry of Planning and Investment, 6/1998.

1.4. Selection of methods to assess environment impacts

The following methods will be used in ER:

- Checklists method
- Comparison
- Expert consultation
- Field survey

1.5. Organization and process to prepare ER

Implementing agency: Environment Research Center- Institute of Meteorology and Hydrology

Cooperation agency:

- National Hydro-Meteorological Center
- Hydro-meteorological Regional Center of the South

- Institute of Ecology and Biological Resources, National Institute of Sciences and Technologies
- National Center for Social Sciences and Humanity
- Departments of Natural Resources and Environment of provinces in the Mekong River Delta.

1.6. Affected area of project

Affected area of project is the Mekong River Delta, that is 8 provinces : Dong Thap, An Giang, Long An, Tien Giang, Can Tho, Hau Giang, Kien Giang, Vinh Long of the Mekong River Delta.

1.7. The main content of ER

Chapter 1 – Introduction: objectives, methods, organization, affected area and summary of content

Chapter 2 – Description of project

Chapter 3 – Description of present status of environment: present status of natural and ecological resources, socio-economy of projected area;

Chapter 4 – Impact assessment: assess the environment impacts in projected area (positive, negative), analysis of measures to mitigate negative impacts, program to supervise and monitor environment.

Chapter 5 – Conclusion and recommendations.

CHAPTER 2. DESCRIPTION OF PROJECT

2.1. Name of project

"Mekong Delta flood warning and motoring system project"
(Under the Natural Disaster Mitigation Project (WB4)).

2.2. The host agency, and agency responsible for Feasibility study

The investor: Ministry of Agriculture and Rural Development (MARD)

Representative of the investor: Project Preparation Unit (PPU)

Agencies building Feasibility Study :

Environmental Research Center – Institute of Meteorology and Hydrology

Agency responsible for ER:

Environmental Research Center – Institute of Meteorology and Hydrology

Locations to do project:

- National Hydro-Meteorological Center
- Hydro-Meteorological Regional Center of the South
- Hydrological stations in the Mekong River Delta

2.3. Objectives and tasks of project

Project "Mekong Delta flood warning and motoring system" has the following objectives:

- Modernization of the hydro-meteorological observation system in the area.
- Modernization of the information and data processing system.
- Strengthening of material basis and equipment for the forecast in Hydro-meteorological Regional Centers and provincial Hydro-meteorological Forecasting Centers.
- Building database on hydro-meteorological conditions, topography and river system to meet the requirements of hydro-dynamic models.
- Building software, hydro-meteorological forecasting and warning model.
- Building flood warning levels and flood warning post in flood area.
- Training of specialized cadres to meet the requirements of modern equipment.

- Organizing training courses for people in the flood area to understand the guidance, notification, and warning on weather conditions, and the evolution of flood and inundation in the area.

2.4. Present status

Project "Mekong Delta flood warning and motoring system" has the objectives to modernize of the existing equipment of the hydro-meteorological agencies, specifically in hydro-meteorological stations in flood area of the Mekong River Delta. Thus, it is possible to provide the forecasts and warnings on weather conditions and flood of the Mekong River Delta most quickly and correctly to minimize the damages caused by flood. Present situation of technical equipment in the hydro-meteorological stations in the Mekong River Delta is as follows:

- Existing meteorological stations
- Existing hydrological stations
- Current flood investigation points in flood area
- Meteorological weather radar stations
- Current database and flood models.

2.4.1 Existing meteorological stations

There are 14 meteorological stations in operation in the Cuu Long River Delta. The parameters observed are air temperature (T_k), ground surface temperature (T_d), air humidity (U), air pressure (P), rainfall (R), sunshine hours (S_h), wind (W) velocity and direction, evaporation (Z), radiation (B), rainfall quality and dust deposited. The equipments/ instruments are obsolete, old fashioned like: ordinary mercury thermometer, psychrometer, Vild meter measuring velocity and direction of wind, pluviometer of container type, etc. The ordinary observation frequency is 4 times a day (at 1:00, 7:00, 13:00 and 19:00 h).

In addition, in the CLD there are 61 rainfall measuring. They are regularly distributed in the CLD, and may meet the requirements for modeling and computation for the meteorological and hydrological regimes over the delta, and serve plan making, construction, agricultural development, etc as well.

2.4.2. Existing hydrological stations

There are 40 hydrological stations, in which five stations are measuring discharge (Q): Tan Chau (Tien river), Chau Doc (Hau river), Vam Nao (Vam Nao river), Can Tho

(Hau river), My Thuan (Tien river). The other stations measure water level (H), rainfall (X), river water temperature (T); some of them observe water quality (C_n), salinity in river water (S). The water level recorders are of Valdai (Russian daily recorder), American weekly, Stevens recorder, French Tital, Switzerland Eobar, Russian GR38. The current meters are usually of propeller type, cup type; only at Tan Chau station (Tien river) the acoustic Doppler current profiler (ADCP) is used. Their data are recorded on paper and may be read out after a day (Valdai) or a week (Stevens), etc. Therefore, the data cannot be timely transmitted to the SHMFC, to other provincial Hydro-meteorological forecasting centers, to other potential users/ beneficiaries.

2.4.3. Existing investigation posts in flooding areas

At the present, there are in total 87 investigation posts distributed in the flooding areas of the CLD. These posts were established at different times for independent projects with the main purposes of investigating the flood water flowing in and out of the DTM and TGLX areas. Only at 21 posts, discharge measurements were made periodically, at the remaining posts only water levels were measured.

2.4.4. Meteorological radar

At the moment, a radar system that (Doppler DWSR from the US EEC Co.) is in the process of installation, experimental operation in Ho Chi Minh City, do not produce valuable rain information yet. So, in the first phase of sub-project implementation (from 2005 to mid 2006) we plan only the integrating and utilization of data from existing radar stations.

2.4.5. Current database and flood models

Although flood forecasting and warning activities for the CLD have been carried out recently, the present flood warning and forecasting system is inconsistent, and inadequate for the ever complicating flooding situations of the area. Mathematical models for describing and forecasting hydrological regimes of the Mekong Delta are the main tools used to forecast the changes of water levels and discharges at different sites in the inundation areas of the Cuu Long River Delta in accordance with different scenarios. However, the hydrological and hydraulic regimes of the Cuu Long River Delta are very complex and depend on lots of factors, which are difficult to define, such as flooding plains,

low-lying areas, and the distribution of flows in dense canal system etc. Flood calculation models for the Cuu Long River Delta have been studied over 30 years (mainly the last 5 years), but these still contain many constraints. Hence, it needs to upgrade mathematical models as well as review and analyze the calculation results seriously. The experiences in construction of hydraulic works in a large area of the Cuu Long River Delta should be carefully studied and then adjustments should be made to the models.

(i) Overview of the hydrological and meteorological models: Hydrological and meteorological models for forecasting purposes are necessary tools in protection and mitigation of adverse affects of storms, flood and flooding. These models should have friendly interface with users, fully automatic, may be connected with other softwares as a unified system. The model output should be accurate enough for decision makers to give directions to the disaster protection and mitigation works, to save people in the vulnerable areas. They may be flexible enough to be upgraded whenever necessary; may be link to GIS in receiving and collecting data/ information, be connected to other modules of the system (to use data stored, to receive real time data of water level, rainfall and forecasted rainfall value, analysis of forecasts, etc). The modules of the model may be:

- Data module: data processing, analysis, check before put into the model;
- Module for checking other component modules;
- Operational forecasting module: for upstream station, downstream station and warning of flooding;
- Post-forecast module: to process forecast results, timely errors record, statistical analysis, forecast bulletin preparation;
- Interface: connection of all component- modules.

In general, hydrological models may be divided into:

- Flood forecasting model for upstream stations;
- Flood forecasting model for delta mainstream station;
- Routing model for forecasting/ warning of flooding in the CLD.

(ii) Some of existing hydrodynamic models used in the CLD are listed below

1) The SSARR (Stream Flow Synthesis and Reservoir Regulation) model. It was developed in 1959 by US corps of engineers and used to study Mekong runoff in 1967. It has 3 components: to compute runoff from rainfall, routing in river channels and estimating

the reservoir regulations affects. It is difficult to be applied for the Vietnam's CLD, but still is applied in Mekong river Commission to make forecast for region upper Kratie.

2) The SOGREAH model. It was developed by French scientists in the years of 1960(s) by the contract made by UNESCO. It may be used to study the over bank flow in trough cells of the delta. Cells may be of boundary type, river type and plain type, that link all together like river and dams. There were 200 hydrologic stations installed to measure flow during July- October in 1963, 1964, 1965 to collect data for the model.

3) The MASTER model. It has been developed on the basis of WENDY (Water Environmental Dynamic) software and suitable for purposes of watershed management, to build hydraulic structures on the channel and is composed of river model delta flood model, delta tidal model. To be applied in the CLD it has trouble with topographic and flow data in the delta.

4) VRSAP (Vietnam River Systems and Plains). It was developed by Vietnamese modelers in the years 1978-1984 and widely used in the Vietnam CLD for planning, designing purposes. It includes about 3000 km canals and up to that date topographic data. It has success in flood planning. But its software is not as flexible as WENDY, does not include water quality aspect (salinity intrusion, mineral dispersion, etc…).

5) The SAL model: it was developed by Dr. Nguyen Tat Dac in 1987 to study salinity intrusion in the Vietnam's CLD in 1990 and the Red river delta in North Vietnam.

6) The MEKSAL model was developed by V. Pareeren in 1974 and modified by Le Huu Ty to study salinity intrusion in the Vietnam's Cuu Long River Delta.

7) The HEC – RAS/UNET model was developed by US Corps of Engineers and based on HEC-2. It is not suitable enough to study the Mekong Delta because it is not able to simulate structure controls and is not particularly suited to non-specialist users, not consider salinity and sediment transport processes.

8) The HYDROGIS model was developed by Dr. Nguyen Huu Nhan in SVRHMC. Its data entry is user friendly, it may be interfaced with GIS, etc. The model is used for inundation mapping, flooding forecasting in the Vietnam's CLD.

9) The ISIS model is jointly developed by Halcrow and Hydraulics Research Wallingford and widely used in UK, Europe. It has advanced features for flood plain modeling and structure controls; it has user friendly data entry, time series, GIS based flood mapping, etc. Its flood forecasting module needs further to be developed.

10) The KOD model is developed by Dr. Nguyen An Nien from the Southern Institute of Water Resource Research in 1974 to be applied in Red river basin planning (1975-1993);

it has links with water quality and 2D components. It has been recently applied to the Mekong delta using similar data input of VRSAP. It is not capable to simulate sedimentation and erosion.

11) The Mike 11 model is developed by Danish Hydraulics institute and has been applied for large number of projects in different parts of the world. It was used to study Cambodian part of the Mekong. It has module for sediment simulation, water quality study. It has module for flood forecasting, but GIS interface takes rather long time.

12) The multivariate regression software. It may be applied to get regression between water level at station in forecast with some nearby water level stations. It is simple in use, may be coupled with tendency analysis, experiences of forecast man to obtain quick, good results. But due to quick changes in flooding areas its parameters may be changed, leading to rough mistakes.

(iii) Model/ software: For model(s) development and running it needs up to date topographic data, for example the channel sections data after historical flood in 2000, flooding areas, topographic data, the roads constructed, the canals, dykes, flood control structures built recently, the regulation rules of spillways, the drainage systems, and especially good, timely collected and transmitted hydrologic, meteorological data, including data collected and stored in various agencies.

2.4.6. Existing data communication system

a) At the time being the Central Center for Hydro-meteorological forecasts has 3 channels linking Hanoi with Global Telecommunication System (75 baud). The channels have some shortages like:

- Time for data collection from abroad to long: more than 5h for every reception.
- The information received is numeric, graphical and pictures, images are unable to receive.
- Data recorded at local stations or posts are mainly on paper and are impossible to timely transmit to Ho-Chi-Minh City's forecasting unit, to other provincial Hydro-meteorological forecasting centers, to other potential users/ beneficiaries.

b) The MSS system has automatic switch on mechanism for automatic data collection, transmission, and storage. It receives information from various channels, transform it into data bulletin, report; it collects Vietnamese information for transmitting abroad and

automatically delivers them as timely scheduled; collects information from international centers to transmit them to regional Hydro-meteorological centers; put the received international data on map for operational forecasting works.

c) The WAN system is for transmission observation data, the operational outputs of the Central Center for Hydro-meteorological forecasts to provincial HMF centers via Dial-up Networking (transmission speed 28800bps). WAN system provides data, information, facsimile map, satellite images, domestic meteorological forecasts from provincial HMFC(s) to Ha Noi. Another WAN links SRHMC with other HMFC(s) in provinces of the Vietnam CLD, creates local WAN. Through this local, regional WAN Ho Chi Minh City center provides forecast outputs to provincial HMF centers.

d) The transmission system is to send data from Central Center for Hydro-Meteorological Forecasts to regional HMC(s) via satellite. This system composes 2 main parts:

- A line has been established to transmit data from CCHMF to Vietnam Central Television Broadcasting Center. It works all day round to transfer data to VTV1 channel.
- At each Regional HMC a parabolic 3.8m diameter has been established to receive information from VTV1 Channel to provide them for provincial HMFC(s) through WAN network.

Existing system remarks

In summary we may see that the available hydrological, meteorological stations do not meet the requirements in flood warnings and forecastings:

- The meteorological stations use obsolete instruments, without data logger and modern two ways radio links. The data colleted cannot serve as direct input to various models for real time forecastings. So it needs to upgrade these stations at least with model equipments meeting the demands for informing of current meteorological conditions, real time meteorological warning and forecasting, real time hydrological models operation.

- The number of hydrological stations measuring discharge still are limited, cannot give solution to the flood diversion/ distribution monitoring in Mekong branches of the CLD. That does not meet the requirement of flooding water release/ drainage. The number of hydrological stations/ posts in flooding areas are very scarce, that does not meet the requirement of current flooding situation information, hydrological warnings and

forecastings. The equipments of the hydrological posts in flooding areas should be automatic warning, water level recorder with data logger, two ways radio links. They should be provide with warning pole for each post to show local people of the current situation (concerning water level warning number 1, 2 or 3, the flood peak levels ever occurred…) in line with the World Bank strategy of Community based Disaster Mitigation (CBDM).

- The current instrumentation in provincial Hydrological forecasting Centers in CLD is under standard level to deal with data collection, information, warning and forecasting for flooding areas; to have smooth, reliable communication with stations/ posts in the province and with SRHMC.

- The available models do not permit hydrological forecasts for stations in the Mekong mainstream and its tributaries/ branches and the posts in flooding areas. Some new models should be developed in meeting these demands.

- The technical staff does not meet the requirements to deal with new instruments/ equipments and models, they should be trained in this relation.

- The data base should be upgraded and modernized in compliance with models newly developed, studied in CLD and for their provision to various users.

- Etc.

2.5. Project Description

"Mekong Delta flood warning and monitoring system project" execution should be carried out in three phases consecutively.

The first phase of project implementation from 2005 to 2006:

- Upgrading available hydrological stations
- Upgrading of 10 available discharge station
- Upgrading of available meteorological stations
- Procurement of 6 ADCP for flow investigation
- Development of meteorological models in CLD
- Development of hydrological models
- Establishment of 44 hydrological posts in flooding areas
- Establishment of warning water levels for the flooding areas
- Training courses

The second phase of project implementation from 2006 to 2007

- Further installation of 44 hydrological posts in the flooding zones.
- The technological transfer of hydrological, meteorological models/ softwares to provincial HMFC(s).
- Hydrological, meteorological data base establishment
- The topographic map

The third phase of project implementation (2008- 2009)

- The establishment of last 44 hydrological posts in the flooding zones.

2.5.1 Modernizing meteorological stations

To meet the demands of data provision, information service, warning, forecasting we should upgrade the available instruments together with their timely, concise, accurate transmission to SHMRC, provincial HMFC(s) and other users, researchers. Among these parameters the vital one for this project is rainfall amount for model(s) development, calibration, running, for rainfall information, forecasts, for computation of flooding severity and so on. The instruments used should have data logger, two way communication/ data transmission, automatic warning, etc.

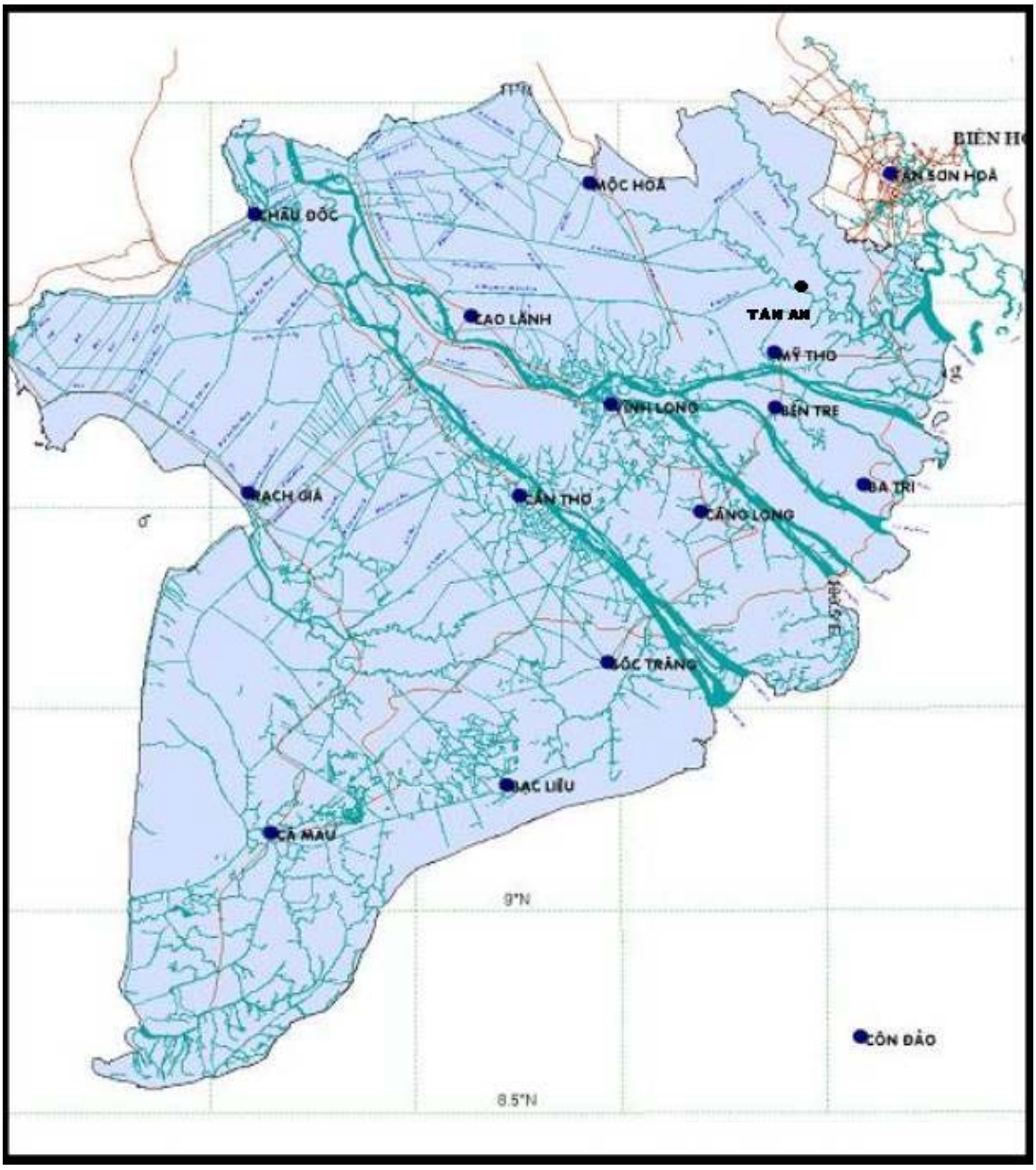

Fig. 2.1. Map of existing meteorological stations in the Cuu Long River Delta

2.5.2 Modernizing hydrological stations

The current meters are usually of propeller type, cup type; only at Tan Chau station (Tien river) the acoustic Doppler current profiler (ADCP) is used. To obtain good results in model(s) running, more stations in the mainstreams should be installed and put in operation like: Vinh Long (Co Chien river), My Tho (Tien river), Cho Lach (Ham Luong river) and Hoa Binh (Tien or Cua Tieu river). These stations, together with five available stations measuring discharge (Tan Chau, Chau Doc, My Thuan, Can Tho, Vam Nao) should be

equipped with ADCP and appropriate boat(s) for discharge measurements. Due to long distance between mentioned stations, ADCP is hopefully provided for each station. A sediment sampler is expectedly provided for each of these stations as well.

For measuring flow going into and out of Dong Thap Muoi, Tu Giac Long Xuyen, Tay Song Hau regions, we propose to equip two ADCP(s) for each of mentioned three regions: one for measuring discharge flowing in and another for monitoring the out flow at the same time. For example, one ADCP at the entrance of Vinh Te canal, another at the end of the canal.

To monitor the flow from Mekong river to Vam Co Tay and Vam Co Dong river, two stations Tan An (Vam Co Tay river), Ben Luc (Vam Co Dong river) in Long An province are proposed to collect discharge data as well.

So ADCP(s) are expectedly provided for 8 stations in the Mekong mainstream, two stations in Vam Co rivers, 6 ADCP for 3 flooding zones for flow monitoring. In total 16 ADCP(s) are needed.

The measurement of discharge flowing into/out of the DTM, TGLX, Tay Song Hau regions is expectedly to be done at 21 posts (points) of the following itineraries:

Chau Doc to Lo Te (An Giang province):	4 posts
Rach Gia to Ha Tien (Kien Giang province):	4 posts
Hong Ngu - Cao Lanh - An Huu (Dong Thap Province):	5 posts
An Huu - Long Dinh- Ben Luc (Tien Giang province):	6 posts
Tan An - Long Khot (Long An province):	2 posts

The discharge should be measured every 2-3 days. It is obvious that flow at these posts (points) would be suffered with backwater either from downstream river (canal) or/and by tide from the Bien Dong Sea and from the Gulf of Thailand. So it is necessary to have additional posts measuring water level to calculate the fall of water slope in rivers/canals. Their number is 16 posts (equipped with water level recorder, with 2 checking observation/ day).

2.5.3 Upgrading ten provincial Hydro- Meteorological Forecasting Centers

The provincial Hydro- Meteorological Forecasting Centers will be upgraded by:

- Provision of necessary facilities, instruments and devices for operational forecasting works.
- Reconstruction of office house

- Transfer of hydrological, meteorological models to each provincial Center and training technical staff to apply these models in hydro- meteorological warning/ forecastings.
- Trainning Course, to train the technicians in provincial Hydro- Meteorological Forecasting Centers.

2.5.4 Establishment of hydrological posts in flooding areas

(i) The objectives of establishment of hydrological posts in flooding areas are the following:

- To collect data of water level (H) and rainfall (X), for monitoring the flooding process in the areas;
- To provide timely H and X data to provincial HMFC(s), SRHMC for timely informing about current condition in area, warning and forecasting of water level and rainfall in the region;
- To provide data for socio-economic development planning, construction (houses, bridges, roads….) and for researches (modeling, planning…).

The concrete hydrologic post location therefore should meet some demands:

- To give real picture of the flow into/ out of the flooding areas, real conditions of the flooding in the district of concern;
- To transmit timely the data collected to SRHMC, provincial HMFC of concern, to local authorities for timely, quick and precise actions thereafter;
- To serve local people with hydrologic data at the station (water level, rainfall, including warning and forecasting values), which is in line with the community-based disaster management strategy of the WB4 project.

(ii) The hydrological posts locations: Hence we propose for the first time to establish 2-5 posts in each district, in average: 3 posts / district. Most of the posts are coincided with the ones proposed by SRHMC. The 132 hydrological posts proposed in this sub-project are listed in annex 1 and their geographical locations are shown in Fig. 2.1. They are distributed in the 8 frequently inundated provinces of the CLD namely: An Giang, Can Tho, Hau Giang, Dong Thap, Kien Giang, Long An, Tien Giang and Vinh Long.

(iii) Post datum, warning levels establishments: The height of a post should match the flood level of that particular site. The elevation of flood warning posts will be taken with

reference to the national datum. On the posts, some critical flood levels will be marked. The field flood survey network is attached to the flood warning posts by automatic water level recorders.

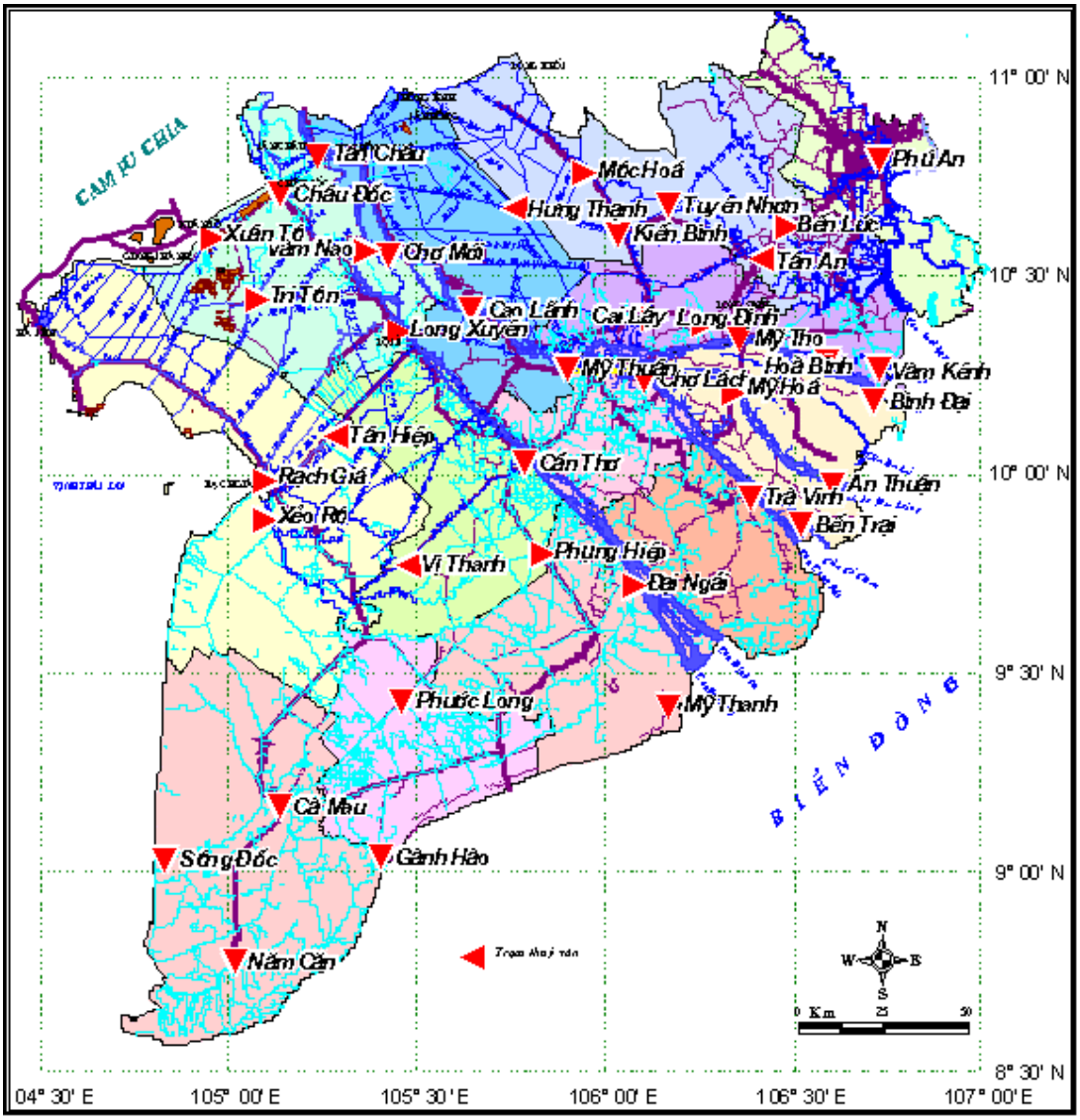

Fig 2.2. Map of existing major hydrological stations in the Cuu Long River Delta

(iv) Equipments, instruments facilities for the posts:

The 132 newly-proposed posts are equipped with water level recorder (the one with automatic warning, two way connection, like the Water Log Model H-350 with data logger, chart recorder, GOES transmitter, remote display, etc.). All posts should be equipped with telephone/ mobile phone or Motorola type phone to keep good connection with SRHMC, provincial HMFC, other posts in the district.

The process of 132 posts installation may have 3 phases:

- In the first phase 44 posts (the key one among three) are installed, one post for each district.
- In next two phases the remaining posts are established, one post for a district in each phase.

The equipments, facilities, transmission devices, etc. should be provided at the time of installation. Staff should be trained adequately, timely in this relation. A training course for local technicians and hydrological post observers, other officers of concern should be organized to guide the participants in operating and using of hydrological, meteorological information / data, warning, forecasting products and local people service in this relation.

(v) Establishment of warning levels for flooding area:

a) At the moment warning levels have been set up for 4 stations in Cuu Long mainstreams and for 2 other stations on Vam Co river, while the flooding depth is varying from 0.5m to 4.5m, the damages of flooding depent so much on natural conditions, methods of planting and plantation diversity. So it is very necessary to establish the warning levels for each sub-zone, basing on that the effective scenerios for flood protection should be developed for sub- zones. The warning levels would be established for each sub- zone on the basis of floods assessment, their impacts on socio- economy in each sub- zone for various flood/ flooding levels with due reference to warning levels at basic stations (Tan Chau on Tien river and Chau Doc on Hau river). For the purpose some 2- 5 posts (in average 3 posts) for each district in flooding provinces should be set up. The water levels in these hydrological posts should be reffered to while issuing the information, warning and forecasts as well as setting up the warning levels for the district. For the purpose some warning pole should be established in each post: the pole height should be higher than maximum water level ever happened at the site, the pole datum should be set up/ connected to the national datum system; warning levels should be clearly marked on it together with historical flood peak levels ever occurred at the post. At each post an automatic warning water level recorder would be installed (the H-350 Water Log device or Motorola equipment for example). The post will have two way connection with local posts, with SRHMC in Ho Chi Minh City and with local (district, provincial) authorities and mass media systems (radio, television…) for flood information/ warning/ forecasts.

b) In this relation the following works would be done:

(1) Establishment of water level posts in flooding areas (in average 3 posts in a district). In total there will be some 132 posts to be set up.

(2) To install warning pole with marks of warning levels, historical flood peak levels ever occurred at the site.

(3) To set up the warning levels (let say level 1, 2 and 3) for each district in the flooding zones.

(4) To train the technicians in provincial Hydro- meteorological Forecasting Centers in relation of hydro-meteorological information, warning and forecast (model running; issuing of information, warnings, forecasts for the locality; hydro-meteorological service of local authorities/ people…).

(5) To guide local people in use of the provided hydro-meteorological information, warning, forcasts.

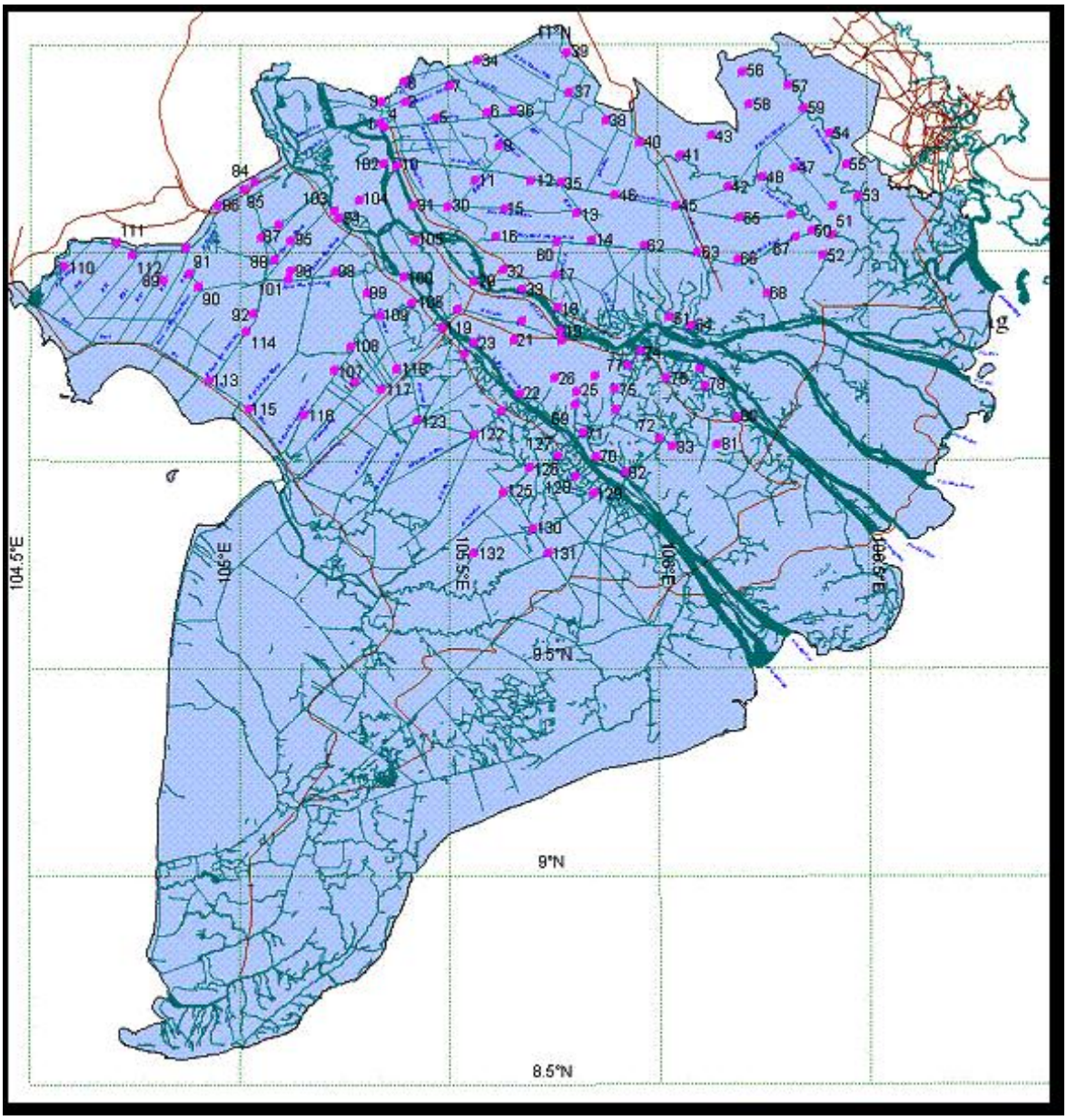

Fig 2.3. Map of 132 newly proposed hydrological posts in the flooding areas of the Cuu Long River Delta.

2.5.5 Meteorological radar

Radar systems are very useful to monitor the intensities of rainfalls and their distribution as well as air turbulence over the area. They greatly help weather and flood forecasting and avert losses from natural disasters. Data acquired from the radar system are not necessarily used for precise modeling purposes like basin modeling, flood modeling, etc. due to low accuracy of obtained data from the radar system. Therefore, both gauge observation network and radar systems should be developed in the basin to meet the requirements. After investigating the possible practical use of weather radar data in Ho Chi

Minh City station, two new weather radar stations at Can Tho and Pleiku (Fig.2.4) covering lower parts of the Mekong river watershed are proposed to be set up ***(but only if additional funds available)***.

(i) Second phase (from mid 2006 to 2007): The preparation works for radar installation should be done:

- To investigate the site of radar location (in Can Tho and Pleiku for example), that should meet the technical demands for radar operation (power line, communication system, etc).
- To get permission from state agency responsible for radar wave frequency use, for the maximum effective radius of the radar…
- To get permission for radar site, radar operation, the area for safe radar operation, etc.
- To get necessary facilities for radar installation like crane, car, etc.
- To build office house, radar foundation, power supply post, etc.

(ii) Third phase (from 2008- 2009)

- Installation of two radar systems newly bought
- Training of 6 specialists: 3 with University degrees (one in radio techniques, two meteorologists), they should be trained on radar meteorology, with good command in English, good computer operation technique.
- For the purposes, training courses should be organized:
  - 1st training course on radar meteorology with one year of practical training abroad (USA/Japan or Australia) for senior staffs (2 persons) in the weather and flood forecasts.
  - 2nd 6 months training course on radar meteorology in USA/ Canada/ Japan/Australia or China for meteorological engineers.
  - 3rd 6 months training course for mechanical engineers (radio technician, information technician).
  - Fourth 1month training course for radar observers.

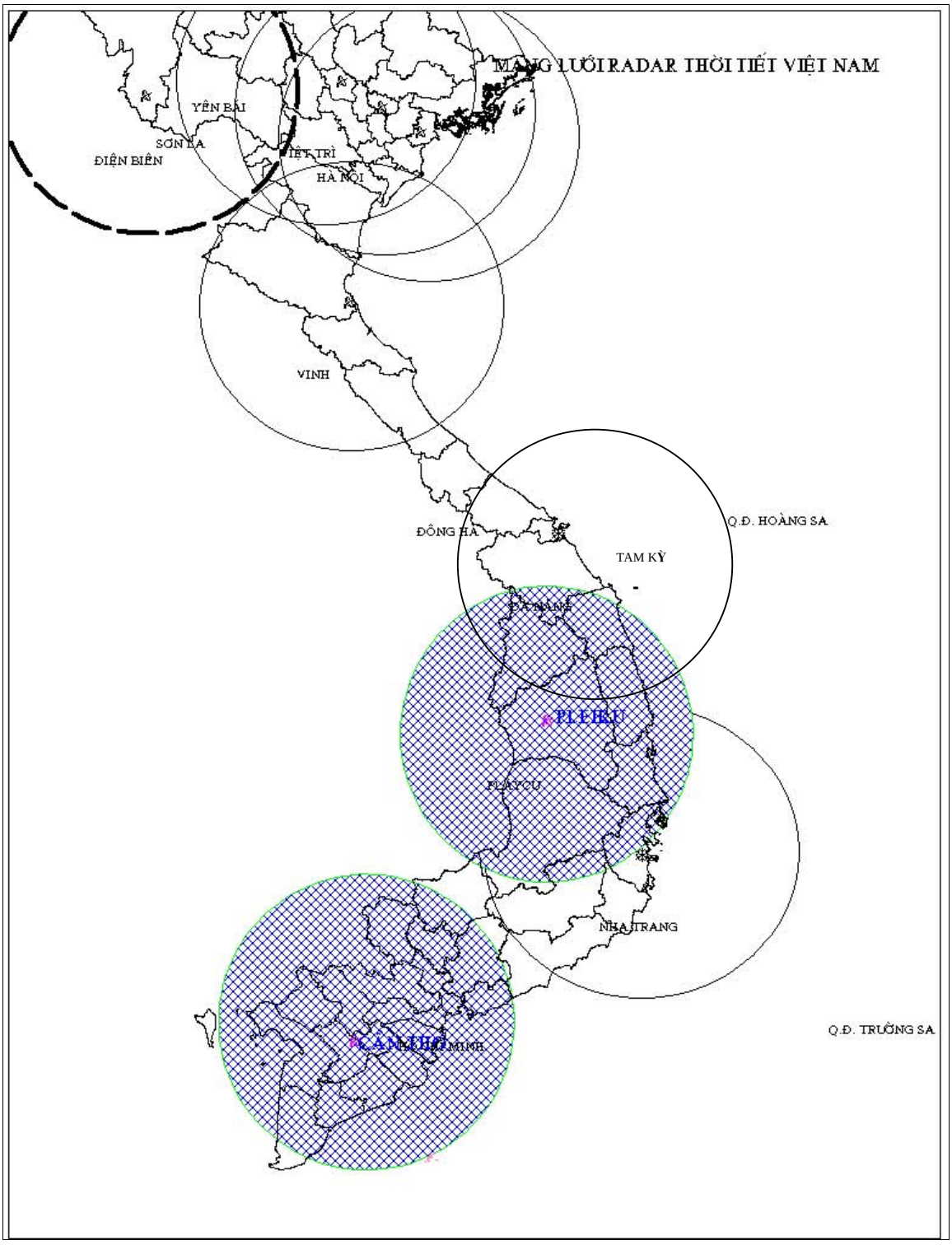

Fig. 2.4. Map of the existing weather radar stations in Vietnam - the blue circles are the footprints of the two new proposed radar stations in Can Tho and Pleiku.

2.5.6 Hydrological and meteorological forecasting models

(i) The flood/ flooding forecasting system: consists of two parts namely hydrological flood modeling and rainfall estimation:

- **Flood forecasting and warning techniques** used in the system are based on latest advanced flood models allowing the forecasting of upstream flood, computing and forecasting the flood in the main stream and in the inundation areas of the CLD. These models take into account the existing hydrological and transportation infrastructures such as bridges, drainages, outer dykes and overflow dykes… In addition, the rainfall forecasted from various numerical models and rain cloud observed from high-resolution satellite is used as input to the flood model in order to increase the forecasting time of the model.

Within this sub-project framework, following hydrological models may be proposed for consideration:

1) Upgrading flood forecasting model for upstream stations (form Kratie downward):

- Module for calculation of runoff from rainfall for upstream stations/ areas.
- Prolong the forecast time by taking into account the water concentration time on the basin.
- Model errors analysis for adjustment of forecast.
- Interface with other modules to receive rainfall forecast from other models.

2) Model for flood routing and flood forecasting for downstream stations:

- Flood routing to forecast water level at downstream stations on mainstream.
- Flood routing for stations on mainstream tributaries.
- Model error analysis to adjust forecasts.

3) Hydraulic model for flood routing and flooding warning in downstream areas. These models will help:

- Flooding areas mapping: submerged areas, flooding depth of various recurrence frequencies.
- Analysis of flood damages, losses and the severity of flood (extension of flooding areas, human lives losses, property damages…).

4) Application of MIKE-11 - GIS developed by Danish Hydraulics Institute (DHI), that composes of NAM model (for flood forecasting from rainfall), MIKE 1- Flood that computes, forecasts river runoff and issues warning of flooding. The latter is widely used in

many countries over the world, in Asia to make flood forecasts in Munchi and Songkla rivers in Thailand, in Bangladesh, Indonesia.

5) ISIS software made by Wallingford Hydraulics Research Institute and Halcrow to compute forecast flood and flooding. That composes of computation module and run off forecast from rainfall values, river flow and flooding warning. That may be used by the Mekong River Commission for the Cuu Long river delta. In Vietnam this model is applied to compute flood diversion and water resources development in Day river basin (donated by the Netherland).

6) National Weather Service River Forecasting System (NWSRFS) software developed by USA National Weather Service (NWS). It includes SACRAMENTO model and SSARR model to makes hydrological forecasts from rainfall and hydraulic model FLDWAV for hydraulic calculations in emergency cases like flood diversion, over-bank flow, dyke breaking, dam breaking. The NWSRFS is ready to be transferred to potential users.

7) HEC-F model developed by Hydrologic Technical Center (USA) and composes of HEC-F model to make rainfall- runoff forecast, UNET model for flood computation in river system. It is widely used in many countries (ASIA) and in Thu Bon river basin of Vietnam. Recently it is modified to HMS and HEC- RAS with graphical interface that is favorable for users.

8) Some models developed and applied in Vietnam:

- DHM model made by Institute of Meteorology and Hydrology and applied to flood/ flooding warning in Thu Bon/ Vu Gia river basin.
- HYDROGIS model made by Dr. Nguyen Huu Nhan and used to make flood/ flooding forecast in MKD.

➢ **Model for rainfall estimation and forecasting**: In order to increase the accuracy of the flood forecasting in the CLD, all hydrological models require input of estimated rainfall or forecasted rainfall at various times for the whole watershed. The existing rainfall should be computed in details in both temporal and spatial dimensions. Therefore, it needs the rainfall estimation by high-resolution cloud imageries and weather radar data combined with the real rainfall observed at various rain gauges over the whole watershed.

The forecasting of heavy rains has been being paid much attention lately due to high interest of governmental decision makers, socio-economic development and natural disasters protection and mitigation of their damages and losses. Heavy rain forecast was studied in many developed countries like USA, Russia, Japan, Australia, Greek, Bulgaria, Romania, India, Italy, etc. The main methods used for the purpose are:

- Synoptic method: the most currently used method to make rainfall forecast in the cases of heavy catastrophic rainfalls. The output is qualitative forecasts of medium/ heavy/ torrential rainfalls;
- Statistical method: it is a simple, objective method and often used in operational meteorology. The accuracy of the method depends on collected data (short/ long term data series);
- Numerical method: it is widely used in developed countries with high resolution and more effective than mentioned above methods;
- Ensemble forecast method: this method is newly developed, used in many operational forecasting centers. It considers the atmosphere as statistical ensemble, may be described and simulated by observations and numerical models. The ensemble of various forecast made may be more precise than single separate one;
- Multivariate regression method;
- Analogue method;
- Etc.

The numerical method has been being used, modeled in many regions like RAMS, ETA, MM5, WRF, RSM (in USA), ALADIN (France), ECMWF (Europe), CCM, DARLAM (Australia), etc.

The MM5 model is a numerical model, requires strong computer system to carry out. Rainfall forecasts may be made for 12, 24 and 36h in advance; horizontal resolution is 15 km. Experimental forecasts were made for Taiwan on 25 May and 25 June 1998. Another version MM5-V3 has been applied for experimental forecasts in Vietnam for 22 and 23 October 2001 for the Nghe An, Ha Tinh provinces; for early July 2001 for the Thai Nguyen, Bac Can provinces and for 12 November 2001 for the Phu Yen, Quang Ngai provinces. The results are fair and require further studies, experimental forecasts for other areas of the country including the Vietnam's CLD. A study team lead by Mr. Hoang Duc Cuong (Institute of Meteorology and Hydrology) has been recently established to study "Heavy rainfall forecast in Vietnam", but the areas of concern so far are Northeastern, Northwestern, Central Vietnam and the Central Highlands. We may hope for additional funding to this

topic to extend study areas to the Vietnam CLD, especially the flooding areas in the DTM, TGLX...

(ii) Topo data input: There has been quite a large change for the terrain and the river system of the CLD recently due to the construction of roads, irrigation and drainage system, river-bank erosion and river course changes in the areas. It is therefore to update digital map (DEM) of the entire CLD at the scale of 1:5000 and the river-bed data to be used for the development of hydrodynamic models of flood/inundation planning and control, hydrological forecasting, floodplain mapping, also for setting up warning levels for sub-regions and flood risk forecasting. The quality data are expected to be available for use at the Department of Land Administration.

2.5.7. Modernizing communication and information

In the geographical conditions of the region with the length of hundreds kilometers, flood and inundation happen over large areas of 8 provinces during the flood season. Due to high level of technology of telecommunication infrastructure of fixed and mobile telephone networks, which could provide reliable communication in very severe flood conditions, so real-time information will be collected to the provincial forecasting centers via telephone lines, and then transmitted to stations via WAN. Hence, we may propose the following communication system in the Vietnam CLD in relation with this sub-project:

1. Telecommunication via dedicated line: telecommunication system by radio between the sites (posts, stations) and the provincial HMFC; and through the dedicated line between the provincial centers and SRHMC in Ho Chi Minh City and the Central Center for Hydro-meteorological forecasts (CCHMF) in Hanoi.
2. Telecommunication via satellite: telecommunication system by radio among the sites (posts, stations), the SRHMC and CCHMF;
3. E-mail through public telephone lines or mobile phone from the sites to provincial HMFC, SRHMC, it needs personal computers and mobile phone at the posts/ stations;
4. E-mail via dedicated line such as optical fibber network from posts (stations) to provincial HMFC, SRHMC.

These are communication systems for hydro-meteorological informing, warning, forecasting purposes. For data collection / processing objectives we may have:

a) Online data collection, processing and archiving: automatic data collection system by radio and through the dedicated line from telemetry stations via provincial centers and to SRHMC;
b) Semi-online data collection with manual data input into the processing, archiving system, into the database (data in readable form sent by public telephone or through dedicated lines);
c) Off-line data collection: manual input to the data collection, processing system (data on FD, CD, reports in journals, in papers, etc.)

In the conditions of flooding areas the mobile phone system/ telephone system may be preferable in conjunction with ordinary post system and automatic two - way connection system set in water level recorders between hydrological posts with provincial HMFC(s), SRHMC and with district, provincial administrator offices.

The responsibilities of each level are:

- CCHMF: to make flood forecasts for upstream stations and at Tan Chau and Chau Doc stations as well;
- SRHMC: to make flood forecasting for stations in the CLD and key posts in the provinces over the entire region, flooding forecast for CLD;
- Provincial flood forecasting centers: to make flood warnings and forecasts for hydrological posts in the province and other sites upon requirements and contracts with local authorities and people.

CHAPTER 3. SUB- PROJECT DESCRIPTION

3.1. Natural condition

3.1.1. Position

As the southernmost part of the Mekong River basin, the sub-project area - the Cuu Long River Delta (CLD) - is located between $104^0$30'-$106^0$48' E Longitude and $8^0$30'-$12^0$30' N Latitude. With an area of 3.978.600 hectares covering more than 5% area of the Mekong basin or 12% of the whole Vietnam territory, the CLD (Fig. 3.1) is bounded in the north by Cambodia-Vietnam border, in the east by the Vam Co Dong river, in the south by the Bien Dong Sea and in the west by the Gulf of Thailand. The CLD has characteristics of a peninsular with the sea-coast line of 700 km.

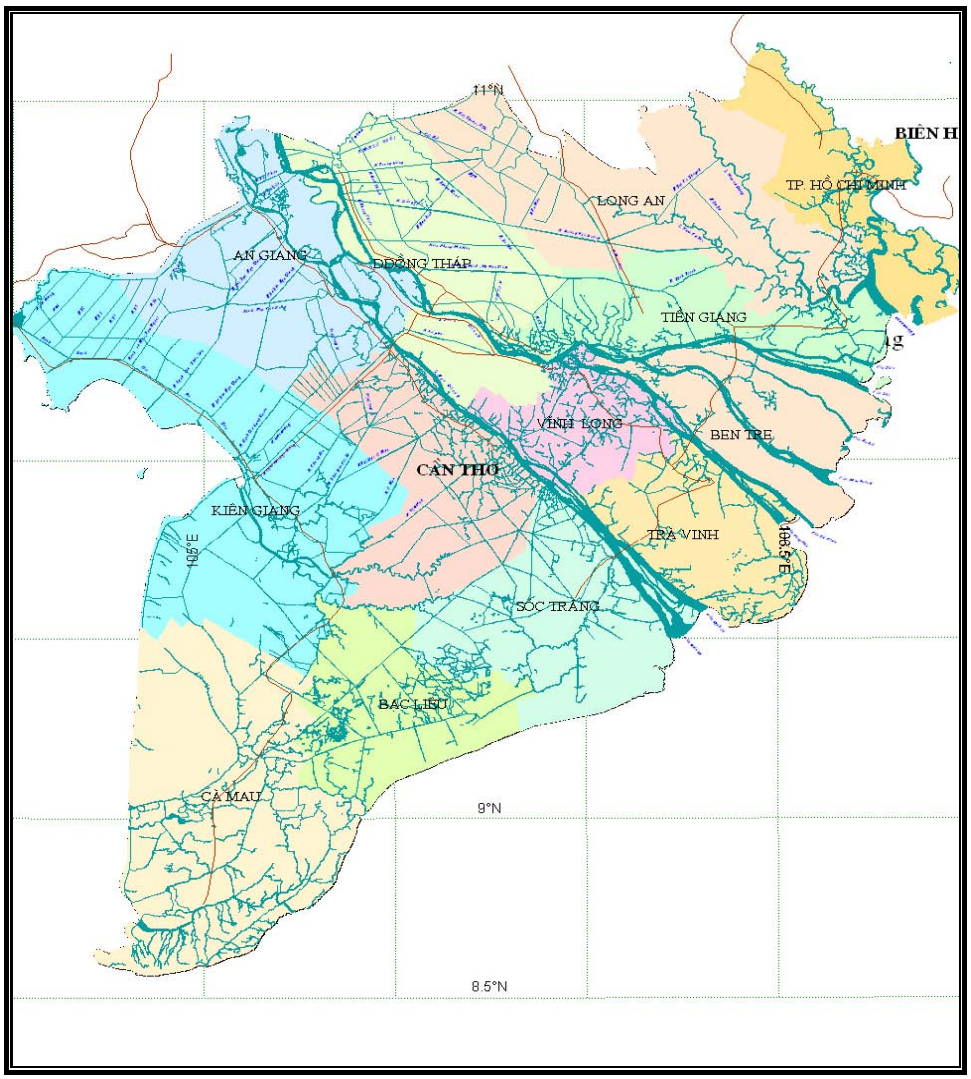

Fig. 3.1 Map of the sub-project area - Administrative map of the Cuu Long River Delta

(Source: DMU website, UNDP project VIE/97/002)

3.1.2. Physico-geographical conditions

3.1.2.1 Topography and landforms

Topographically, the CLD is considered to be low-lying alluvial deposits and rather flat. Except for a small mountainous area with altitude over 100m in An Giang and Kien Giang provinces, most of the lands are at the elevation from 0.5-3.0m above mean sea level (a.m.s.l). In general the topography tends to lower from the north to the south and approximately 60% of area is under the elevation of 1.0m a.m.s.l. Along the Vietnam-Cambodia border, there is an old sedimentation edge with elevations from 1.0 to 4.0 m declining to the south. Due to sedimentation, land along the Tien (Mekong) river and the Hau (Bassac) river is high, with elevations of from 1.0 to 3.0m a.m.s.l. Generally, inundation areas of the Mekong Delta in Vietnam are grouped into four large areas such as: the Dong Thap Muoi (DTM) area; the Long Xuyen Quadrangle (TGLX); the Western Part of the Bassac river; and the area between the Mekong river and the Bassac river. The Dong Thap Muoi area was a naturally formed closed inundation area. The area between the Mekong river and the Bassac river was formed in a gutter-like shape with high elevation along the rivers and low elevation in the middle. The land forms of the western part of the Bassac river, and the Long Xuyen Quadrangle decline from the Bassac river to the Gulf of Thailand side, so the flooded areas here are called open inundation areas.

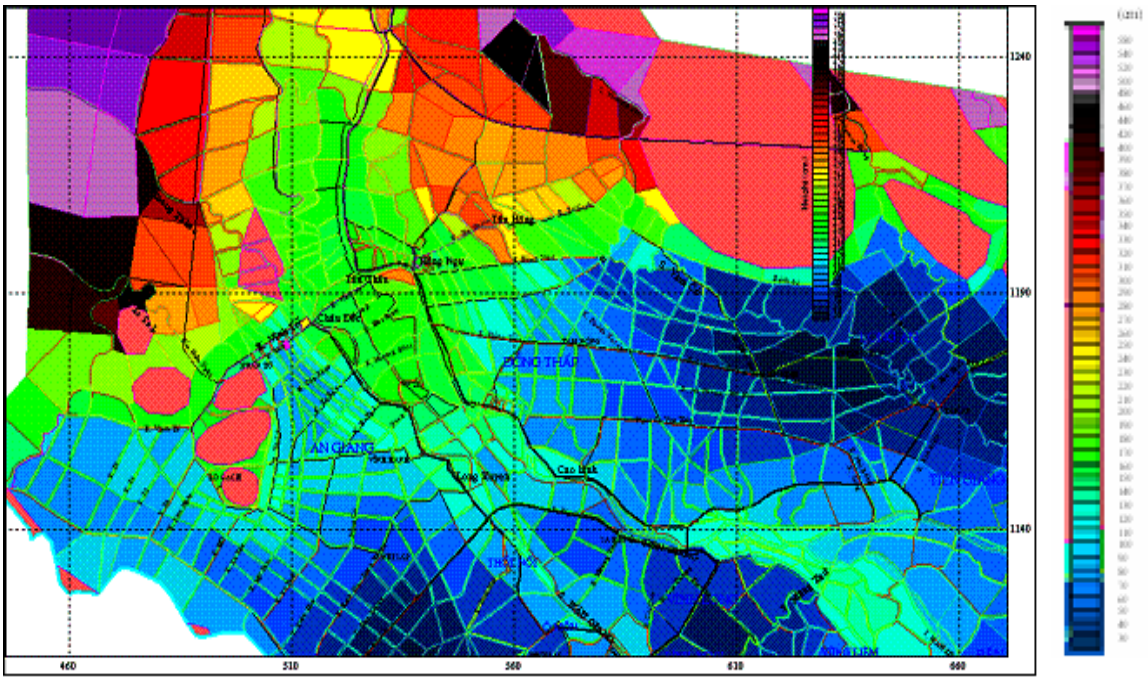

Fig. 3.2 The topography of the Northern Cuu Long River Delta (CLD)

3.1.2.2. Geology and soil characteristics

(i) Geology: The CLD in general and the inundation areas in particular is covered by Quaternary sediments, which is underlain by Mesozoic rock. Except in the northern part of the TGLX area, which was created by wind blown soils and the northern part of the DTM area, which was created by old alluvial soils, the remaining area was created by fluviogenic and marine alluvial soils. The Holocene (Q_{IV}) is a predominantly clay and sandy marine formation with a thickness between 20 and 50 m. Under Holocene layer, Pleistocene and Neogene marine sediments of sandy clays, clay were determined. In the center the depth of the bedrock increases in Southeastern direction, from about 100 m near the Cambodian border to over 1,000 m at the mouth of the Bassac river. Airborne magnetic survey suggests that the basement is faulted by NNE-SSW trending faults of uncertain age along the current course of the Bassac river. In general, soils in the CLD are weak in structure so their formation has to be considered duely.

(ii) Soils and land-use: Surface soils of the CLD were formed by fluviogenic and alluvial soils. There are 9 different soil types in the CLD Delta (Table 3.1). The alluvial soil concentrates along the river-banks in the area between the Mekong and Bassac rivers. The acid sulfate soil dominates in the Dong Thap Muoi, Long Xuyen quadrangle and Ca Mau peninsula, where this soil takes large part in comparison with natural area such as 51% for the DTM (concentrated in Tram Chim, Bo Bo and Bac Dong), 53% for the Ca Mau peninsula (concentrated in U Minh), 44% for the Long Xuyen Quadrangle (concentrated in Tra Su canal, Hon Dat and Ha Tien Quadrangle). Due to climatic and hydrological regimes, in the rainy season, land is inundated, but in the dry season land is dried out which promotes acidification. In the early rainy season, rainfall dissolves the toxic substances of the land and affects soils. Annually, floods overflow the areas bringing new silt sediment as well as dilute the toxic substances, acidity and salinity in these soils. Among total area 3.98 million hectares of the CLD, 2.46 million ha (63.2%) is used for agriculture and aquaculture and 0.38 million ha (9.77%) for forestry (in fact only 0.20 million ha is actually under forest). The remainder consists of settlement (0.2 million ha), uncultivated land (0.4 million ha), rivers, creeks and canals (0.2 million ha), and special use or unclassified land (0.25 million ha). The potential of expanding agricultural land is roughly 0.2 million ha.

Table 3.1. Distribution of soil types in the Cuu Long River Delta

No	Soil types	Area (ha)	Ratio (%)
1	Island	4318	1.11
2	Alluvial	1169857	29.34
3	Saline	744547	18.67
4	Acid sulfate soil	1590263	39.88
	- non saline	904374	22.68
	- saline	685889	17.20
5	Peat soil	34027	0.85
6	Gray soil	115872	2.91
7	Hill and Mountainous soil	20725	0.77
8	Alluvial plain	10688	0,27
9	River, canal	247303	6,20
	Total	***3978600***	***100,00***

Source: Vu Van Vinh, 1994, Evaluation of Water quality changes in the Mekong Delta

3.1.3 Climate and meteorological conditions

The CLD is characterized by the tropical monsoon climate, although cold air from Siberia and China occasionally penetrates the CLD. The general circulation is dominated by two monsoon flows: the northeast in winter and southwest one in summer periods (Fig. 3.3, 3.4). The southwest monsoon or the rainy season, normally affects the basin from mid-May to early October and the northeast one lasts in dry season from early November to mid-March. The boundary zones between the two flows is called Equatorial Through Zone (ETZ). Transitional period is characterized by variable winds that occur in the intervals between these two dominant patterns. The main characteristics as temperature, humidity, sunshine and radiation are rather stable year round and favorable for agricultural development. The mean annual temperature is above 27^0C, total annual temperature is from 9,700 to 10,000 ^{0}C. Annual solar radiation is about 150 kcal/cm^2.year, varying less than 2.5% over the months in the years. Maximum sun-shine hours in a month are 10–12 hour/day, in average 5–8 hour/day. Average daily evapo-transpiration recorded by Piche tube is about 2-3mm/day in the rainy season, and 3-4 mm/day in the dry season. Average humidity of the Mekong Delta is about 85% in the rainy season, and about 80% in the dry season. The rainfall is rather abundant and mostly concentrates in the rainy season (up to

90% of the annual values) and makes massive excess of water causing waterlogging in rainy season but scarce fresh water situation in dry season, especially in the places far away from the Mekong river. In the CLD, the rainfall has clear temporal and spatial distribution patterns (Fig. 3.5). In the south-west area of the Delta (Ca Mau, Rach Gia, Ha Tien, Dai Ngai and Soc Trang) the rainfall (of 2400 mm) is much higher than that (1200 mm) in the coastal area of East Sea (Go Cong, My Tho and extended to central of Dong Thap Muoi, Tan Chau and Chau Doc). In the early months of rainy season, sometimes there is either no rain or evaporation higher than precipitation, which causes a drought situation (named meteorological drought) in the remote areas of CLD. Rarely do storms occur in the CLD. However, when they occur in adjacent areas they cause heavy rains. These factors are the main hindrances for the socio-economic development of the CLD.

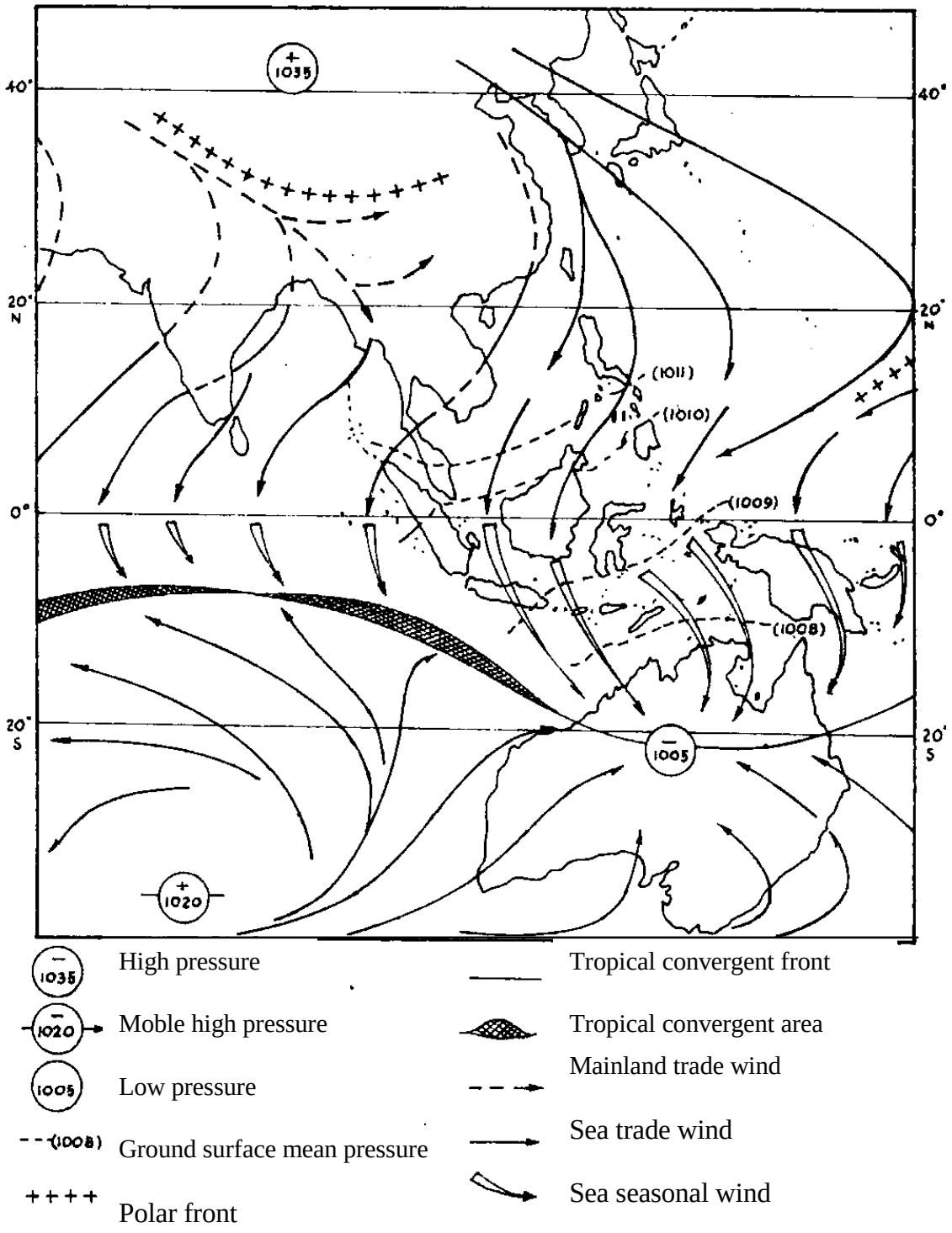

Fig. 3.3 The South-east Asian air circulation in January.

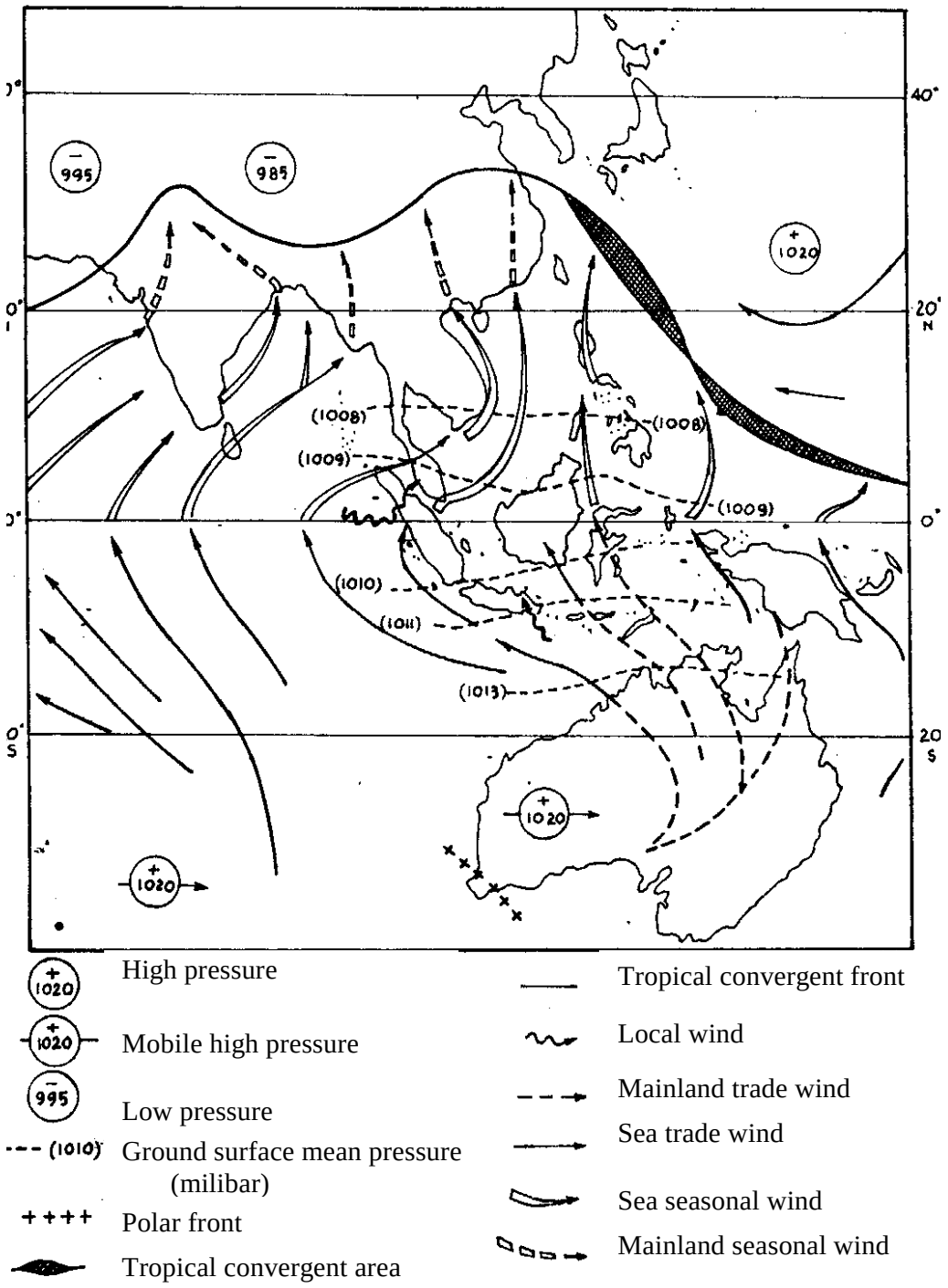

Fig. 3.4 The South-east Asian air circulation in July.

Table 3.2 **C**omparison of climate characteristics of the CLD and tropical region standards

Climate characteristics	Tropical region standards	Cuu Long River Delta
Annual total temperature	7500-9500^{0}C	9700-10000^{0}C
Mean annual temperature	>21^{0}C	26,8-26,9^{0}C
Months with temperature < 20^{0}C	< 4 months	0
The lowest temperature	> 18^{0}C	> 25^{0}C
Temperature fluctuation	1-6^{0}C	approximately 3^{0}C
Annual rainfall	800-1800 mm	1200-2200 mm

Source : Walker, 1974, Climate Characteristics of the Cuu Long River Delta

Table 3.3 Ratio of seasonal rainfall to annual rainfall at 24 stations of Mekong Delta

No	Stations	Rainy season		Dry season		No	Stations	Rainy season		Dry season	
		(mm)	(%)	(mm)	(%)			(mm)	(%)	(mm)	(%)
1	Ca Mau	2152	91	224	9	13	Go Cong	1190	96	52	4
2	Bac Lieu	1599	95	87	5	14	Cai Lay	1169	97	35	3
3	Vinh Long	1328	93	99	7	15	Tra Vinh	1410	96	53	4
4	Can Tho	1588	94	95	6	16	Chau Doc	1164	88	160	12
5	Soc Trang	1714	94	115	6	17	Long Xuyen	1345	91	135	9
6	Cao Lanh	1264	93	92	7	18	Cho Moi	1288	93	103	7
7	Ben Tre	1388	96	60	4	19	Tan Chau	1075	90	113	10
8	Moc Hoa	1453	92	119	8	20	Vi Thanh	1656	94	108	6
9	My Tho	1298	94	84	6	21	Dai Ngai	1775	96	74	4
10	Rach Gia	1878	91	176	9	22	Tan Hiep	1666	94	103	6
11	Tan An	1443	94	93	6	24	Ha Tien	1711	88	235	12
12	Ben Luc	1490	95	82	5	25	HCM City	1807	94	125	6

Source : Trieu Thi Sam, 1992, Meteorological Characteristics in the Mekong Delta

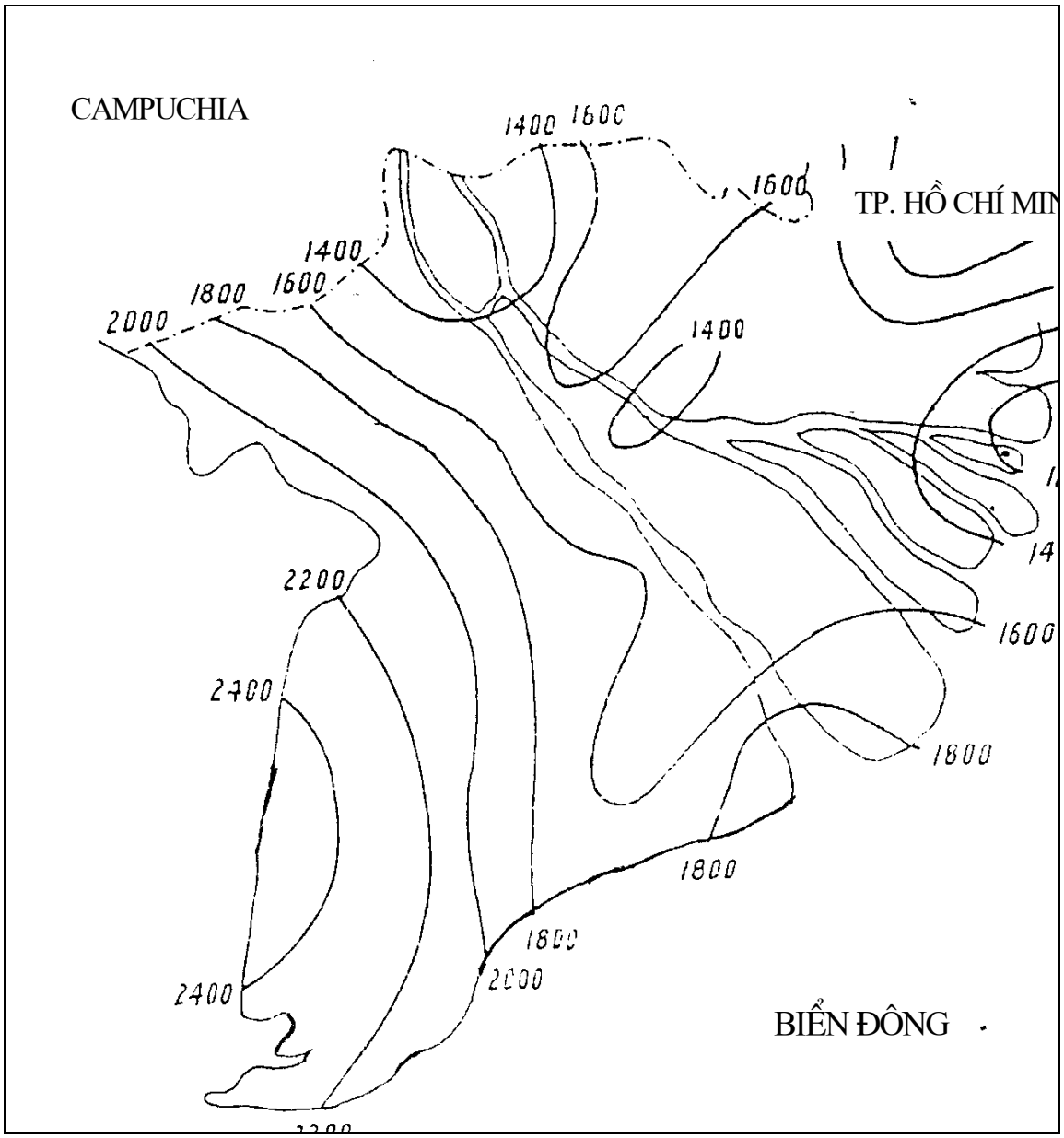

Fig. 3.5 The isohyetal map in the Cuu Long River Delta.

3.1.4 Hydrological conditions

The major rivers and canal systems of the CLD play three important roles: fresh water supply, drainage and navigation. The flood season normally follows the rainy seasons after about 0.5-1 month. The hydrological regime of the CLD is governed by water (hydraulic) regime of the Mekong upstream, tidal regime, local rainfall, topography and human activities.

(i) River and canal systems: A dense river and canal system in the CLD comprises a natural river system and a man-made canal system (Fig. 3.6). The main water volume is

transferred to the Bien Dong Sea through the Tien (or Mekong of about 800-1200m in width, 240 km in length from the Vietnam-Cambodia border to the Bien Dong sea) and Hau (or Bassac of about 500-1200m in width, 220 km in length) rivers. Connecting the Mekong and Bassac rivers together, the Vam Nao river runs from north-east to south-west with the length of above 7 km and the width of about 600-700 m. This river plays an important role in flow regulation from the Mekong to the Bassac rivers. The inland rivers, such as Vam Co Dong, Vam Co Tay, My Thanh, Ganh Hao, Bay Hap, Ong Doc, Cai Lon, etc. are capable to release flood-water from the Mekong River. The main river mouths in the CLD are Cua Tieu, Cua Dai, Cua Ham Luong, Cua Cung Hau, Cua Co Chien, Cua Dinh An, Cua Tran De and Cua My Thanh, Cua Rach Gia, etc.

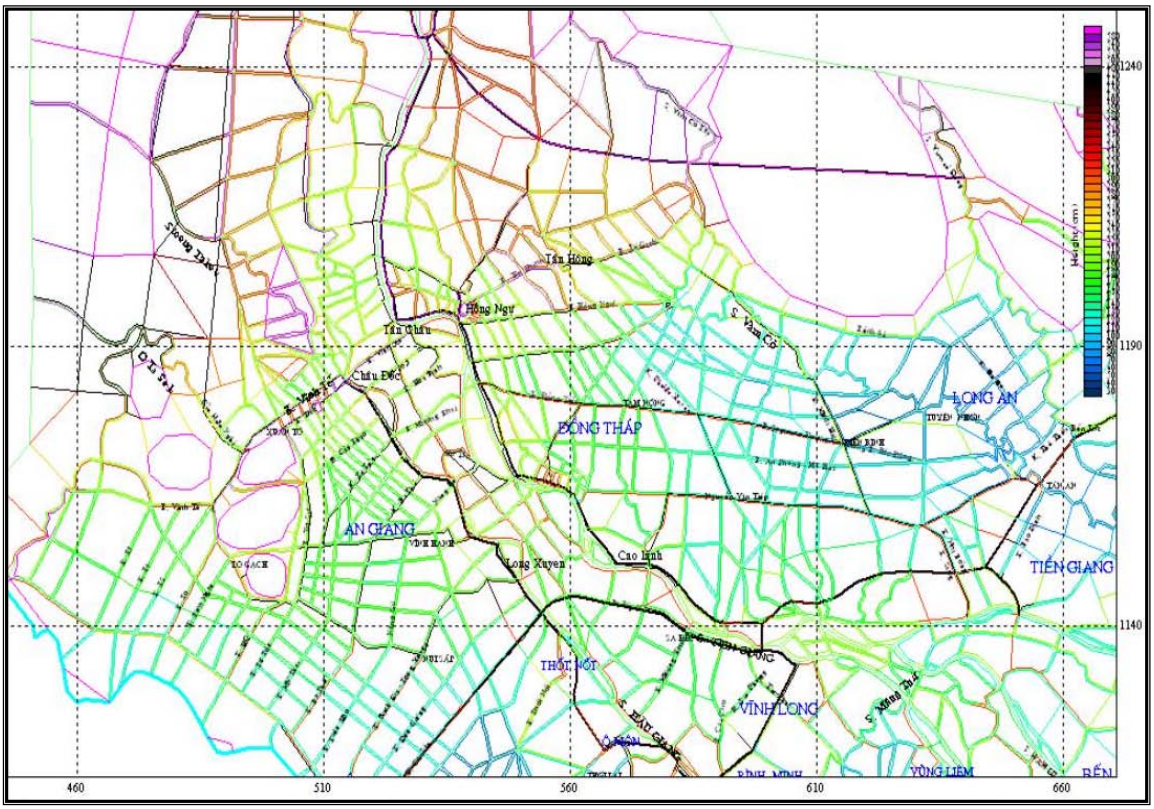

Fig. 3.6 The dense river and canal network in the Cuu Long River Delta (CLD)

In addition to that, there is a dense canal system, creating a network for transferring flood water from the rivers to lowlands in Dong Thap Muoi and Long Xuyen Quadrangle, and vice versa. Some main canals are Hong Ngu, Dong Tien, Phuoc Xuyen, Nguyen Van Tiep in Dong Thap Muoi; Vinh Te, Tri Ton, Ba The, Rach Gia- Long Xuyen, in the Long Xuyen Quadrangle; Thot Not, O Mon, Xa No, Lai Hieu, Quan Lo – Phung Hiep in the Tay Song Hau area and Ca Mau peninsular. These canals and creeks play important role in conducting water to the field for agriculture, flood drainage, washing off acid-sulfate and

salinity in the soil, water-borne navigation and in the same time, they also bring floods, tides faster and deeper into the fields.

(ii) Flow regime: The flow of the Mekong river is mainly supplied by the rainfall on the basin. The heavy rain in the whole basin cause floods in the Mekong river and over the wide area of the CLD as well. The heavy rains in the Mekong basin are often formed by the south-west monsoon appeared in the rainy season and storm or tropical low pressure originated in the Pacific ocean, entering to the central part of Vietnam. Thus, the flood occurrence and its intensity depend mainly on specific annual rainfall regime. During recent 40 years (1961-1999), big floods were mainly induced by storm rains, tropical depressions and Inter-Tropical Convergence Zone (ITCZ) in combination with strong S/W monsoon. Flow regime of the Mekong basin is characterized by two distinct seasons: the flood season with 85–90% of total annual flow from July to November and the dry season with 10–15% of total annual flow from December to June. In the CLD, flood peaks occur from the end of September to the beginning of October. The flood rises slowly, about 2–4 cm/day due to the regulation effect of the Great Lake (Tonle Sap) and low lands in Cambodia. Low flow period prolongs from December till June next year. Every year, the Mekong River brings about 500 km^3 of water through the CLD, among this value about 23 km^3 are generated by local rains in the CLD and 478 km^3 from the upstream areas. The Mekong flow contributes up to 59% of total annual flow of all rivers in Vietnam. Maximum Mekong River discharge measured in 1978 at Kratie was 68,000 m^3/s. About 70–80% of flood volume of the Mekong River flows to the Bien Dong sea in Tien river (84%) at Tan Chau and Hau river (16%) at Chau Doc. The connecting channel – the Vam Nao pass (river) accepts about 40% of the Tien river flows and transfers it to the Hau river during the high-flood stages. The smaller flow in the Hau river is just equalized with that of the Tien river below the Vam Nao river.

The flooding usually occurs when water level at Tan Chau (Tien river) surpasses 2.7m- 3.0mm. The submerged depth is from 0.5m to 4.0m, for example, at Chau Thanh and Chau Phu districts the depth is 2m, at the vicinity of Chau Doc town the depth is more than 3m. At Kien Tan (Tan Hiep district of Kien Giang province) the submerged depth over 1.5m lasts for 71 days, over 2m- for 31 days, at Tri Ton (Tri Ton canal) the depth over 3m lasts for 71 days, over 3.5m for 43 days.

The flood peak frequency in the CLD is as follows:

- From 21 to 31 August: 4%
- From 1 to 20 September: 17%
- From 21 September to 21 October: 69%

- From 21 October to 20 November: 10%

During the period from 1975- 2001 the early flood peak might surpass 3.0m at Tan Chau (Tien river) in July, August (on 1st August 2000 it was 4.22m); in 24 years flood peak might surpasses 4.5m at Tan Chau (31.6%) with the highest peak in 1961: Hmax = 5.12m. From 1926 to 1960 the flood peak at Tan Chau was never higher than 5.0m but from 1961 to now there happened three floods higher than 5.0m at Tan Chau: in 1961 H_{max} = 5.12m; in 1966 H_{max} = 5.11m; in 2000 H_{max} = 5.06m of recurrence surpassing frequency of 3-4%. At the same time it might be due to El-Nino in 1997-1998 the H_{max} = 2.81m in 1998 was the lowest flood peak value over many years (recurrence surpassing frequency of 95.5%).

Flood water enters the Dong Thap Muoi (DTM) sub-region by two ways: from the flooding area of Cambodia across the Vietnam-Cambodia border (along the So Ha - Cai Co canal, about 85-90% of total volume) and from the Tien river (10-15% of the total volume). The flood volume enters DTM is about 62-70 km^3 (Q_{max} = 10,500-13,000 m^3/s) from Cambodia and 1-2 km^3 (Q_{max} = 200-400 m^3/s) from the Tien river. Then, the water is drained to the Vam Co Tay river (about 16-20 km^3), to Tien river (13-15 km^3) and downward to Tien Giang, Vinh Long provinces 20- 30km^3. Flood water enters Long Xuyen Quadrangle (TGLX) sub-region from Cambodia of about 12.5-15 km^3 (Q_{max} = 2,500-3,200 m^3/s), from the Hau river of about 3-4 km^3 (Q_{max} = 500-700 m^3/s). Then, the water is drained into the Gulf of Thailand of about 12-14 km^3 (Q_{max} = 1,600-2,000 m^3/s); back to the Hau river about 2-4 km^3 (Q_{max} = 200-500 m^3/s) and finally downward to Can Tho, Soc Trang, Ca Mau provinces of about 3-5 km^3 (Q_{max} = 400-700 m^3/s). These are enormous values if we compare them with annual flow of Thu Bon river in the Central Vietnam (catchment area of 10,350km^2, river length of 205km) of 20.1 km^3; Ba river (A= 13,900km^2, L = 388km) W = 9.5km^3.

So to give solution to the problem of flood protection, flooding drainage in DTM, TGLX and the area between the Tien and Hau rivers (the Tay Song Hau sub-region), we should increase the hydro-meteorological data collection in the mainstreams (Tien, Hau, Co Chien, Ham Luong, Ba Lai, Cua Tieu, Cua Dai, etc.) and in the flooding areas. The data collected are of great help to model initialization, running, various studies, socio-economic development, construction as well as in hydro-meteorological real-time informing, warning, forecasting to mitigate the losses of human lives and property damages.

(iii) Tidal regime: Three sides of the Delta are blocked by the sea with unequal semi-diurnal tidal regime in the East Sea and diurnal tide in the West Sea, resulting in an year-

round tidal affect of about 2-4m on the CLD. The tidal effects are more prominent in low flow period when discharge in the Mekong River is normally about 2,000 m^3/s. In low flow period salinity may deeply penetrate in the rivers/canals, disturbs the water provision for domestic use, for agriculture, for industrial use, etc. At the river discharge in Hau and Tien river of 2000m^3/s the $1^0/_{00}$ salinity may penetrate up to 50km, the $4^0/_{00}$ to 43km in Cua Tieu river; the corresponding values in Cua Dai river are 54km and 45km. The $4^0/_{00}$ salinity may intrude further My Tho for 4-5km on the Tien river, further My Hoa on the Ham Luong river, further Tra Vinh on the Co Chien river and further Dai Ngai for 7-8 km on the Hau river. The areas suffered with salinity intrusion every year are about 1.7 million ha. The areas with acid sulfate water are of 1-1.2 ha with pH<5 in the CLD. The main areas suffered with acid sulfate are DTM, TGLX and Ca Mau peninsular. The time of the event lasts from April to June (about less than 3 months in dry season).In flood season the tide may prevent the normal drainage of water in flooding areas, may heighten the level and prolong the flooding time.

(iv) Sedimentation and mineral concentrations:

The suspended sediment concentration in Mekong river in Vietnam territory is not high, varying from 500g/m^3 to 1660g/m^3 (from July to September) at Tan Chau on Tien river and from 250 to1200g/m^3 at Chau Doc on Hau river. The value decreases to 550g/m^3 by the end of flood season (October, November). The sediment concentrations in canals and creeks are small, usually less than 50g/m^3 but somewhere may reach 70-100g/m^3. Especially, sediment is often deposited at 10-15km of the canal beginning and sediment concentration is much reduced in middle and end of the canals. The total yearly volume of sediment in the CLD rivers is about more than 215 million tons. The sediment particle sizes are of 0.23mm in average at Tan Chau (Tien river); 0.21mm at Sa Dec (Tien river) and 0.2mm at Vinh Long (Co Chien river).

The mineral concentration in rivers of the CLD is from 100 to 150mg/l, varying not so much along the river. The value in flood season is smaller than in low flow period. The river water belongs to hydro-carbonate group of calcium type. The HCO_3^- ion makes 75-80% of the anion; the Ca^{2+} ion makes half of cation. Other ions are of small concentration. The pH value varies from 6.7 to 7.7; the water hardness is about 1 mg/l. The Fe total is 0.2-0.45 mg/l, sometime higher than 1 mg/l. The SiO_2 concentration is less than 10 mg/l (2-5

mg/l). The chemical oxygen demand COD is smaller than 2-3 mg/l in flood season. The dissolved oxygen value is 5-8 mg/l.

The nutrients in Mekong river suspended sediment are as follows: total N: 0.24-0.54 mg/l; PO^{3-}_4 -P: 0.012-0.052 mg/l, total P: 0.024-0.106 mg/l. Therefore, the Mekong river water quality still is good, meeting the demands of economics and domestic water, two big quality problems here are salinity intrusion and acid sulfate water .

(v) Salinity intrusion:

Following the tide, salinity from the sea intrudes into rivers and canals. Salinity intrusion depends on the water volume from the upstream, the intensity of tide, special sea wind (the modified north east wind blowing from the east or south east into the Southern coastal area from November to April of the next year) and topographic and hydraulic conditions of the part of river. The deeper it intrudes into the river, the more the salinity decreases. Salinity also changes with season, especially with tide regime. The peak and foot of salinity often appear 2-3 hours after the ones of tide, respectively.

Salinity intrudes into the Mekong River Delta from two sources: the East Sea and the West Sea. From the middle of dry season, particularly from February to May, salinity intrudes deeply into rivers and canals. The highest salinity often appears in late March and early May.

3.2. Socio-Economic Conditions

Administratively, the project area includes 13 provinces namely: Dong Thap, An Giang, Long An, Tien Giang, Hau Giang, Vinh Long, Kien Giang, Can Tho, Ben Tre, Tra Vinh, Soc Trang, Bac Lieu and Ca Mau. The population of the CLD was estimated at 16.9 million persons in 2000 accounting for 22% of the total population of Vietnam. The average annual growth rate during the years from 1990 to 1994 was 2.2% and dropped to 2.0% in 1995. The ratio of men and women in the whole area was 47/53. About 84% of the population is living in rural area with dispersed settlement pattern. The average population density is 406 persons/km^2 and average household size is 5.4 members. The main ethnicity is Kinh, while the remaining are Hoa (Chinese people) and Khmer. Hoa people live mainly in the cities and the towns and the Khmer people live along the Vietnam-Cambodia border and scattered in An Giang, Kien Giang provinces. People's incomes mainly depend on agriculture production based on cultivable farm-land area of about 27,000 km^2. The labour force is estimated at 40% of the total population, of which 56% are working in the

agricultural sector. Agricultural production accounts for 55% of the regional GDP. Industrial activities in the Delta still in a low level development, annual products from industry account for only 10% the GDP. The main industrial activity in the Delta is rice processing for export (capacity about 3- 4 million ton/year). Beside, there are small mechanic repairing stations; sea product processing plants, which have small capacity; and some small chemical factories. According to statistics, income from other jobs is only about 10-30% of total income in accordance with areas and households. The average GDP per capita is about 300 US$/year in recent years. However, it is not evenly distributed. Rich families are about 30%, and 20-30% live under poor conditions. The advantage of the CLD lays in food and other goods production, vegetable and fruits, cattle and poultry, the biggest aquacultural and fisheries sources of the country. The area contributes nearly 55-60% of the aquacultural products (in 2000 it was 1,11 million tons) and large portion of exported food of the country, playing a decisive role in maintaining food security in Vietnam. Based on a MRC report, four major trends in macroeconomic activity seem likely to appear in the CLD in the coming decade: increasing agricultural specialization and commercialization, increasing non-resource based industrial developments, increasing urbanization and increasing sub-regional integration. Nevertheless, in the CLD, more than 84% of total population depends on agriculture for their livelihood and as such, is vulnerable to flooding and drought. The large area of about 2 million hectares or 50% of the CLD in the north is annually affected by flooding from the Mekong river. This includes An Giang, Dong Thap, Long An, Kien Giang, Can Tho, Tien Giang, Vinh Long and Ben Tre provinces. The annual flood season lasts for 3 - 4 months, during which thousands of families, mostly the poor ones have to evacuate to avoid the flooding; people have to live in homelessness. Manufacturing and producing activities in the area become stagnant during this time of the year.

Table 3.4 Population indicators by provinces in the CLD

Provinces	**Population** *(thousands)*	**Population density** *(per km^2)*	**Growth rate** *(annual %)*	**Rural population** *(%)*	**Dependency ratio** *(%)*	**Migrant population** *(%)*
Long An	1,305.7	290.7	1.2	83.8	57.5	2.3
Dong Thap	1,566.6	438.8	1.3	85.7	59.5	1.6
An Giang	2,044.4	600.2	1.1	78.4	59.5	1.2
Tien Giang	1,604.2	677.7	0.4	87.0	55.7	1.4
Vinh Long	1,010.5	685	0.2	85.8	54.0	1.5
Ben Tre	1,299.0	561.1	0.3	91.7	55.5	1.1
Kien Giang	1,497.6	238.9	1.9	78.0	66.7	2.1
Can Tho	1,809.4	606.0	0.8	78.3	56.0	2.3
Tra Vinh	966.9	434.4	0.9	87.2	60.3	1.1
Soc Trang	1,172.4	363.8	0.6	82.2	61.8	1.1
Bac Lieu	735.1	291.6	0.8	75.5	60.7	1.7
Ca Mau	1,118.8	215.4	1.7	81.4	65.5	1.6

Source: Population census 1999, Statistical Office

Floods have significant negative affects on socio- economic development of the CLD. The 2000 floods in the Mekong River were the worst in the region in last 40-50 years. High levels of flooding in 2000 were followed by serious floods in 2001 and 2002. Due to this pattern of recent flooding, people and governments in the delta have suffered substantial direct, indirect and cumulative economic and social impacts. In addition to the economic losses, there is the social instability due to natural disasters including the damages to human health and life in the areas. For a developing country like Vietnam, it is essential to maintain a stable socio-economic development to ensure sustainability.

Fig. 3.7 Frequently inundated Area in the Cuu Long River Delta (*dark green area*)

Within the CLD, the sub-areas under severe influence of floods and flooding are provinces of Kien Giang, An Giang, Dong Thap, Long An and some districts of Tien Giang,

Ben Tre, Vinh Long and Can Tho provinces. The damage levels of recent floods in the CLD are summarized as follows:

Table 3.5 The damage levels in human life and property caused by recent floods in the CLD

Items	Unit	1978	1984	1991	1994	1995	1996
I. Population							
1. People death	Person	87	105	158	407	199	217
2. Damage households	h-holds	66010	50504	197477	505906	28240	78859
3. Evacuated households	h-holds	245500	10744	15600	20125	11431	38735
4. Relief-need households	h-holds					59262	175441
II. Production							
1. Inundated rice areas of yield-reduced	Ha	113600	111879	88837	202189	62399	107707
- Complete loss	Ha	307100	175628	171898	26868	11101	43249
2. Upland crop areas of reduced yield	Ha						50
- Complete loss	Ha						17466
3. Inundated fruit tree areas	Ha						76396
4. Inundated fish ponds	Pond					16336	69505
5. Poultry dead	head					242	18965
III. Infrastructures							
1. Inundated class-rooms	Room						11093
2. Pupils absent	Pupil					217412	905302
3. Inundated infirmaries	infirmary					156	509
4. Inundated canal	M3					5512226	4431000
5. Destroyed bridges & sluices	Bridge, sluice					2722	24478
6. Inundated store houses	house					372	2411
IV. Land erosion							
1. Erosion areas	M2					506880	356935
2. Affected households	Households						5543
Total damage	10^9 VND	2469	2492	2217	2284	700	2182

Source: Natural disaster protection program KC08; Project KC08- 14 on flood identification, forecast and control in CLD.

In addition, the big floods in three consecutive years of 2000, 2001 and 2002 have caused total damages of 4,000; 1,536 and 785 billion VN Dong and losses of 500, 390 and

298 human life respectively. These losses set back the socio-economic development not only in the Vietnam's CLD but also for the whole country as well.

3.3 Current status of soil, water and air quality

3.3.1 Current status of air quality

- *In Dong Thap province*: The air environment in urban area and production places is still polluted, without signs of improvement compared to recent years, especially in dust and noise. The dust levels in most of towns exceed the allowed criterion (the allowed criterion < 0.3 mg/m^3). In traditional trade villages (which produce refined flour and keep livestock) there are still smell pollution and pollution due to smoke from brick producing villages. Apart from industrial areas under construction and industrial centers, the air environment in rural area in general is still clean. The results of air environment observations in some points of Dong Thap province are presented in annex 2.
- *In Long An province*: The data of investigation and survey in populated district towns in the province (see annex 3) show that the air environment in vicinity and at urban areas is polluted by dust in both rainfall and dry seasons. Other pollution parameters (CO, SO_2, NO_2, H_2S) are in the allowed criteria, only Pb content around national road 1A exceeds that.
- *In Kien Giang province*: the air quality at urban areas is polluted mainly by bust and noise. The concentration of suspended dust fluctuates from 0.235- 0.46 mg/m^3, SO_2 0.037- 0.079 mg/m^3, NO_2 0.068- 0.189 mg/m^3, CO 7.12- 16.86 mg/m^3, noise level during 6- 18 hr is 55-80 dBA. The concentration of suspended dust at Rach Soi T-junction fluctuates from 0.227-0.46 mg/m^3 in dry season. At industrial areas, dust is the main pollution. The air environment in rural areas in general is good, apart from places of trade villages with kilns where pollution increases, especially smoke and dust.
- *In Tien Giang province*: The air pollution evaluated at 17 measurement points of 4 surveys exceeds the allowed criteria; the average dust concentration is 1.76 mg/m^3. The concentration of CO, SO_2, NO_2 are below the allowed criteria.
- *In An Giang province*: The concentrations of SO_2, NO_2 in urban area of Long Xuyen city and Chau Doc town are in the allowed limits. The average dust content slightly exceeds the allowed criteria. The average concentrations of SO_2 and NO_2 in general exceed the allowed limits. At industrial areas of province such as stone exploitation, rice mill, and construction material production, the air pollution is mainly by dust.

- *In Vinh Long province*: The air in urban and industrial areas of the province in general is polluted by dust, other elements such as CO, NO_2, SO_2 are below the allowed criteria (see annex 4). The air in rural area is not yet polluted, apart from some areas around national road with high traffic density have the sign of dust and noise pollution.
- *In Can Tho province*: Because the industrial production here is not yet developed, the industrial sources are not yet the main cause of decrease in air quality. The important cause is the daily communication means and the activities of building roads, houses and other structures. The observation data of air quality in industrial areas, urban and rural areas in the province show that there is dust pollution (the dust concentration is equivalent or more than 0.3 mg/m^3), the concentrations of NO_2, SO_2 in general have not exceeded the allowed limits.

These facts have indicated that in general, the air quality over the CLD is no problem in the rural areas. However, in cities, towns, due to industrial development, high urbanization rate… dust pollution is occurring, and we should face with the air pollution problem in the near future.

3.3.2 Present status of water resources

3.3.2.1 Surface water

<u>- River water resources:</u>

Total average annual runoff of the Mekong River through the Mekong River Delta to the sea is about 500 billion m^3, in which about 23 billion m^3 is from rainfall in the Mekong River Delta and 478 billion m^3 flowing in from outside (30 billion m^3 in 478 billion m^3 is from Nam Ron, Se Bang Hieng, Se Cong, Se San and Xre poc Rivers inside our territory). Thus, total runoff of the Mekong River occupies 59% total runoff of the country. Therefore, it is possible to see that the Mekong River Delta has the most rich surface water resources of our country with annual supply capacity up to $14{,}000.10^3$ m^3/km^2 or $31{,}2.10^3$ m^3/person, which is 5 and 3 times the average annual water supply capacity over $1km^2$ area and 645.10^3 m^3/km^2 and 1438 m^3/person.

<u>- Flood and inundation in the Mekong River Delta:</u>

Flood and inundation in the Mekong River Delta mainly depends on the flood from the upstream. About 70-80% flood water of the Mekong River flows through Tien and Hau Rivers, the rest flows from Cambodia through the border into Dong Thap Muoi and Long Xuyen Quadrangle. Dong Thap Muoi and Long Xuyen Quadrangle are two depressions with

the most serious flood in the Mekong River Delda. The flooded area can be from 1.5 – 2 million ha, the flood duration is from 3- 5 months, generally from August to November. The flood level and duration is affected not only mainly by the food of the Mekong River but also by the tide and rainfall in the field. When there is high tide, the flood flows to the sea very slowly, and the inundation lasts long. With heavy rainfall in the field, the flood is more serious.

However, the infrastructure such as irrigation system, especially the dams, the drainage system to the West Sea of Long Xuyen Quadrangle, the road system and the protection banks around the population areas have made the distribution of flood between Tien River and Hau River, the inundation and drainage of flood in the Mekong River delta more complicated.

The typical feature of the Mekong River Delta is that a large area with dense river system lacks water in dry season and has too surplus water in rainy season.

- Water quality:

The average turbidity with suspended sediment in early months of flood season (July - September) fluctuates from 500 g/m^3 to 1660 g/m^3 at Tan Chau and 250- 1200 g/m^3 at Chau Doc. It decreases to 100- 550 g/m^3 in late and middle months of flood season (October - November). Down to Vam Nao, because the water from Tien River flows through Vam Nao River into Hau River, the turbidity of Hau River below Vam Nao River (at Long Xuyen) is sometimes bigger than the one at Chau Doc.

In the canals, the turbidity is rather small, often below 50 g/m^3, at some places 70- 100 g/m^3. Especially, the sediment often settles down in around 10- 15 km at the beginning of the canal, therefore the turbidity at the end of the canal decreases much. Total average annual suspended sediment of the Mekong River flows into the Mekong River Delta is estimated over 215 million tons. When coming to the river mouth, a part of sediment settles down and creates sand islands in the coastal area. The important thing is that the sediment brings about the fertility for the Mekong River Delta, very useful for agriculture.

The mineral content of the river water is about 100- 150 mg/l, and changes not much along the river, it is lower in flood season than in dry season. The river water belongs to hydrocarbonic class of calcium group, type I; ion HCO_3- often occupies 75- 80% total equivalent of anions; ion Ca^{2+} often occupies about half of total equivalent of cations. Other ions have low contents. The pH varies from 6.7- 7.7. Stiffness of river water is low, at approximate 1me/l, the alkalinity is slightly bigger than the stiffness. Total ferric content is often 0.2- 0.45 mg/l, sometimes higher than 1mg/l. The content of SiO_2 is smaller than 10

mg/l (2- 5mg/l). Chemical oxygen demand (COD) in flood season is often smaller than 2- 3mg/l. Dissolved oxygen (DO) is 5- 8 mg/l. The contents of toxins such as alkaline, Cu, Pb , cadmium are often small: Zn 0.02mg/l, Cd 0.009 mg/l, Pb 0.04 mg/l, Cu 0.09mg/l. The nutrients in the alluvial water of the Mekong River are as follows: total N 0.24- 0.54 mg/l, PO_4^{3-} (P) 0.012- 0.052 mg/l, total P 0.024- 0.106 mg/l. In brief, the water quality of Tien and Hau Rivers is still good, meets the requirements of production and life. However, acidity and salinity are 2 big problems in the Mekong River Delta. Every year, the area affected by acidity in the Mekong River Delta is about 1- 1.2 million ha with pH <5. 3 areas under rather serious acidity are Dong Thap Muoi, Long Xuyen Quadrangle and Ca Mau peninsular. The duration of acidity is about 3 months, i.e. the end of dry season to early rainy season (the end of April to June).

The salinity intrusion: because most of the Mekong River Delta is lower than 3m, the tide amplitude is rather big, and the river and canal system is dense, the salinity can intrude deeply into rivers and canals, especially in dry season when the water flowing into the Mekong River Delta decreases significantly. Every year, the area with salinity intrusion amounts to 1.7 million ha. In this area, 2 sources of salinity intrusion are from the East Sea and the West Sea. Due to stronger tide amplitude of the East Sea, the salinity from this Sea intrudes deeper than the one from the West Sea (Thailand Bay). There are 4 areas with different salinity intrusion:

+ Long Xuyen Quadrangle
+ Ca Mau peninsular
+ Dong thap Muoi
+ The area between the Tien River and Hau River

The limit of salinity of 4 ‰ can be 5- 7km beyond My Tho on the Tien River, beyond My Hoa on the Ham Luong River, up to Tra Vinh on the Co Chien River, 7- 8km beyond Dai Ngai on the Hau River. The time of deep salinity intrusion is April in Long Xuyen Quadrangle, in March and April in Ca Mau peninsular, in April and May in the coastal area of the West Sea, in April in Dong Thap Muoi. On branches of the Mekong River of the Mekong River Delta, the salinity has high value in January - April (over 32‰) and comes down to 29‰- 30‰ in September and October.

3.3.2.2 Present status of groundwater

Groundwater reserve of the Mekong Delta is rather high. Safe exploited production is estimated at about 1 millions m^3/day, mainly based on the upper Pleistocen which is one

of 5 layers storing water in the Mekong Delta. Present exploited production of groundwater has been mainly used for domestic purposes, which is estimated at about 250.000 m^3/day. Groundwater quality, in general, is good for domestic and drinking water. However, in some places, there are some compositions higher than that of the safe criteria, such as iron (Fe) in the Plain of Reeds, sulfate (SO_4^{-2}) in Can Tho province… At present, the groundwater exploitations are strongly developing, especially in household scope when inhabitants use this water source for domestic purposes.

3.3.3 Present status of landuse and soil quality

Due to climatic and hydrological regime, in rainy season the land is flooded, but when dry season comes, the soil is exhausted of water leading to acidity. In early rainy season, the rain water dissolves the toxins in the soil, and affects the water quality. Every year, the water floods the hollow area, creating a sand layer settled down and dissolving the toxins, acidity, and salinity in the soil.

Table 3.6 Present status of land use in Cuu Long Delta

Unit: Thousand ha

Region	Total area	Agricultural land	Forestry land	Specially used land	Homestead land
Cuu Long Delta	3970.6	2977.2	342.3	228.6	101.1
Long An	449.2	331.2	45.4	28.6	11.0
Đồng Tháp	323.8	249.1	14.3	21.8	15.7
An Giang	340.6	256.1	13.7	27.3	18.4
Tiền Giang	236.7	180.6	9.7	16.2	7.7
Vĩnh Long	147.5	119.1		7.9	4.5
Bến Tre	231.6	167.3	6.2	11.4	7.0
Kiên Giang	626.9	412.0	120.0	37.1	10.8
Cần Thơ	298.6	254.6	3.4	18.0	8.8
Trà Vinh	221.5	181.3	6.0	8.7	3.2
Sóc Trăng	322.3	262.7	9.9	20.5	4.9
Bạc Liêu	252.4	210.8	5.9	13.6	3.5
Cà Mau	519.5	352.4	107.8	17.5	5.6

(Statistical yearbook 2001)

Table 3.7 Contructure of used land in Cuu Long Delta

Unit: %

Region	Total area	Agricultural land	Forestry land	Specially used land	Homestead land
Cuu Long Delta	100.0	75.0	8.6	5.8	2.5
Long An	100.0	73.7	10.1	6.4	2.4
Đồng Tháp	100.0	76.9	4.4	6.7	4.8
An Giang	100.0	75.2	4.0	8.0	5.4
Tiền Giang	100.0	76.3	4.1	6.8	3.3
Vĩnh Long	100.0	80.7	0.0	5.4	3.1
Bến Tre	100.0	72.2	2.7	4.9	3.0
Kiên Giang	100.0	65.7	19.1	5.9	1.7
Cần Thơ	100.0	85.3	1.1	6.0	2.9
Trà Vinh	100.0	81.9	2.7	3.9	1.4
Sóc Trăng	100.0	81.5	3.1	6.4	1.5
Bạc Liêu	100.0	83.5	2.3	5.4	1.4
Cà Mau	100.0	67.8	20.8	3.4	1.1

(Statistical yearbook, 2001)

At present, due to the changes in land use, the construction and transform of canal system, and the dyke which retains the salinity... the soil becomes acid, saline and degraded.

+ Pollution of soil and degradation due to acidity

The reclaiming of virgin soil, embankment of canals, building of bridges and culverts, and the making the bank for prevention of saline water are the reasons to promote the process of soil degradation due to acidification. All of these activities will mix up the soil and affect the potential acidification layer. When this potential acidification layer contacts with the air, there will be the oxidizing and transfer to active acidity, which is mainly the transformation from pyrit to jarosit. This transformation changes the soil structure in surface organic matters, decreases the fertility and increases the acidity (low pH) of the soil, especially the presence of soil toxins such as: Al^{3+}, Fe^{2+}, Fe^{3+}, SO_4^{2-}. Some forms of acidification in the area:

- Acidification in potential acid area due to in dry season, the low water level makes the potential acid soil expose, leading to the acidification of the potential acidification layer of pyrit to become active acid layer, with the presence of much Al^{3+}, Fe^{2+}, Fe^{3+}, SO_4^{2-}, and low pH.

- Acidification due to acid water from other places coming through the irrigation system, making the soil acid or promoting the active acidity in those soils that formerly were only saline without acidity.
- Acidification due to earth digging and embankment, discard of acid soil, leading to oxidizing the acid water flowing out from this soil that creates acidification of water and soil of the receiving place.

+ Pollution and degradation of soil due to salinization

The prevention of saline water, digging of canals, and continuous gardening at present has made the soil become saline. Soil quality at some places in the area is presented in result table of annex 5.

3.4 Biological resources and natural ecosystems

3.4.1 Natural ecosystems

(1) Plant resources

Projected area includes the flood plain, separated with the sea by mangrove forest and cajuput forest. Two kinds of forests that exist in the delta plain are mangrove forest in saline flood area, and cajuput forest in the inland swamp.

a) Mangrove forest

Mangrove forest is the growth place of crab, shrimp and different kinds of fish due to its high organic content. The encroachment or destruction of mangrove forest may lead to the decreasing of the coastal community, including larvae of saline fish and shrimp, due to not only the loss of food source and the habitat, but also the latent pollutants in coral reefs and submerged rocks. The erosion in areas of cleared mangrove is also the cause of deposition in communication canals.

The erosion has become more and more serious because of human activities during recent decades has emphasized the importance of mangrove forest in retaining the earth and as the buffer blocking mud and sand. Mangrove forest plays an important role in transforming the earth. The mangrove forest not only delays the erosion due to tide, but also have the tendency of accumulating earth around their roots. This root system is particularly effective in linking mud, sand and decreasing the speed of runoff. Presently, mangrove forest makes the erosion decrease, so it is often planted to protect the sea coast. Because the forest moves towards the sea, the forest border will become higher, drier and this part will

be integrated into dry forest inland. This area will finally become sustainable area for cultivation of rice and other food crops. Mangrove and cajuput are important sources of wood and wood materials in the delta.

b) Cajuput forest

Cajuput forests include 46 species (a document published in 1999 mentioned 100 species) including *Rhizophora, Avicennia*, *Bruguiera*, *Nipa* etc. In the past, these forests occupied about 250,000 ha. During the war against the American, 124,000 ha of cajuput has been destroyed by American defoliation agent. After the liberation (1975), the scale and quality of cajuput forests have gone down drastically due to wood exploitation, the expansion of cultivation and husbandry. In 1998, the Mekong River Delta has about 77,000 ha of cajuput forest, which mostly belongs to Ca Mau province. The distribution of species depends on their salinity enduring capability. In general, from the sea towards the land, the predominant cajuput species are *Avicennia, Bruguiera, Rhixophora* and *Nipa*.

Following is the plant resources of some provinces in the Mekong River Delta:

- The plant system of Can Tho province is very typical of the flooding area, but due to long time of cultivation of rice and fruit trees, or people's settlement, the species of agricultural ecosystem most develop. The plants of high economic values in this area are rice, coconut, vegetable, bean, bamboo and scattered trees. The hollow and acid lands (in the South West) are suitable for cajuput, sugarcane, gregarious plants…

- Soc Trang province has the total forest area of 15,145 ha, divided into 2 main types of mangrove forest (coastal protection forest) and production forest in acid and brackish area. *Mangrove forest* occupies 10,336 ha, scattering along 72 km of sea coast of 2 districts Vinh Chau and Long Phu, the coverage area of which is about 3,750 ha, the remaining areas are 4,639 ha forest and 1,947 ha of other land. Mangrove forest includes *Rhizophora, Bruguiera, Avicennra*, cork tree and nipa. *Production forest in acid and brackish water* has the total area of 4,810 ha, mainly cajuput forest distributed in hollow and acid area of 2 districts My Tu and Thanh Tri. Its coverage area is 3,418 ha, with 1,090 ha of forest, and the remaining is other land.

- The typical forest of Bac Lieu province is the coastal mangrove forest stretching 54 km from adjacent area of Soc Trang proving to Ganh Hao river mouth. Mangrove forest has 64 plant species of 27 families, mainly *Rhizophora*; *Bruguiera*; *Avicennra*; and *Ceriops*.

- Ca Mau province has the flooding area of 520,880 ha with natural ecosystems such as mangrove forest, swamp and inundated area, and river mouth. Ca Mau has the two biggest flooding forest ecosystems of the country, which are cajuput forest and mangrove forest, with 228 plant species. Plants here are mainly bush trees, liana, and only 3 arbor species: *Gmelina elliptica* of Vebeceae family, *Ficus rumphii* of Maraceae family, *Bruguiea gymorriza* of Rhizopraceae family. In which: 19 species of fern belong to 10 families, 135 species of two seed-leaves belong to 20 families (43 species of arbor tree group belong to 21 families, 20 species of bush trees belong to 10 families, 23 species of liana group belong to 10 families, 49 species of grass group belong to 10 families), 74 one seed-leaf species (group of caulis: 68 species belonging to 15 families, group of liana: 03 species belonging to 02 families, group of arbor: 03 species belonging to 01 families. Mangrove forest has *Rhizophora*, *Bruguiera*, *Aegiceras*, *Avicennra*, chili plum, cork tree and date, mainly distribute in the west belt-line of Ngoc Hien district.

The ecosystem of flooding forest has more simple plant components, including 192 species. Around the river mouth, river and canals there are also nipa, acanthus, Ken toad and some other trees.

- Kien Giang province has 211 plant species belonging to 60 families and 160 branches; these species belong to 3 phyla: fern with some popular species, in which gymnospermus phylum has only some species, mainly they concentrate in the remaining 2 classes of magnoliophyta that are classes of 2 seed-leaves 1 seed-leaf. Species analysis shows that there are 185 species of wild plants, 16 of perennial trees, 42 of bush trees, 31 of arbor trees, 20 of medium arbor, 33 of small arbor, 78 of fine herbaceous plants. Analysis following use value of these species shows that there are 69 species can be exploited for wood or in consumption industry, 18 species of fruit trees, 53 of medicinal herbs, 27 species belonging to mangrove forest or forest flooded in brackish water, 75 species covering the land, keeping the soil from being washed away or exhausted, or they are used as green manure, and 6 ornamental plants.

Present status of vegetation coverage of Kien Giang province is the mixing up of some typical ecosystems for each area such as: ecosystem of coastal limestone mountain, ecosystem of mangrove forest, ecosystem of acid forest and much affected by coastal tide, ecosystem of perennial trees in the foot of mountain of typical forest side.

Vegetation coverage on the saline flooding sea coast is a population of typical mangrove forest trees, but poorly developed and depauperate, including almost all species in

mangrove forest which on this area can be divided into 2 belts; the outer belt belongs to bindweed family with liana plants mainly living on small mobile sand dunes, inside of this belt is typical mangrove forest trees such as: *Rhizophora, Bruguiera, Avicennra*...

Vegetation coverage on acid flooding area is affected by tide and salinity, especially very high salinity in dry season, but being washed away in rainy season, here there is the mixing up between species of each particular ecosystem both of brackish water and saline water, and acid one. That is the appearance of Malaleuca leucadendron, Nifaflulicants, Flagella indica, *Rhizophora, Bruguiera,* Lumitzera racemosa and Eucalyptus, Acanthus officinalis.... Particularly on the high land, Lumnizera develops into forest, creating very special landscape of the area. The deeper into the limestone mountain, the more developed the trees which can endure flood and acidity such as: cajuput, eucalyptus, glyceria reed.

Vegetation coverage on coastal limestone mountain or inside area of Hon Chong shows the population of trees that can endure drought and heat, sea wind, and has high adaptability; they are wild plants very typical for lime stone mountain, without big arbor trees.

- In Vinh Long province, due to large scale agricultural activity, there are very few natural areas. Agricultural ecosystems such as fruit tree garden, rice fields, other crops... are predominant. Water ecosystems are not diversified due to too strong runoff. Forest ecosystems almost does not exist any more (there are only industrial trees in scattering form).
- Most of lands in Long An province belong to flooded group, mainly occupy in Dong Thap Muoi, and are divided into 3 principal sub-ecosystems: the riparian flooded plain: the natural plants such as Gao, Ca na, nipa... in this area there is still cultivation of rice, sugar cane and perennial fruit trees, moreover, there are some trees of high economic value such as Sao den, Dau nuoc. The closed flooded plain – swamp ecosystem and cajuput forest ecosystem: cajuput population is typical for this area; moreover there are other natural ecosystems such as lotus, nenuphar, flagella indica, Lac, Mom moc... The coastal plain – river mouth ecosystem: formerly, the plant population such as *Rhizophora, Bruguiera, Aegiceras, Avicennra,* and nipa are typical and predominant. Nowadays, most of natural forest has been destroyed, and these forests have been destroyed for cultivation of rice and other crops, although with not high productivity.

(2) Animal resources

In the swamps of projected area, wild animals are very rich; including 23 mammals such as crab eating monkey, *Cervus unicolor, Sus scrofa, Lutra lutra, Macaca minata, Vivera zibetha, Felis viverrine, Tupaia glis, Calloscriurus pygerythrus* etc. Most of these animals are discovered in mangrove forest and cajuput forest in U Minh, Nam Can.

The swamps of projected area create a favorable environment for the development of reptiles including *Python reticulatus, P.molurus, Ptias mucasus, Bulgarus fasciatus, Naja naja, Gekko gekko, Cuora amboinensis, Maylyemus subtrijuga* etc.

Swamps of projected area are the habitat for birds, which are mostly water birds. They include also rare birds such as *Grus antigone sharpll, Xynorhynchus asiaticus, Ibis leucocephalus, Leptoptilos javanicus or Leptotilos dubius, Threskiornis melanocephalus* etc.

Human activities such as resettlement, war, agricultural production and hunting have caused a series of impacts on wild animals, including the birds. Six amphibians, 18 reptiles, 41 bird species and 15 mammals have been specified in 1989 in Nam Can mangrove forest lying about more than 10 Km from national route 10. It was shown that there are some rare species which are endangered according to Regulations No. 18/H§BT promulgated on 17/1/1982. They are panther, *Lutra lutra, Neofelis nebulosa,* but now they have disappeared.

The brackish water and the coastal area have the biggest fish output owing to good water quality with high nutrition from mangrove forest and inland runoff, especially from sources of breed and food in mangrove forest. In this area, more than 300 fish species belonging to 30 groups have contributed to aquatic output. They include fresh and salt water fish species. The predominant groups are *Clupeidea*, *Scombidae*, *Polynemidae*, Leiognathidae; they swim against the stream according to season, reproduce at sloping area or fresh water in river mouth. Apart from fish species with fin, shell animals (clam, oyster, mussel, particularly shrimp (more than 20 species)), there are also many big fresh water fish, Macrobrachium rosenbergli, Pennaeus monodo and Penaeus merguiensis.

Fresh water area including river, lake and rice field in the inland has about 152 species, which are divided following their dwelling sites into 2 popular groups as follows: (a) group of river fish (carp, hyphthalmichthys, Asian catfish, Linh ong fish, river gurnard etc.) that require water of good quality and easily sensitive with changes of environmental elements and toxicants; (b) group of rice field fish (anabas, gourami, snake-head mullet, proboscisfish, catfish, eel etc.) that lives mainly in rice field and pond, can endure the lack of oxygen, and live in polluted environment with high acidity or alkalinity.

Can Tho province, in general, is a fresh water ecological area with the presence of 173 fresh water and brackish water fish species in the Mekong River Delta. The main fish families are Cyprinnidae (35 species, among which we should mention carp, Linh ong fish, hypophthalmichthys etc.), Gobiidae (5 species, among which we should mention goby), Cralidae (among which we should mention catfish), Siluridae (8 species, among which we should mention Leo fish, Chen bau fish), Ophicephalidae (4 species, among which we should mention snake-head mullet), Schilbeidae (11 species, among which we should mention Asian catfish, Vo fish, Hu fish, bass).

Soc Trang province lies at the end of downstream of Hau River and Mekong River, close to the East Sea, with 72 km sea coast, so its biodiversity is also divided into 2 different areas that are fresh water ecosystem and brackish water ecosystem of river mouth. Fresh water fish of Soc Trang province has 2 popular groups, which are the river fish (carp, hypophthalmichthys, Asian catfish, Linh ong fish, river gurnard etc.) and rice field fish (anabas, gourami, snake-head mullet, proboscisfish, catfish, eel etc). Fish of brackish water and river mouth at Hau River has more than 150 species belonging to 13 defined assortments, in which the one with highest number of species is Perciformes (42 species), Cyprinifomes (40 speciesi), Plaronectiformes (4 species), Tetradontifomes (3 species), Siluriformes (35 species), Beloniromes (5 species).

Most of fish system in river mouth is sea fish and brackish water fish, but sometimes, in the river mouth there is also fresh water fish such as: Protus Anquilcaudatus, Leiocatis Siamensis, Siluriliesthys pheriosoma, Kryptopterns, Clarias macrocephalus, Clarias batrachus, Trichogaster trichopterus. Moreover, crustacean also has high density in the coastal region and river mouth. In the Mekong River Delta, it was discovered 32 shrimp species, the most popular is Penaeidae family, the important species of which are: *Pnaeus merguiensis, P. indicus, P. monodon, P. semisuleatus, Menapenaeus ensis, M. Lysianassa, M. mutatus* and *parapenaeopsis hardwickii.* Moreover, there are also big amount of species such as: oyster, meretrix, clam etc. of the coastal river mouth.

The coastal sea of Bac Lieu province has 99 fish species and 27 shrimp species of economic value. The reserve of fish and shrimp is about 125,000 tons. The salt water fish species of high economic value such as: snapper, Huong fish, gowler, lungfish, red mullet, palmer, mackerel, Sau fish, Rung fish, Duong fish, sardinella, Thieu fish, threadfin, Goc fish, Su fish etc. Following are the proportions of shrimp species with high economic value: white shrimp: 54.6%, Chi shrimp: 34.3%, Nhang shrimp: 5.2%, Sat shrimp: 4.4%; other

shrimp species: 1.5%. There are plenty of sea crab, clam, and oyster. Hiep Thanh commune has 84 ha of *Meretrix Lyrata* and *Tegilllarca Granosa* with density of 0.46 – 381.3 pieces/m^2.

At cajuput forests of Ca Mau province, there are rare and precious species of birds and animals such as ring-necked, Dai chicken, Soi chicken, bald eagle, crow, wild boar, sambar, and monkey. Wild animals in ecosystem of mangrove forest in Nam Can have 6 amphibian species, 18 reptiles, 41 birds, 15 mammals; at present, the remaining of some precious and rare species of fish and animals such as spotted snake-head, white catfish, Chang be, Giang sen, Soi chicken, ring-necked, crocodile, yellow monkey, wild boar, golden sambar etc. is negligible.

The total number of birds surveyed at 19 bird grounds of Ca Mau province is 54.200 including 62 species belonging to 24 families. The swamp birds often occupy 80-90% total of birds. In 3/2000, UK experts in cooperation with Can Tho University have discovered 03 new migration bird species in Ca Mau, which are Choat mang lon, greater yellowlegs and especially Chinese stork (*Egertta culophotes*).

Ca Mau has great potential in aqua-culture in fresh water, brackish and salt water. The special aqua-products of fresh water (pantheon, crocodile, snake, eel, tortoise etc.) and brackish water (blood ark-shell, Len snail, crab etc.) are widely developed. Apart from those of natural tradition farming such as snake-head mullet, catfish, striped gourami, anabas, featherback, green tiger prawn, earth prawn, banana prawn, and crab, now there are many more species such as grass shrimp, meretrix, tilapia, grass carp, major carp, carp, hypophthalmichthys, big goby, bat fish, hybrid catfish, sea-bass, palmer etc.

3.4.2 Biodiversity

Animals of cajuput forests of U Minh and Long Xuyen Quadrilateral include 4 main following groups:

- Group of animals with tail includes 20 species, in which there are rare and precious species such as: sambar, wild boar, otter, pangolin, monkey, grey-bellied squirrel;
- Group of feather animals includes 81 species, in which there are valuable species such as: tree duck, mangrove, white pelican, stork...
- Group of reptiles include 33 species, in which there are valuable species such as: snake, tortoise, pantheon, gecko, varan...

- Group of amphibians include 11 species, in which there are valuable species such as: toad, frog, hyla

Following study of NAGA (1957-1961), zooplankton at the sea of Kien Giang province includes 23 shrimp species belonging to 10 families, which originates from salt and brackish water, and it was defined that the families of the most economic value are Penacidac (8 species), Palacmonidac (6 species), Sergestidac (1 species) Atyidac (1 species), Alpheidac (1 species), Mysidac (1 species) Squillidac (1 species) Palinuridac (1 species).

Following report of Branch II of Aqua-culture Institute, the fish species defined in Thailand Bay are 315, in which there are about 50 species of economic value. In the East Sea, the Saudirac family occupies 35%, Carangidac occupies 31%, Lutianidac, Priacanthidac, nomipteridac, Sciacnidac, Pomadasyidac and Engraulidac occupy from 1 to 5% total caught fish. The distribution of sea fish obviously depends on salinity and oceanography characteristics in dry season (November to April). Fish concentrates near the shore in rainy season (May to October), and due to effect of fresh water from inland, fish concentrates farther the shore.

Wild animals in ecological area of inundated forest (cajuput forest) have rather rich components and number. At the special use forest of Vo Doi, there are 12 amphibian species, 32 reptile species, 100 bird species, 18 tailed-animal species. Moreover, cajuput forest has rare and precious bird species such as: ring-necked bird, Doi chicken, Sui chicken, sea eagle, crow, wild boar, sambar, monkey.

Wild animals in ecological area of mangrove forest in Nam Can have 6 amphibian species, 18 reptile species, 41 bird species, 15 tailed-animal species.

Animals on island in general are poor in species and individuals.

Table 3.8 Component of animal species in Ca Mau province

No.	Item	Animal in mangrove forest	Animal in cajuput forest	Animal on island
1	Amphibian	06 species	11 species, 05 families	
2	Reptile	36 species, 10 families	32 species, 10 families	07 species, 06 families
3	Bird	154 species, 36 families	97 species, 35 families	20 species, 10 families

4	Form	24 species, 01 families	19 species, 09 families	02 species, 02 families

Source: Center for Research and Application of Minh Hai mangrove forest in 1999 and of Dr. Nguyen Dinh Hung

The decrease in forest area has changed the living environment and habit of animal species, annihilated some aquatic species, precious and rare birds such as: spotted snake-head mullet, white catfish, Chang bo, Giang sen, Sui chicken, ring-necked bird, crocodile, yellow monkey, wild boar, golden sambar... some are extinct, the rest has insignificant number.

Ecosystem of bird grounds

When saying the ecosystem of flooded area of Ca Mau, we should mention the ecosystem of bird grounds. Ca Mau has 2 bird grounds (Cha La and Dam Doi) and a bird garden of cajuput forest (Ho Thi Ky). Following survey data of Center for Research and Application of Minh Hai flooded forest in 12/1998, apart from 03 above-mentioned bird grounds, Ca Mau has also 16 other bird grounds, bird gardens and landing areas. More special is that in the middle of Ca Mau city, there is also a bird garden of more than 8000 individuals of different kinds coming there to live and reproduce. Total number of birds counted in this survey at 19 bird grounds and gardens is 54,200. The swamp bird species often occupy 80-90% total number. Total number of observed bird species is only 62 species of 24 families.

Bird grounds and gardens are often distributed in ecosystems of mangrove forest (17) and cajuput forest (2), specifically in localities: in Dam Doi forest: 09; Ngoc Hien district: 06; Cai Nuoc district: 02; Thoi Binh district: 01 and Ca Mau: 01.

Ca Mau has some grounds to which birds migrate from other continents. In 1991, at Ngoc Hien a red beak bird was found with a number plate at its leg, migrating here from the former Soviet Union in 3/2000. UK expert in cooperation with Can Tho University have discovered 03 species of new migrating birds in Ca Mau, which are Choat mang lon, greater yellowlegs and especially Chinese stork (egertta culophotes). At present, the alluvial ground has been restored as a natural ecological area that will be attractive to many precious bird species from remote area coming here to live. Most of migrating bird species concentrate in tide ground around big mangrove forest in the north side at this area and Dat Mui reserve.

3.5 Sensitive areas

3.5.1 Natural reserve zones

There are natural reserve zones in the project area (Cuu Long Delta) as follows:

Name	Province	Style	Features
Vồ Dơi	Cà Mau	Inland	Indigo forest and grasslands
Bãi Bồi	Cà Mau	Coastal	Warp, emigrated birds
Đất Mũi	Cà Mau	Coastal	Warp, emigrated birds
Đầm Dơi	Cà Mau	Coastal	Deteriorating Mangrove Forest
Cà Mau Birdgrounds	Cà Mau	Birdgrounds	Large birdgrounds
Hà Tiên	Kiên Giang	Inland	Grasslands, threaten birds
U Minh Thượng	Kiên Giang	Inland	Indigo forest and grasslands, large birdgrounds
Trà Sư	An Giang	Inland	Indigo forest and grasslands, large birdgrounds
Tỉnh Đội	An Giang	Inland	Indigo forest and grasslands
Bình Minh	An Giang	Inland	Indigo forest
Bạc Liêu Birdgrounds	Bạc Liêu	Birdgrounds	Large birdgrounds
Lung Ngọc Hoàng	Cần Thơ	Inland	Indigo forest and grasslands
Hòa An	Cần Thơ	Inland	Laboratory, Indigo forest and rice field
Thới An Birdgrounds	Cần Thơ	Bird sanctuary	Large birdgrounds
Tràm Chim	Đồng Tháp	Inland	Grasslands, threaten birds
Xẻo Quýt	Đồng Tháp	Inland	Indigo forest, traditional revolution education place
Láng Sen	Long An	Inland	Indigo forest near river
Bàu Biển	Long An	Inland	Lagoon
Trà Cú Bird grounds	Trà Vinh	Bird sanctuary	Large bird sanctuary

Name	Province	Style	Features
Duyên Hải	Trà Vinh	Coastal	Mid- natural phellum forest
Duyên Hải Bird sanctuary	Trà Vinh	Bird sanctuary	Large bird sanctuary
Chùa Hang Bird grounds	Trà Vinh	Bird sanctuary	Large bird sanctuary
Thạnh Phú	Bến Tre	Coastal	Planted mangrove forest
Hàm Vồ Birdgrounds	Bến Tre	Birdgrounds	Large bird sanctuary
Bảo Thuận	Bến Tre	Coastal	Planted mangrove forest
Cần Giờ	HCM City	Coastal	Planted mangrove forest (adult forest)
Tân Phước	Tiền Giang	Inland	Small area of Indigo forest and grasslands
Gò Công Đông	Tiền Giang	Coastal	Planted mangrove forest
Long Phú	Sóc Trăng	Coastal	Planted mangrove forest

Source: Institute of Ecology and Biological Resources

Positions of the natural reserved zones are presented in map (see annex 6).

3.5.2. Cultural and historical relics

In the project area (flooded and flooding area in Cuu Long Delta), there are several cultural and historical relics as follows:

- Quan Co Tran Van Thanh relic, 50 km away from Long Xuyen city, An Giang
- Oc Eo relic, Thoai Son District, 30 km away from Long Xuyen city, An Giang
- Tuc Dup Historical relic, An Giang
- Nui Sam relic zone, An Giang
- Gieng Isle (on Tien river), An Giang
- Giong Thanh pagoda (Giong Huong Tu), Phu Tan district, An Giang
- Tay An pagoda, Chau Doc town, An Giang
- Xa Ton pagoda, Tri Ton, An Giang
- Thoai Ngoc Hau Tomb, Vinh Te commune, Chau Doc town, An Giang
- Temple of Ba Chua Su, An Giang
- Long My relic, Hau Giang
- Provincial Committee Revolutionary base relic, Phung Hiep, Hau Giang

- Binh Ta relic zone, Long An
- Ton Thanh pagoda, Long An
- Vinh Trang pagoda, Tien Giang
- Go Thap relic zone, Dong Thap
- Historical relic zone of Nguyen Sinh Sac, Dong Thap

CHAPTER 4. ALTERNATIVE ANALYSIS

4.1 Without Project

In recent years flood in CLD area more and more dangerous and unaible to foresee. For example, the 2000 year flood caused enormous losses in human lives and properties (about 500 people died-mostly children, 4000 billion VND damages). With available instrumentation the Hydro-Meteorological service can not meet the demands for forecasting, warning of weather and flood in CLD.

- The meteorological stations and rainfall posts in CLD still use the obsolete, old fashioned instruments that do not meet the requirements of measuring accuracy and in information, warning and forecasting of weather for responsible agencies in order to make good, timely arrangements for flood protection, keeping local people well informed and timely evacuated from flood vulnerable area, and to have adequate storage of foods, goods, medicaments in flood/storm season.

- The hydrological station and flood investigation posts in flooding area of CLD still use old-fashioned, obsolete instruments like water level recorders with recording paper (to be checked/ changed daily/ weekly) and later on data processing; so can not inform timely, quickly to provincial Hydro-Meteorological forecasting centers, to Southern RHCM in Ho Chi Mink city. The delay in informing hourly, daily data (hydrological, meteorological) leads to inaccurate weather/flood forecasts especially the long term ones. That is the reason why large damages of storm/flood still remain.

- The number of discharge stations still are limited, does not meet the demands in flow distribution in tributaries and flow into/out of Dong Thap Muoi, Long Xuyen Quadrangle regions. The measuring devices do not have data logger and two way radio links…and make it difficult for flood/flooding modeling and forecasting.

- The hydrological, meteorological forecasting model do not meet the requirements in forecasting floods, storms, surges, rainfall and the flood diversion in delta rivers, flooding in CLD.

-Not timely and inaccurate hydro-meteorological forecasts make people in flooding area unable to plan adequately their production/plantation, to protect from flood in rainy/storm season. At the same time the decision makers are unable to make planning, management and rational use of water resources; to store water for the following dry season, to drain water in t\raining season. That is very important for stable socio-economic

development in CLD. For example the forest fire in U Minh Ha region some years ago might be due to (partially) irrational water resources management that led to heavy losses in living resources and tourism of the area.

- Additionally, no need for relocation of households in project area: the people living in project area will not be impacted, disordered in daily life except some 100 households that may be relocated due to newly installed hydrological post in flooding area.

4.2 With Project

If the project is implemented, it will solve significantly disadvantages above. Of course, the project will cause some negative impacts on natural environment and socio-economic in the project area but the impacts could be prevented and be mitigated by mitigation measures.

Impact assessments (positive and negative ones) on natural environment and socio-economic in project area are presented in chapter V.

CHAPTER 5. ENVIRONMENTAL IMPACT ASSESSMENT AND MEASURES FOR MITIGATION

5.1 Objectives of ER

The Cuu Long Delta (CLD) is the greatest rice production area of the country and plays important role in the food security for the whole country. But in some recent years the natural disasters like flood, flooding and drought frequently occurred, threatened, impacted on the rice production, aquaculture, fruit tree raising… more over storm and flood also influenced on the economy, social life of the people in flooding areas. Especially the 2000 year flood caused great losses in lives and properties in the CLD. Contributing to the country's construction plan and the disaster mitigation programme, the feasibility study for Mekong Delta flood warning and monitoring system project has been developed and aimed at heightening the capacity of hydro- meteorological information, warning, forecasting flood/flooding in CLD that help the agencies of concern and people in flooding zones to have accurate information about weather and flood conditions and then to make suitable measures in flood/flooding protection as well as adequate arrangements of crop rotation to suit the weather condition.

The impact assessment examines the possible project influences (positive and negative ones) on the environment, socio-economic development and to the health of the community in the project area. As the results to propose the measures for mitigation of negative impacts on environment, life of people in the project area.

5.2. Some major impacts of the project in the phases

The project is aiming to improve the warning, forecasting and informing in CLD. That will be realized through the heightening and modernizing the instruments in hydrological, meteorological stations, training the staff for these instruments management and use. At the same time it is planned to build some new 132 hydrologic posts and 2 radar systems (if fund is available) in order to gather data for more accurate and timely forecasts to train and propagandize the people and authorities in flooding area in understanding and effective use of information, forecast, to help the authorities in planning, development of the area and people in flooding zones to have active plan for production arrangements and life stabilization in order to reduce the losses caused by flood/flooding and hence to enhance socio-economic development.

The project may cause also some negative impacts like rehabitation, the environmental influences due to hydrological posts construction and 2 radars installation (if fund is available)…

Typical Impacts and Mitigation Measures of Hydrological posts and Meteorological station building Sub-projects

Environmental and Social Components	Impacts	Mitigation Measures
Physical Environment		
Soils	• Bank collapsing, sinking and affects to dykes/ dyke safety corridors leading to station falling down, bank erosion (because many hydrological stations proposed to build near rivers and canals) • Contamination from waste materials	- Before station installation it needs to carry out the geological surveys and to comply with dykes protection ordinance (do not break dykes/ dyke safety corridors) - Protection of soil surfaces during construction; control and daily cleaning of construction sites; provision of adequate waste disposal services
Water Resources	• Clogging of drainage works • Decline in water quality due to contamination • Introduction of construction material wastes and domestic wastes (discharged by construction workers)	- Special attention to deposition in channel bed, influencing the flow, to insure no influence of drainage and flow - Collect waste construction material; - Adequate sanitation and disposal system for waste
Air Quality	• Dust during exploitation, construction material transportation and construction • Degrade air quality • Odor problems (from WC)	- Dust control by water spraying or other means; appropriate - Adequate design and position of sub-project
Acoustic Environment	• Noise pollution during construction	- Restrict material transportation and construction activities at night

Environmental and Social Components	Impacts	Mitigation Measures
Biological Environment		
Natural Habitats	• Disturbance of natural habitat	- Consideration of alternative alignments or sites
Fauna and Flora	• Loss or degradation of vegetation • Disruption or destruction of wildlife	- Minimize loss of natural vegetation during construction; consideration of alternative sites; various special measures for sensitive species
Social Environment		
Landscape	• Debris	- Cleaning-up of construction sites; provision of adequate solid waste disposal systems
Historical/Cultural Sites	• Degradation of sites • Disturbance to structures	- Consideration of alternative sites; special measures to protect buildings and other cultural resources/areas
Human Health	• Construction accidents • Source of inflect from immigrant workers	- To strictly observe labor safety - To control healthy status of immigrant workers
Human Communities	• Involuntary resettlement • Loss of buildings, property, or economic livelihood	- Compensation per OD 4.20; good sites; community participation in environmental assessment

To have good assessment of these impacts we carry out the works in 3 phases as follows.

- Pre-project implementation phase
- Project implementation phase
- Post project implementation phase

5.2.1. Pre-project implementation phase

5.2.1.1. Positive impacts

- No extra staff in available hydrological, meteorological stations

- The meteorological stations in CLD observe many element (like presented in chapter 2, in current status of the station). There have 4 observations in a day (at 1:00, 7:00, 13:00, 19:00h), in all year round. The available instruments are obsolete, old fashioned and require large staff (the persons working in meteorological stations are numerous).

- The similar situation happens to hydrological posts: old, obsolete instrument like water level recorders with records on paper, that need daily or weekly visit and record paper change so require substantial human resources.

5.2.1.2 Negative impacts

- Relocation process and people: Flood protection and mitigation are in priority of the Government and usually supported by people in disaster vulnerable areas, so the displacement and relocation problems of the project will not meet substantial difficulties. In this project some 132 hydrological posts will be installed in flooding areas that require the land of some 100 households, the other posts are expected to be set up in communal lands. But lands appropriated are small (about 100m^2 for each post, in a district about 3 posts) and scattered so much. The process of displacement and relocation will be voluntary, based on the agreement of two sides according to the Law of land of SR of Viet Nam and the compensation policy of the World Bank (WB). The reimbursement for one household is estimated at 200.000.000VND. These households are not heavily influenced, not disturbed so much in living and earning.

5.2.2. The project implementation phase

The impacts in project implementation phase include:

- The influences of hydrological posts construction;
- The impacts of 2 radars installation;

- The installation of meteorological automatic stations.

The people mainly impacted in this phase are that live around the posts newly constructed or around the 2 radars installed, around the meteorological automatic stations.

- The impacts of construction of newly set up hydrological posts in flooding areas are the pollution of the environment due to construction material transportation, spilling, digging… The post location are usually along the rivers/canals; so due attention should be paid on excavation for station foundations that may affect on dyke base, on the subsidence of dyke corridor of safety, the construction materials spilling and their falling into rivers/ canals may lead to deposition in channel bed, influencing the flow and local water quality. The transportation of materials and living activities of the construction workers would impact on environment and on nearby households. But they are estimated not to be significant due to small number of workers (about ten persons) for each post and their short time residence (some months).
- Two radars installation (if fund is available) is expected to be in Can Tho and Pleikou cities. The construction of radar foundation and office house may cause some small impacts on environment and local people due to digging, transportation of materials during construction. These affects are not so much and may be easy to recover.
- To install automatic weather stations in the site of available meteorological stations. In the process, due attention should be paid on thunder strike to pole of automatic weather station due to its height (12m) and steel material that may attract thunder strike, causing dangers to station area.

5.2.3 Post project implementation phase

5.2.3.1 Positive impacts

a) Enhancement of the capacity for hydrological, meteorological information, warning, forecasting; upgrading stations with hydrological, meteorological modern equipments for intensification of data collection that will meet the requirements for two- way information communication and provision to responsible agencies with timely and accurate information on weather and flood in CLD for having good, timely decisions in flood protection, mitigation.
b) Having got accurate hydrological/ meteorological information, warnings and forecasts, especially the long term forecasts, the responsible persons would issue the announcements, warnings to local people in the fastest ways so that people could

have adequate production plan, the plantation and animal structures, the crop rotation suitable to annual weather and flood conditions.

That means the stabilization of living, socio- economic conditions of people in the inundation areas.

c) To heighten the knowledge of decision makers on flood/ flooding, contributing to the scientific bases for refinement of development planning the CLD, of flood control planning, intensification of effective use of Mekong river water resources for socio- economic development. The CLD has obvious characteristics: lack of water in dry season and excessive water in rainy season; moreover CLD has diverse biological resource with specific purpose forests, protective forests, large birds ground, etc. Without rational management of water resources it may lead to forest fire.

d) The training courses plan is organized in this project will heighten the knowledge of hydro- meteorological technical staff and then improve the hydro- meteorological data collection and forecasting.

e) The courses also improve the understanding of people in flooding areas about flood/ inundation about the flood warning water level (3 grades), they improve capacity in using various information, warning, forecast about flood/ flooding, in changing the people's behaviors concerning flood severity and damages. On this basis to develop plan for people's life and property protection, to store foods, medicals in flood season for the sake of community's health.

5.2.3.2 Negative impacts

a) After the project completion, the hydrological and meteorological stations will be equipped with automatic instruments like automatic current meters for river discharge measurement, automatic weather stations... that may record, warn and run automatically many works done by hand in previous time. So, staff number of these hydro- meteorological stations will be certainly reduced.

b) The newly set up hydrological posts may cause bank collapsing, sinking and affect the safety of river/ canal shores/ banks and dykes. In flood season these posts may be collapsed or swept away, that would severely affect the material bases and life of posts staff.

c) In meteorological stations newly equipped with automatic weather station of 12m in height, made of steel and set up at exposed places, that may have great chance to be hit by thunder (if they are not provided with lightning protection system).

5.3 The mitigation measures

5.3.1 General measures:

Some commonly used measures for mitigation of negative affects are:

+ Preventive measures: do not take any activities that may cause or intensify negative affects;

+ Mitigation measures: to limit the scale, level of activities or processes causing negative affects;

+ Correction measures: to adjust the affects by repairing, recovering or restoring the affected environment;

+ Protection and maintenance measures: mitigate or exclude the affects after a period of time by maintaining or preserving the working capacity.

+ Excluding measures: to prohibit the activities causing negative affects.

+ Compensation measures: to reimburse the losses by replacement or provision of other resources/ man- power or by creation of substitute environment.

5.3.2 Some activities for reducing negative affects in the project

5.3.2.1 Pre-project implementation phase

- In the design stage it is necessary to select the sites for installation of 132 hydrological posts in flooding areas so that these places do not belong to sensitive locations like conservation areas, cultural/ historical relics (heritages)... and to minimize the occupation of available households. Map analyzing result showed that the post No38 which is about 300m away from Tram Chim Tam Nong on An Binh canal is the closest to the sensitive area.
- Due to the specificness of hydrological post location in flooding areas, the post site may be moved to nearby place to minimize the relocation affect.
- Before station installation it needs to carry out the geological surveys at the sites to avoid bank collapsing, sinking and affects to dykes/ dyke safety corridors leading to station falling down, bank erosion.

5.3.2.2 Project implementation phase

- To reduce negative affects of the project on surface water, air, channel bed deformation/ erosion/ deposition. During the construction process it needs to reduce noise pollution for local people due to construction materials transportation, construction activities; do not make these works at night time for protection of population good sleep. During transportation of construction materials it needs to avoid their scattering out on roads, rivers/ canals. The domestic and construction wastes should be collected and transported to fixed/ defined sites.
- The land compensation, relocation of households (for hydrological posts location) should be done according to the Vietnam Laws and compensation policy of the World Bank. It needs to give all possible favors to relocated households at new accommodations and to stabilize their life, to provide them earning chances to live better than before displacement.

The World Bank guides: *The people affected by the project should be helped to improve living conditions, earning/-working capacities or at least to restore their former gaining levels.*

The World Bank policy also says: *Do not consider the lack of licence for land use as an element preventing the compensation process. All affected people by the project, especially the poor ones, the homeless people should be reimbursed, relocated and compensated.*

5.3.2.3 Post project implementation phase

- The excessive staff (due to upgrading, modernizing equipments and automation) at hydrological, meteorological stations may be moved to newly established hydrological posts. That may help in reduction of excessive staff and in use of every capacity of the staff.

- For 2 radars operation it is necessary to take into account the radar safe corridor, the permission for radar wave frequency use, for maximum effective radar radius at responsible Wave Management Agency to avoid bad affects upon population health at nearby areas and not disturb the works of other agencies using radio/ electronic waves such as Post and Communication, Airborne navigation...

- To set up lightning protection system in automatic weather stations for the safety of human resources and properties at the sites.

- To establish working rules and labor safety regulations for the safety of the staff working at the two weather radars newly set up, for their protection from bad influence of

radio/ electro- magnetic waves of radar stations. For radar station, attention should be paid on the following:

+ to set up safety corridor for radar operation, to install equipment for protection from bad affects of radar waves on people living nearby.

+ to set up working rules and labor safety regulations for technicians working at radar stations and protect them from negative affects of Matheson lamps generating electro-magnetic waves.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1.Conclusions:

1) The project of "Mekong Delta flood warning and monitoring system" would bring many substantial benefits:

- The project will help in heightening the awareness on flood, flooding, will contribute to scientific bases for refinement of development planning the Cuu Long river Delta, of flood control planning, improvement of the effective exploitation of the water resources of the Me kong river for the sake of socio-economic development.

- After the completion of the project an integrated system of software and hard wares will be installed for timely service of hydro-meteorological operation.

The station network would increase data collection in flood season regularly, timely, accurately about the weather, flood, flooding, that would help the communication process, operation of forecast models, issuing warning, forecasting timely and more accurately.

- This project would have large socio economic effects in flooding areas of CLD because flood/ flooding in CLD have tendency to increase in scale, occurrence frequency and damages. In CLD the strategy "living together with flood" would exploit rationally the water resources, to implement at the same time structural and non-structural measures because the later one will bring significant benefits. Experiences show that good warning, forecasting on flood/flooding, timely provision of accurate information about them will reduce substantially the damages caused by flood/flooding. Improvement of flood forecasts, especially long term forecasts, enhancement of the awareness of the population on flood, inundation would help farmers to have good crop rotation, to harvest timely the crop, to change the plantation and cattle structures, stabilize the living conditions and production. So, the project will bring benefits, reduce the losses in human lives and properties, but will stabilize the production process, life of million people in flooding areas. That are urgent requirements for sustainable development.

2) The results of ER of the project, the possible environmental impacts may be as follows:

-The negative impacts in pre-project phase: there may have some 100 households scattering in 7 provinces of CLD to be moved for installation of 132 hydrological posts in the flooding areas (in average 3 posts for a district, each station may occupy 100m^2). The

remaining posts may be installed on the public lands. No historical/cultural estates (heritages) are to be moved, there will be no violation to any conservation areas.

- In project implementation phase: to move some 100 households in project area, to get agreement for land compensation and relocation. The people to be relocated are not of great number; the lands for compensation are dwelling ones so the impacts on living and earning conditions are not so much. During the installation of 132 hydrological posts in flooding areas their construction process would cause insignificant affects on surrounding environment due to scattering of land, sand, wastes, construction materials. The construction activities would have some impacts to local people but not substantial. So, the supervisors and managers of the posts construction in flooding areas should pay due attention on this process to avoid or mitigate the negative affects.
- In the operation phase of the project no substantial negative affects on environment are expected.

This project belongs to non-structural one and is the environment protection project. The negative impacts of the project are small, scattering and may be overcome easily. So it needs only some rational measures for the purpose instead of setting up special program for monitoring and managing the environment.

6.2. Recommendations

- For the effective project implementation, it needs good cooperation and coordination of the project implementing agency and local authorities, the supports from local population. There should create favor conditions for relocated households to have new houses for stabilization of their life.
- To carry out the propagation, education, training for local people on hydro-meteorological information, warning, forecasting on 3 warning water levels. That will help them to recognize the danger level and possible losses due to flood/ flooding and to actively take measures for life and property protection.
- It needs good cooperation with mass media to inform timely, accurately to responsible local agencies and people about the flood and weather developments, to help the responsible agencies issuing suitable instructions for storm, flood damages reduction.
- The Ministry of Agriculture and Rural Development and Project Preparation Unit should strictly follow the Law on Environment protection of Vietnam and the

environment policy of the World Bank. We recommend the Environment decision makers to approve this Environment Impact Assessment report to facilitate the project implementation as planned.

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ANNEX

Annex 1

Table: List of the hydrological posts in the flooding areas of the CLD proposed in this sub-project.

No	Station code	Long.	Lat.	Notes (Canal & creek, location)
1	1	105.20201	10.48294	Đầu Rạch phía sông Tiền, Rạch Hồng Ngự, Tỉnh Đồng Tháp
2	2	105.39900	10.86000	Kênh Tân Thành - Lò Gạch, Bình Thuận, Hồng Ngự, Đồng Tháp
3	3	105.20307	10.51330	Làng Tân Hội, Sông Sở Thượng, H. Hồng Ngự, Đồng Tháp
4	4	105.34600	10.80400	Hồng Ngự (Chân cột máy thuỷ văn tự ghi Hồng Ngự), H. Hồng Ngự, Đồng Tháp
5	5	105.47200	10.81800	Ng.Hữu Thanh, cửa hàng vật liệu số 3 An Thọ, Xuân Phước, Tân Hồng, Đồng Tháp
6	6	105.59400	10.83000	Võ Văn Đua, tường phía trước nhà, Hoàng Việt, Tân Phước, Tân Hồng, Đồng Tháp
7	7	105.50600	10.89900	Tân Thành - Lò Gạch, Tân Hồng, Đồng Tháp
8	8	105.23472	10.54361	Gò Chùa, Làng Bình Phú, sông Sở Hạ, Tân Hồng, Đồng Tháp
9	9	105.62200	10.74900	K.Phước Xuyên (Chân cột phải nhà Công an xã Tân Công Sinh, Tam Nông), Đồng Tháp
10	10	105.37800	10.70700	Đồng Tiến & Sông Tiền, Tam Nông, Đồng Tháp
11	11	105.56600	10.67300	Trạm TV huyện Tam Nông (K.Đồng Tiến), Đồng Tháp
12	12	105.41594	10.40063	Đồng Tiến & Tân Công Sinh, Tháp Mười, Đồng Tháp
13	13	105.48335	10.35311	Kinh 26 - xã Mỹ Hoà, Tháp Mười, Đồng Tháp
14	14	105.84400	10.52400	K.Nguyễn Văn Tiếp (TV Mỹ An, TT Mỹ An, Tháp Mười), Đồng Tháp
15	15	105.63400	10.60600	An Phong - Mỹ Hoà, Cao Lãnh, Đồng Tháp
16	16	105.61600	10.53200	K. Nguyễn Văn Tiếp (số 94, ấp 2, X. Tân Nghĩa, Cao Lãnh), Đồng Tháp
17	17	105.75300	10.44500	K.Số 1 & K.Cái Bèo, Cao Lãnh, Đồng Tháp
18	18	105.76200	10.36100	Rạch Cái Bẩy, X. Bình Hàng Tây, Cao Lãnh, Đồng Tháp
19	19	105.45421	10.18164	Phường 3, Sa Đéc, sông Tiền, Đồng Tháp
20	20	105.46000	10.17068	Làng Tân Phú Đông, Sa Đéc, Đồng Tháp
21	21	105.39307	10.17131	Lai Vung, Kênh Tắt Đu, Lai Vung, Đồng Tháp
22	22	105.40225	10.09312	Làng Phong Hoà, kênh Mương Khải, Lai Vung, Đồng Tháp
23	23	105.33506	10.16552	Láng Tân Phước, sông Hậu, Lai Vung, Đồng Tháp

No	Station code	Long.	Lat.	Notes (Canal & creek, location)
24	24	105.51018	10.12072	Xã An Khánh, Kênh Xẻo Mít, Châu Thành, Đồng Tháp
25	25	105.48248	10.09440	Xã Tân Hoà, Kênh Nha Mân, Châu Thành, Đồng Tháp
26	26	105.45176	10.11477	Xã Tân Phú, kênh Bà Xã Hợi, Châu Thành, Đồng Tháp
27	27	105.31243	10.21357	Lấp Vò, Kênh Cái Tầu Thượng, Lấp Vò, Đồng Tháp
28	28	105.35323	10.20398	Long Hưng B, kênh Lấp Vò, Lấp Vò, Đồng Tháp
29	29	105.33473	10.25379	Xã Mỹ An Hưng A, sông Tiền, Lấp Vò, Đồng Tháp
30	30	105.51200	10.61300	An Phong & Kháng Chiến, Thanh Bình, Đồng Tháp
31	31	105.25030	10.36433	Ấp Nhất, An Phong, Cao Lãnh, Đồng Tháp
32	32	105.37569	10.27221	Phường 1, Cao Lãnh, kênh Nhị Thanh, Cao Lãnh, Đồng Tháp
33	33	105.40387	10.24345	Xã Tinh Thới, sông Tiền, Cao Lãnh, Đồng Tháp
34	34	105.34182	10.57326	Xã Hưng Điền B, sông Cái Cỏ, Tân Hưng, Long An
35	35	105.46171	10.03025	Xã Vĩnh Đại, Đồng Tiến - Phước Xuyên, Tân Hưng, Long An
36	36	105.39320	10.50198	Tân Hưng, kênh 28, Tân Hưng, Long An
37	37	105.47312	10.52590	Vĩnh Hưng, kênh 28, Vĩnh Hưng, Long An
38	38	105.52416	10.49003	Xã Tuyên Bình, sông Vàm Cỏ Tây, Mộc Hoá, Long An
39	39	105.47114	10.58412	Cuối kênh Long Khốt, Vĩnh Hưng, Long An
40	40	105.57347	10.45389	Trạm thuỷ văn Mộc Hoá, sông Vàm Cỏ Tây, Mộc Hoá, Long An
41	41	106.05700	10.72900	K. Ba Hồng Minh (Phạm Văn Trai, X.Bình Phong Thạnh, Mộc Hoá, Long An)
42	42	106.10167	10.39144	Thạnh Hoá, kênh Tân Thạnh - Thanh Hoá, Long An
43	43	106.07553	10.46399	Tân Hiệp, kênh 61, Thạnh Hoá, Long An
44	44	106.19146	10.35173	Xã Mỹ An, kênh Bắc Đông, Thạnh Hoá, Long An
45	45	106.02415	10.36318	Tân Thạnh, kênh Dương Văn Dương, Tân Thạnh Long An
46	46	105.89900	10.63600	K. Dương Văn Dương (CĐ21, Thạnh Đông, H.Tân Thạnh, LA - Quán Năm Dũng), Long An
47	47	106.19491	10.42055	Xã Long Thuận, Kênh Bo Bo - T5, Thủ Thừa, Long An
48	48	106.15011	10.40374	Ấp 1, Long Thạnh, sông Vàm Cỏ Tây, Mộc Hoá, Long An
49	49	106.25149	10.36267	Thủ Thừa, kênh Bo Bo - Thủ Thừa, Long An
50	50	106.22143	10.33004	Rạch Chanh & Vàm Cỏ Tây, Tân An, Long An
51	51	106.25063	10.32160	Trạm Tân An, sông Vàm Cỏ Tây, Tân An, Long An
52	52	106.23422	10.29220	Xã An Vĩnh Ngãi, Kênh Rào Định, Tân An, Long An
53	53	106.28471	10.37511	Trạm Bến Lức, sông Vàm Cỏ Đông, Bến Lức, Long An
54	54	106.24467	10.46555	Ấp 5, Xã Thạnh Lợi, sông Vàm Cỏ Đông, Bến Lức, Long An

No	Station code	Long.	Lat.	Notes (Canal & creek, location)
55	55	106.27176	10.42243	Ấp 6, xã Lương Hoà, kênh Xăng, Bến Lức, Long An
56	56	106.12197	10.55529	Ấp 5, Mỹ Quý Tây, Đức Huệ, Long An
57	57	106.18488	10.53571	Thị trấn Đông Thành, sông Vàm Cỏ Đông, Đức Huệ, Long An
58	58	106.13177	10.51108	Xã Bình Thành, kênh Bo Bo, Đức Huệ, Long An
59	59	106.35000	10.84300	Bo Bo & Trà Cú Thượng (Hùng Mai, Ấp Hoà Khánh Tây, Trà Cú Thượng, Đức Hoà, Long An)
60	60	105.45427	10.31212	Ng. Văn Tiếp & Cái Bèo, Cái Bè, Tiền Giang
61	61	106.01471	10.20312	Cái Bè, kênh Phước Xuyên, Cái Bè, Tiền Giang
62	62	105.96600	10.50900	Tháp Mười, Hậu Mỹ Bắc A, Cái Bè, Tiền Giang
63	63	106.09600	10.49500	12 & Nguyễn Văn Tiếp, Cai Lậy, Tiền Giang
64	64	106.04503	10.19163	Xã Hội Xuân, Rạch Ba Rài, Cai Lậy, Tiền Giang
65	65	106.19700	10.58000	K.Bắc Đông (Ng. Văn B, X. Tân Hoà Tây, H. Tân Phước, Tiền Giang
66	66	106.19300	10.47500	Rạch Chanh & Nhị Bình, Tân Phước, Tiền Giang
67	67	106.19569	10.32056	Phú Mỹ, kênh Rạch Chanh, Tân Phước, Tiền Giang
68	68	106.15430	10.23514	Trạm Long Định, kênh Kinh Xáng, Châu Thành, Tiền Giang
69	69	105.48120	10.07498	Xã Nguyễn Văn Thành, kênh Tầm Vu, Bình Minh, Vĩnh Long
70	70	105.51118	10.00230	Xã Đông Thành, kênh Trà Ôn, Bình Minh, Vĩnh Long
71	71	105.49208	10.03490	Cái Vồn, kênh Xẻo Mít, Bình Minh, Vĩnh Long
72	72	106.00200	10.02539	Tam Bình, kênh Mang Thít, Tam Bình, Vĩnh Long
73	73	105.54057	10.07102	Phú Thịnh, kênh Bảo Kê, Tam Bình, Vĩnh Long
74	74	105.57359	10.15342	Vĩnh Long, sông Cổ Chiên, T.P. Vĩnh Long
75	75	105.53520	10.10088	Xã Thạnh Quới, kênh Bà Loan, Long Hồ, Vĩnh Long
76	76	106.01111	10.11426	Long Hồ, sông Bình Hoà, Long Hồ, Vĩnh Long
77	77	105.55459	10.13328	Xã Tân Hạnh, kênh Tân Thạnh, Long Hồ, Vĩnh Long
78	78	106.06451	10.10417	Cái Nhum, kênh Cái Nhum, Mang Thít, Vĩnh Long
79	79	106.06088	10.13089	Xã An Phước, kênh Cái Kê, Mang Thít, Vĩnh Long
80	80	106.11257	10.06019	Vũng Liêm, kênh Vũng Liêm, Vũng Liêm, Vĩnh Long
81	81	106.08268	10.01472	Xã Trung An, kênh Ngoạ Hầu, Vũng Liêm, Vĩnh Long
82	82	105.55215	9.58095	Trà Ôn, sông Mang Thít, Trà ôn, Vĩnh Long
83	83	106.02107	10.01499	xã Hoà Bình, Sông Hoà Bình, Trà Ôn, Vĩnh Long
84	84	105.02216	10.38910	Vĩnh Tế (Cầu Tha La), Thị xã Châu Đốc, An Giang
85	85	105.00557	10.37306	Vĩnh Tế (Cầu Trà Sư), Thị xã Châu Đốc, An Giang

No	Station code	Long.	Lat.	Notes (Canal & creek, location)
86	86	104.56077	10.36150	Cầu Hữu Nghị, TT. Xuân Tô, kênh Vĩnh Tế, Tịnh Biên, An Giang
87	87	105.05500	10.53000	Cầu số 1& Cần Thảo (Khôi phục lại), Tịnh Biên, An Giang
88	88	105.08600	10.47500	Tri Tôn (Xã Tân Lập, H. Tịnh Biên (Phía Tri Tôn), An Giang
89	89	104.82200	10.43000	Xã Ba Chúc, Tri Tôn, An Giang
90	90	104.90300	10.41200	Tám Ngàn & Ngô Đình Diệm, Lương An Trà, Tri Tôn, An Giang
91	91	104.88400	10.44600	T6& Kênh Mới (ấp An Thành, X. Lương Phi), Tri Tôn, An Giang
92	92	105.03800	10.35100	Tri Tôn & Ba Thê Mới (ấp Tô Phước, X. Cô Tô, H. Tri Tôn), An Giang
93	93	104.86700	10.50900	Vĩnh Tế &T5, Vĩnh Gia, Tri Tôn, An Giang
94	94	105.14249	10.34483	Cái Dầu, sông Tiền, Châu Phú, An Giang
95	95	105.12700	10.52300	14 & Tri Tôn (ấp Hưng Thạnh, Xã Hữu Cảnh, H. Châu Phú), An Giang
96	96	105.12600	10.45300	16 & Mười Châu Phú (ấp An Bình, Xã Bình Phú, H. Châu Phú), An Giang
97	97	105.09600	10.56100	13&Cần Thảo, An Long Vĩ, Châu Phú, An Giang
98	98	105.23200	10.45100	Núi Tróc & Chắc Năng Gù (xã Vĩnh Hanh, H. Châu Thành), An Giang
99	99	105.30700	10.40100	Vĩnh Trạch (Cầu số 10) - Phòng thuế xã Vĩnh Lợi, Châu Thành, An Giang
100	100	105.23481	10.26197	An Châu, kênh Chắc Cần Đạo, Châu Thành, An Giang
101	101	105.07198	10.26042	Xã Vĩnh An, Mười Châu Phú- Mạc Cần Dưng, Châu Thành, An Giang
102	102	105.20520	10.42430	Chợ Vàm, sông Tiền, Phú Tân, An Giang
103	103	105.13482	10.35552	Phú Bình, sông Hậu, Phú Tân, An Giang
104	104	105.17265	10.37290	Phú Xuân, Thần Nông - Mương Khải, Phú Tân, An Giang
105	105	105.25180	10.31318	Kiến Thành, rạch Ông Chưởng, Chợ Mới, An Giang
106	106	105.24560	10.22395	Mỹ Khánh, kênh Long Xuyên, Thị xã Long Xuyên, An Giang
107	107	105.22900	10.21500	B & RG-LX (Tổ 19, ấp Tây Huề, xã Thoại Giang, H. Thoại Sơn), An Giang
108	108	105.26800	10.27200	Núi Sập & RG-Long Xuyên (TT. Thoại Sơn, H. Thoại Sơn), An Giang
109	109	105.33900	10.34600	Rg-LX & Vĩnh Trạch (ấp Vĩnh Tiến, xã Vĩnh Trạch, H. Thoại Sơn)

No	Station code	Long.	Lat.	Notes (Canal & creek, location)
110	110	104.58000	10.46600	Xã Mỹ Phú, Kiên Lương, Kiên Giang
111	111	104.70800	10.52100	Cầu Vĩnh Điền, Huyện Kiên Lương, Kiên Giang
112	112	104.74900	10.49300	T3, Kiên Lương, Kiên Giang
113	113	105.55542	10.11234	TT Hòn Đất, Tri Tôn - Rạch Giá - Hà Tiên, Hòn Đất, Kiên Giang
114	114	105.01076	10.18289	Xã Nam Thái Sơn, Tri Tôn - số 7, Hòn Đất, Kiên Giang
115	115	105.01325	10.07209	Sóc Sơn, Ba Thê -RG - Hà Tiên, Hòn Đất, Kiên Giang
116	116	105.09277	10.06250	Tân Hội, kênh Rạch Giá - Long Xuyên, Tân Hiệp, Kiên Giang
117	117	105.34000	10.17400	Kênh F (Đầu kênh, ấp Phùng Thạnh, X. Thanh An, Thốt Nốt, (Cần Thơ) Mốc thuỷ văn
118	118	105.37800	10.21300	Bốn Tổng & Cái Sắn, Thốt Nốt, Cần Thơ
119	119	105.29182	10.18586	S.Hậu &Cái Sắn, Thới Thuận, Thốt Nốt, Cần Thơ
120	120	105.32300	10.15108	Trung Kiên, Kênh Thốt Nốt (Cái Bé), Thốt Nốt, Cần Thơ
121	121	105.27900	10.18600	Đòn Giông & C (ấp C1, xã Thạch Thắng, H. Thốt Nốt, Cần Thơ)
122	122	105.56300	10.06000	Mốc cầu, Thới Lai, Ô Môn, Cần Thơ
123	123	105.42600	10.09000	Kênh Bốn Tổng, Thốt Nốt, thị trấn Cờ Đỏ, Ô Môn, Cần Thơ
124	124	105.37356	10.06560	Ô Môn, kênh Ô Môn, thị trấn Ô Môn, Ô Môn, Cần Thơ
125	125	105.63100	9.92611	Mốc thuỷ văn, Tân Thuận, Châu Thành, Cần Thơ
126	126	105.41396	9.58504	Nhơn Nghĩa, Xà Nô - Cần Thơ, Châu Thành, Cần Thơ
127	127	105.45441	10.00292	Hưng Thạnh, Sông Cần Thơ, Thành phố Cần Thơ, Cần Thơ
128	128	105.48154	9.57358	Đông Phú, kênh Cái Dầu, Châu Thành, Cần Thơ
129	129	105.50505	9.55022	Ngã Sáu, kênh Kênh Xáng, Châu Thành, Cần Thơ
130	130	105.42112	9.49586	Hoà Mỹ, Đồng Lợi - Nàng Mau, Phụng Hiệp, Cần Thơ
131	131	105.44160	9.46307	Hiệp Hưng, Kênh Long Mỹ- Hậu Giang, Phụng Hiệp, Cần Thơ
132	132	105.33430	9.46307	Nàng Mau, Kênh Nàng Mau, Vị Thuỷ, Cần Thơ

Annex 2

Result table of air quality in Dong Thap province

Parameter / Site	Noise (dBA)	Dust (mg/m^3)	SO_2 (mg/m^3)	NO_2 (mg/m^3)	CO (mg/m^3)
Brick- kinl zone (Chau Thanh District)	60- 70	1.26	0.07	0.00	0.15
Post office, Sa Dec town	70-80	1.5	0.1	0.00	0.5
Tan Quy Tay Industrial Park	60-75	0.7	0.6	0.00	0.2
Sa Dec Industrial Park	50-55	0.05	0.00	0.00	0.00
Van Nghe Crossroads, Cao Lanh town	60-65	1.2	0.05	0.00	0.3
Tran Quoc Toan Industrial Park	55-65	0.9	0.02	0.00	0.6

(Source: Technologic Scientic Applying Center- 3/2003)

Annex 3

Result table of town air quality in Long An province at the begining of dry season of 2001

Meas. site	Temp. (O^oC)	Hum. (%)	Noise (dBA)	Pollutants concentration (mg/m^3)					
				Dust	CO	SO_2	NO_2	H_2S	Pb
1	29.5	20.5	67.6	0.41	0.90	0.10	0.04	0.000	0.0010
2	32.8	21.1	63.9	0.83	0.12	0.15	0.04	0.000	0.0020
3	31.8	16.8	75.6	0.83	1.70	0.18	0.08	0.010	0.0015
4	33.0	15.5	80.6	1.25	3.50	0.20	0.015	0.000	0.0048
5	32.0	15.4	77.8	0.15	2.50	0.17	0.12	0.005	0.0020
6	30.0	15.5	76.4	0.56	3.40	0.35	0.17	0.000	0.0140
7	29.1	16.7	42.6	0.95	2.20	0.27	0.18	0.420	0.0000
8	33.1	15.9	54.4	0.25	1.70	0.10	0.02	0.000	0.0010
9	38.1	14.9	55.0	1.26	3.50	0.22	0.15	0.000	0.0032
10	40.8	14.8	75.9	0.55	1.50	0.12	0.06	0.000	0.0015
11	36.9	14.8	55.0	0.65	1.90	0.15	0.06	0.000	0.0030
12	32.7	14.9	72.0	0.35	1.80	0.15	0.10	0.000	0.0015
13	33.2	14.8	83.5	0.55	4.20	0.30	0.20	0.000	0.0220
14	40.8	14.8	75.9	1.55	1.50	0.12	0.06	0.000	0.0015
15	36.9	14.8	55.0	0.85	1.90	0.15	0.06	0.000	0.0030
16	32.2	14.8	69.5	0.25	1.50	0.15	0.06	0.000	0.0018
VN Stand.	**-**	**-**	**60**	**0.3**	**40**	**0.50**	**0.40**	**-**	**0.005**

(Source: HCM city Labour safety Sub- Institute- 11/2001)

Measuring site location:

1. Duc Hue Post office, Duc Hue District
2. Hiep Hoa town, Duc Hoa district
3. Hau Nghia town, Duc Hoa district
4. Can Duoc town, Can Duoc district
5. Can Giuoc town, Can Giuoc district
6. Contiguous site of Long An and Ho Chi Minh City
7. Rubbish dump Tan An town, Tan An town
8. Tuyen Nhon T- junction, Thanh Hoa district
9. Tan Thanh town, Tan Thanh district
10. Tan An town
11. Chau Thanh town, Chau Thanh district
12. Tan Tru town, Tan Tru district
13. 5 precinct zone, Tan An town
14. Moc Hoa town, Moc Hoa town
15. Vinh Hung town, Vinh Hung town
16. Thu Thua town, Thu Thua district

Annex 4

Result table air pollutants average concentration of several site on main roads in Vinh Long province, from 1998 to 2002

Parameters	**1998**	**1999**	**2000**	**2001**	**2002**	**5 years average**	**VN Standard 5937- 1995**
Dust(mg/m^3)	0.40	0.26	0.17	0.26	0.19	0.26	0.3
SO_2 (mg/m^3)	0.07	0.02	0.03	0.01	0.081	0.04	0.5
NO_2 (mg/m^3)	0.06	0.08	0.06	0.13	0.165	0.1	0.4
CO (mg/m^3)	2.30	2.21	5.48	4.01	12.5	5.3	40
Noise (dBA)	73	71	71	65	-	-	-

(Source: Department of Science, Technology Environment of Vinh Long province)

Annex 5

Result table of saline soil quality in Bac Lieu- Ca mau area

Parameter	Average	Max.	Min.
pH kh«	5.57	8.30	3.10
pH -ít	103.93	1772.0	3.80
EC (μS/cm)	1667.15	1996.0	190.00
Fe tæng (mg/100g)	165.64	265.50	60.80
Al^{3+} (mg/100g)	10.24	66.96	1.08
OM (%)	10.33	65.20	2.28
CEC (meq/100g)	54.02	71.20	39.60
P_2O_5 (mg/100g)	20.99	46.95	0.16
NO_3^- (mg/100g)	9.12	184.60	0.00
Na^+ (ppm)	1793.66	1928.00	134.95
Mn^{2+} (ppm)	53.17	191.90	0.10
Cd (ppm)	0.12	0.50	0.00
Pb (ppm)	1.24	2.40	0.10
Cu (ppm)	1.94	8.40	0.20
Zn (ppm)	13.00	28.20	1.70

(Source: The current environment report of An Giang in 2001

Annex 6

Map of natural resevered zones positions in South of Vietnam (including Cuu Long delta)