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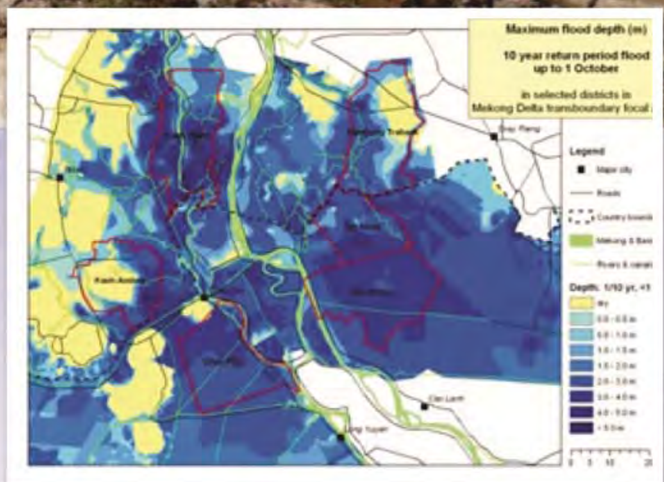
MEKONG RIVER COMMISSION FOR SUSTAINABLE DEVELOPMENT

Flood Protection Criteria for the Mekong Delta, Viet Nam



The Flood Management and Mitigation Programme,
Component 2: Structural Measures & Flood Proofing in the Lower Mekong Basin

May 2010
Final Report, Volume 6D

Deltares
Enabling Delta Life
Delft Hydraulics

ROYAL HASKONING

UNESCO

Mekong River Commission

Flood Management and Mitigation Programme

Structural Measures and Flood Proofing in the Lower Mekong Basin

Flood Protection Criteria for the Mekong Delta, Viet Nam

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Office of the Secretariat in Phnom Penh (OSP)
576, National Road #2, Chak Angre Krom,
P.O. Box 623, Phnom Penh, Cambodia
Tel. (855-23) 425 353. Fax (855-23) 425 363
Office of the Secretariat in Vientiane (OSV)
Office of the Chief Executive Officer
184 Fa Ngoum Road,
P.O. Box 6101, Vientiane, Lao PDR
Tel (856-21) 263 263. Fax (856-21) 263 264
Website: www.mrcmekong.org
Email: mrcs@mrcmekong.org

SUMMARY

This report presents the findings of the FMMP-C2 Demonstration Project that aims to assist Viet Nam in formulating flood protection criteria for the Vietnamese part of the Mekong Delta. Since the Mekong Delta covers a vast area, the analysis was carried out for six representative districts representing different levels of flooding and also different types of land use.

Flood Hazard
The flood hazard has been assessed with the VRSAP model, using the most up to date data on the physical representation of the existing infrastructure and boundary conditions for discharges, local rainfall, water use etc. Flood hazard has been analysed with a historical time series of 97 years of discharges in the Mekong River at Kratie.

Flood Damages
The flood damages have been assessed through analysis of official flood damage data as is being inventoried by the districts in the Mekong Delta. The data has been categorised into three groups, damages to: i) a wide range of public services facilities, referred to as Infrastructure; ii) domestic properties referred to as Housing; and iii) Agriculture, also comprising losses in aquaculture. Flood damages have first been translated into flood damage curves (for eight years of available data), the simulated historical discharge series were then subjected to the flood damage functions to produce the flood damage probability curves for each of the three damage categories (and the total).

Flood Risk
Through integration of the flood damage probability curves, the annual flood risks have been determined for a series of frequencies of exceedance, for example the risk at a 1% probability of exceedance of river (system) discharges, translated into water levels, is as follows:

Flood Risk in six out of 34 districts in the Mekong Delta USD/year.

District	Total	Infrastructure	Housing	Agriculture	I	H	A
Chau Phu	514	394	117	3	77%	23%	1%
Long Xuyen	758	656	92	10	87%	12%	1%
Tam Nong	1,056	481	433	143	46%	41%	14%
Tan Hong	933	433	408	92	46%	44%	10%
Sa Dec	420	114	204	101	27%	49%	24%
Cai Be	1,935	417	346	1,173	22%	18%	61%

It should be noted that the detailed methodology for food risk assessment have been further developed in the framework of the Joint Demonstration Project on Flood Risk Management in the Border Zone between Cambodia and Viet Nam, Volume 6E of the Final Report of FMMP Component 2.

Impacts of upstream developments in the Mekong Basin and impacts of climate change on river flows and sea level rise have not been taken into account in this Demonstration Project (DP) in view of time and budget limitations. Potential impact of upstream developments on floods in the Mekong Delta is among others reported in Volume 2A. Impact in the delta of climate change on upstream river flood flows is also reported in Volume 2A. Impact on the delta of sea level rise is reported in Volume 2B.

Actual Level of Flood Protection
From the damage probability curves, the currently prevailing level of flood protection can be derived for each category of damages:

Actual Flood Protection Levels in the Mekong Delta in Viet Nam.

	Frequency				Return period			
Ditrict	Combined	I	H	A	Combined	I	H	A
Tam Nong	30%	25%	35%	12%	3.3	4.0	2.9	8.3
Tan Hong	25%	25%	35%	13%	4.0	4.0	2.9	7.7
Chau Phu	25%	24%	32%	8%	4.0	4.2	3.1	12.5
Long Xuyen	10%	10%	23%	10%	10.0	10.0	4.3	10.0
Sa Dec	30%	25%	27%	37%	3.3	4.0	3.7	2.7
Cai Be	20%	12%	30%	18%	5.0	8.3	3.3	5.6

The order of magnitude of the actual flood protection in the deeply flooded areas in the part of the Mekong Delta in Viet Nam is about 25% (1 in 4 years) for infrastructure and housing and about 10% (1 in 10 years) for agricultural land.

For the shallow flood areas the protection levels vary, Long Xuyen being located in between the deep and shallow flooded area having a 10% (1 in 10 year) degree of protection, while for Sa Dec and Cai Be this is not more than 20 to 30% (1 in 3 to 5 years), whereas in these two districts the protection level for agricultural land is less than half of that of the deep flooded area.

Conclusions

What would be the optimal level of flood protection?

Through a preliminary engineering analysis of what would be required in terms of civil engineering works to increase flood protection levels for a series of flood exceedance frequencies, the optimum level of protection can be derived through an economic cost/benefit analysis.

The results of that cost/benefit analysis show very clearly:

For the deep flooded areas, it appears that there is no economic ground whatsoever to justify aiming for higher flood protection levels for land that is used for double cropping of paddy. This finding confirms that the policy of Government of Viet Nam for that area (at least as far as it is related to land used for agriculture) to provide only for early August flood protection, is confirmed as the right approach and should be continued for many years to come. These deeply flooded areas are already protected against early flooding with an average probability of exceedance of 10%. Costs for works that provide higher protection levels with regard to agricultural production far outweigh the benefits that could be obtained by such measures.

On the other hand, the analysis also shows that in the deep flood-prone areas (Plain of Reeds, Long Xuyen Quadrangle) providing for an enhanced flood protection level at community or village level is economically highly beneficial. It would enhance living conditions of the population in these areas. Their businesses, the district governmental administration and all kinds of district public services as for example education and public health services are affected by high flood events, as has been expressed in the damage functions.

The findings also demonstrate that providing higher than the existing flood protection in urban areas such as Long Xuyen and Sa Dec also turns out not to be economically feasible.

Recommendations

1. Damage categories are based on actual and official flood damage obtained from district authorities, the dataset obtained was complete for the categories that were applied. It is recommended that other damage categories such as on public health, tourism, road and waterways transport etc. will also be inventoried by the districts. In that way

expanding and improving the flood damage database and the analysis of flood protection criteria that could be adopted.

2. Flood damage data was collected from 2000 till 2007, though having a reasonable spread in flood events from big to small, the period is rather short. It is recommended that a procedure is put in place by the Vietnamese Line Agencies to annually collect the damage data from all flood prone districts in the delta and maintain a central database.

3. The preliminary engineering designs for the measures in the sample areas are based on experience, no detailed topographical surveys and geotechnical investigations could be carried out in the framework of this Demonstration Project. Slope stability and dyke strength are assumed to comply with the requirement. In each specific case field surveys and detailed design of works may lead to different typical dyke profiles. It is recommended that the Vietnamese Line Agencies establish and test typical designs of various types of flood protection measures that can be technically and economically applied in the delta.

4. Water levels have been simulated with the aid of VRSAP, though this is a very comprehensive model of the Mekong Delta, it provides a representation of the situation and contains uncertainties. It is recommended that the VRSAP model is updated regularly and that a procedure and funding is arranged for carrying out surveys of river and canal cross sections and profiles on a regular basis in order to keep the model up to date.

5. It is recommended that the demonstration of best practices in flood risk assessment and its application in assessing actual and potential flood protection levels as undertaken for the Mekong Delta is brought to the attention of the relevant ministries and Line Agencies in Viet Nam. The methodologies can also be applied for other flood prone areas throughout Viet Nam.

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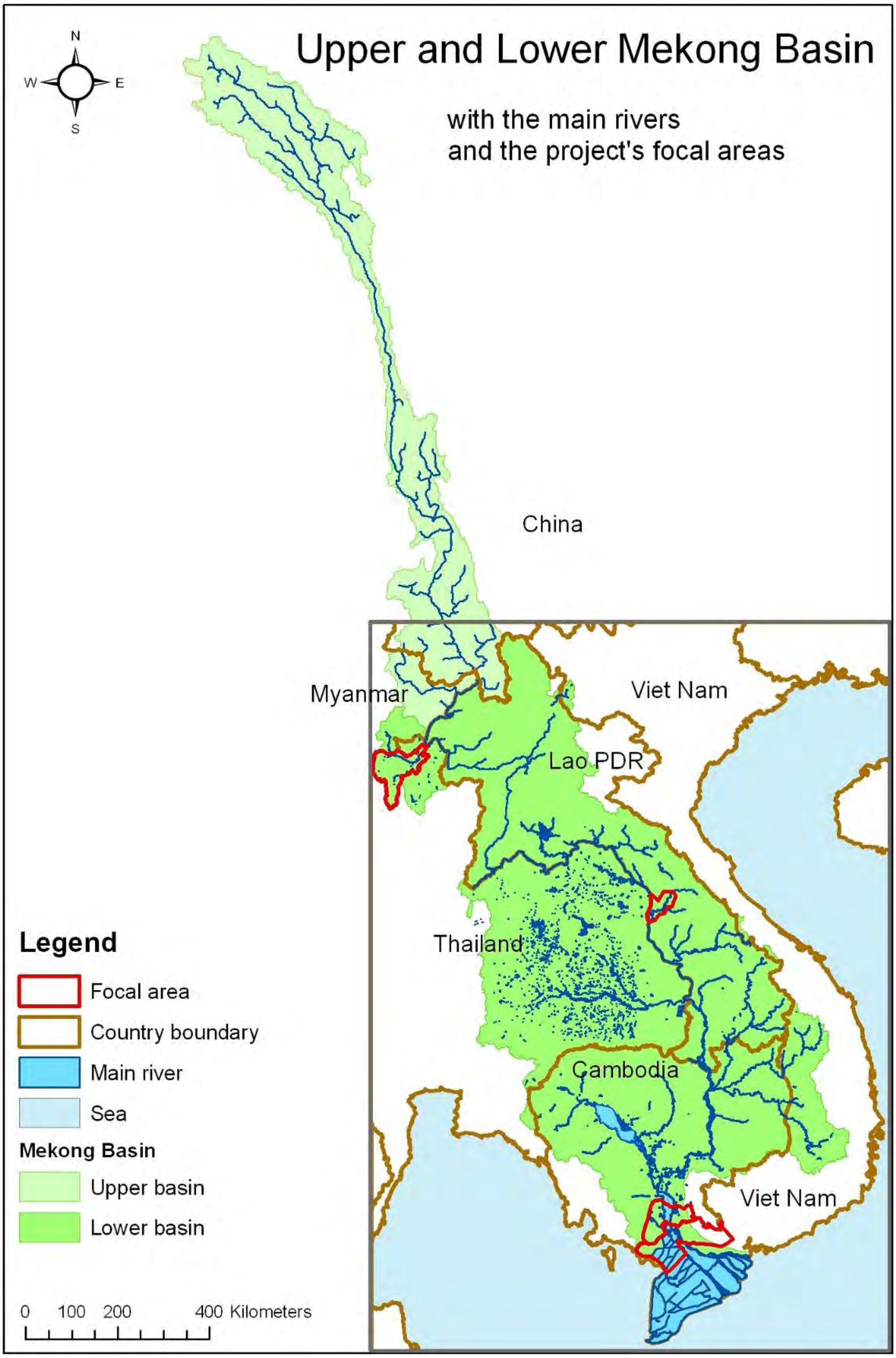
Upper and Lower Mekong Basin
with the main rivers
and the project's focal areas
N
W
E
S
China
Myanmar
Viet Nam
Lao PDR
Thailand
Cambodia
Viet Nam
Legend
Focal area
Country boundary
Main river
Sea
Mekong Basin
Upper basin
Lower basin
0 100 200 400 Kilometers

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
amsl	above mean sea level
BDP	Basin Development Planning Programme (MRC)
CLD	Cuu Long Delta (Mekong Delta)
DEM	Digital Elevation Model
DP	Demonstration Project
DSF	Decision Support Framework
DTM	Digital Terrain Model
DWR	Department of Water Resources of Thailand
EIA	Environmental Impact Assessment
FMM	Flood Management and Mitigation
FFMP	Flood Management and Mitigation Programme (MRC)
FMMP-C1	Component 1 of the MRC FMMP: Establishment of the Regional Flood Management and Mitigation Centre (RFMMC)
FMMP-C2	Component 2 of the MRC FMMP: Structural Measures and Flood Proofing
FMMP-C3	Component 3 of MRC FMMP: Enhancing Cooperation in Addressing Transboundary Flood Issues
FMMP-C4	Component 4 of the MRC FMMP: Flood Emergency Management Strengthening
FMMP-C5	Component 5 of the MRC FMMP: Land Management
FRM	Flood Risk Management
GEV	Generalised Extreme value
GIS	Geographic Information System
HHs	Households
IFRM	Integrated Flood Risk Management
IKMP	Information and Knowledge Management Programme (MRC)
ISIS	Hydrodynamic simulator for modelling flows and levels in channels and estuaries, used by MRC
IWRM	Integrated Water Resources Management
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NGO	Non-Governmental Organisation
NMC	National Mekong Committee
NR80	National Road Nr 80 (Viet Nam)
POR	Plain of Reeds
ProDIP	Project Development and Implementation Plan
TCEV	Two Component Extreme Value
TOR	Terms of Reference
VND	Viet Nam Dong, currency of Viet Nam
VRSAP	Viet Nam River System And Plains; hydrodynamic model
WUP	Water Utilisation Programme of MRC
WUP-A	WUP Basin Modelling and Knowledge Base Project
WWF	World Wildlife Fund
1D/2D/3D	One Dimensional/Two Dimensional/Three Dimensional

GLOSSARY

Cuu Long Delta	Mekong Delta
Damage curve	The functional relation between inundation characteristics (depth, duration, flow velocity) and damage for a certain category of elements at risk.
Direct damage	All harm which relates to the immediate physical contact of flood water to people, property and the environment. This includes, for example, damage to buildings, economic assets, loss of standing crops and livestock, loss of human life, immediate health impacts and loss of ecological goods.
Exposure	The people, assets and activities that are threatened by a flood hazard.
Flood control	A structural intervention to reduce the flood hazard.
Flood damage	Damage to people, property and the environment caused by a flood. This damage refers to direct as well as indirect damage.
Flood damage risk (= Flood risk)	The combination or product of the probability of the flood hazard and the possible damage that it may cause. This risk can also be expressed as the *average annual possible damage*.
Flood hazard	A flood that *potentially may* result in damage. A hazard does not necessarily lead to damage.
Flood hazard map	Map with the predicted or documented extent/depth/velocity of flooding with an indication of the flood probability.
Flood proofing	A process for preventing or reducing flood damages to infrastructural works, buildings and/or the contents of buildings located in flood hazard areas.
Flood risk management	Comprehensive activity involving risk analysis, and identification and implementation of risk mitigation measures.
Flood risk management measures	Actions that are taken to reduce the probability of flooding or the possible damages due to flooding or both.
Flood risk map	Map with the predicted extent of different levels/classes of *average annual possible damage.*
Hydrological hazard	A hydrological event (discharge) that may result in flooding.
Indirect damage	All damage which relate to the disruption of economic activity and services due to flooding.

Integrated flood risk management	The approach to Flood Risk Management that embraces the full chain of a meteorological hazard leading to flood damages and considers combinations of structural and non-structural solutions to reduce that damage.
Meteorological hazard	A meteorological event (storm) that may result in a hydrological hazard and, eventually, in flooding.
Resilience	The ability of a system/community/society to cope with the damaging effect of floods.
Susceptibility	The opposite of resilience, that is to say the inability of a system/ community/society to cope with the damaging effect of floods.
Vulnerability	The potential damage that flooding may cause to people, property and the environment.

CHAPTER 1

INTRODUCTION

1 INTRODUCTION

1.1 Guide to the reporting structure of the Flood Management and Mitigation Programme - Component 2, Structural Measures and Flood Proofing

Component 2 on Structural Measures and Flood Proofing of the Mekong River Commission's Flood Management and Mitigation Programme was implemented from September 2007 till January 2010 under a consultancy services contract between MRCS and Royal Haskoning in association with Deltares and UNESCO-IHE. The Implementation was in three Stages, an Inception Phase, and two implementation Stages. During each stage a series of outputs were delivered and discussed with the MRC, the National Mekong Committees and line agencies of the four MRC member countries. A part of Component 2 - on 'Roads and Floods' - was implemented by the Delft Cluster under a separate contract with MRC.

The consultancy services contract for Component 2 specifies in general terms that, in addition to a Final Report, four main products were to be delivered. Hence, the reports produced at the end of Component 2 are structured as follows:

Volume 1	**Final Report**
Volume 2	**Characteristics of Flooding in the Lower Mekong Basin**
Volume 2A	*Hydrological and Flood Hazard in the Lower Mekong Basin;*
Volume 2B	*Hydrological and Flood Hazard in Focal Areas;*
Volume 2C	*Flood Damages, Benefits and Flood Risk in Focal Areas, and*
Volume 2D	*Strategic Directions for Integrated Flood Risk Management in Focal Areas.*
Volume 3	**Best Practice Guidelines for Integrated Flood Risk Management**
Volume 3A	*Best Practice Guidelines for Flood Risk Assessment;*
Volume 3B	*Best Practice Guidelines for Integrated Flood Risk Management Planning and Impact Evaluation;*
Volume 3C	*Best Practice Guidelines for Structural Measures and Flood Proofing;*
Volume 3D	*Best Practice Guidelines for Integrated Flood Risk Management in Basin Development Planning, and*
Volume 3E	*Best Practice Guidelines for the Integrated Planning and Design of Economically Sound and Environmentally Friendly Roads in the Mekong Floodplains of Cambodia and Viet Nam*[1]*.*
Volume 4	**Project Development and Implementation Plan**
Volume 5	**Capacity Building and Training**
Volume 6	**Demonstration Projects**
Volume 6A	*Flood Risk Assessment in the Nam Mae Kok Basin, Thailand;*
Volume 6B	*Integrated Flood Risk Management Plan for the Lower Xe Bang Fai Basin, Lao PDR;*
Volume 6C	*Integrated Flood Risk Management Plan for the West Bassac area, Cambodia;*
Volume 6D	*Flood Protection Criteria for the Mekong Delta, Viet Nam;*
Volume 6E	*Flood Risk Management in the Border Zone between Cambodia and Viet Nam.*

The underlying report is **Volume 6D** of the above series.

[1] Developed by the Delft Cluster

The FMMP Component 2, Structural Measures and Flood Proofing, was developed in three steps: the Inception Phase and Stages 1 and 2 of the Implementation Phase. The Inception Phase began at the end of September 2007 and concluded in accordance with the Terms of Reference with a Regional Workshop in Ho Chi Minh City at the end of January 2008, only 4 months after project initiation. The original TOR envisaged the Stage 1 Implementation Phase to be carried out in a period of 6 months, leaving 12 months for the Stage 2 Implementation Phase. See for reference *Final Report*, Volume 1.

1.2 Background

In the Stage 1 Workshop of the Component 2 of the Flood Management and Mitigation Program (FMMP-C2), held in Ho Chi Minh City on 25 September, 2008, it was agreed that the development of flood protection criteria in the Mekong Delta in Viet Nam will be one of the Demonstration Projects (DP) during the Stage 2 Implementation of the FMMP-C2.

The scope of this project was presented in the Workshop as follows:

1. The demonstration project focuses primarily on the methodology for the development of criteria for dyking schemes for flood protection in the Vietnamese part of the delta.
2. The link between protection criteria, flood risk and risk acceptance will be formulated. For areas with known flood risks, it will be shown for different protection criteria what the economic impact is and what the residual risk would be.
3. The output of this demonstration project will be a document to be used in the societal discussion in Viet Nam on flood protection criteria.

The output of this project should allow formulating answers to the following questions.

1. How to assess the actual protection level (probability of inundation) in different parts of the Delta?
2. What is the residual risk in relation to the actual protection level in these parts of the Delta?
3. What are the net benefits of increasing the protection levels in these parts of the Delta?
4. What is needed, in terms of dyke heightening, to increase the protection levels in different parts of the Delta?

Regarding the implementation of this project it was agreed that a "Working-group" will be established that will have a dual function, i.e.:

1. Provide guidance to the FMMP-C2 consultants in the implementation of the Demonstration project, especially regarding policy, strategy and institutional issues.
2. Participate in technical sessions that allow for the transfer of technology from the side of the consultants to the technical working-group members.

The Demonstration Projects in FMMP-C2 are also meant to apply the Best Practice Guidelines for various IFRM issues that are being developed under the FMMP-C2. The following best practice guidelines are intended to be used in the implementation of this Demonstration Project:

1. Guidelines for Flood Risk Assessment;
2. Guidelines for IFRM Planning and Impact Evaluation.

This Demonstration Project has been carried out simultaneously with the implementation of the joint Cambodia - Viet Nam Demonstration Project on flood risk mitigation in the border zone. The results of the two demonstration projects had been envisaged to benefit from each other.

1.3 Scope of the Demonstration Project

The primary objective of this DP is to facilitate the decision making regarding the level of protection to be given to a certain area in the Mekong Delta (Cuu Long Delta). Protection levels refer to water levels that occurred during a certain historical period. In this DP the actual prevailing protection levels are being related to an "acceptable" flood risk.

It is not the intention of this DP to consider other causes of flooding than overtopping of dykes, as could be caused by dyke failure due to for example insufficient quality of design of works, poor quality achieved in construction of the works or of its maintenance, or any other type of collapse of flood protection infrastructure during extreme flood events. If such failure mechanisms would occur they are in the domain of disaster management rather than flood management.

Criteria for flood protection are closely related to flood risk, whereas flood risk is related to potential damage that may occur as a result of flooding. Potential damage is related to land-use in its distinctive categories like infrastructure, housing and agriculture. Therefore, districts have been selected in the Mekong Delta showing distinct different types of land use and potential damage. Districts were selected in the deep flooded areas that were already surveyed during Stage 1 of FMMP-C2 and for which district damage curves were prepared (Chau Phu District, An Giang Province; Tan Hong and Tam Nong districts, Dong Thap Province).

Additionally, in Stage 2 of FMMP, three more districts were selected: Long Xuyen City (An Giang Province), Sa Dec Town (Dong Thap Province) and Cai Be District (Tien Giang Province) to investigate flood risk for urban settlements in Long Xuyen and Sa Dec; and flood risk for fruit tree plantation in Cai Be District.

The socio-economic survey and flood damage data collection for the three districts in the deeply flooded area were collected during Stage 1 of FMMP-C2 and additional data collection on socio-economic indicators and flood damages were collected for the three other districts in the shallowly flooded area during Stage 2. In short, sample household and business survey for the 2006 flood, indirect flood costs spent by related district departments in 2006 flood, district socio-economic indicators and land-use in 2007, district direct flood damages from 2000-2008 were available for the study.

1.4 Study area

The deeply and shallowly flooded areas in the CLD of interest to this study are shown in Figure 1-1.

Figure 1-2 shows the location of the selected representative districts in the CLD for which a flood damage assessment was carried out, and for which at a relatively small sample area within these districts requirements for increased levels of flood protections have been investigated.

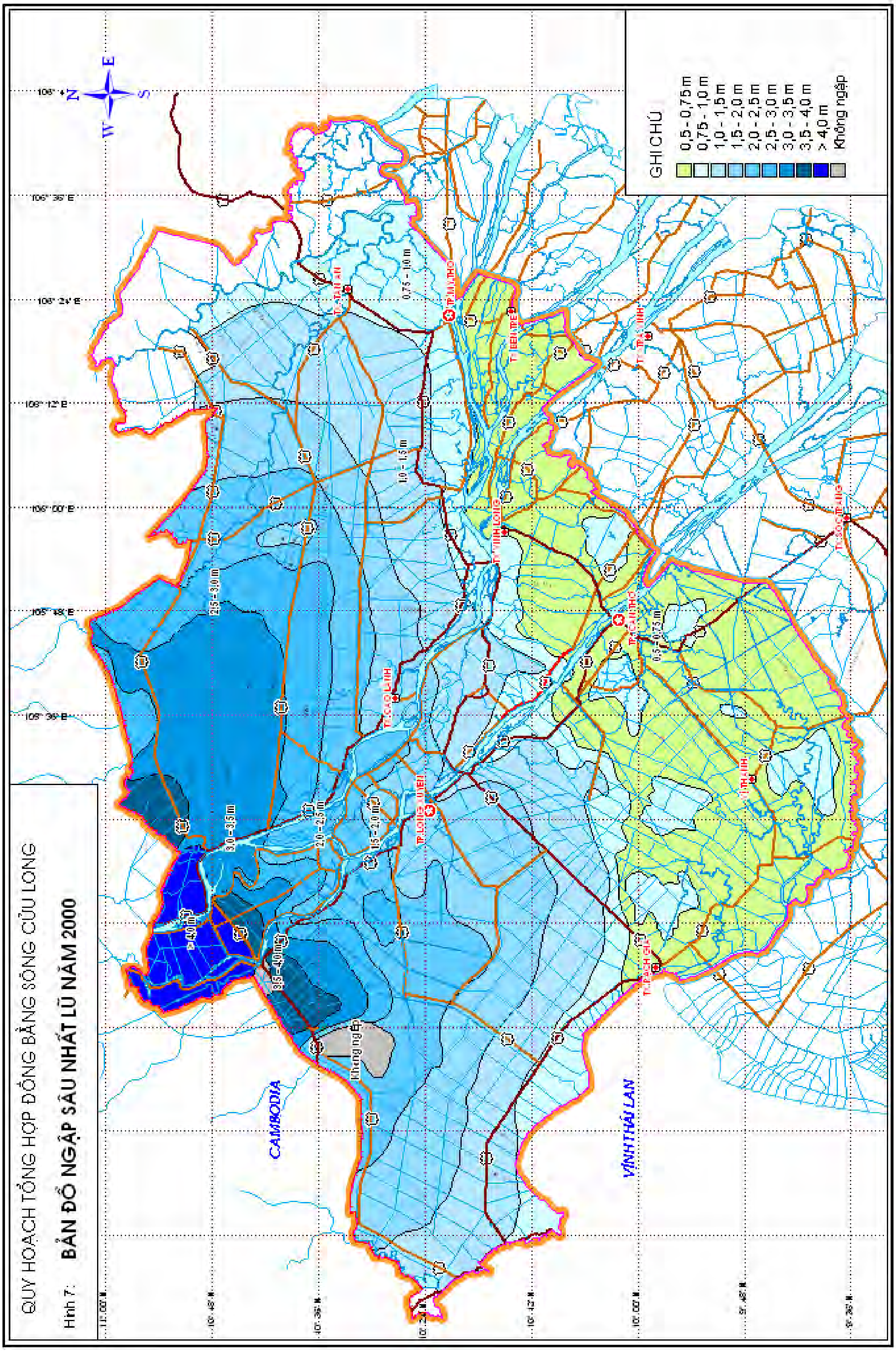

Figure 1-1 Flooding in the Mekong Delta in 2000.

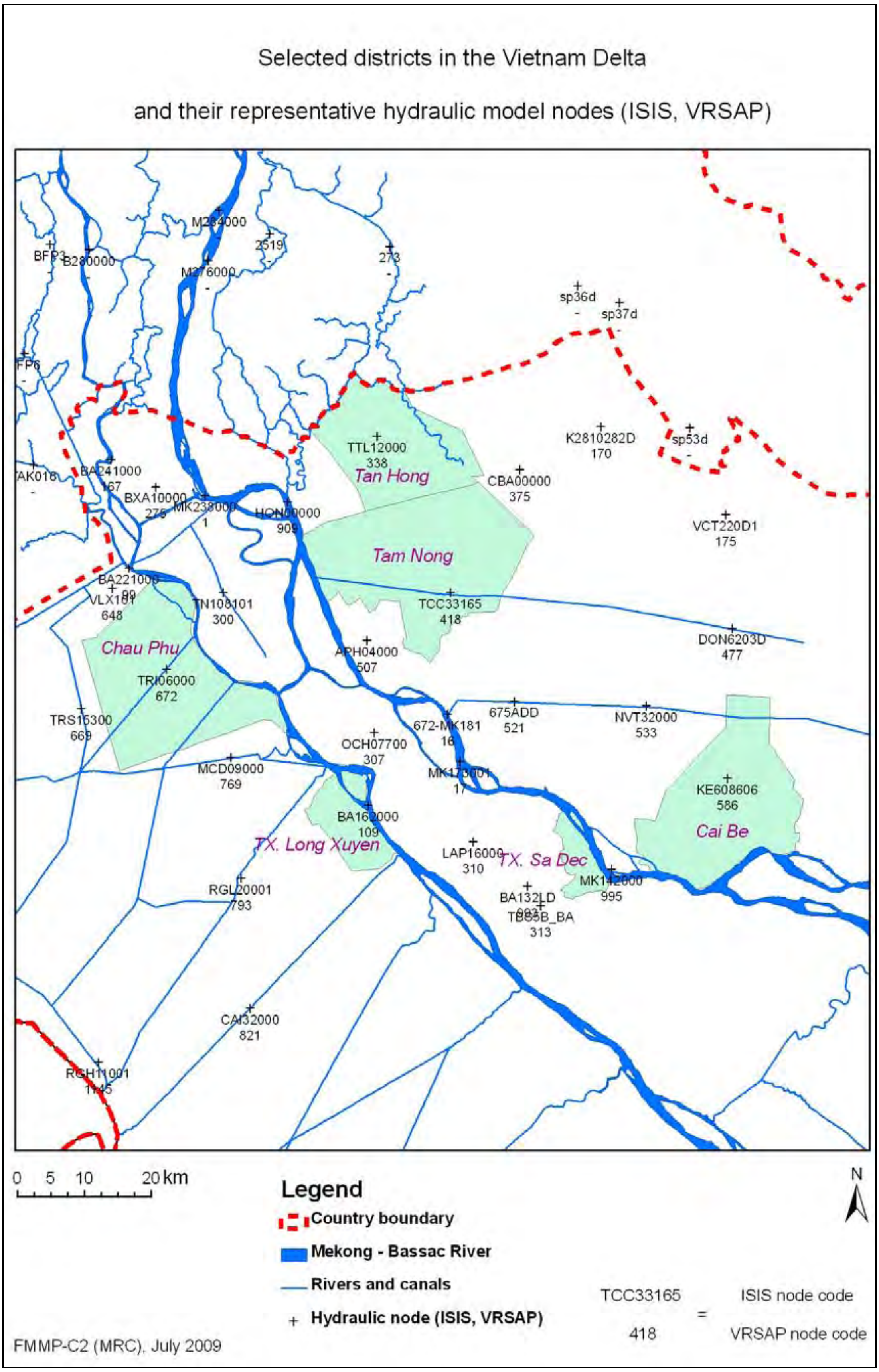

Figure 1-2 Location of selected districts data collection and processing.

The deep flooded area in the Vietnamese part of the Mekong Delta covers the Plain of Reeds and the Long Xuyen Quadrangle. During the Stage 1 of the FMMP-C2, the three districts in focal areas in Viet Nam: Chau Phu, Tan Hong and Tam Nong were selected and intensive socio-economic survey (household and business) and district data collection were carried out.

Three representative districts in shallow flooded area: Long Xuyen City, Sa Dec Town, and Cai Be District were selected for additional secondary data collection carried out during the Stage 2 (March-April 2009).

A dataset was obtained at district level covering: (i) direct damages for selected years for the period 2000-2007; (ii) district socio-economic indicators and land-use 2007; (iii) survey on the 2006 flood damage for household/business; (iv) indirect costs spent in the 2006 flood by district departments; and (v) Focal Group discussions.

CHAPTER 2

DATA

2 DATA

2.1 Population

According to 2007 District statistics, a large population was found in Chau Phu Long Xuyen and Cai Be districts (250,000-300,000 persons) and a small population was found in Tan Hong, Tam Nong districts , and Sa Dec Town (80,000-100,000 persons). The size of family was in the range of 3-5 persons. The poverty rate was still high in Tan Hong, Tam Nong at about 13-14%, while a low poverty rate was found in Long Xuyen City.

Population density was high in Long Xuyen City (24 person/ha) and Sa Dec Town (17 persons/ha). Population density in other districts was 6-7 person/ha in Chau Phu and Cai Be, and 2-3 person/ha in Tan Hong and Tam Nong. See Table 2-2

Table 2-1 District population.

Items	Chau Phu	Tan Hong	Tam Nong	Long Xuyen	Sa Dec	Cai Be
Population	**252,066**	**81,817**	**99,464**	**275,519**	**103,646**	**293,470**
Male	123,343	42,058	48,638	134,238	50,375	142,407
Female	128,723	39,759	50,826	141,281	53,271	151,063
Urban	19,537	10,842	9,998	241,515	68,292	18,227
Rural	232,529	70,975	89,466	34,004	35,254	275,243
Number of HH	**55,230**	**22,508**	**20,138**	**61,957**	**25,998**	**66,884**
Size of Family	4.56	3.64	4.94	4.45	3.99	4.39
Poverty rate	8%	14%	13%	4%	NA	9.8%
Pop density (P/ha)	6	3	2	24	17	7

Source: Annual statistics 2007

2.2 Flood damages

Direct flood damages data were collected from provincial and/or district authorities from annual reports with standard format used for collecting direct flood damages by local authorities. The format is very intensive with more than 100 types of damage items. The direct damages were grouped into three damage categories presented in Appendix 2. Total direct and indirect flood damages were estimated based on indirect-direct damage ratios which were taken from the Household and Business surveys for the districts Chau Phu (An Giang Province) and Tam Nong and Tan Hong (Dong Thap Province). A relation between indirect and direct damages was derived for 2006 flood at a level of 64% for the Housing category[2].

From the secondary data collection at district level, indirect flood damage data for the districts Chau Phu, Tam Nong and Tan Hong, a relation between indirect and direct damages for the Infrastructure & Relief category was derived for the 2006 flood. This relation was used to increase the direct damages as reported for the provincial level for the years 2000-2007 with 30% to obtain the total damages for this category.

The total flood damages were deflated to the 2007 fixed price and they are presented in the Table 2-2.

[2] Details are presented in FMMP-C2, Stage I Evaluation Report, Annex 2: Flood Damages and Flood Risks in the Focal Areas, August 2008.

The flood damage in Mekong Delta was very high in the year 2000 not only due to high flood water level but also it arrived too early in July when most of the paddy had not yet harvested.

Flooding in 2001, 2002 and 2006 was above average, while flooding in the remaining year in Mekong Delta was very low. The damages were low or there was no damage especially in the shallow flooded areas (Long Xuyen, Sa Dec, Cai Be).

Table 2-2 District flood damages (USD 1,000 at 2007 constant price).

Year	2000	2001	2002	2003	2004	2005	2006	2007
Chau Phu	**4,682**	**1,232**	**1,128**	**0**	**154**	**109**	**5**	**3**
Infrastructure	3,796	802	786	0	108	95	0	3
Housing	748	429	339	0	46	14	5	0
Agriculture	138	1	3	0	0	0	0	0
Tan Hong	**8,157**	**3,945**	**953**	**0**	**247**	**165**	**322**	**44**
Infrastructure	3,777	1,282	545	0	241	144	203	41
Housing	1,747	2,485	408	0	6	0	119	3
Agriculture	2,633	178	0	0	0	21	0	0
Tam Nong	**12,533**	**4,382**	**975**	**28**	**65**	**29**	**191**	**153**
Infrastructure	4,296	1,691	470	16	14	26	50	136
Housing	2,340	2,353	505	12	51	0	141	17
Agriculture	5,897	338	0	0	0	3	0	0
Long Xuyen	**7,061**	**928**	**360**	**0**	**95**	**25**	**22**	**37**
Infrastructure	6,053	508	323	0	79	18	22	37
Housing	896	408	34	0	16	7	0	0
Agriculture	111	12	3	0	0	0	0	0
Sa Dec	**4,071**	**1,677**	**712**	**0**	**32**	**24**	**3**	**3**
Infrastructure	1,256	353	161	0	32	24	1	0
Housing	1,837	841	546	0	0	0	2	2
Agriculture	978	482	5	0	0	0	0	1
Cai Be	**35,396**	**7,287**	**3,432**	**0**	**0**	**0**	**0**	**0**
Infrastructure	6,720	1,423	1,716	0	0	0	0	0
Housing	2,947	2,119	1,712	0	0	0	0	0
Agriculture	25,729	3,746	4	0	0	0	0	0

Source: District/province data and consultant estimates

2.3 Land use and agriculture

Land use in the selected districts is mainly for agriculture production occupying more than 80% except long Xuyen City and Sa Dec Town where agricultural production land is about 60%. The forest land is mainly in Tam Nong District where Tram Chim national park exists.

Non-agricultural land consists of residential area, special land (institutions, military, security, commercial, public lands), and others (religious, cemetery, river/water body), occupies about 10-18% of total land area in districts and about 35-40% of total land in Long Xuyen City and Sa Dec Town.

Fruit trees prevail in Cai Be District and Sa Dec Town which are located in shallow flooded areas. The fruit tree area in Cai Be District was about 50% of agricultural production land and it has been increased. Details are presented in Table 2-3.

Table 2-3 District land-use.

Items	Chau Phu	Tan Hong	Tam Nong	Long Xuyen	Sa Dec	Cai Be
Total Land	**45,101**	**31,127**	**47,433**	**11,543**	**5,980**	**42,090**
1. Agriculture	**40,174**	**25,410**	**42,711**	**7,006**	**3,826**	**34,606**
Agricultural production	39,729	25,063	34,449	6,786	3,740	34,437
+Annual crop land	*39,022*	*24,812*	*33,749*	*6,537*	*2,393*	*18,709*
+Perennial trees	*707*	*251*	*700*	*249*	*1,347*	*15,728*
Forest land	0	110	8,116	0	0	59
Fishery	444	214	146	219	84	109
Others	0	23	0	0	2	0
2. Non-agriculture	**4,927**	**5,717**	**4,721**	**4,511**	**2,152**	**7,405**
Residential	1,145	1,120	708	1,804	479	1,360
Special land	2,538	2,888	3,270	1,329	620	2,287
Others	1,244	1,709	743	1,379	1,052	3,758
3. Un-used land	0	0	0	26	2	79
4. Coastal land	0	0	0	0	0	0

Source: Provincial Department of Natural Resource & Environment, 2007

Agricultural production in the selected districts is mainly paddy: double cropping system in deep flooded areas and triple cropping system in shallow flooded areas. Most crops in the area are under irrigation. There are some non-rice crops planted in the area such as maize, beans, vegetables, soy-bean at a small scale in shallow flooded areas or full flood protection areas. See Table 2-4.

There are three main crop seasons:

- Summer-Autumn crop is planted in March-April and harvested in July-August which is potentially affected by early flood during the harvesting period.
- Rainy seasonal crop is planted in July-August and harvested in November which falls in main flooding season. This crop is cultivated in shallow flooded area and in full flood protection areas.
- Winter-Spring crop is planted in November-December and harvested in March-April. The crop planted after flood and required full irrigation during dry season. It is hardly affected by flood except in some case late flood would damage a newly sown area.

According to the District statistics, there are small crop areas under full flood protection in Chau Phu and Tan Hong districts. They are about 1,900 ha occupying 6% of paddy field in Chau Phu and about 2,100 ha occupying 10% of paddy field in Tan Hong. As the price of rice in the world market has been increasing, this may have an impact on future expansion of the third crop in the deep flooded areas. The third paddy crop is planted in August and harvested in November, which is in main flood season of the Mekong Delta.

The fruit trees are mainly planted in Cai Be District and Sa Dec Town. There are many types of fruit trees however, oranges, mango, pomelo, longan are prevailing fruits in the shallow flooded area. See Table 2-5.

Table 2-4 Main annual crops (ha) and production (ton).

Items	Chau Phu	Tan Hong	Tam Nong	Long Xuyen	Sa Dec	Cai Be
WS Paddy Area	34,383	21,599	30,506	5,591	1,935	18,432
production	260,176	140,761	207,086	42,570	12,182	124,861
SA Paddy Area	33,959	21,624	30,004	5,433	1,455	17,989
production	182,954	114,682	140,069	30,470	5,506	81,581
RS Paddy Area	6,389	2,542	0	100	406	17,723
production	38,768	13,191	0	434	1,501	17,723
Maize Area	98	83	63	6	24	135
production	486	421	242	29	91	390
Beans Area						68.72
production						179.8
Soy-bean Area	311	3	1	39	506	215
production	1,076	5	2	79	1,113	536
Vegetables Area	2,382	938	1,017	360	271	297
production	44,736	16,368	22,041	7,845	3,547	10,237

Source: Statistics, 2007

Table 2-5 Fruit trees in Cai Be and Sa Dec.

Items	Cai Be (ha)	Cai Be (%)	Sa Dec (ha)	Sa Dec (%)
Oranges	3,451	22%	98	11%
Mango	3,373	22%	596	65%
Pomelo	2,569	16%		
Longan	1,873	12%	200	22%
Guava	975	6%		
Mandarin	906	6%		
Lemon	717	5%		
Banana	306	2%		
Coconut	215	1%	17	2%
Rose-apple	195	1%		
Durian	136	1%		
Other Fruit trees	549	4%		
Other perennial trees	385	2%		
Total perennial trees	**15,650**	**100%**	**911**	**100%**

Source: Statistics, 2007

2.4 Crop-benefits

2.4.1 Annual crops in the deep flooded area

The paddy yield in a deep flooded area varies from 4-7 ton/ha depending on season. The highest paddy yield is in dry season at about 7 ton/ha. Lowest paddy yield is in rainy seasonal paddy when there is limited sunshine and too much rain.

It is also true for a full flood protection area where people can grow the third paddy crop. This season main effort is drainage of local rain water from the field instead of irrigation. The net benefit of paddy cultivation is about 680 USD/ha for WS Rice, 230 USD/ha for SA Rice, and 120 USD/ha for rainy seasonal rice. For details see Table 2-6.

The amount of fertilisers applied was about 350-400kg/ha/season mainly Urea and DAP. Agrochemicals include pesticides, herbicides and fungicides have been widely used in the area with a value of 2-3 mln VND (equivalent to 100-200 USD) per ha per season.

2.4.2 Annual crops in the shallow flooded area

Annual crop cultivation in the shallow flooded area is a triple crop system. It would be triple paddies, or double paddies plus upland crop, or triple upland crops. The paddy yield varies from 4 to 6 ton/ha. Highest yield is found in dry season crop, and lowest yield is rainy seasonal crop.

Net benefit from paddy cultivation was about 750 USD/ha for WS rice, 280 USD for SA rice, and 340 USD/ha for rainy seasonal rice.

Amount of fertilisers application in shallow flooded area is more than that in deep flooded area in an order of 450-500 kg/ha/season. Agrochemicals use at a value of 1-1.2 mln VND (equivalent to 50-100 USD) per crop per season.

Other non-rice crops in both deep and shallow flooded areas as maize and beans have net benefits of 700-900 USD/ha. However amount of fertilisers used for upland crops is more than paddy by about 100kg/ha.

Table 2-6 Crop-budgets for paddy in deep flooded area.

	Annual Crops Planting month Harvesting month **Technique**	Unit	**WS Rice** December March **Irrigated**	**SA Rice** May August **Irrigated**	**AW Rice** August December **Rain-fed**
1	Total production	Kg	6,900	5,260	4,000
2	Total revenue	VND	24,150,000	18,410,000	14,000,000
3	Total Inputs	VND	12,642,600	14,582,400	11,989,000
4	Physical input	VND	7,556,000	8,016,000	8,889,000
	Seed	VND	800,000	960,000	1,020,000
	Fertilisers	VND	2,406,000	2,406,000	2,769,000
	Agrochemical	VND	1,950,000	1,950,000	2,500,000
	Mechanisation	VND	2,400,000	2,700,000	2,600,000
	Cow/buffalo	VND	0	0	0
	Other inputs	VND	1,146,600	2,126,400	0
5	Labor	Wd	62	66	68
6	Other expenditures	VND	1,200,000	1,500,000	0
7	**Net Benefit**	**VND**	**11,507,400**	**3,827,600**	**2,011,000**
		USD	**677**	**225**	**118**

Source: Socio-economic data collection, April 2009

Table 2-7 Crop-budgets for paddy in shallow flooded area.

	Annual Crops Planting month Harvesting month **Technique**	Unit	**WS Rice** December April **Irrigated**	**SA Rice** May August **Irrigated**	**Rainy Seasonal Rice** August December **Rainfed**
1	Total production	Kg	6,000	5,000	4,200
2	Total revenue	VND	25,200,000	17,500,000	16,800,000
3	Total Inputs	VND	12,423,190	12,671,190	11,101,900
4	Physical input	VND	8,713,190	8,961,190	7,861,900
	Seed	VND	770,000	770,000	770,000
	Fertilisers	VND	3,011,000	3,011,000	2,691,000
	Agrochemical	VND	1,250,000	1,250,000	1,000,000
	Mechanisation	VND	960,000	960,000	960,000
	Cow/buffalo	VND	800,000	800,000	800,000
	Other inputs	VND	1,922,190	2,170,190	1,640,900
5	Labour	Wd	81	81	70
6	Other expenditures	VND	0	0	0
7	**Net Benefit**	**VND**	**12,776,810**	**4,828,810**	**5,698,100**
		USD	**752**	**284**	**335**

Source: Socio-economic data collection, April 2009

2.4.3 Fruit trees in the shallow flooded areas

Fruit trees are planted at large scale in shallow flooded areas in Dong Thap, Tien Giang, and Vinh Long provinces. The fruit farms have full flood protection by embankment, either at individual farm of a few ha or a group of farms at 50-100ha. Fruit garden establishment cost varies 20-56 mln VND/ha (1,200-3,300 USD) for the first year. Annual expenditures for harvesting would be 18-34 mln VND/ha. And annual benefit in harvesting years is 25-46 mln VND/ha. However, considering all investments, the annual Net Benefit at 12% discounted rate is 700-1200 USD/ha. See Table 2-8.

Table 2-8 Crop-budgets for fruit trees in shallow flooded areas.

	Fruit Trees		**Mango**	**Star apple**	**Dragon**	**Orange**
1	**Investment (1st year)**	VND	**25,917,000**	**20,885,000**	**56,175,000**	**33,487,200**
2	Economic cycle	year	30	40	10	10
3	Year starting harvest	year	5	5	4	4
4	Year having high yield	year	10-20	15-30	5-8	5-8
5	Average yield	ton	9.5	15.0	20.0	11.0
6	High yield	ton	13.5	19.5	25.5	15.0
7	Inputs before yielding	VND/year	5,500,000	10,087,000	11,070,000	9,135,200
8	Inputs at average yielding	VND/year	17,959,000	19,815,500	34,236,000	23,029,000
9	Inputs at high yielding	VND/year	20,842,000	25,131,000	41,448,000	28,693,000
10	Benefit (average yield)	VND	39,041,000	25,184,500	45,764,000	42,971,000
11	Benefit (stable yield)	VND	60,158,000	33,369,000	60,552,000	61,307,000
12	Annual Labour	Wd	129	107	130	200
13	Net Present Value-12%	VND	164,180,607	94,019,319	117,253,045	129,072,555
14	Annual NB - 12%	VND	20,128,647	11,359,904	18,253,625	20,093,653
	Net Present Value (12%)	**USD**	**9,658**	**5,531**	**6,897**	**7,593**
	Annual NB at 12%	**USD**	**1,184**	**668**	**1,074**	**1,182**

Source: Socio-economic data collection, April 2009.

CHAPTER 3

FLOOD HAZARD ASSESSMENT

3 FLOOD HAZARD ASSESSMENT

VRSAP hydraulic model was used to simulate flood water levels in the entire Mekong Delta, Viet Nam. The output of daily water level from 1910-2006 at representative locations for each selected districts was used for flooding hazard analysis.

Yearly maximum flood level and maximum flood level before 1 August were used for vulnerability analysis for the 6 selected Chau Phu, Tam Nong, Tan Hong, Cai Be districts, Long Xuyen City and Sa Dec Town. See Appendix 1[3].

The damages to infrastructure and housing depend on the magnitude of flooding (yearly maximum flood level); meanwhile crop damage depends on early flood in deeply flooded areas when Summer-Autumn Paddy is being harvested. Harvesting time varies from district to district. Early harvesting time in upstream districts 1-31 July and later harvesting time in downstream districts (15 July-15 August). In general, the harvesting period in the VN Delta is from 1 of July to 15 of August. In flood damage assessment for agriculture, we select a “mid-point” before 1 of August to relate the damage to maximum water level before 1 August. We could do it for a different date in July and August, however since maximum water levels during that period have a strong inter-correlation, so using different dates would not be significant in flood risk assessment. After the 15 of August, all crops in the field are harvested and flooding would have no impact at all. However, in shallow flooded areas, where a triple cropping system is in place, damage to crops would depend on yearly maximum flood levels, especially fruit trees.

3 Updated flood hazard maps for various probabilities of exceedance will be added in the final report.

CHAPTER 4

FLOOD DAMAGE ASSESSMENT

4 FLOOD DAMAGE ASSESSMENT

4.1 Methodology and approach for flood damage assessments

There are basically two approaches for flood risk assessment[4]: absolute approach (top-down) and relative approach (bottom-up). In the absolute approach, historical damage data for an (administrative) area are used to assess the flood damage risk in that area. In the relative approach inundation-damage relationships are developed on a unit (ha, % of house value) basis, and the flood damage risk is assessed by applying the per unit risk to the number of units in the concerned area.

In this study, considering resources, time and data availability, the absolute approach has been followed for flood damage assessment to Housing, Agriculture, and Infrastructure. The Housing category covers individual houses and properties. The Agriculture category covers crops, livestock, and aquaculture. The Infrastructure category covers industry, irrigation, transportation, power utilities and water supply, institutions, public utilities and commercial areas.

The overall approach seeks the relation between protection levels and the residual risk that is considered acceptable. The assessment of the residual risk under different levels of protection is, therefore, the key issue of the exercise.

A first step in this approach is the proper assessment of the flood hazard, i.e. the flood levels with different exceedance probabilities. In Stage 1 such assessment was made with the help of the MRC ISIS model for the deep flooded areas in the northern part of the Delta. In this DP the VRSAP model will be used for the flood hazard assessment.

The second step is the assessment of residual risks under different levels of protection. For this purpose use will be made of district damage curves.

A third step is the assessment of the existing protection levels by comparing the flood hazard levels with existing dyke elevations.

One important element in the evaluation of the acceptability of the residual risk refers to the costs that are involved to reduce this risk. An attempt will be made to make a first estimate of costs related to increase the heights of protection dykes.

The grand total of damages caused by a flood in a certain area is the total of direct damages plus the total of indirect damages. Direct damages are obtained from local authorities at provincial and district levels from 2000-2008. It covers loss of life, damages to housing, agriculture, and infrastructure broken down into departments. The indirect-direct damage ratios are used information from detail survey during the phase 1 for focal areas in Viet Nam to estimate the grand total of damages.

For analysis purposes three main damage categories have been distinguished: (i) Infrastructure; (ii) housing, and (iii) agriculture.

4.2 Flood Damage Data Used for analysis

The deeply flooded area in the Mekong Delta in Viet Nam covers part of the Plain of Reeds and the Long Xuyen Quadrangle. During the Stage 1 of FMMP-C2, the three districts in focal area,

4 Best Practice Guidelines for Flood Risk Assessment, Volume 3A.

Viet Nam: Chau Phu, Tan Hong and Tam Nong were selected and intensive socio-economic survey (household and business) and district data collection were carried out.

Three representative districts in shallow flooded area: Long Xuyen City, Sa Dec Town, and Cai Be District were selected for additional secondary data collection carried out during the Stage 2 (Mar-Apr 2009).

A dataset was obtained at the district level covering (i) direct damages for selected years for the period 2000-2007; (ii) district socio-economic indicators and land-use 2007; (iii) survey on the 2006 flood damage for household/business; (iv) indirect costs spent in the 2006 flood by district departments; and (v) focal group discussions.

The results of the flood risk assessment is provided in Chapter 5, the resulting flood damage probability curves have been derived from that analysis.

4.3 Flood damage curves

Flood damage assessment is specified in the Guidelines for Flood Risk Assessment. Considering data availability, resources, and study objectives the absolute damage assessment methodology is used for the DP.

Flood damage curves or damage functions would be established by relationship between yearly flood water levels at representative location of the district (at or near the centre) and yearly flood damages in the district by three main categories: Infrastructure, Housing, and Agriculture. There are 18 flood damage curves representing for the 6 selected districts and city as shown in the following figures. There are 9 damage functions having R-square more than 0.9, And only 4 damage functions having R-square less than 0.7. The low R-square happens for the damage function with low damage value as the case in Long Xuyen, Tan Hong and Sadec. See details in Table 4-1.

Table 4-1 R squares of the flood damage functions.

R Square	Chau Phu	Tan Hong	Tam Nong	Long Xuyen	Sa Dec	Cai Be
Infrastructure	0.95	0.94	0.88	0.92	0.64	1.00
Housing	0.99	0.56	0.72	0.63	0.77	0.97
Agriculture	1.00	0.99	0.99	0.75	0.49	0.81

The flood damage curves for the six districts and for the various damage categories are presented in Figure 4-1 to Figure 4-6.

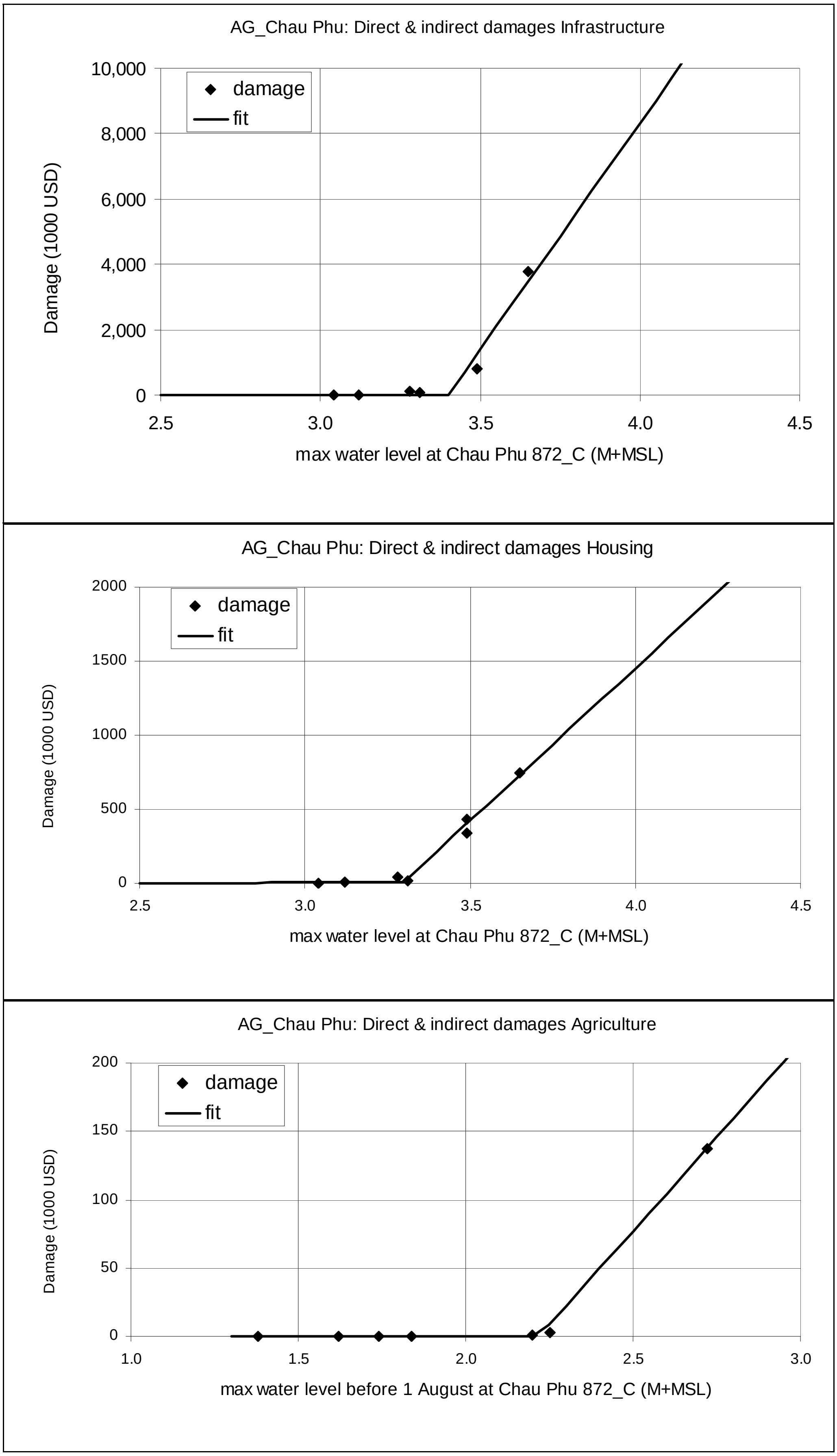

Figure 4-1 Flood damage curves Chau Phu District.

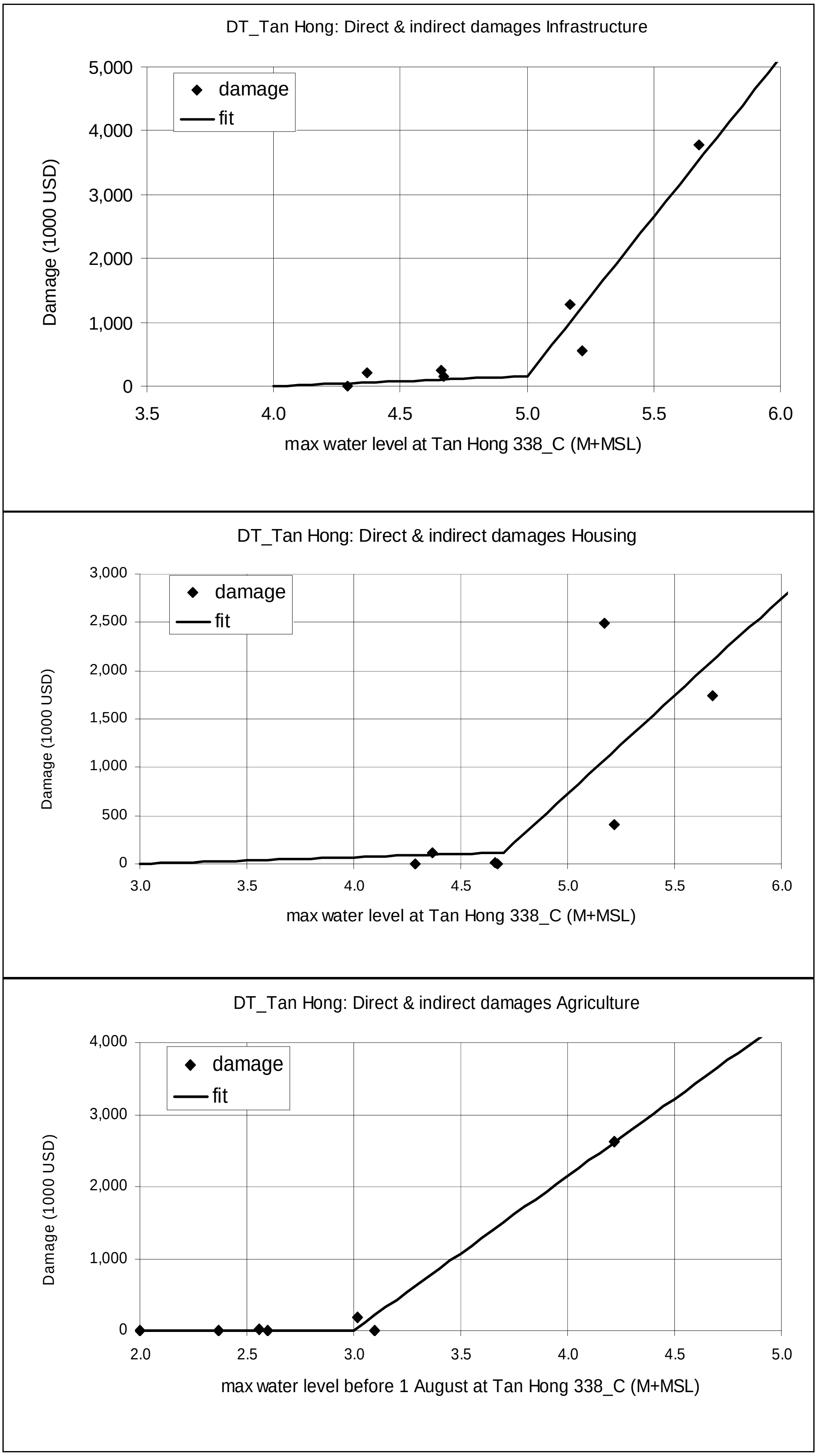

Figure 4-2 Flood damage curves Tan Hong District.

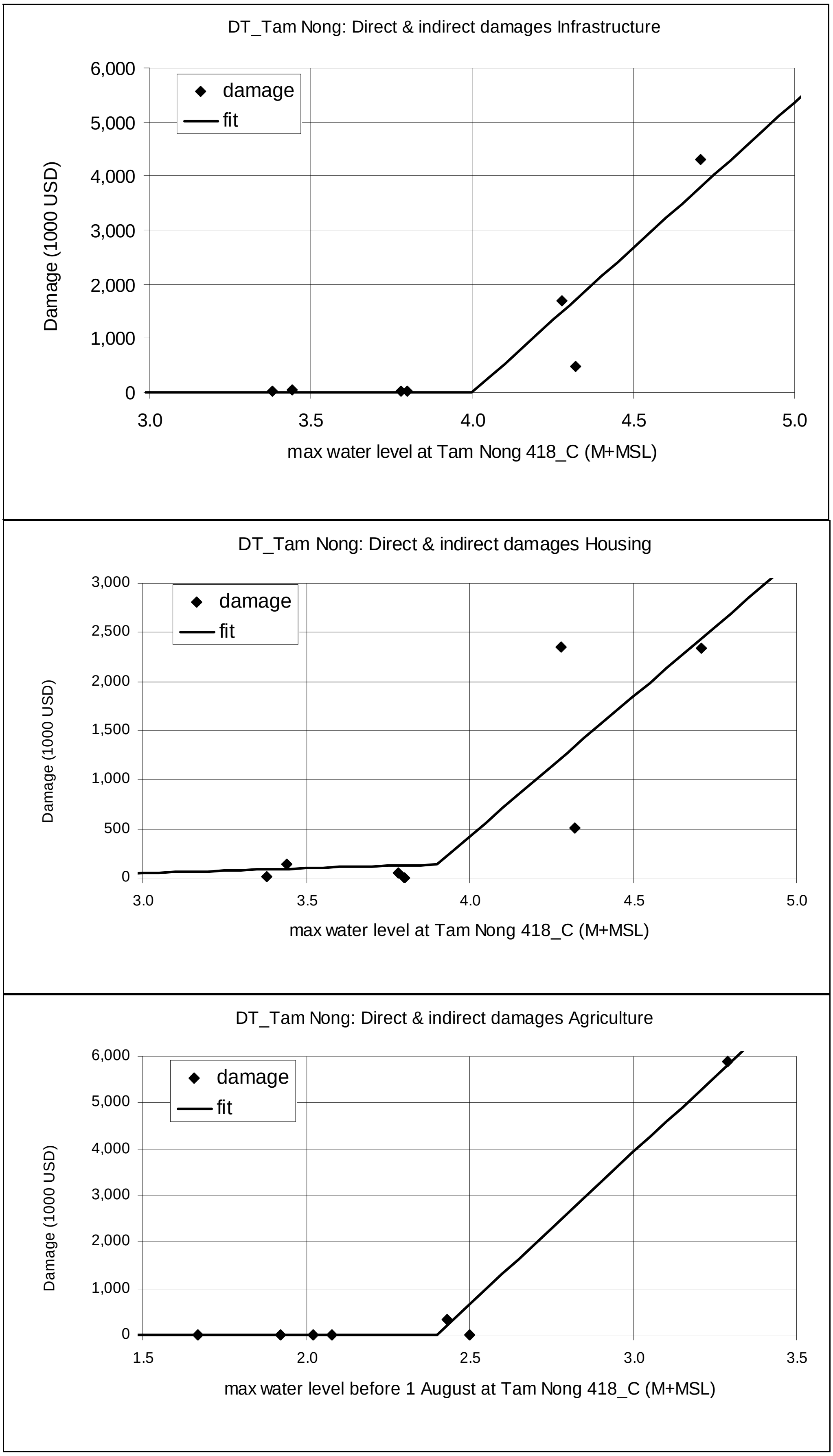

Figure 4-3 Flood damage curves Tam Nong District.

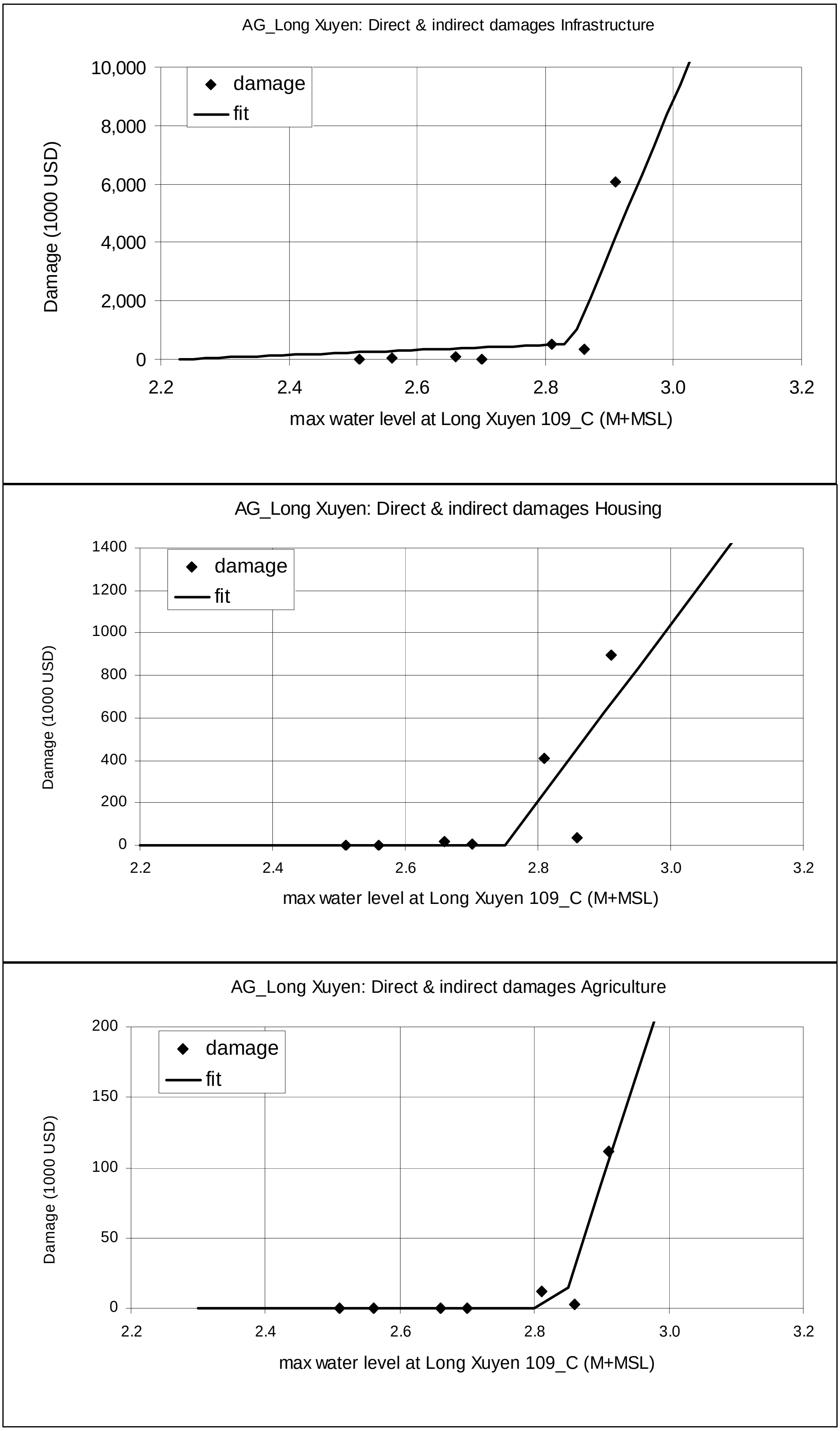

Figure 4-4 Flood damage curves Long Xuyen City.

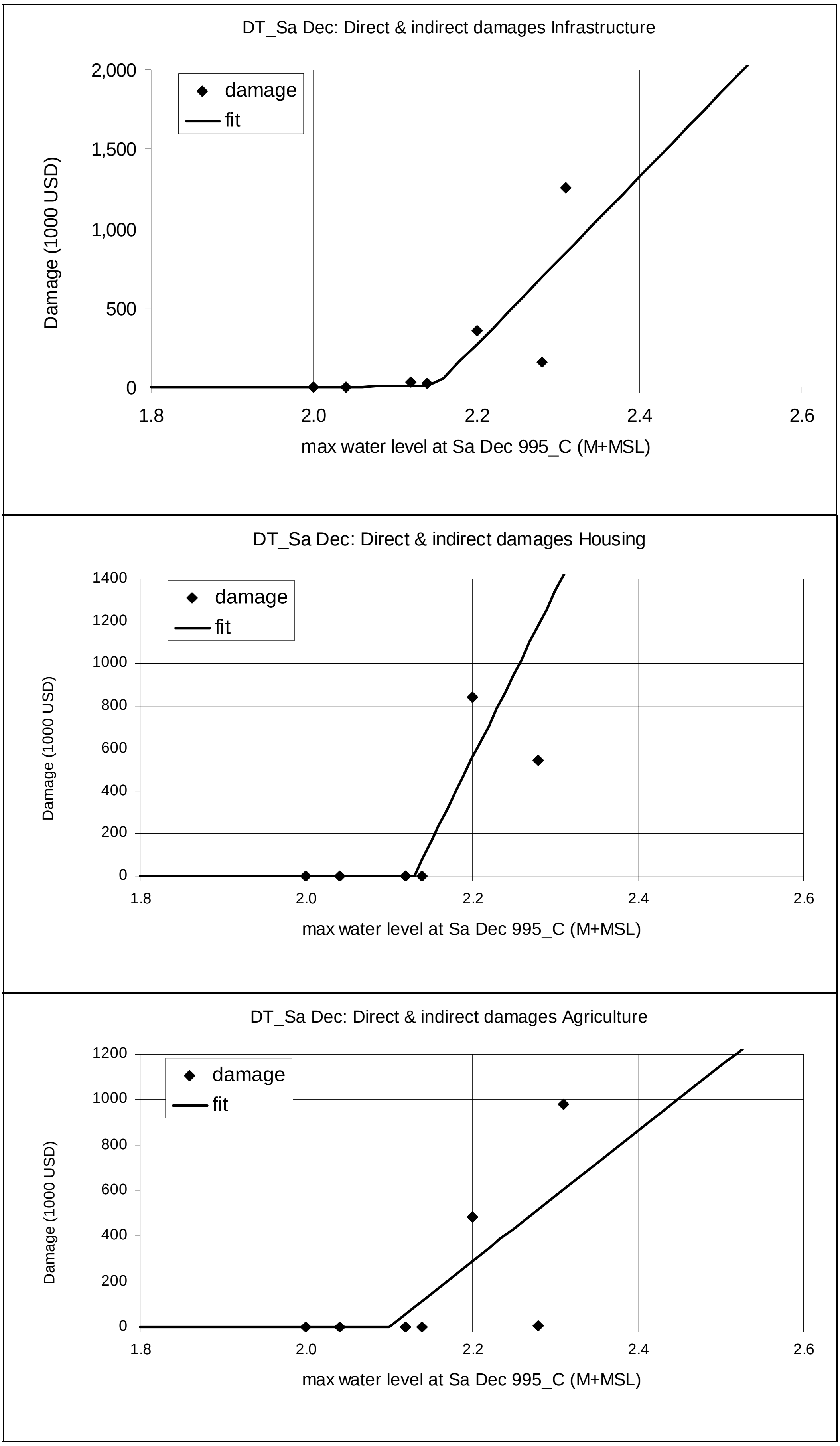

Figure 4-5 Flood damage curves Sa Dec Town.

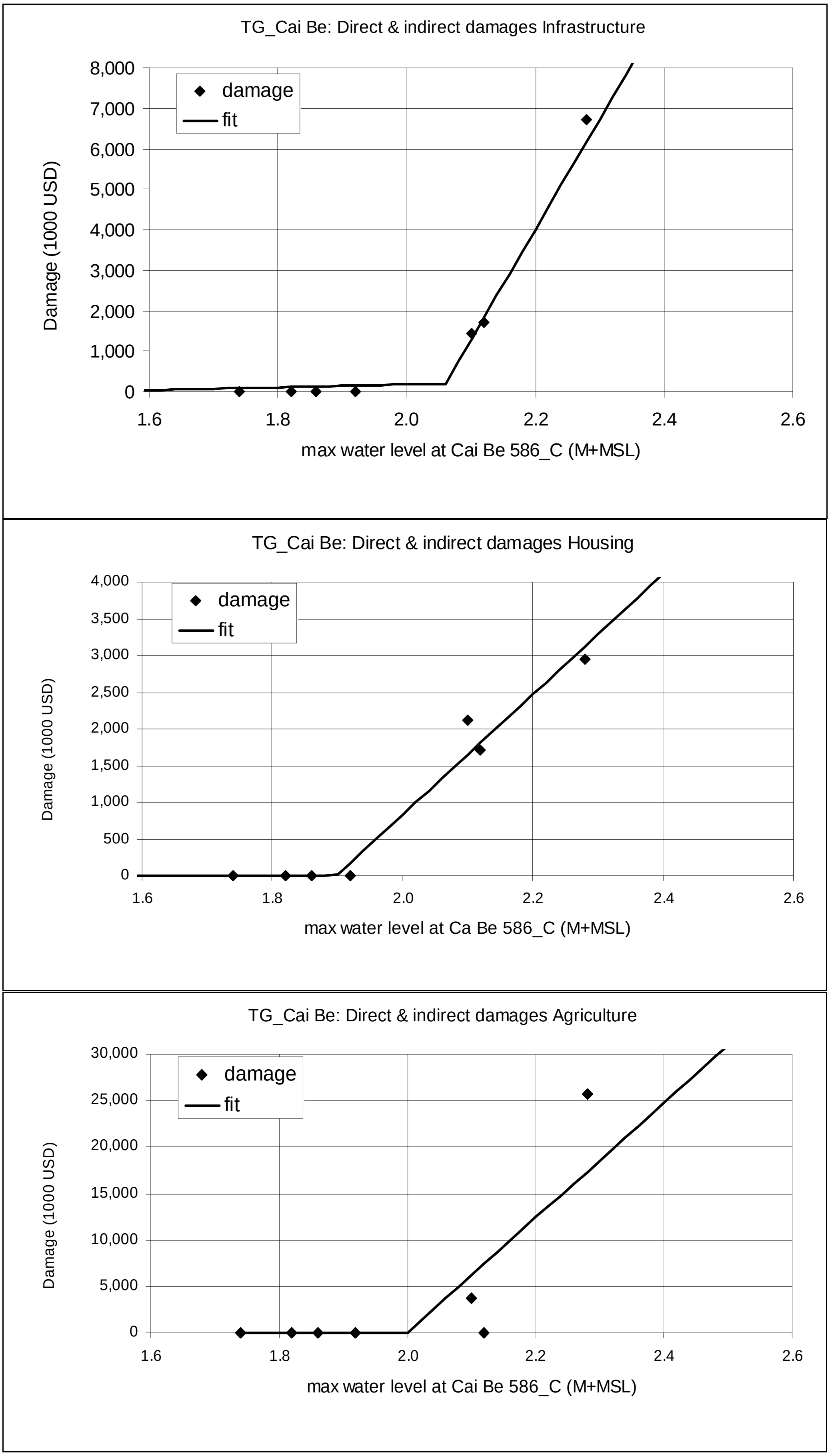

Figure 4-6 Flood damage curves Cai Be District.

4.4 Flood Damage Probability Curves

Establishment of flood damage probability is an important step of flood risk assessment. It combines flood hazard probability analysis and flood damage assessment to develop flood damage probability.

The flood damage probability curves for the 6 selected municipalities in the demonstration project were prepared and presented in the following sections.

4.4.1 Chau Phu District

Flood damage in Chau Phu District is considered as low level. The damage is mainly for infrastructure occupying about 80% of the total flood damage in the district. The remains are for housing occupying about 18% and for agriculture occupying about 2%. See Figure 4-7, and Table 4-2.

There would be insignificant flood damage for infrastructure, housing, and agriculture at a probability of 25%, 30%, and 10% or higher respectively.

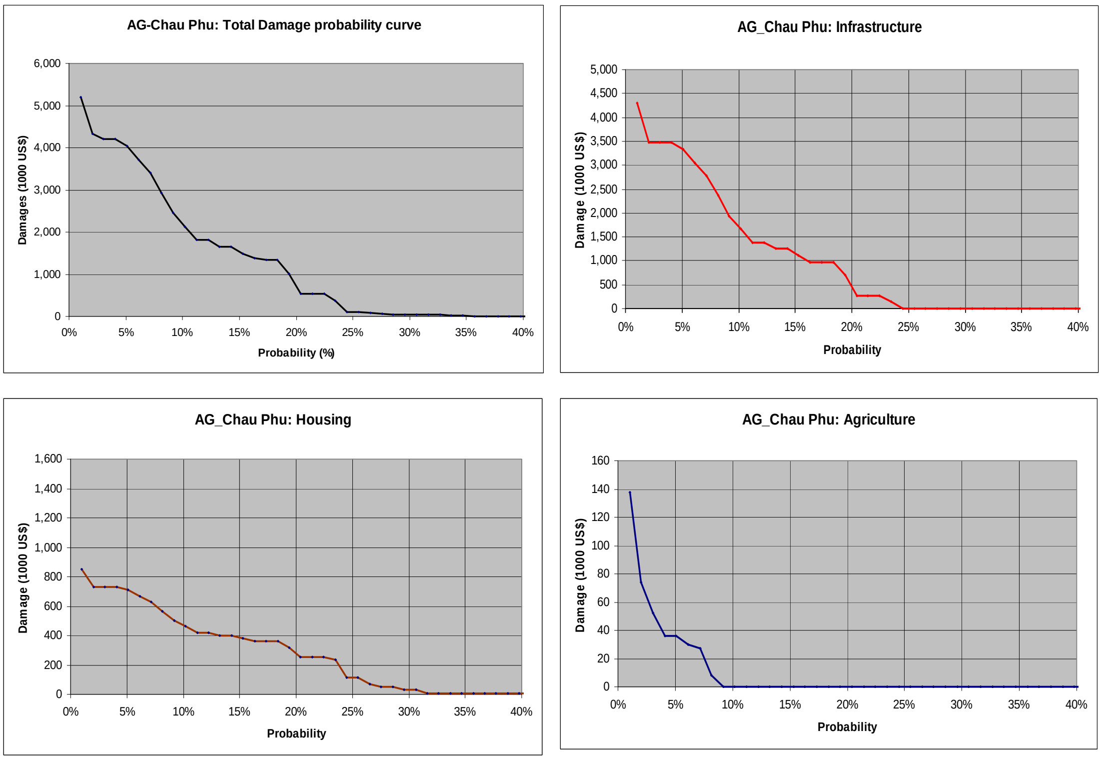

Figure 4-7 Flood damage probability curves, Chau Phu District.

Table 4-2 Flood damage probability, Chau Phu District (USD 1,000).

T (year)	**100**	**50**	**25**	**10**	**5**	**2**
P(%)	**1%**	**2%**	**4%**	**10%**	**20%**	**50%**
Infrastructure	4,301	3,469	3,469	1,665	277	0
Housing	854	730	730	462	256	7
Agriculture	137	74	36	0	0	0
TOTAL	5,293	4,273	4,235	2,127	533	7

4.4.2 Tan Hong District

Flood damage in Tan Hong district is considered as average level. The damage is mainly for infrastructure occupying about 50% of the total flood damage in the district. The remainder is for housing occupying about 30% and for agriculture about 20%. See Figure 4-8, and Table 4-3.

There would be insignificant flood damage for infrastructure, housing, and agriculture at a probability of 25%, 40%, and 10% or higher respectively.

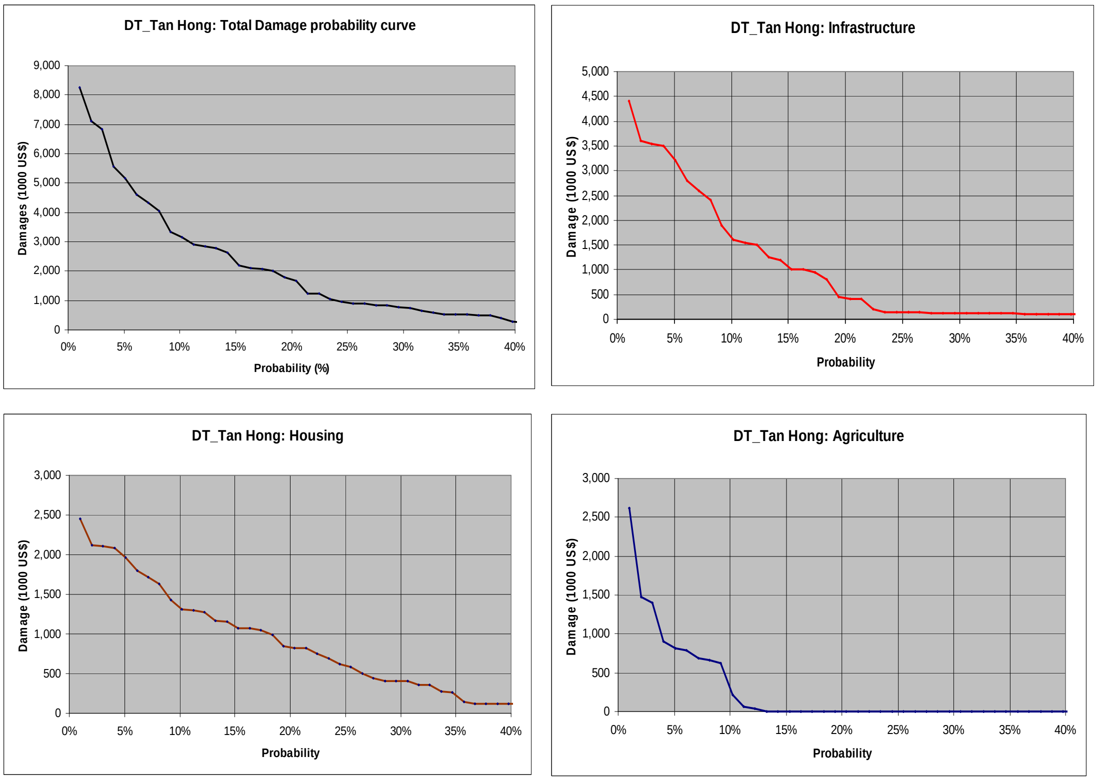

Figure 4-8 Flood damage probability curves, Tan Hong District.

Table 4-3 Flood damage probability, Tan Hong District (USD 1,000).

T (year)	**100**	**50**	**25**	**10**	**5**	**2**
P(%)	**1%**	**2%**	**4%**	**10%**	**20%**	**50%**
Infrastructure	4,398	3,599	3,499	1,603	405	87
Housing	2,447	2,123	2,083	1,313	827	108
Agriculture	2,617	1,480	901	214	0	0
TOTAL	9,462	7,202	6,483	3,130	1,231	195

4.4.3 Tam Nong District

Flood damage in Tam Nong District is considered as high level. The damage is mainly for infrastructure occupying about 40% of the total flood damage in the district. The remainder is for housing, and agriculture occupying about 30% each. See Figure 4-9, and Table 4-4. There would be insignificant flood damage for infrastructure, housing, and agriculture at a probability of 25%, 50%, and 10% or higher respectively.

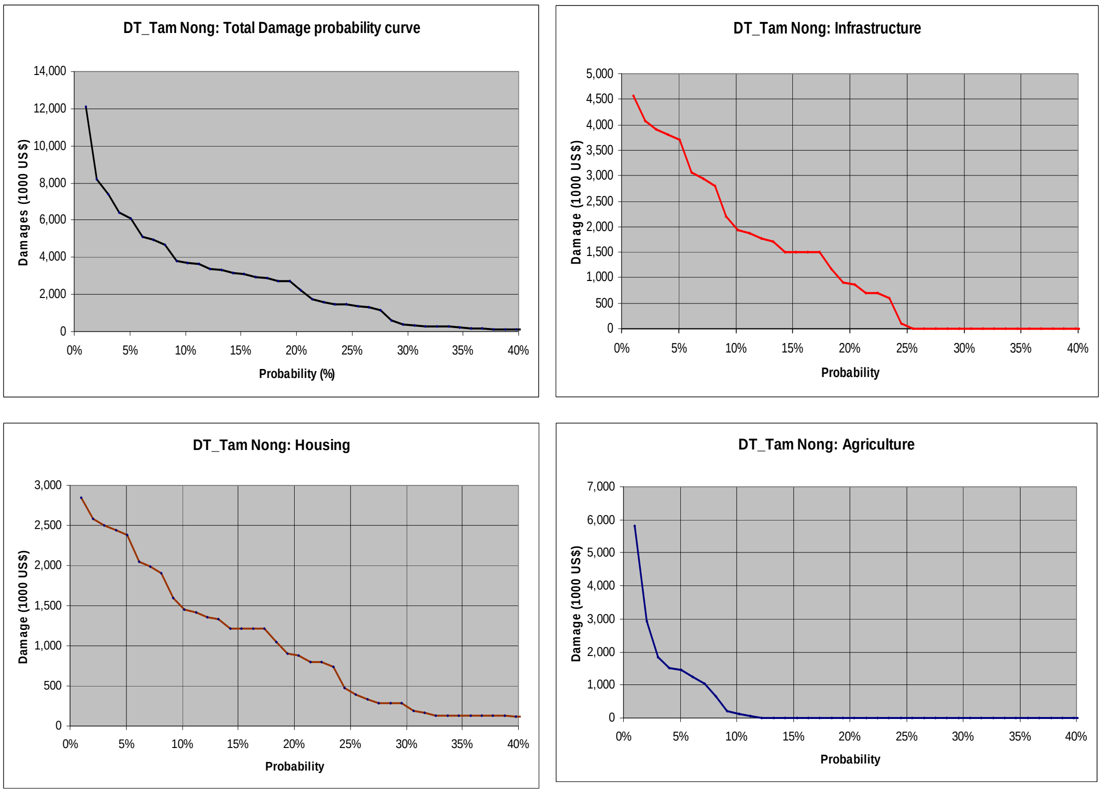

Figure 4-9 Flood damage probability curves, Tam Nong District.

Table 4-4 Flood damage probability, Tam Nong District (USD 1,000).

T (year)	**100**	**50**	**25**	**10**	**5**	**2**
P(%)	**1%**	**2%**	**4%**	**10%**	**20%**	**50%**
Infrastructure	4,559	4,077	3,808	1,931	858	0
Housing	2,841	2,585	2,443	1,447	878	109
Agriculture	5,828	2,947	1,506	131	0	0
TOTAL	13,229	9,609	7,757	3,509	1,736	109

4.4.4 Long Xuyen City

Flood damage in Long Xuyen City is considered at average level. The damage is mainly for infrastructure occupying nearly 90% of the total flood damage in the city. The remainder is for housing occupying about 10% and for agriculture about 2%. See Figure 4-10, and Table 4-5. There would be insignificant flood damage for infrastructure, housing, and agriculture at a probability of 10%, 25%, and 10% or higher respectively.

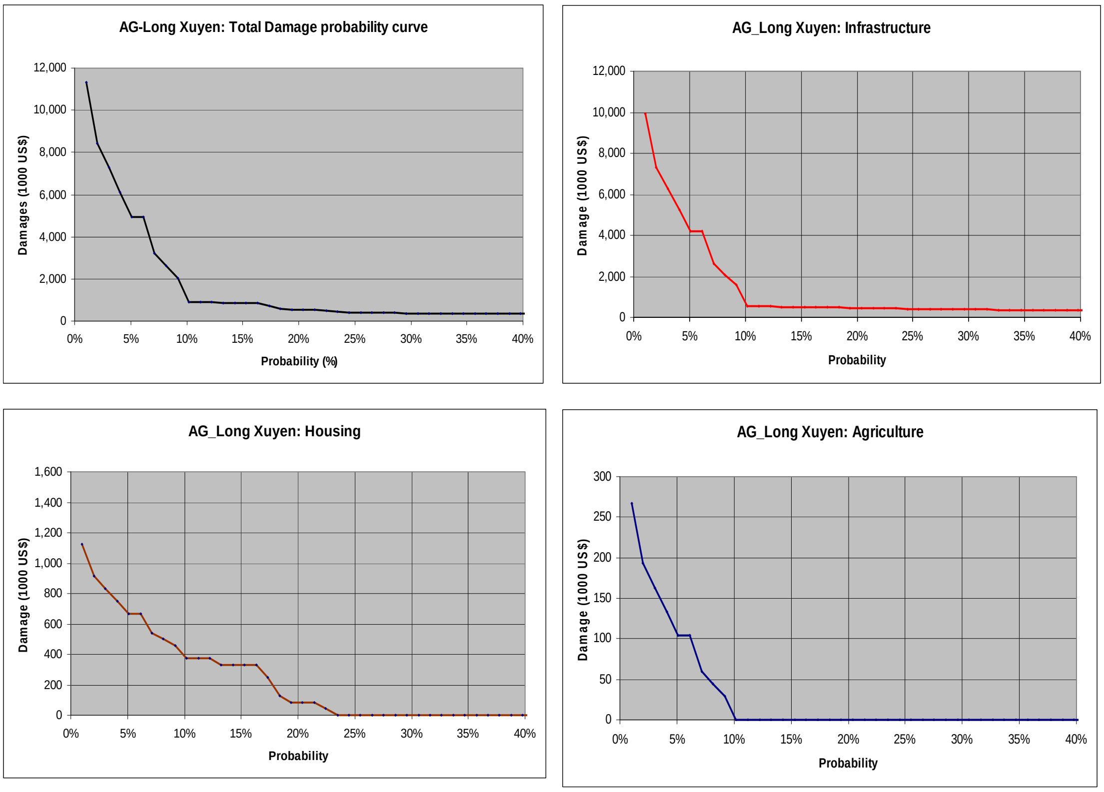

Figure 4-10 Flood damage probability curves, Long Xuyen City.

Table 4-5 Flood damage probability, Long Xuyen City (USD 1,000).

T (year)	**100**	**50**	**25**	**10**	**5**	**2**
P(%)	**1%**	**2%**	**4%**	**10%**	**20%**	**50%**
Infrastructure	9,945	7,327	5,233	521	461	307
Housing	1,122	914	748	374	83	0
Agriculture	267	193	133	0	0	0
TOTAL	11,334	8,434	6,114	895	544	307

4.4.5 Sa Dec Town

Flood damage in Sa Dec Town is considered at low level. The damage is mainly for infrastructure occupying nearly 30% of the total flood damage in the town. The remainder is for housing, occupying about 50% and for agriculture occupying at 20%. See Figure 4-11, and Table 4-6. There would be insignificant flood damage for infrastructure, housing, and agriculture at a probability of 25%, 30%, and 35% or higher respectively.

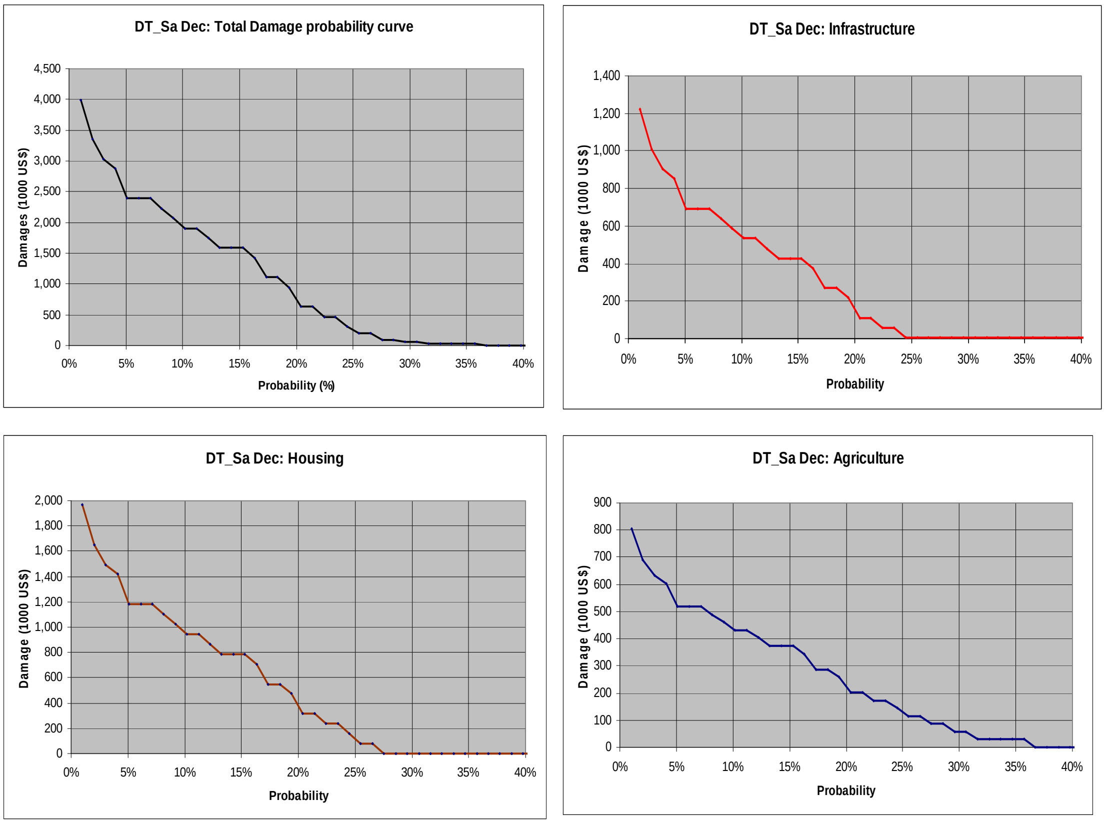

Figure 4-11 Flood damage probability curves, Sa Dec Town.

Table 4-6 Flood damage probability, Sa Dec Town (USD 1,000).

T (year)	**100**	**50**	**25**	**10**	**5**	**2**
P(%)	**1%**	**2%**	**4%**	**10%**	**20%**	**50%**
Infrastructure	1,220	1,009	850	533	111	3
Housing	1,968	1,653	1,417	945	315	0
Agriculture	805	690	604	431	201	0
TOTAL	3,993	3,352	2,871	1,909	627	3

4.4.6 Cai Be District

Flood damage in Cai Be District is considered at high level. The damage is mainly for agriculture occupying nearly 65% of the total flood damage in the district. The remainder is for infrastructure, occupying about 23% and housing about 12%. High flood damage for agriculture in Cai Be District was due to high concentration of fruit trees in the area. See Figure 4-12, and Table 4-7. There would be insignificant flood damage for infrastructure, housing, and agriculture at a probability of 15%, 30%, and 15% or higher respectively.

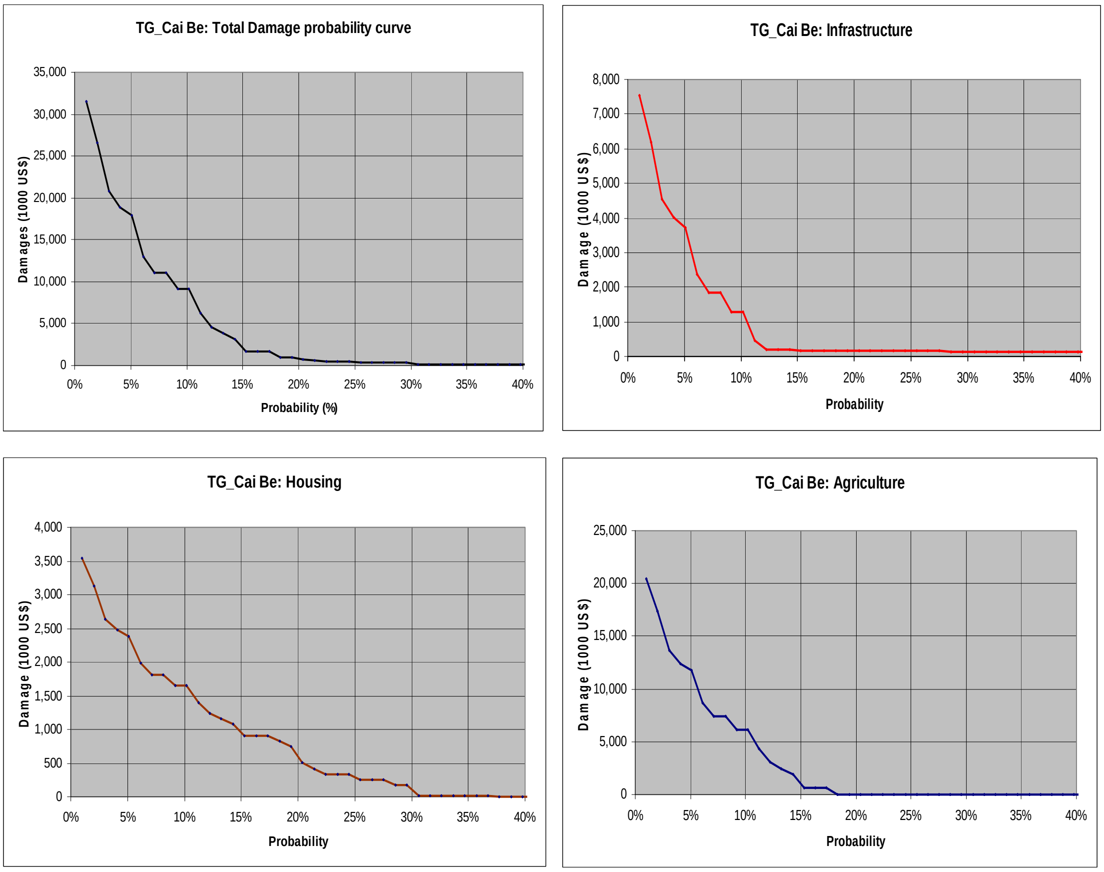

Figure 4-12 Flood damage probability curves, Cai Be District.

Table 4-7 Flood damage probability, Cai Be District (USD 1,000).

T (year)	**100**	**50**	**25**	**10**	**5**	**2**
P(%)	**1%**	**2%**	**4%**	**10%**	**20%**	**50%**
Infrastructure	7,539	6,179	4,004	1,284	162	116
Housing	3,537	3,126	2,470	1,650	501	7
Agriculture	20,426	17,332	12,381	6,192	3	1
TOTAL	31,501	26,637	18,854	9,126	665	124

CHAPTER 5

FLOOD RISK ASSESSMENT

5 FLOOD RISK ASSESSMENT

5.1 Flood Risk Analysis

The flood risk is an area below the flood damage probability curve from p=99.9% up to the specific probability p (say 20%, 10%, 5%, 1% etc.). The area represents annual expected damage caused by floods which are equal or smaller flood at the specified probability p. The term "potential flood risk" is the same as "flood risk reduction" when flood protection measures are provided to control the flood at certain probability p.

Flood risk assessment for the six selected districts showed that the potential flood risk is high in Cai Be and Tam Nong districts (1.0-1.9 mln USD/year) for the whole district at probability of 1% or higher, and low risk is found in Sa Dec Town and Chau Phu District (0.4-0.5 mln USD/year). Flood risk in Long Xuyen City and Tan Hong District is in an average between the two ends.

Composition of flood risk by the three categories varies from district to district. High rates were found in Chau Phu and Long Xuyen (70-90%) for infrastructure risk; in Cai Be District (61%) for agriculture. See Appendix 3 and details for other probabilities are presented in Table 5-5.

Table 5-1 Flood risk at P=1% (USD 1,000/year).

District	Total	Infrastructure	Housing	Agriculture	I	H	A
Chau Phu	514	394	117	3	77%	23%	1%
Long Xuyen	758	656	92	10	87%	12%	1%
Tam Nong	1,056	481	433	143	46%	41%	14%
Tan Hong	933	433	408	92	46%	44%	10%
Sa Dec	420	114	204	101	27%	49%	24%
Cai Be	1,935	417	346	1,173	22%	18%	61%

Considering the flood risk on the potential damage USD/year in Table 5-2, ranking the risk level in an order of district, which would suffer the most and second, etc. was carried out. The highest risk level is found at Cai Be District in total risk, at Long Xuyen City in infrastructure, at Tam Nong District in housing, and at Cai Be District in agriculture.

Table 5-2 Ranking risk levels based on USD 1,000/year.

District	Total	Infrastructure	Housing	Agriculture
Chau Phu	5	5	5	6
Long Xuyen	4	**1**	6	5
Tam Nong	2	2	**1**	2
Tan Hong	3	3	2	4
Sa Dec	6	6	4	3
Cai Be	**1**	4	3	**1**

Note: 1: high risk (high damage $/year); and 6: low risk (low damage $/year)

Another way for presenting potential flood risk is expressing the risk per unit of land use associated with damage. Residential land including rural and urban is used for housing damage analysis, special land use covering institution, commercial, public utilities, roads, etc. is used for infrastructure damage analysis, and agricultural production land covering annual crop and fruit trees is used for agricultural damage analysis. See land use formation in Table 2-3.

The risk per unit of land in overall is highest in Sa Dec (87 USD/ha/year). It is followed by Long Xuyen (76), Cai Be (51), Tan Hong (32), Tam Nong (27) and Chau Phu (12). Flooding risk for infrastructure land is highest at Long Xuyen (494 USD/ha/year), and it is followed by Sa Dec Town, Cai Be District (182-184), and Chau Phu, Tan Hong and Tan Nong districts (147-155). The risk for residential land is highest at Tam Nong (612), it is followed by Sa Dec and Tan Hong (365-426), Cai Be and Chau Phu (102-255), and lowest at Long Xuyen (51). The risk for agricultural production land is highest at Cai Be (34 USD/ha/year). It is followed by Sa Dec (27), Tam Nong and Tan Hong (4) and lower ends in Long Xuyen and Chau Phu (0.1-1.4). See Table 5-3, and Table 5-4. Detailed information on potential flood damage by categories and by probability are presented in Appendix 3. Detailed information on potential flood damage by categories and by probability are presented in Appendix 3.

Table 5-3 Potential flood risk per ha at P=1% (USD/year/ha).

District	Overall	Infrastructure	Housing	Agriculture
Chau Phu	12	155	102	0.1
Long Xuyen	76	494	51	1.4
Tam Nong	27	147	612	4.1
Tan Hong	32	150	365	3.7
Sa Dec	87	184	426	27.1
Cai Be	51	182	255	34.1

Table 5-4 Ranking risk levels based on USD/year/ha.

District	Total	Infrastructure	Housing	Agriculture
Chau Phu	6	4	5	6
Long Xuyen	2	1	6	5
Tam Nong	5	6	1	3
Tan Hong	4	5	3	4
Sa Dec	1	2	2	2
Cai Be	3	3	4	1

Note: 1: high risk (high damage $/year/ha); and 6: low risk (low damage $/year/ha)

The national program of living with flooding in the Mekong Delta by providing flood free settlement areas and early flood control for crops has significant impact on reduction of flooding risk in the area, especially for households. There were 817 flood free projects in the 8 provinces in Mekong Delta during 2000-2008 to move 125,000 households (HHs) already in the flood safe areas have reached 84% of the national government target. A national workshop on flood free settlements[5] was held in Long An Province on September 23, 2008 and was chaired by Vice Prime Minister Hoang Trung Hai. It was held to review the program and prepare for the second phase of 2,400 billion VND to bring an additional 52,300 HHs to safe places.

The living with flood program would gradually reduce the flood risk for housing of the people living in the Delta, especially the poor in the deep flooded areas.

[5] http://www.baobinhduong.org.vn/detail.aspx?Item=58188

Table 5-5 Flood risk by damage categories (USD 1,000).

	T (year) P(%)	Land use (ha)	100 1%	50 2%	25 4%	10 10%	5 20%	2 50%
1	**Chau Phu**	**43,412**	**514**	**465**	**379**	**176**	**26**	**3**
	Infrastructure	2,538	394	355	284	120	8	0
	Housing	1,145	117	108	94	56	18	3
	Agriculture	39,729	3	2	1	0	0	0
2	**Tan Hong**	**29,071**	**933**	**848**	**706**	**402**	**178**	**48**
	Infrastructure	2,888	433	392	320	162	52	13
	Housing	1,120	408	385	342	238	125	34
	Agriculture	25,063	92	71	44	2	0	0
3	**Tam Nong**	**38,427**	**1,056**	**940**	**767**	**412**	**135**	**35**
	Infrastructure	3,270	481	437	357	177	26	0
	Housing	708	433	405	354	233	109	35
	Agriculture	34,449	143	98	56	1	0	0
4	**Long Xuyen**	**9,918**	**758**	**657**	**509**	**291**	**212**	**102**
	Infrastructure	1,329	656	568	440	261	210	102
	Housing	1,804	92	81	64	30	2	0
	Agriculture	6,786	10	7	4	0	0	0
5	**Sa Dec**	**4,840**	**420**	**383**	**320**	**178**	**33**	**1**
	Infrastructure	620	114	103	84	43	5	1
	Housing	479	204	186	155	85	13	0
	Agriculture	3,740	101	94	81	50	15	0
6	**Cai Be**	**38,084**	**1,935**	**1,639**	**1,195**	**417**	**115**	**44**
	Infrastructure	2,287	417	347	248	109	82	41
	Housing	1,360	346	312	257	137	33	3
	Agriculture	34,437	1,173	980	690	171	1	0

5.2 Benefits of Flooding

In the six Focal group Discussions held in focal areas (Chau Phu, Tan Hong and Tam Nong districts) during the Stage 1 of FMMP-C2, farmers mentioned that floods have significant benefit for crop cultivation. After a big flood, application of fertilisers and pesticides to Winter-Spring Paddy (November-March) is less than in a normal flood year by total value of 2-3 mln VND per ha (about 100-200 USD/ha) but the yield is higher by 0.5-1.0 ton/ha. Flood benefits for agriculture would be 3-5 mln VND/ha (about 200-300 USD/ha). Assuming big flood frequency of one third, the annual flood benefit for agriculture would be 60-100 USD/ha.

Almost all families in the deeply flooded areas fish during the flood season. Duration for fishing varies between focal areas, short durations for Long Xuyen Quadrangle (20-45 days) and longer duration for the Plain of Reeds (30-120 days) depending on the duration of the flood. The benefit of flood for capture fisheries of people in deep flooded areas are 1-5 mln VND/household (about 100-300 USD/household) in normal flood years and about 2-12 mln VND/household during big flood years. According to the MRC[6]-Technical Paper, average amount of fish catch from rice fields in the Mekong Delta Floodplain (deep water flooded areas) would be 80-119 kg/ha resulting in a value of 30-40 USD/ha.

[6] MRC-Technical Paper, No:16, October 2007:Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin

CHAPTER 6

ACTUAL LEVEL OF FLOOD PROTECTION

6 ACTUAL LEVEL OF FLOOD PROTECTION

6.1 Methodology for assessment of actual level of flood protection

There are basically two approaches for assessment of the actual level of protection in the Mekong Delta: 1) based on the current levels of ring dyke systems, and 2) based on the start of occurrence of damages.

Historical damage data for administrative areas have been used in the flood damage assessment (Chapter 4). In this study, considering resource, time and data availability, we follow the approach of the start of occurrence of damages and verify the results with the current levels of embankments.

The overall approach seeks the actual probability of exceedance of water levels that cause damages; we do this at district level, for the six selected districts out of 34 flood prone districts in the CLD, three in the deeply flooded areas and three in the shallowly flooded areas.

A first step in this approach is the proper assessment of the flood hazard, i.e. the flood levels with different exceedance probabilities. In Stage 1 such assessment was made with the help of the MRC ISIS model for the deep flooded areas in the northern part of the Delta. In this DP the VRSAP model is used for the flood hazard assessment.

A third step is the assessment of the existing protection levels by comparing the flood hazard levels with existing dyke elevations. For this purpose use will be made of district flood damage probability curves as presented in Section 4.4.

For analysis purposes three main damage categories have been distinguished: i) Infrastructure; ii) housing; and iii) agriculture.

6.2 Actual levels of Flood Protection

From the damage probability curves presented in Chapter 4, the currently prevailing level of flood protection can be derived, this is summarised in Table 6-1.

Table 6-1 Actual Flood Protection Levels in selected district of the MD in Viet Nam.

	Frequency				Return period			
Ditrict	Combined	I	H	A	Combined	I	H	A
Tam Nong	30%	25%	35%	12%	3.3	4.0	2.9	8.3
Tan Hong	25%	25%	35%	13%	4.0	4.0	2.9	7.7
Chau Phu	25%	24%	32%	8%	4.0	4.2	3.1	12.5
Long Xuyen	10%	10%	23%	10%	10.0	10.0	4.3	10.0
Sa Dec	30%	25%	27%	37%	3.3	4.0	3.7	2.7
Cai Be	20%	12%	30%	18%	5.0	8.3	3.3	5.6

It can be concluded that the order of magnitude of the actual protection level against flooding in the deeply flooded areas is 25% (1 in 4 years) for infrastructure, 35% (1 in 3 years) for housing, and about 10% (1 in 10 years) for agricultural land.

For the shallow flood area the protection levels vary, Long Xuyen having a 10% (1 in 10 year) degree of protection while for Sa Dec and Cai Be this is not more than 20 to 30% (3 to 5 year), whereas in these two districts the protection level for agricultural land is less than half of that in the deeply flooded areas.

Long Xuyen and Sa Dec towns could also be considered as being located in between the deep and shallow flood prone areas; nevertheless, actual protection levels in Long Xuyen are remarkably higher than in Sa Dec.

6.3 Verification with embankment levels

The embankment levels in each district vary widely, each district having a number of ring dykes. Most of the embankments were built by local authorities and communities resulting in a high variation range of dyke crest elevations. There is a logical tendency of higher elevations of dykes at the upstream side and lower elevations at the downstream side of dyking systems.

We have no detailed information relating to elevations of embankments etc. in Long Xuyen City and Sa Dec Town due to small areas and a very dense streets/roads network. Some of streets/roads were raised after the 2000 flood. We can assume elevation of embankments at Long Xuyen City are 30-40 cm below the 2000 flood level, and at Sa Dec 25-30 cm below the 2000 flood level.

The average elevations of embankments are shown in the following figures, together with the simulated water levels over the historical 97 years of flow records under the current infrastructure situation in the Mekong Delta.

These figures do not distinguish between categories of damage caused by flooding.

However, the graphs do confirm the actual protection levels for agricultural land which accounts for some 80 to 90% of the land-use.

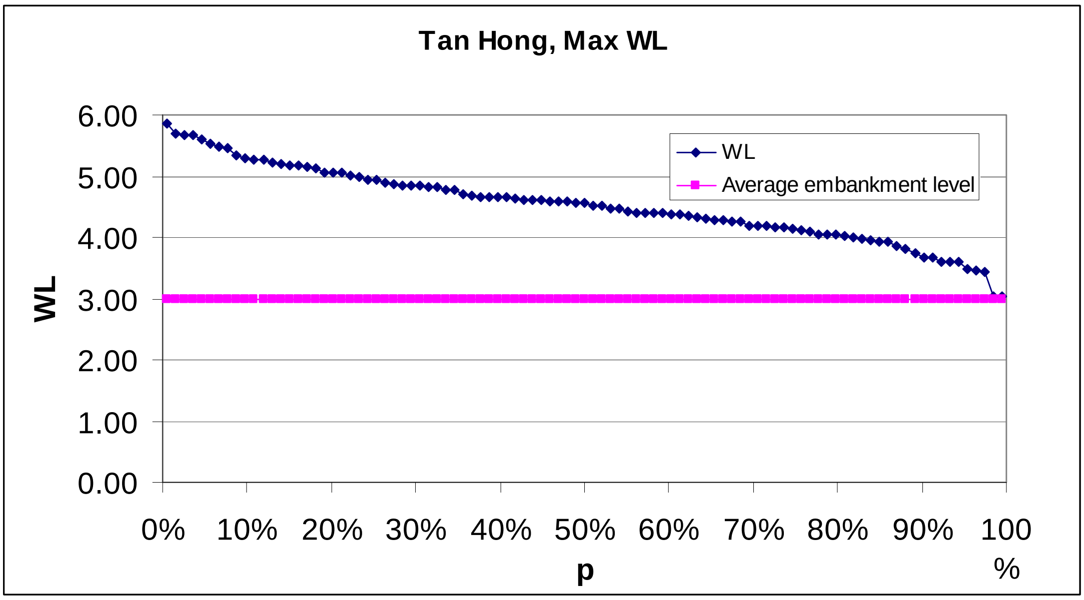

Figure 6.1 Frequencies of maximum water level in Tan Hong.

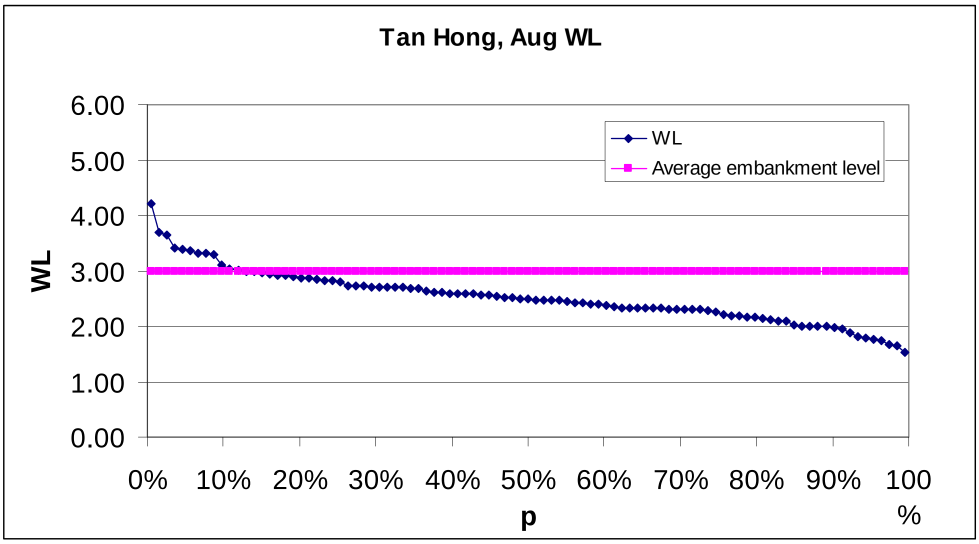

Figure 6.2 Frequencies of water levels in month of August in Tan Hong.

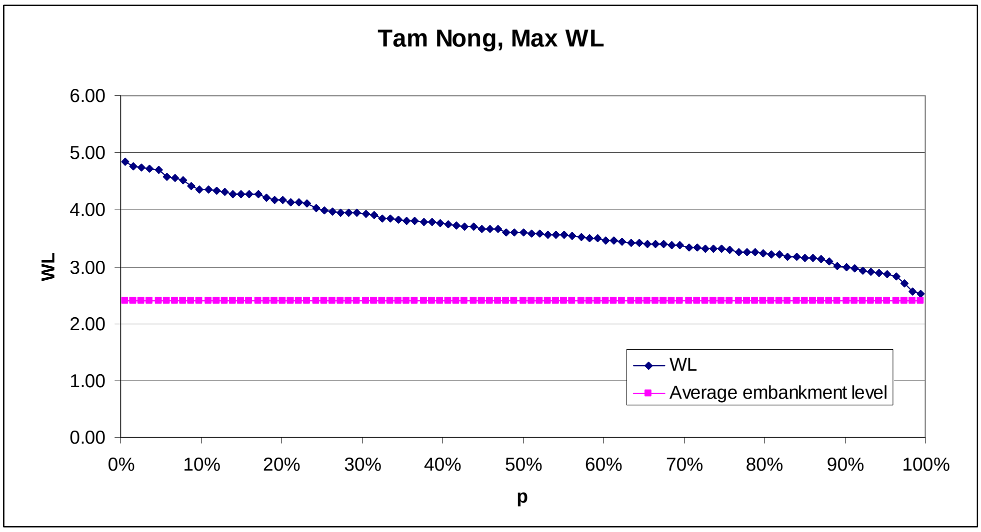

Figure 6.3 Frequencies of maximum water level in Tam Nong.

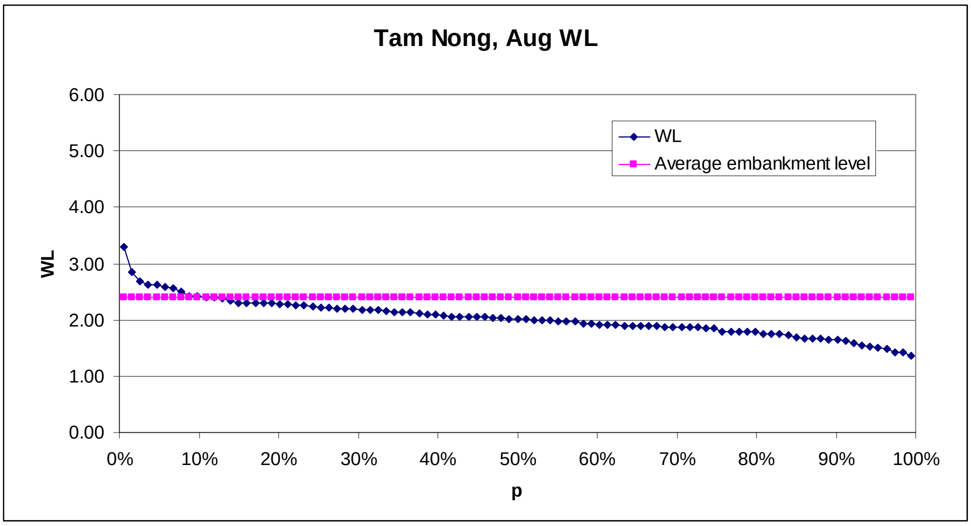

Figure 6.4 Frequencies of water levels in month of August in Tam Nong.

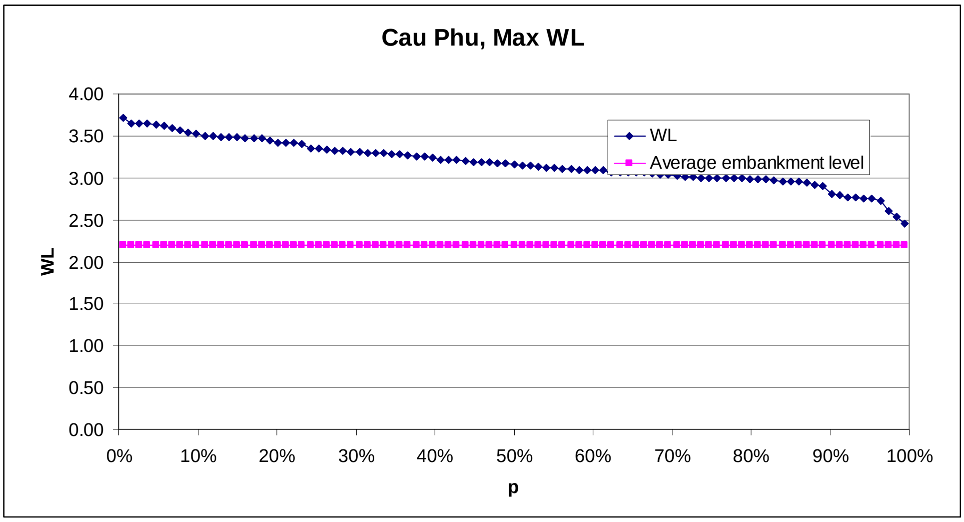

Figure 6.5 Frequencies of maximum water level in Cau Phu.

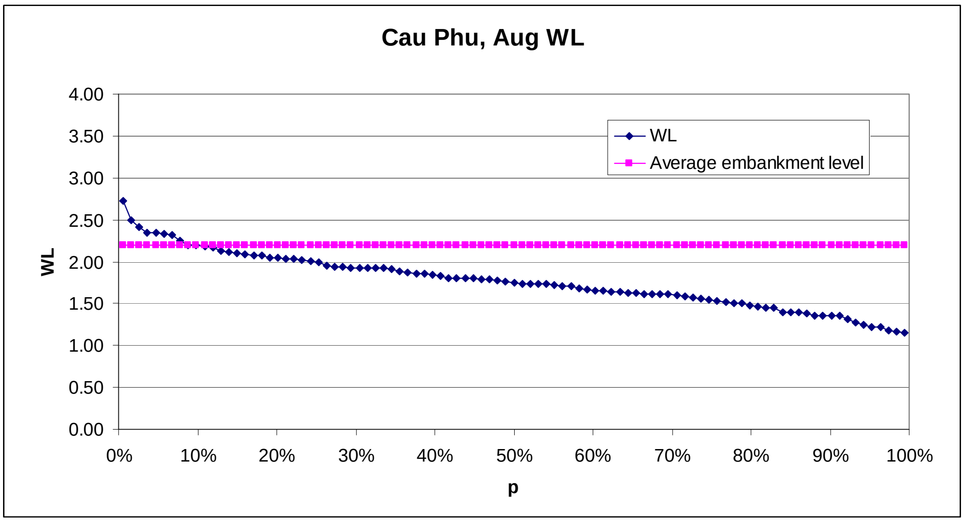

Figure 6.6 Frequencies of water levels in month of August in Cau Phu.

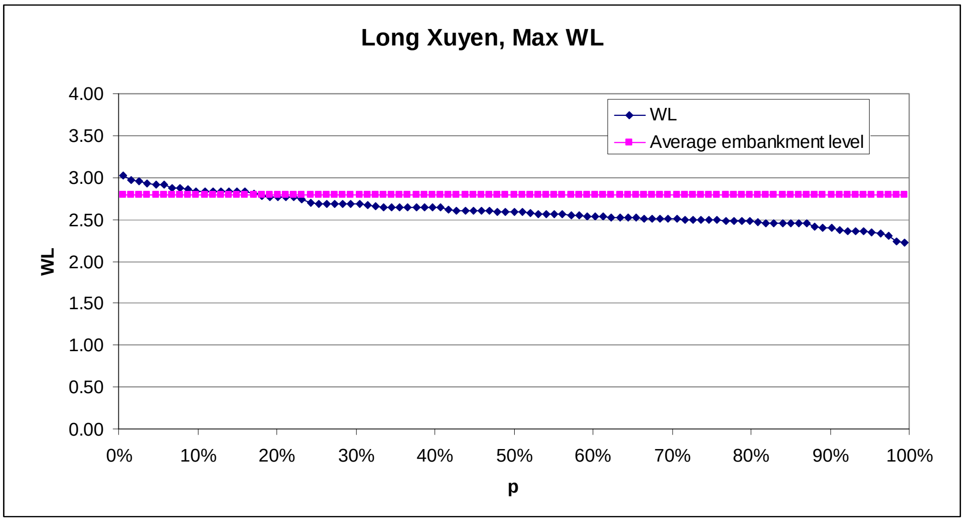

Figure 6.7 Frequencies of maximum water level in Long Xuyen.

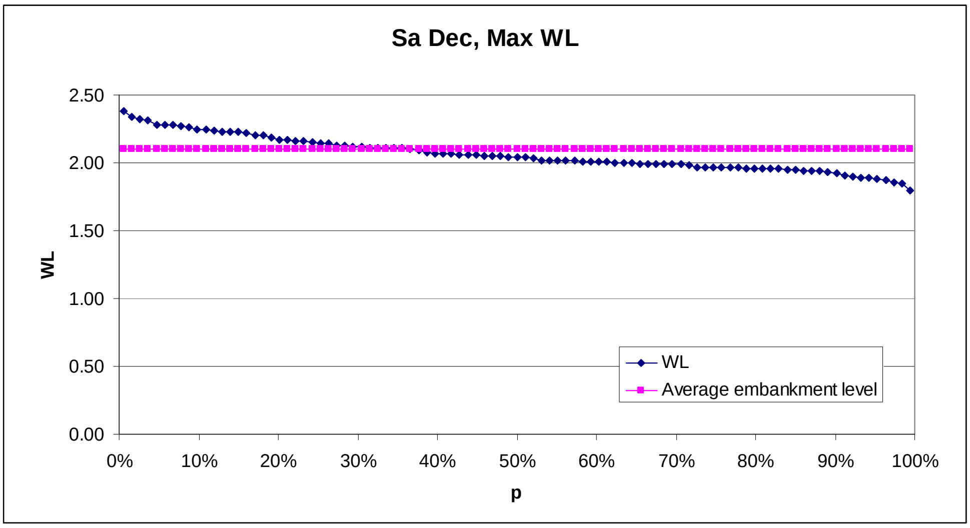

Figure 6.8 Frequencies of maximum water level in Sa Dec.

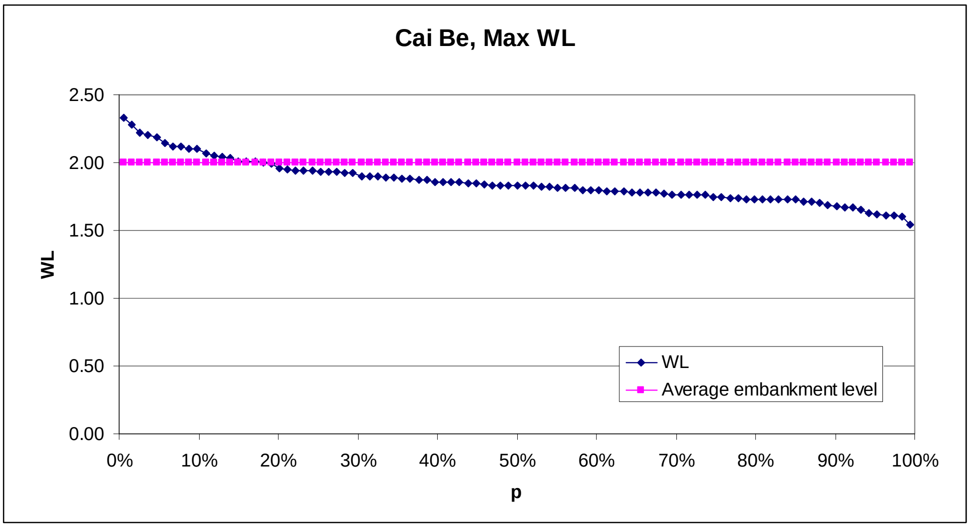

Figure 6.9 Frequencies of maximum water level in Cai Be.

CHAPTER 7

MEASURES TO INCREASE FLOOD PROTECTION LEVEL

7 MEASURES TO INCREASE FLOOD PROTECTION LEVELS

7.1 Introduction

The Cuu Long Delta (CLD) is an area of approximately 3.9 mln ha. It is an important area with respect to agricultural production in Viet Nam. Rice and fruit are the main products in this area and they are used for both domestic consumption and export. The CLD product supply occupies about 50% of agricultural product export in Viet Nam. The CLD has a population of about 18 mln people, 80% of whom work in agriculture. The CLD has a significant number of densely populated areas.

Annual floods in the CLD cause damage at different levels in agriculture, especially in fruit-tree and rice areas. They have large impacts on the social – economic development of the CLD. Therefore, flood control in this area is considered a high priority. The current practice for the design of flood control works is to use the floods of 2000 (with an estimated frequency of exceedance of about 2%) and 2001 (10%) as design events.

To choose the optimal frequency for designing flood control works in the CLD is the concern for both designers and decision makers. This choice should be based on a cost-benefit analysis. The costs are related to the construction of flood control works that are required to reduce the flood frequency to the design frequency. The benefits are the reductions in flood damages.

In this chapter, the potential for flood control in six areas with different characteristics are investigated. The research aims at defining engineering indicators for investing in flood control works to provide an optimal solution in terms of cost-benefit ratios.

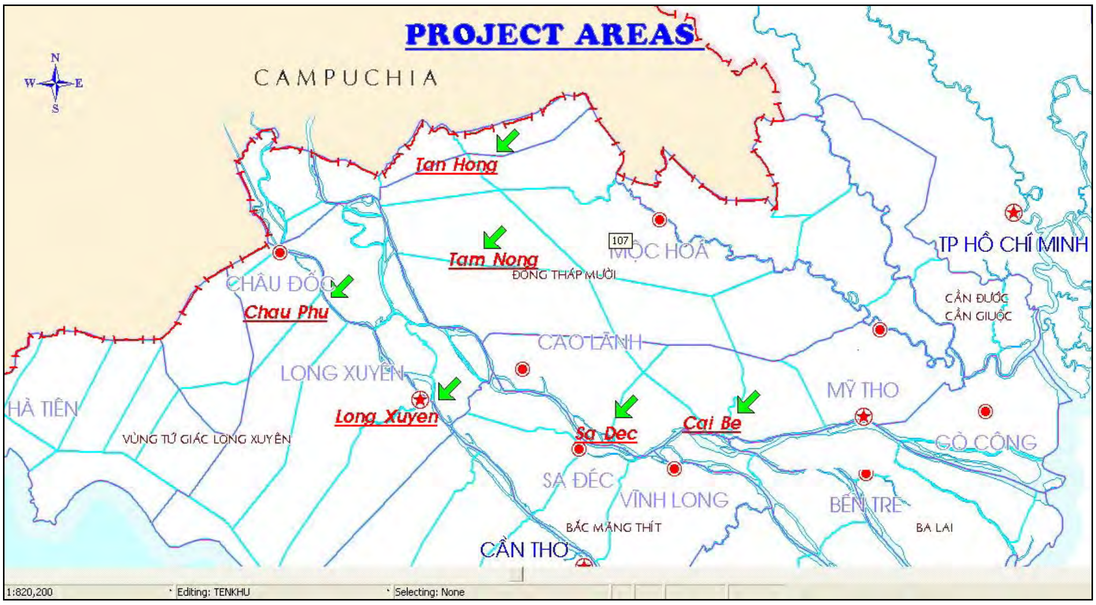

Figure 7-1 Location of sample areas.

7.2 Current situation in the selected areas

In total six study areas have been chosen, three of which are mainly urban (city or town), two are 2-crop areas and one area is a fruit tree area. Table 7-1 presents an overview of the main features of these areas.

Table 7-1 Main features of the six selected areas.

Sample areas	Subjects for flood control	Flooded feature	Requirements of flood control	City/Province
Chau Phu District	2-crop areas	Deep inundation	Early August flood	An Giang
Tan Hong District	2-crop areas	Deep inundation	Early August flood	Đồng Tháp
Tam Nong Town	Residence, infrastructure	Deep inundation	Year-round flood	Đồng Tháp
Long Xuyen	Residence, infrastructure	Deep inundation	Year-round flood	An Giang
Sa Dec Town	Residence, infrastructure	Shallow inundation	Year-round flood	Đồng Tháp
Cai Be District	Fruit-tree areas	Shallow inundation	Year-round flood	Tiền Giang

Chau Phu and Tan Hong and are located in deep flooded areas and these districts can cultivate 2 crops a year. Agricultural flood damages in these areas occupy a relatively small rate (about 2 to 10%) of the total flood damages. To mitigate flood damage in agricultural production, especially for 2-crop area, the existing flood control dyke system were realised many years ago and they are generally at the level of the secondary canals. This flood control dyke system is insufficient, since the area is inundated each flood season. This dyke system therefore urgently requires major improvements.

Tam Nong Town is a deeply flooded area. The residential areas are gathered around five corners of Dong Tien channel. Inhabitants settle down in narrow lines along the riverside where foundation is enhanced against floods. Nevertheless, in years of high or extreme flows, residential areas and infrastructure are inundated. In the year 2000, the inundated depth on roads was about 0.3 – 0.6 m on average, which caused significant damage.

Long Xuyen is a deep flooded area. The urban area in Long Xuyen is located at narrow lines along the right side of Hau River and along National Road Nr 91 (NR91). This urban strip is about 0.6 – 1.5 km wide. The area between Vam Cong and Long Xuyen channel is densely populated. Over the years, the foundations of inhabitant areas and infrastructure have been gradually enhanced. Nevertheless, Xuyen Town is seriously flooded in years of high or extreme flows. In years of small or moderate flows, flood damages are negligible. In the year 2000, the flood water level at Long Xuyen was MSL +2.91 m (Ha Tien level), a level with an estimated frequency of exceedance of approximately 2%. The inundated depth on roads was about 0.3-0.4 m.

Sa Dec Town is in a shallowly flooded area. Foundation of the settled areas has been formed after many years of reclamation of the CLD and its elevation is not uniform. Flood levels in Sa Dec Town are less severe in comparison with areas [1] and [2]. Population density and investments in infrastructure grow rapidly and consequently the potential damages as well. In the 2000 flood, the water level at Sa Dec was MSL+ 2.31 m. The inundated depth on Sa Dec roads was about 0.25-0.3 m.

Cai Be is one of the main areas concentrating on cultivating fruit-trees in the CLD. Nowadays, flood control dykes for fruit-tree areas are constructed on both small scale (protecting tens of hectares) to larger scale (protecting hundreds of hectares). In the year 2000, almost all fruit-tree areas in Cai Be District were flooded.

7.3 Flood control requirements for the sample areas

With respect to subjects for flood control, the six selected areas are divided into three classes:
1). Flood control for residential areas and their infrastructure systems;
2). Flood control for fruit-tree areas; and
3). Flood control for 2-crop areas.

Each class has different requirements for flood protection. For instance the first two classes require year-round flood protection, whereas for the 2-crop areas it is sufficient to protect the land from flooding in the early flood season (until early August). Key parameters of sample areas are summarised in Table 7-2 and Table 7-3.

Table 7-2 Surface area and length of dykes of the 6 selected areas.

Area	code	surface of protected areas (ha)	dyke length (km)
Châu Phú	CP	1,000	14,000
Tân Hồng	TH	1,000	14,000
Tam Nông	TN	336	7,980
Long Xuyên	LX	499	21,060
Long Xuyên 1	LX1	198	6,240
Long Xuyên 2	LX2	170	7,460
Long Xuyên 3	LX3	76	4,260
Long Xuyên 4	LX4	55	3,100
Sa Đéc	SD	370	8,145
Cái Bè	CB	1,000	14,000

7.4 Options for flood control

The following options for flood control in residence areas in CLD are available:
1. *Foundation enhancement*. Densely populated areas are often located at higher elevated areas compared to agricultural areas. A possibility for flood control is to further enhance these foundations. This approach has often been implemented in recent years. However, for large areas this is a very expensive measure.

2. *Closing of the flood control dyke system*. This approach has also been used for many such as Sa Rai (Tan Hong Town), Vinh Hung, Cao Lanh, Hong Ngu, etc.). Formation of these protected areas also requires drainage from inside the dyke ring areas to outside. Since the water level outside the dyke ring is generally higher than the water level inside, pumps are used to drain and control floods during the flood season.

3. *Non-structural measures.* Flood damage mitigation by means of non-structural measured is an effective solution, but has not been considered.

The above solutions have been applied for specific areas in the CLD. In these sample research areas, closing flood control dykes is the most suitable solution.

7.5 Flood water levels

The hydrodynamic model VRSAP has been applied to compute water levels at a number of locations in CLD over a simulation period of 97 years. Subsequently, flood frequency curves have been derived from the resulting 97 annual maximum water levels and maximum water levels up to August 1 for the first two areas.

Table 7-3 Water level (m+amsl) with various frequency of exceedance at different locations.

Area	Code	frequency of exceedance				
		1%	2%	5%	10%	20%
Châu Phú	CP	268	236	221	212	203
Tân Hồng	TH	384	338	316	303	291
Tam Nông	TN	507	460	436	423	409
Long Xuyên	**LX**	303	290	283	279	275
Long Xuyên 1	LX1	303	290	283	279	275
Long Xuyên 2	LX2	303	290	283	279	275
Long Xuyên 3	LX3	303	290	283	279	275
Long Xuyên 4	LX4	303	290	283	279	275
Sa Đéc	SD	237	227	222	220	217
Cái Bè	CB	224	212	206	202	198

7.6 Preliminary design of dykes

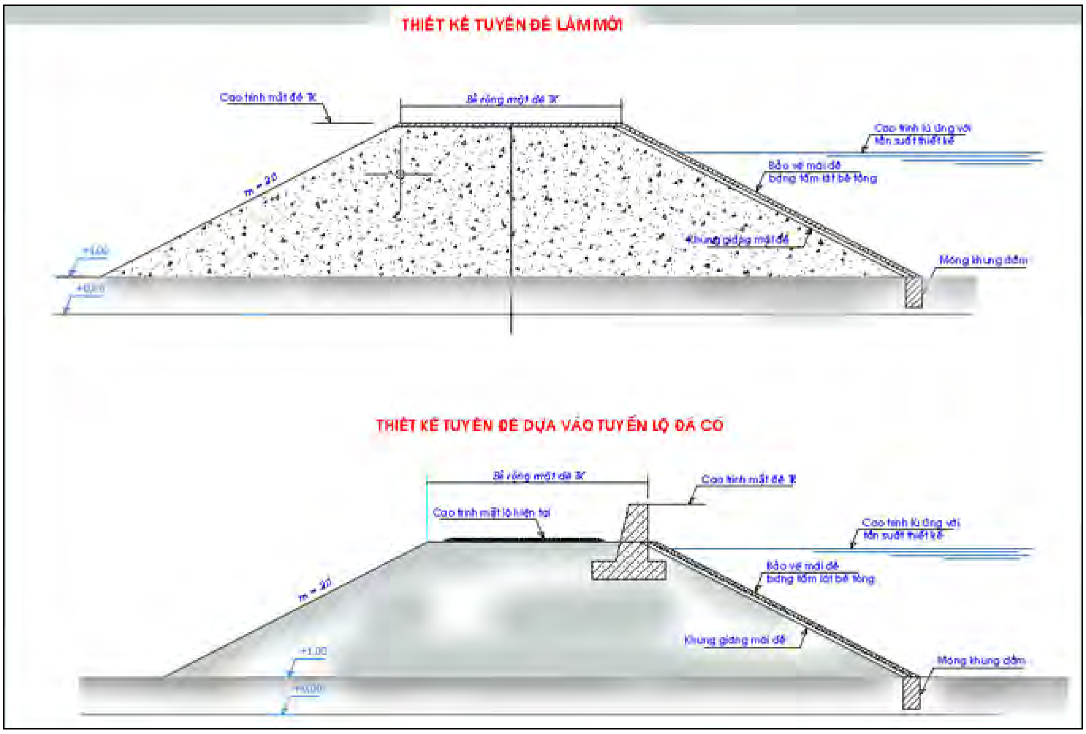

Figure 7-2 Typical cross-sections of embankment for new and upgrading dyke.

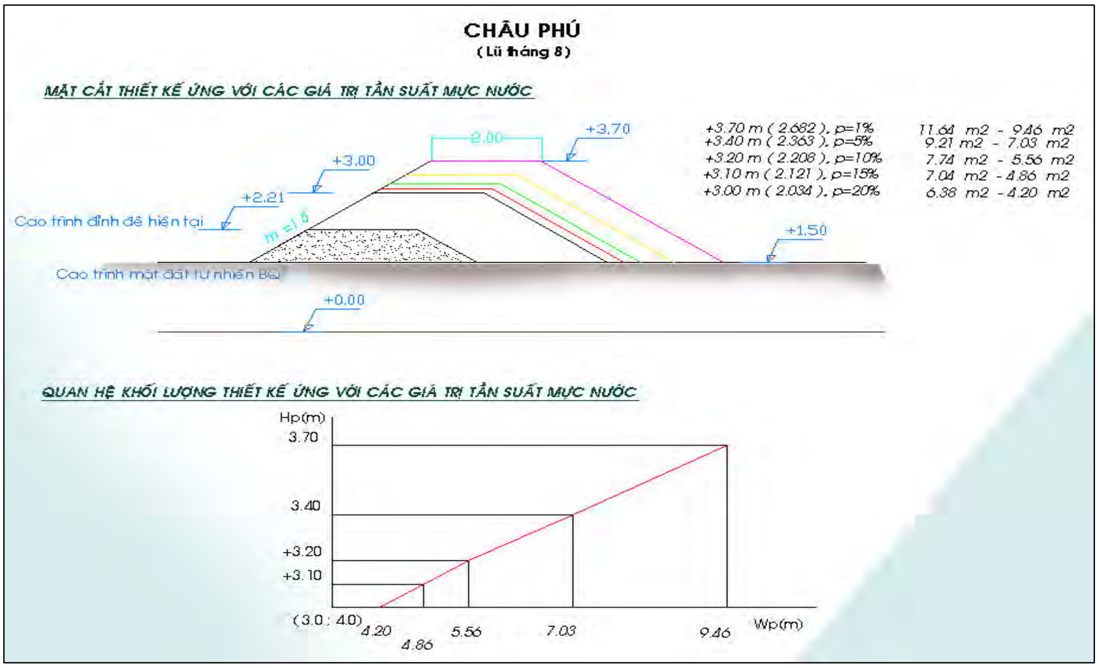

Figure 7-3 Typical cross-section of embankment for Chau Phu District.

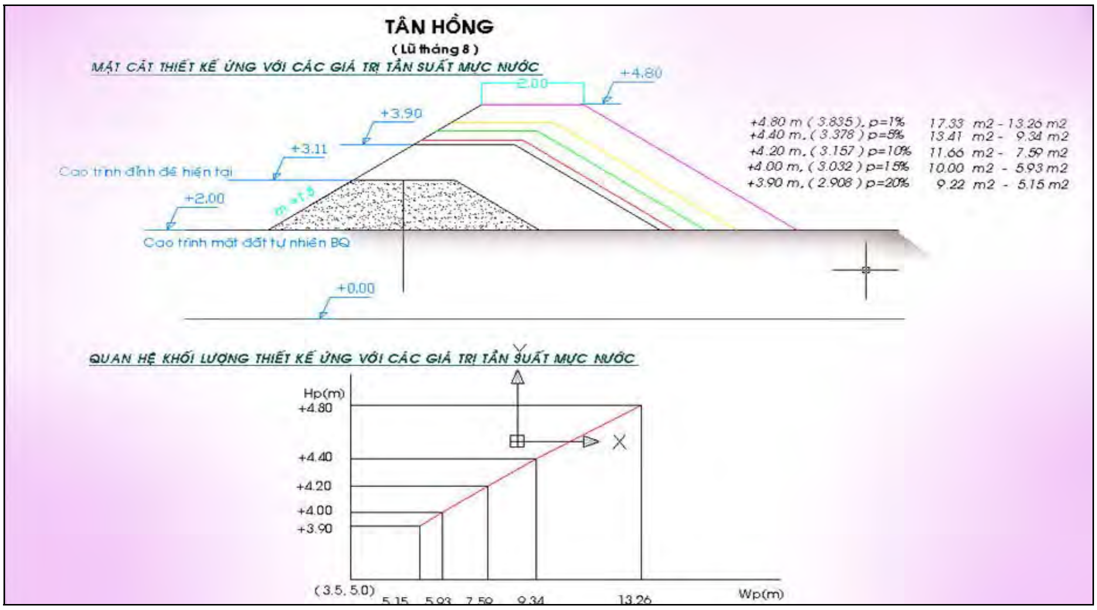

Figure 7-4 Typical cross-section of embankment for Tan Hong District.

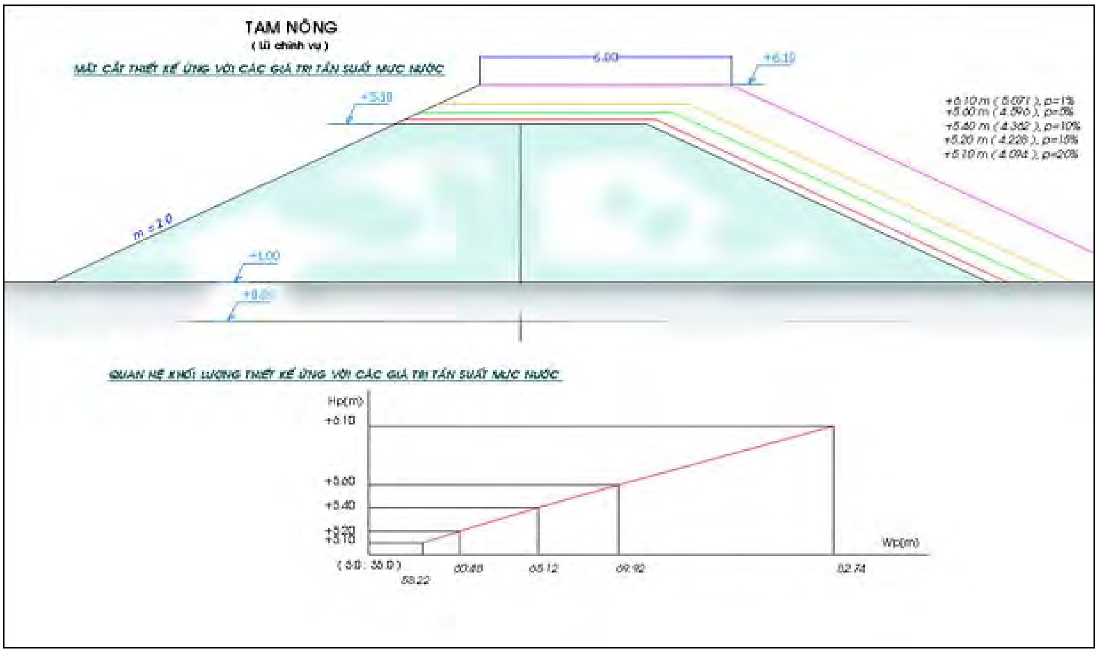

Figure 7-5 Typical cross-section of embankment for Tam Nong Town.

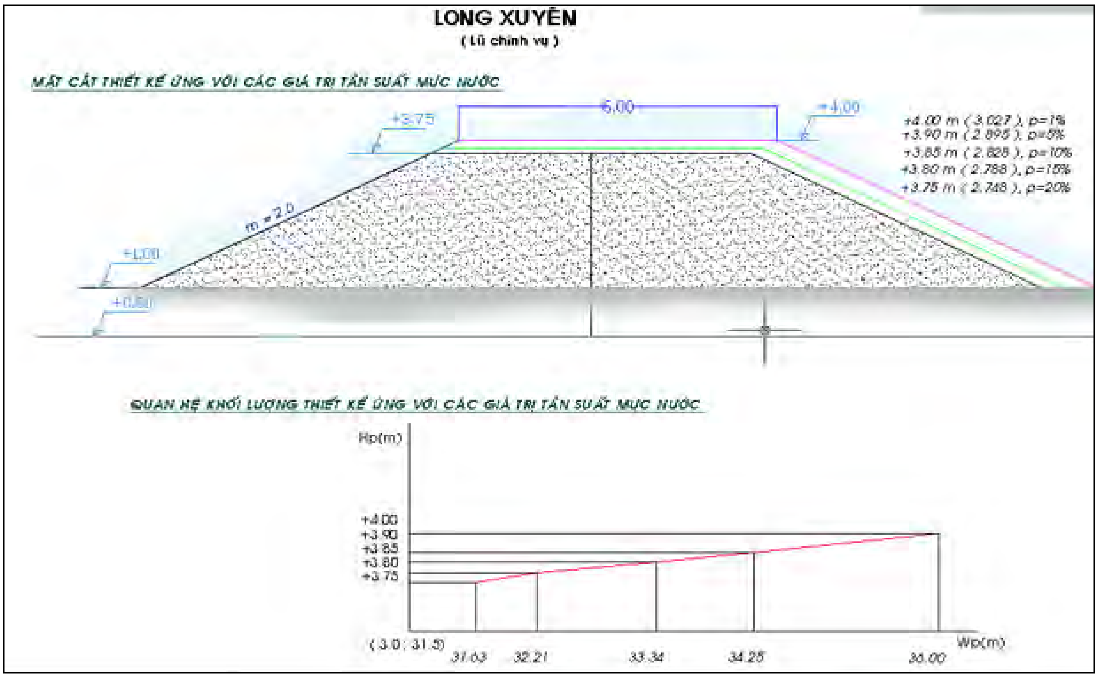

Figure 7-6 Typical cross-section of embankment for Long Xuyen City.

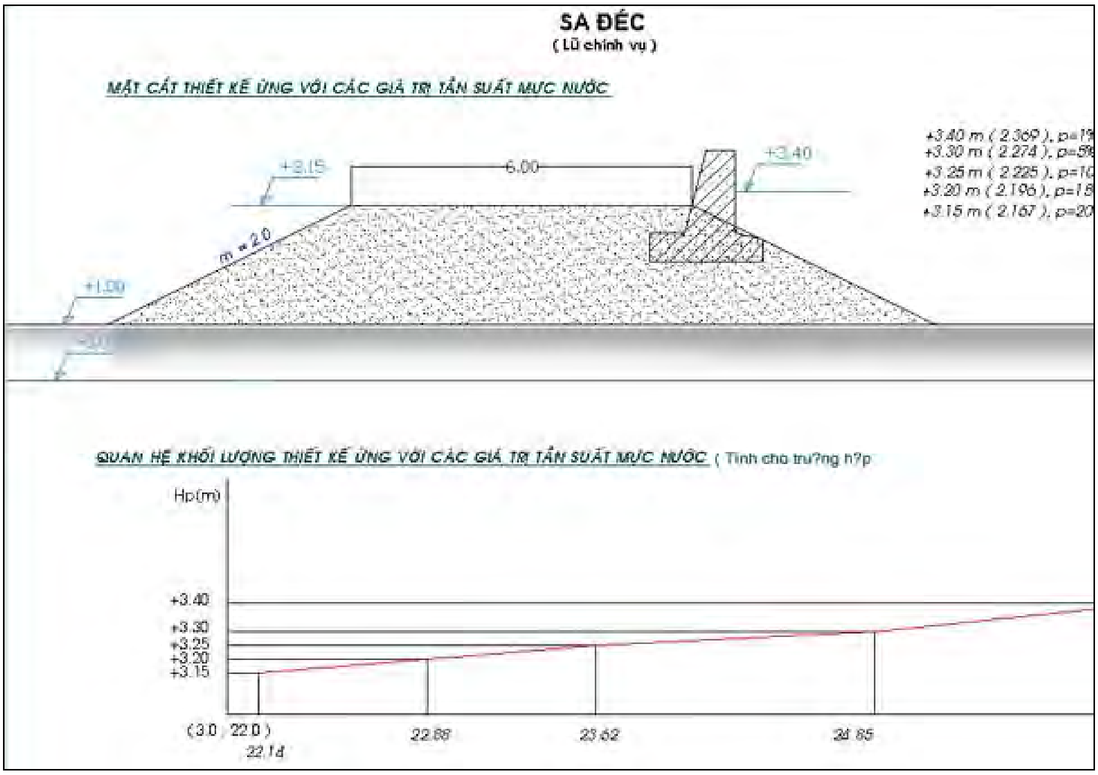

Figure 7-7 Typical cross-section of embankment for Sa Dec Town.

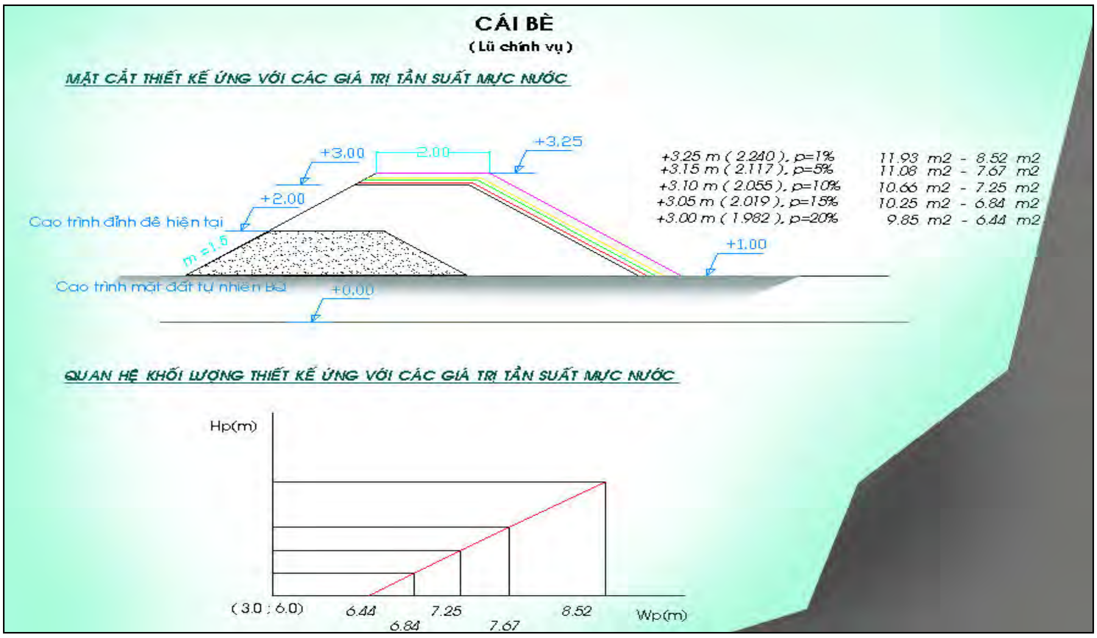

Figure 7-8 Typical cross-section of embankment for Cai Be District.

7.7 Proposed flood control measures for sample areas

Chau Phu

Flood control measures in Chau Phu are similar to the ones in Tan Hong, but in Chau Phu early August flood water levels are lower than those in Tan Hong.

Tan Hong

The Tan Hong area is protected against floods in the early flood season to prevent loss of un-harvested crops. The early flood control dyke model is to protect two-crop areas of flooding from second class canals. The protected area is 1,000 ha with a 14 km long dyke system. The primary and secondary embankments are enhanced according to the design flood water level.

Tam Nong area

The plan for Tam Nong area is developed from the riverside towards the field to form a protected area of 336 ha. The total levee length is 7.98 km as shown in Figure 7-9.

Figure 7-9 Flood control dyke in Tam Nong Town.

Long Xuyen area

Long Xuyen Town is divided into 4 small areas for flood control as LX1, LX2, LX3 and LX4. Each has an area of 50 – 200 ha. The total surface of protected areas is 499 ha and the dyke length is 21 km. The dykes are formed at existing or renewed roads.

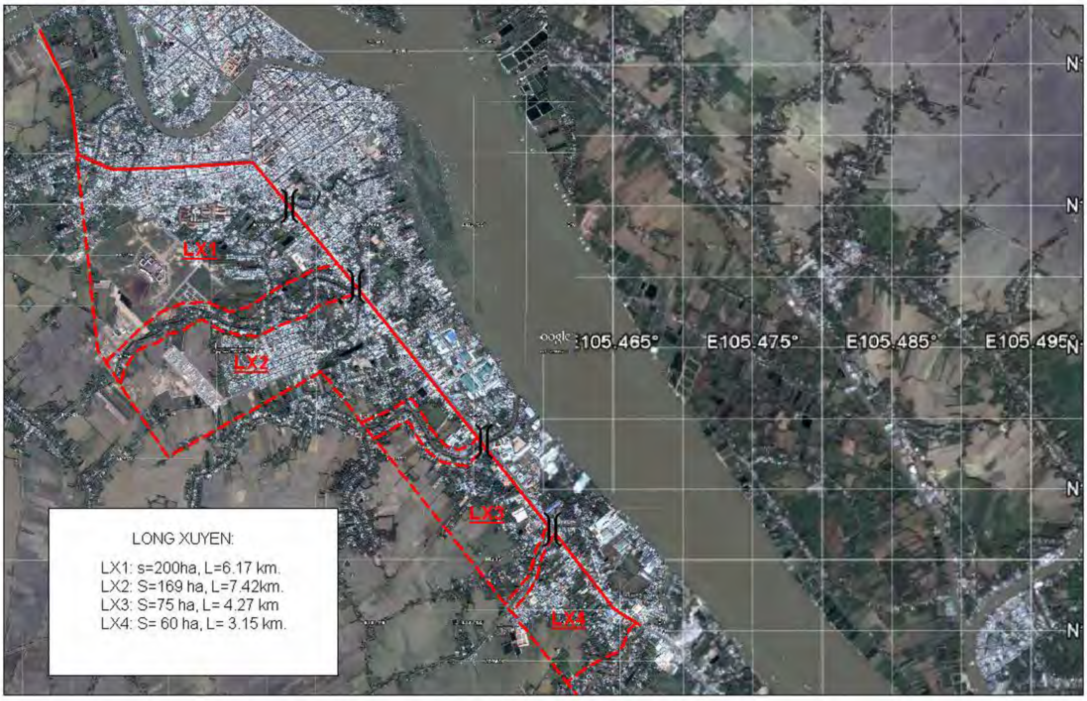

Figure 7-10 Long Xuyên area.

In Long Xuyen, the proposed dyke line formation is as follows:

- NR91 is used as a protection dyke.
- Create a new dyke to use as urban byway, parallel with NR91. Dig canal lines parallel to the dyke to use soil for dyke construction.
- Dig a canal and implement dyke lines perpendicular to NR91 to form traffic road and drainage axis.
- Install a pump in each protected area for drainage purposes.

Sa Dec typical area:

The existing road lines in Sa Dec Town (NR80 and inner town road beside Hau River) are in a favourable condition to be used as protection dykes. After the floods of 2000, 1.5 km of NR80 was upgraded to ensure flood protection with 1% probability of exceedance. Compared with embankment standards, the elevations of other roads lines in this area are lower. Therefore, an easy solution for flood control is to build a revetment wall along the road. The optimal revetment wall height will be follow from the cost/benefit analysis.

Figure 7-11 Flood control dyke in Sa Dec Town.

Cai Be

- The surface of the subareas of Cai Be District vary from several hectares to thousands of hectares in which the biggest one is about 5,000 ha.
- A reasonable option to enhance the flood control dykes for fruit-tree areas is based on the fourth canal scale. The distance between two first class canals is 5 km and the distance between two second class canals is 2 km.
- The surface of the protected zone is about 1,000 ha the associated dyke length is about 14 km; 10 km along the first class canal and 4 km along the second class canal.
- The protection level along the system of first and second class canals is enhanced to ensure a protection level for various exceedance frequencies.

7.8 Design of flood control structures

7.8.1 New dykes

Flood control dykes are made up of soil that is dug from a channel parallel to the dyke. The resulting channels are used as drainage channels or for as passage ways for boats. The cross-section has a top width of 6 m and a slope of 1.5 m. On top of the design water level, an additional freeboard of 1 m is added to account for wave run-up and dyke settlement. To ensure the security of dyke line, the side slopes are consolidated by concrete slabs with 0,2 m thick or by mortared stone M100 with the thickness of 0.2 – 0.3 m. Renewed dyke lines can be combined with traffic road, in case of traffic requirement (top width B > 6 m) the extra cost is not considered in this report. For agricultural areas, no new dykes are required, i.e. the existing dykes can be upgraded.

7.8.2 Dykes based on existing roads

A revetment wall is added along the roads to ensure the required flood protection level. The revetment wall is made of reinforced concrete. The foundation and infiltration treatment are relatively simple because it is confronted with relatively small differences in water level. The cross-section of the revetment wall has a top width of 0.5 m and a slope of 1.0 – 1,25 m. Flood control embankments for protection of agricultural areas already exist and in this report, its crest level is based on the results of damage analysis. Other parameters such as crest width and slope are 2 m and 1.5 m in respectively.

7.8.3 Drainage method

To drain inhabited areas an electric pump is installed. The pump capacity is generally HTD 2400 or equivalent, depending on the scale of the protected area. Previous experiences from implementing round year protected areas in the CLD have given a drainage coefficient of 8 – 10 l/s/ha. A HTD 2400 pump can drain up to 80 ha. In the design, the required number of pumps will be rounded and 20% is added for the purpose of "standby". Canals or culverts collecting rainfall and domestic sewage can also be used for inner traffic and infrastructure. Therefore, the cost and quantity of these canals and culverts are not considered in the flood control system design. Small pumps are used to drain water from field to the secondary canals for agricultural and fruit-tree area and the drainage coefficient is about 3 – 4 l/s/ha.

7.9 Required work volumes for relevant exceedance frequencies

Based on the preliminary design, the requested earth work volumes for a number of design frequencies are presented in Table 7-4.

Table 7-4 Works quantities in selected sample areas.

Areas Item	Unit	Frequency of exceedance				
		1%	2%	5%	10%	20%
Châu Phú						
Earth	m3	132,440	98,420	77,840	68,040	58,800
Dig	m3	158,928	118,104	93,408	81,648	70,560
Tân Hồng						
Earth	m3	185,640	130,760	106,260	83,020	72,100
Dig	m3	222,768	156,912	127,512	99,624	86,520
Tam Nông	m3					
Earth	m3	427,209	412,247	404,855	354,791	334,232
Dig	m3	512,651	494,696	485,826	425,749	401,079
Beton	m3	6,186	6,042	5,970	5,467	5,251
Pump HTD 2400		5	5	5	5	5
Long Xuyen City	**m3**	**714,929**	**687,127**	**647,758**	**614,466**	**576,178**
Earth	m3	368,440	354,234	334,115	317,089	297,493
Dig	m3	442,128	425,081	400,937	380,507	356,991
Beton	m3	21,069	19,968	18,419	17,138	15,698
Pump HTD 2400	Cái	11	11	11	11	11
LX 1						
Earth	m3	89,893	86,427	81,518	77,364	72,583
Dig	m3	107,871	103,712	97,821	92,837	87,099
Beton	m3	7,895	7,450	6,826	6,312	5,737
Pump HTD 2400		4	4	4	4	4
LX 2						
Earth	m3	143,588	138,052	130,211	123,576	115,939
Dig	m3	172,306	165,663	156,253	148,291	139,127
Beton	m3	6,342	6,033	5,596	5,233	4,824
Pump HTD 2400		4	4	4	4	4
LX 3						
Earth	m3	83,420	80,204	75,649	71,794	67,357
Dig	m3	100,104	96,245	90,778	86,152	80,828
Beton	m3	3,500	3,331	3,094	2,897	2,675
Pump HTD 2400		2	2	2	2	2
LX 4						
Earth		51,538	49,551	46,737	44,355	41,614
Dig		61,846	59,462	56,084	53,226	49,937
Beton		3,332	3,154	2,903	2,695	2,462
Pump HTD 2400		1	1	1	1	1
Sa Đéc						
Beton	m3	11,717	11,207	10,498	9,920	9,281
Pump HTD 2400		6	6	6	6	6
Cái Bè						
Earth	m3	119,280	107,380	101,500	95,760	90,160
Dig	m3	143,136	128,856	121,800	114,912	108,192

7.10 Cost estimates

The investment costs per ha is presented in Table 7-5:

Table 7-5 Investment for flood protection at various exceedance frequencies (USD/ha).

Areas	Frequency of exceedance				
	1%	2%	5%	10%	20%
Châu Phú	185	138	109	95	82
Tân Hồng	260	183	149	116	101
Tam Nông	8,248	8,071	7,983	7,372	7,114
TP.Long Xuyên	14,578	13,949	13,063	12,328	11,502
LX1	13,378	12,753	11,875	11,150	10,339
LX2	13,556	13,024	12,273	11,649	10,944
LX3	16,525	15,875	14,958	14,195	13,331
LX4	19,371	18,452	17,160	16,090	14,889
Sa Đéc	10,160	9,790	9,277	8,858	8,394
Cái bè	167	150	142	134	126

The required investments for each sample areas at various protection levels are also depicted in Appendix 6.

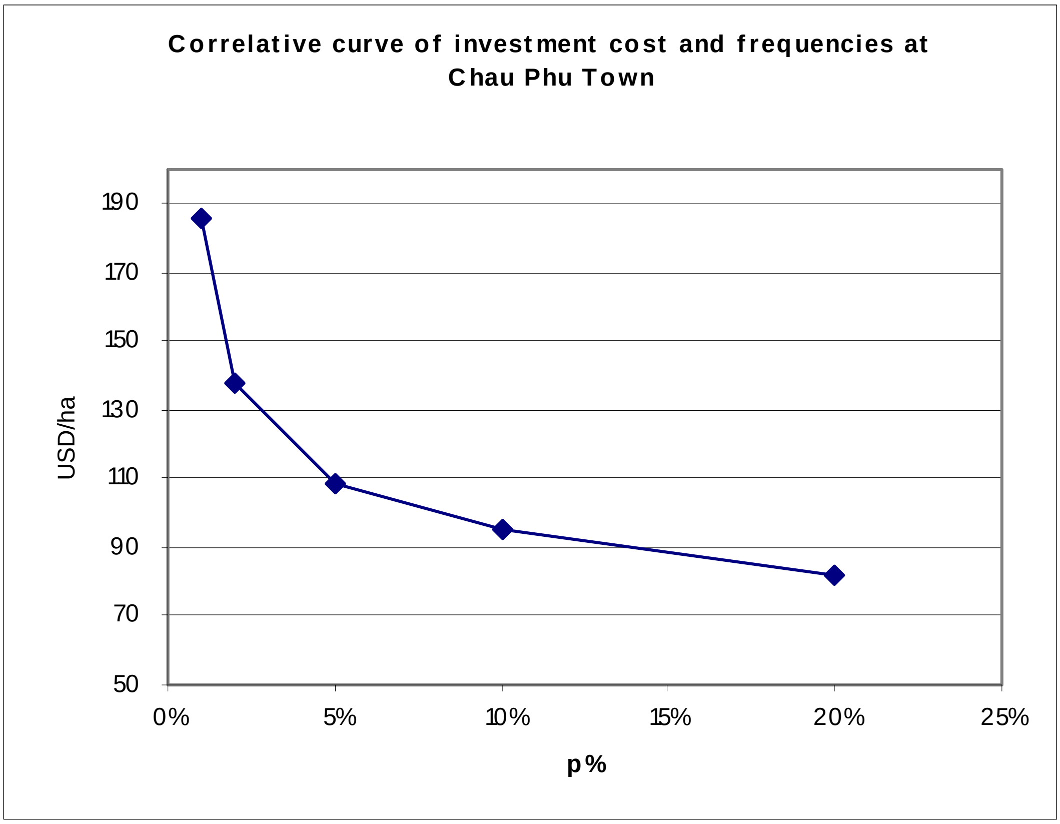

Figure 7-12 Investments at various exceedance probabilities, Chau Phu.

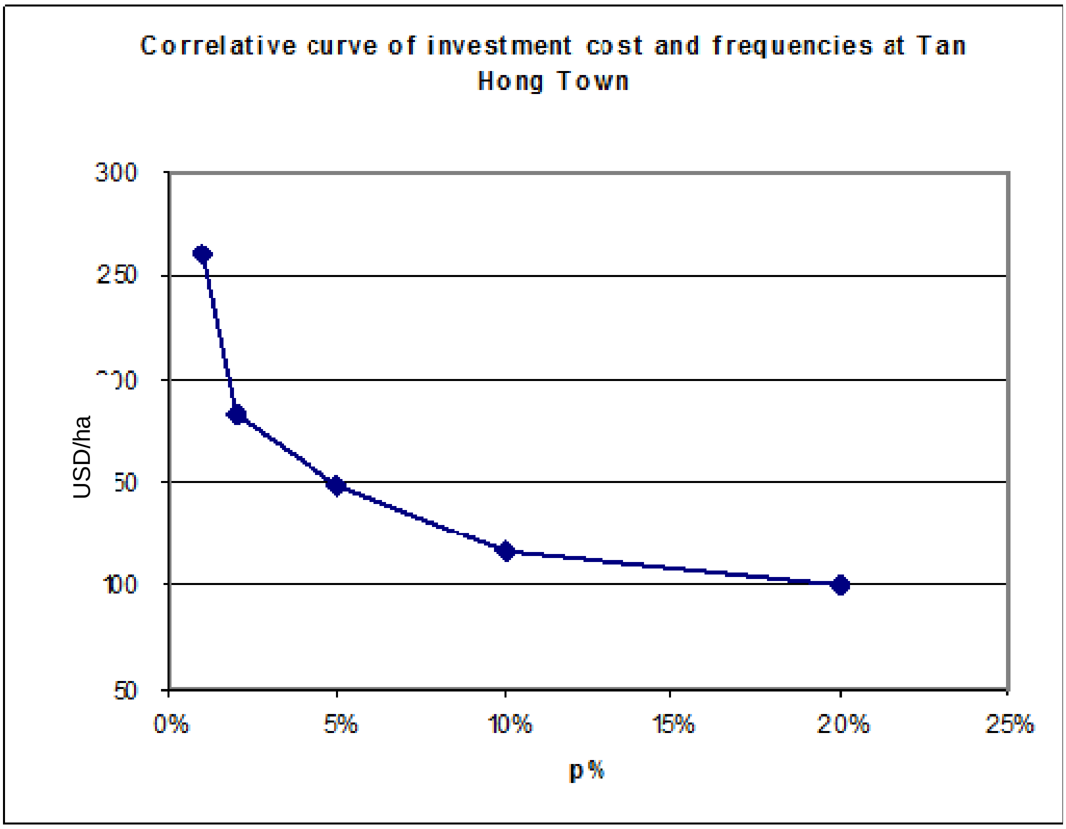

Figure 7-13 Investments at various exceedance probabilities, Tan Hong.

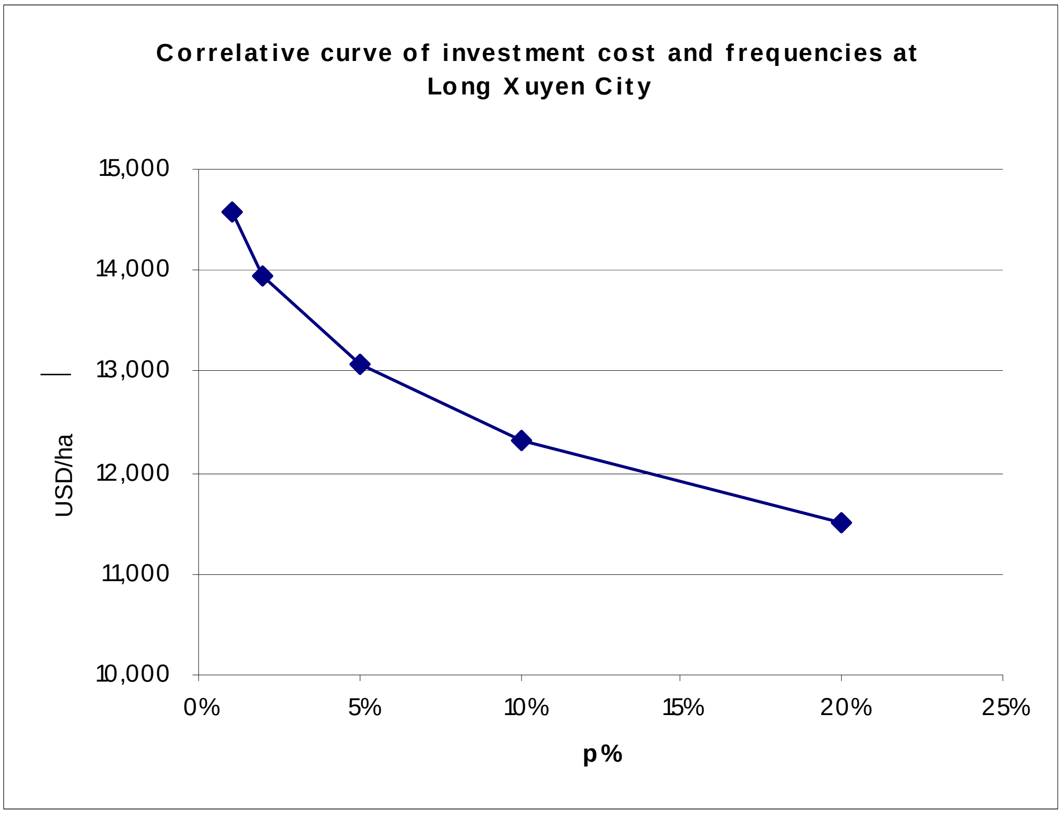

Figure 7-14 Investments at various exceedance probabilities, Long Xuyen.

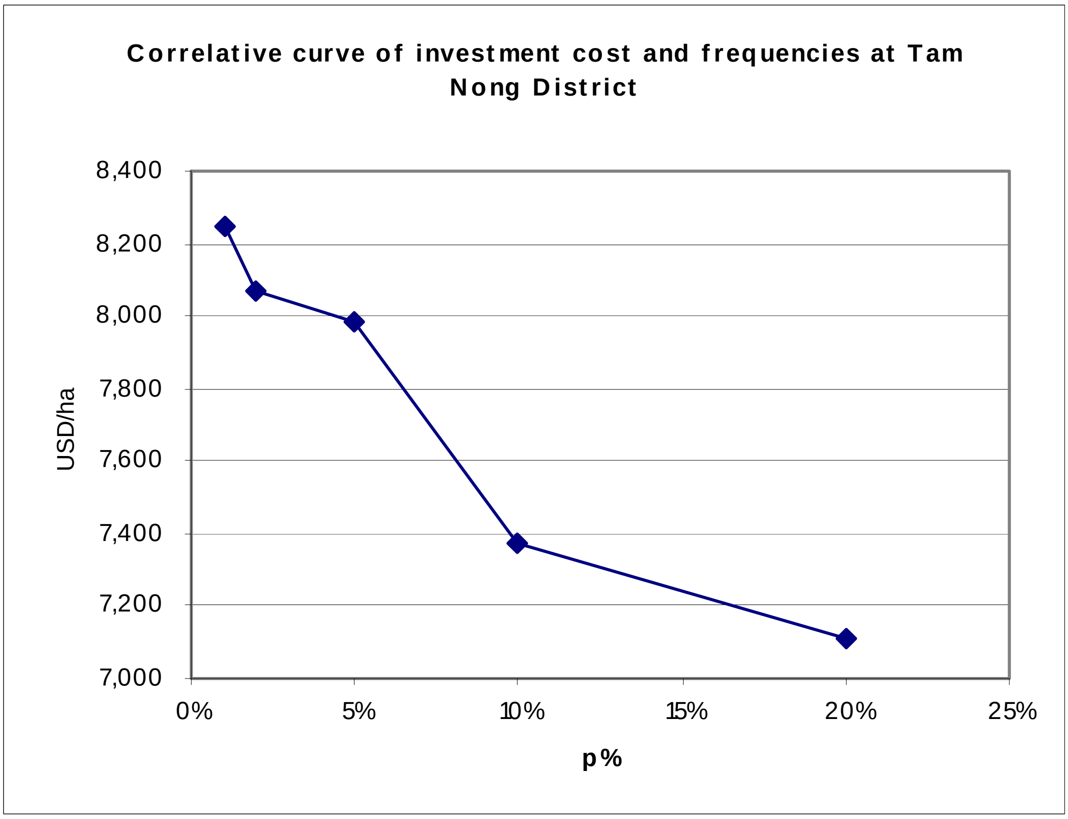

Figure 7-15 Investments at various exceedance probabilities, Tam Nong.

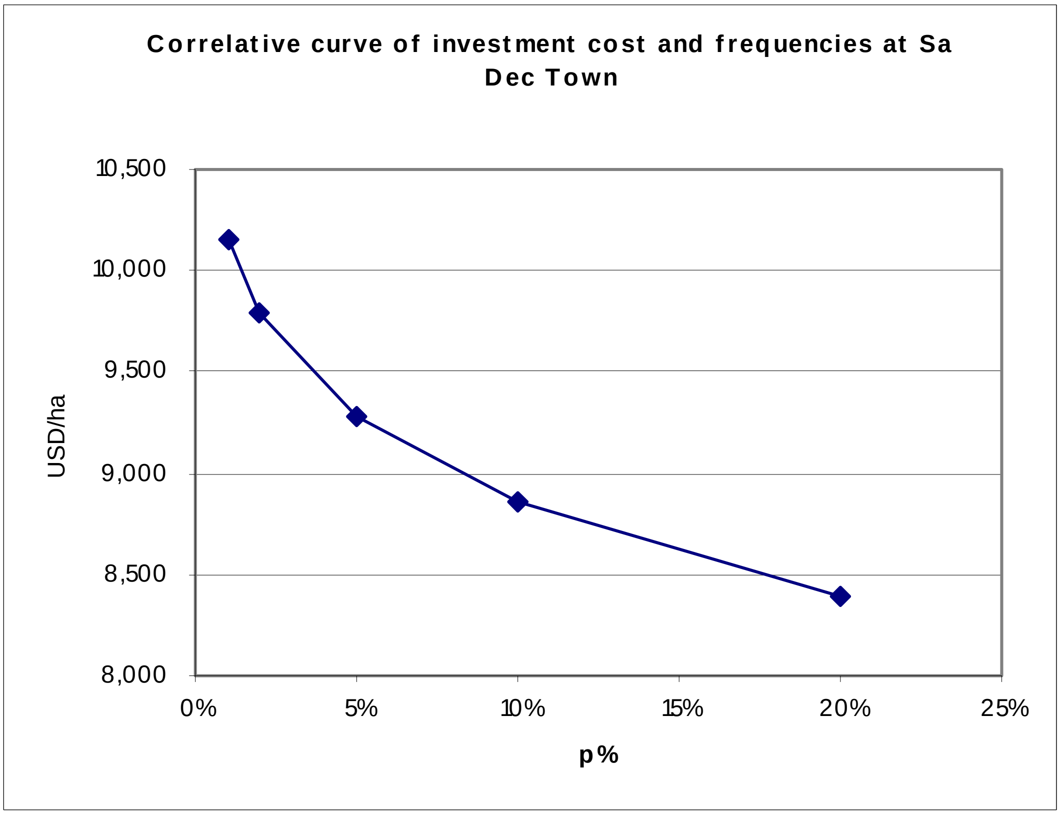

Figure 7-16 Investments at various exceedance probabilities, Sa Dec.

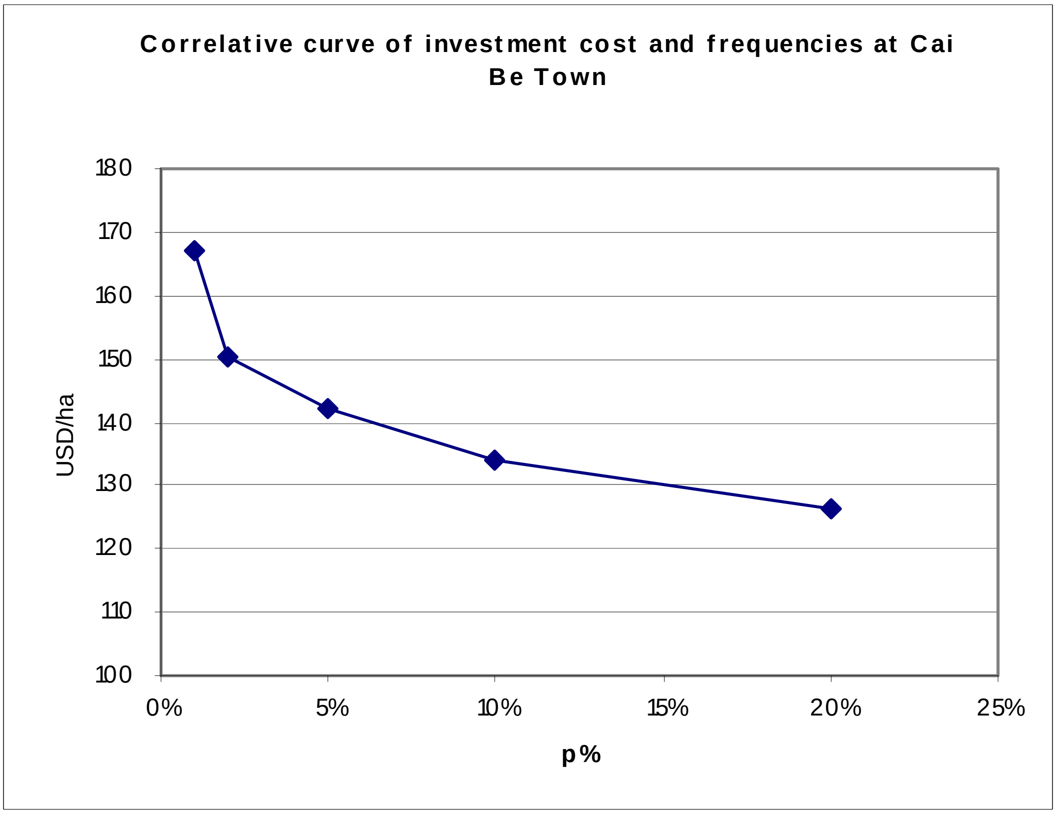

Figure 7-17 Investments at various exceedance probabilities, Cai Be.

CHAPTER 8

COST BENEFIT ANALYSIS

8 COST BENEFIT ANALYSIS

8.1 Methodology for Cost/Benefit Analysis

From the Flood Risk Assessment, the actual flood protection levels that have been identified and the measures that would be required for increased protection levels we can investigate at which level the protection would be optimal in economic terms.

Cost estimates for flood protection works have been converted to an annuity in USD/ha/year, including:

- The Investment (construction in year 1);
- annual O&M at 2% of investment;
- Replacement of electromechanical equipment (pumps) where relevant;
- A Standard Conversion Factor of 0.85 to arrive at the economic price of the works (removing transfer payments like taxes, subsidies, land acquisition, and shadow prices);
- A discounting rate of 10%.

Benefits of the works have been converted and expressed in USD/ha/year, these follow directly from the Flood Risk Assessment.

The Benefit/Cost ratio is applied to test the economic efficiency of each scheme under the various probabilities of exceedance of water levels at the sample areas.

Distinction is made between the three categories: Infrastructure, Housing and Agriculture. Since protection of agricultural land in the deeply flooded areas is only up to the beginning of August and is already at about 10% on average, the focus in the deep flooded areas is to find an optimum for protection of Infrastructure and Housing. Taking into account that in most situations in these three districts flood protection measures would protect these two categories at the same time, we have also estimated the B/C ratio for these two categories combined.

Results of the analysis are presented in Table 8-1 where the highlighted figures (in green) show B/C ratios higher than 1, meaning that those frequencies are economically feasible for those categories.

Table 8-1 B/C ratios of flood protection works.

T (year)	100	50	20	10	5
P(%)	1%	2%	5%	10%	20%
Infrastructure					
B/C					
Châu Phú	7.94	9.61	8.54	4.72	0.39
Tam Nông	0.16	0.16	0.12	0.07	0.01
Tân Hồng	5.47	7.03	6.30	4.57	1.71
Long Xuyen	0.31	0.29	0.21	0.15	0.13
Sa Đéc	0.17	0.16	0.13	0.07	0.01
Cái Bè	10.34	9.56	6.09	3.36	2.68
Housing					
B/C					
Châu Phú	5.20	6.52	6.55	4.88	1.77
Tam Nông	0.68	0.67	0.55	0.42	0.21
Tân Hồng	13.29	17.80	18.28	17.29	10.52
Long Xuyen	0.03	0.03	0.02	0.01	0.00
Sa Đéc	0.39	0.38	0.30	0.19	0.03
Cái Bè	14.44	14.47	11.37	7.13	1.80
Infrastructure plus Housing					
B/C					
Châu Phú	7.09	8.65	7.92	4.77	0.82
Tam Nông	0.26	0.25	0.19	0.13	0.05
Tân Hồng	7.65	10.04	9.65	8.13	4.17
Long Xuyen	0.15	0.14	0.10	0.07	0.06
Sa Đéc	0.26	0.25	0.20	0.12	0.02
Cái Bè	11.87	11.39	8.06	4.77	2.35
Agriculture					
B/C					
Châu Phú	0.00	0.00	0.00	-	-
Tam Nông	0.00	0.00	0.00	0.00	-
Tân Hồng	0.13	0.15	0.09	0.01	-
Long Xuyen	0.00	0.00	0.00	-	-
Sa Đéc	0.02	0.02	0.02	0.01	0.00
Cái Bè	1.93	1.79	1.10	0.35	0.00
Total					
B/C					
Châu Phú	0.61	0.74	0.67	0.40	0.07
Tam Nông	0.03	0.03	0.02	0.01	0.00
Tân Hồng	1.17	1.51	1.41	1.13	0.57
Long Xuyen	0.05	0.05	0.03	0.02	0.02
Sa Đéc	0.08	0.08	0.06	0.04	0.01
Cái Bè	2.88	2.71	1.76	0.77	0.23

8.2 Optimum Protection Levels

Optimum levels of protection can be found by plotting the B/C ratios in graphs, this is only useful for three districts Tan Chau, Tan Hong and Cai Be, see Figure 8-1 to Figure 8-3. For the other three districts providing increased protection levels costs far more than the benefits it will deliver.

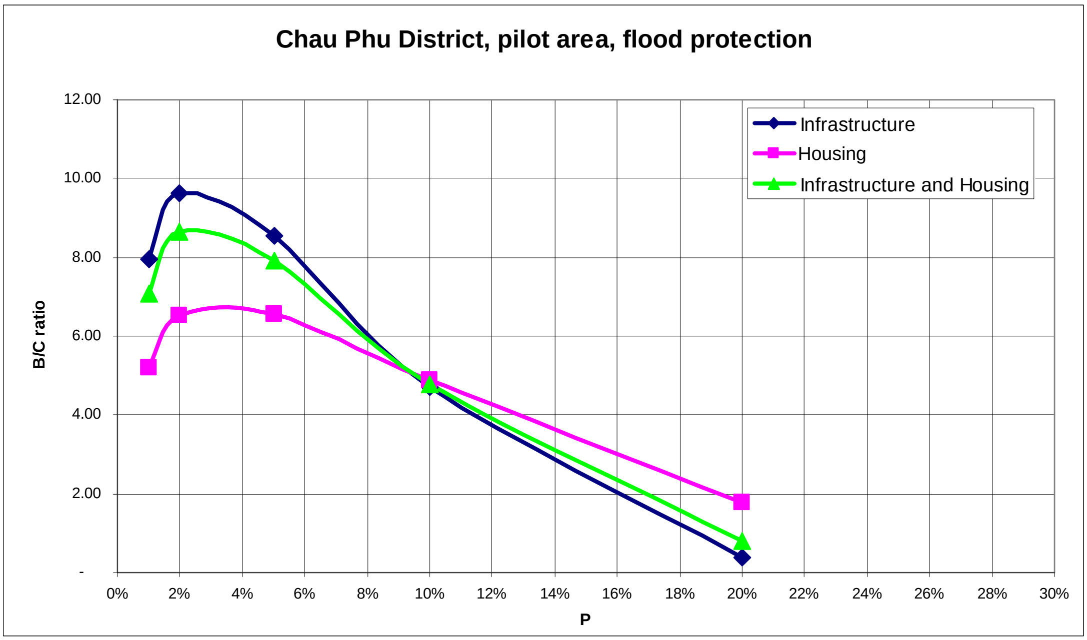

Figure 8-1 B/C ratios for different frequencies and damage categories, Chau Phu District.

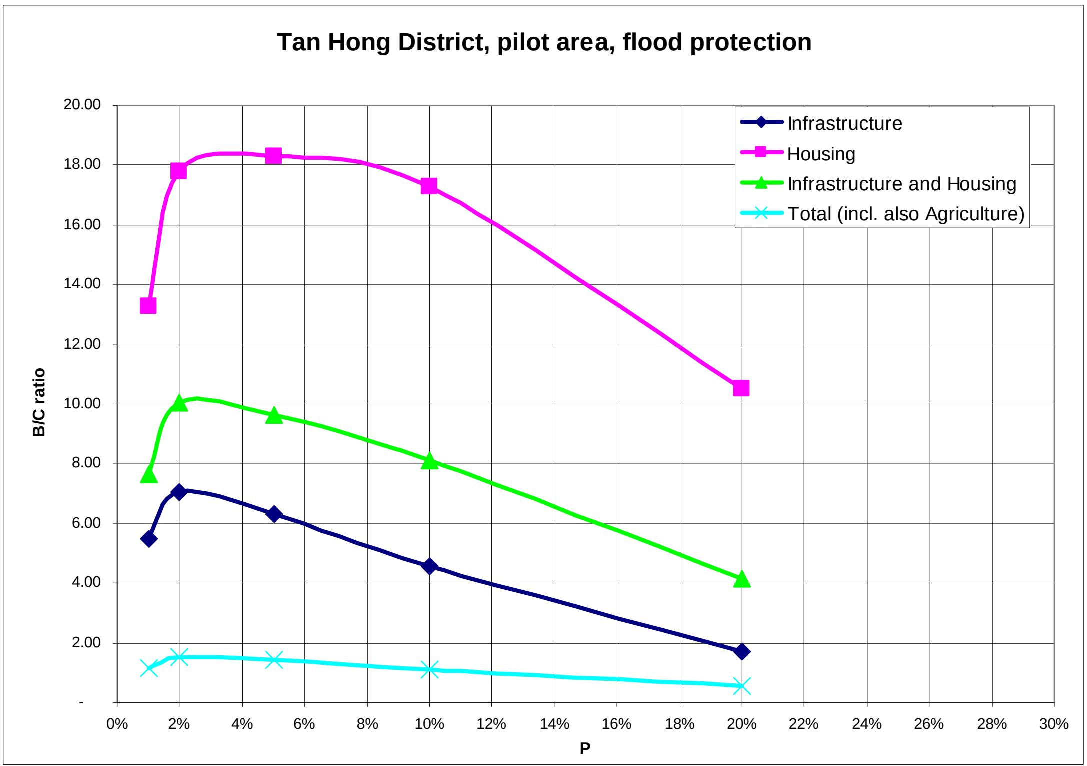

Figure 8-2 B/C ratios for different frequencies and damage categories, Tan Hong District.

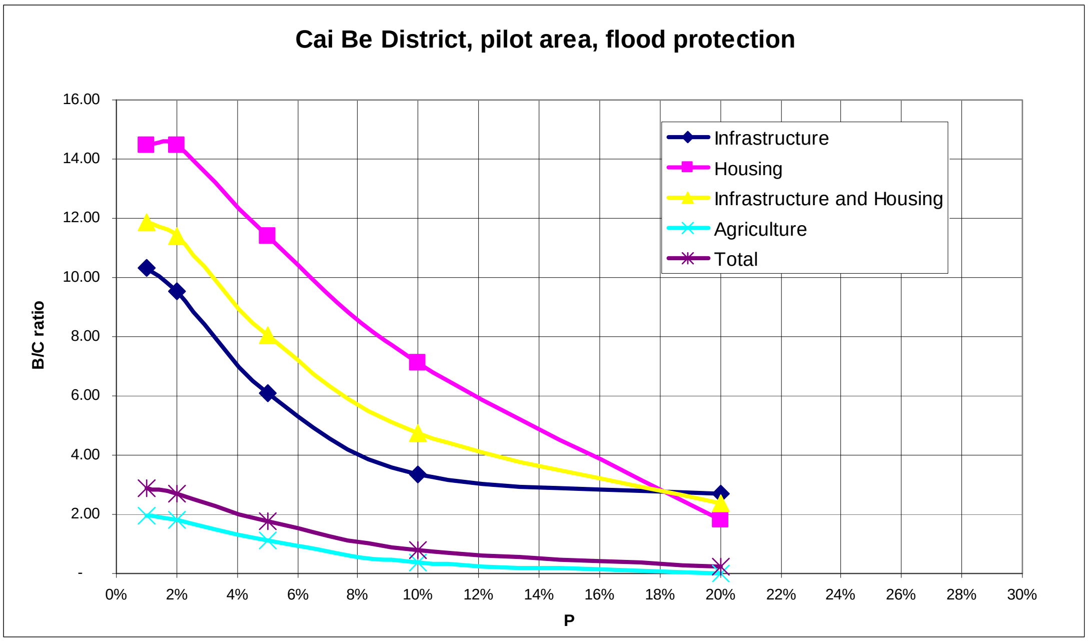

Figure 8-3 B/C ratios for different frequencies and damage categories, Cai Be District.

8.3 Observations

8.3.1 Protection for agricultural land

Though the flood damage assessment includes agricultural damages in Long Xuyen City and Sa Dec Town, these areas are in fact urban areas and the agricultural damage is of little importance.

In the deeply flooded areas the protection level is already at around 10% and as per the governing policy of Viet Nam, this will remain so. The B/C ratio findings for these three districts confirm that there is nothing to be gained by providing higher protection levels.

Only for Cai Be, is there a potential benefit in providing higher levels of protection also for agriculture, but here also benefits would really come from protecting infrastructure and housing. However, so far for this polder type of protection the current cost estimate do not yet include costs for pumping that will be required for drainage of excess rain water.

8.3.2 Protection for infrastructure and housing

For the urban areas Long Xuyen and Sa Dec, no economically feasible solution has been found, this is caused by the very high investment required due to the urban environment where raising of existing dykes through earthwork would require too much land acquisition and replacement costs, instead concrete walls on top of existing dykes are considered. Pumped drainage is added for drainage of excess rain water.

For Tam Nong the situation is rather complex, in developing the sample area protection measures a choice was for providing space for town development, in other words, providing the sample area with full year-round protection, which from the above analysis appears not to be feasible, however this conclusion may not hold when future urban/industrial and commercial land use would be integrated in the analysis, which is not likely as the lack of data on what that would entail. Hence the outcome for Tam Hong is not representative for the district as a whole, as the district would most likely have B>C ratios similar to those of Chau Phu and Tan Hong.

Protection of infrastructure and housing at the village level is feasible for villages in the deeply flooded areas and would provide very high benefits. Optimal protection level would then be at 2% probability of exceedance. This is also the case for villages in shallow flood areas where full flood protection is not yet available. Cai Be serves then as an example.

When compared to the actual levels of protection for infrastructure and housing, in these areas, upgrading by 2% generally means a more than tenfold increase in safety.

8.3.3 Limitations in the analysis

The presented analysis has a number of limitations and uncertainties.

Damage categories are based on actual and official flood damage obtained from district authorities; the dataset obtained was complete for the categories that we have used, other damage categories such as on public health, are not being inventoried by the districts, damages might be greater if those would be inventoried.

Flood damage data was collected from 2000 till 2007, and though there is a reasonable spread in flood events from big to small, the time period is rather short.

The preliminary engineering designs for the measures in the sample areas are based on experience, no detailed topographical surveys and geotechnical investigations could be carried out in the framework of this DP. Slope stability and dyke strength are assumed to comply with the requirements. In each specific case, field surveys and detailed design of works may lead to different typical dyke profiles.

Dyke crest width has been taken at 6.00 m, which may be too much for flood protection but is selected for road transport reasons, costs may therefore be on the high side, but we believe that removing part of the cost that is attributable to transport would have no significant impact on the B/C ratios that we found.

Water levels have been simulated with the aid of VRSAP, though this is a very comprehensive model of the Mekong Delta, it provides a representation of the situation and contains uncertainties. Usually this is taken care of as an element in the determination of the freeboard that is to be applied.

CHAPTER 9

REFERENCES

9 REFERENCES

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[3] Roads and Floods, Best Practice Guidelines for the Integrated Planning and Design of Economically Sound and Environmentally Friendly Roads in the Mekong Floodplains of Cambodia and Viet Nam, October 2008; Flood Management and Mitigation Programme Component 2: Structural Measures and Flood Proofing.

[4] Best Practice Guidelines for Integrated Flood Risk Management, Planning and Impact Evaluation, The Flood Management and Mitigation Programme Component 2: Structural Measures and Flood Proofing, June 2009.

[5] Best Practise Guidelines for Flood Risk Assessment in the Lower Mekong Basin, Flood Management and Mitigation Programme Component 2: Structural Measures and Flood Proofing, April 2009.

APPENDICES

Appendix 1 Flood water level in represented locations (amsl - Ha Tien datum)

No	District Node	Hmax_Year Tan Hong 338_C	Hmax_Year Tam Nong 418_C	Hmax_Year Chau Phu 672_C	Hmax_Year Long Xuyen 109_C	Hmax_Year Sa Dec 995_C	Hmax_Year Cai Be 586_C	Hmax_Aug Tan Hong 338_C	Hmax_Aug Tam Nong 418_C	Hmax_Aug Chau Phu 672_C
1	1910	4.40	3.53	3.17	2.56	1.99	1.78	2.34	1.90	1.66
2	1911	4.11	3.26	2.98	2.48	1.94	1.73	2.98	2.33	2.11
3	1912	4.62	3.67	3.18	2.59	2.02	1.83	2.18	1.79	1.48
4	1913	4.35	3.46	3.07	2.54	2.02	1.80	2.48	2.00	1.75
5	1914	5.29	4.35	3.47	2.78	2.19	1.96	2.89	2.26	2.05
6	1915	3.68	2.98	2.90	2.40	1.99	1.76	2.02	1.68	1.40
7	1916	3.82	3.10	2.92	2.46	1.94	1.71	2.17	1.80	1.52
8	1917	4.32	3.41	3.07	2.52	2.01	1.79	2.31	1.88	1.61
9	1918	5.28	4.41	3.57	2.88	2.26	2.10	2.48	2.01	1.76
10	1919	5.35	4.36	3.35	2.60	2.05	1.88	2.30	1.88	1.55
11	1920	4.71	3.81	3.30	2.69	2.11	1.85	2.72	2.12	1.87
12	1921	4.13	3.30	3.02	2.52	1.98	1.76	2.36	1.92	1.65
13	1922	4.89	3.95	3.32	2.68	2.15	1.92	2.58	2.06	1.81
14	1923	5.85	4.85	3.65	2.91	2.27	2.14	2.82	2.29	2.01
15	1924	5.21	4.28	3.41	2.68	2.12	2.01	3.38	2.42	2.18
16	1925	4.86	3.95	3.31	2.65	2.10	1.93	2.64	2.13	1.88
17	1926	4.37	3.49	3.09	2.52	2.00	1.83	2.27	1.86	1.58
18	1927	4.61	3.60	3.09	2.51	2.01	1.83	3.32	2.41	2.19
19	1928	4.20	3.33	2.99	2.47	1.96	1.76	3.37	2.56	2.33
20	1929	5.05	4.13	3.42	2.77	2.16	1.90	2.69	2.20	1.93
21	1930	5.05	4.13	3.42	2.77	2.16	1.90	2.69	2.20	1.93
22	1931	3.87	3.13	2.96	2.46	1.97	1.73	1.75	1.49	1.22
23	1932	4.03	3.24	2.99	2.50	1.97	1.76	2.87	2.21	1.99
24	1933	4.05	3.18	2.95	2.49	1.96	1.69	2.57	2.05	1.81
25	1934	5.16	4.28	3.50	2.83	2.23	2.04	2.31	1.87	1.60
26	1935	4.27	3.40	3.05	2.51	2.00	1.80	2.97	2.30	2.10
27	1936	4.56	3.60	3.14	2.58	2.04	1.82	2.70	2.14	1.91
28	1937	5.69	4.76	3.71	3.02	2.38	2.33	3.65	2.63	2.35
29	1938	4.84	3.91	3.30	2.67	2.13	1.94	2.94	2.37	2.13
30	1939	5.61	4.73	3.65	2.84	2.20	2.12	2.87	2.25	2.04
31	1940	5.67	4.69	3.64	2.97	2.34	2.22	2.91	2.28	2.07
32	1941	4.40	3.50	3.12	2.56	2.01	1.83	2.49	2.04	1.74
33	1942	4.58	3.74	3.27	2.65	2.11	1.89	3.03	2.39	2.17
34	1943	5.13	4.28	3.52	2.87	2.25	1.99	2.83	2.24	2.02
35	1944	4.17	3.31	2.99	2.42	1.96	1.74	2.48	1.99	1.73
36	1945	4.82	3.95	3.35	2.74	2.17	1.93	2.81	2.28	2.03
37	1946	4.98	4.11	3.47	2.83	2.23	2.00	2.58	2.10	1.83
38	1947	5.06	4.17	3.47	2.84	2.25	2.03	3.42	2.68	2.41
39	1948	5.49	4.52	3.54	2.84	2.28	2.19	2.62	2.10	1.86
40	1949	4.84	3.97	3.42	2.77	2.17	1.93	1.98	1.65	1.35
41	1950	4.78	3.82	3.26	2.65	2.11	1.94	2.72	2.17	1.93
42	1951	4.82	3.85	3.24	2.65	2.06	1.86	2.52	2.05	1.81
43	1952	5.01	4.16	3.48	2.83	2.24	2.05	2.28	1.86	1.56
44	1953	4.04	3.25	3.00	2.51	1.97	1.73	2.39	1.94	1.68
45	1954	4.61	3.66	3.21	2.65	2.07	1.80	1.54	1.37	1.15
46	1955	3.43	2.83	2.72	2.35	1.87	1.62	2.30	1.88	1.61
47	1956	4.67	3.79	3.25	2.65	2.11	1.89	2.32	1.91	1.63
48	1957	4.04	3.25	3.00	2.48	1.99	1.77	2.44	1.98	1.72
49	1958	4.52	3.57	3.13	2.59	2.06	1.81	2.50	2.02	1.77
50	1959	3.97	3.22	3.01	2.50	1.96	1.73	1.82	1.54	1.27
51	1960	4.46	3.56	3.16	2.59	2.06	1.86	1.76	1.50	1.22
52	1961	5.45	4.55	3.62	2.95	2.32	2.20	2.70	2.21	1.94
53	1962	4.29	3.40	3.07	2.54	2.02	1.78	2.70	2.17	1.94
54	1963	4.20	3.39	3.10	2.55	2.01	1.78	2.54	2.04	1.79
55	1964	4.58	3.67	3.18	2.61	2.07	1.87	2.14	1.74	1.47
56	1965	3.59	2.90	2.75	2.33	1.89	1.63	2.71	2.20	1.95
57	1966	5.27	4.33	3.45	2.76	2.22	2.07	2.73	2.16	1.93
58	1967	4.10	3.31	3.04	2.52	1.97	1.75	2.10	1.74	1.40
59	1968	4.40	3.45	3.06	2.51	1.99	1.76	1.79	1.52	1.25
60	1969	3.93	3.18	2.94	2.46	1.96	1.73	2.91	2.30	2.07
61	1970	4.84	3.92	3.33	2.69	2.14	1.95	2.84	2.30	2.05
62	1971	4.59	3.71	3.21	2.62	2.04	1.87	3.69	2.85	2.49
63	1972	4.25	3.37	2.99	2.46	1.92	1.75	2.20	1.80	1.53
64	1973	4.46	3.55	3.15	2.59	2.05	1.81	2.32	1.90	1.64
65	1974	4.40	3.51	3.09	2.54	1.99	1.81	2.01	1.67	1.39
66	1975	4.51	3.60	3.17	2.61	2.07	1.84	2.43	1.98	1.71
67	1976	3.61	2.92	2.77	2.36	1.95	1.70	2.00	1.66	1.36
68	1977	3.48	2.86	2.76	2.37	1.88	1.61	1.88	1.58	1.31
69	1978	5.17	4.22	3.50	2.83	2.23	2.01	2.70	2.17	1.92
70	1979	3.94	3.15	2.95	2.48	1.94	1.68	2.52	2.05	1.79
71	1980	4.65	3.73	3.22	2.65	2.09	1.83	2.19	1.80	1.50
72	1981	4.64	3.70	3.09	2.46	1.95	1.78	3.29	2.62	2.35
73	1982	4.16	3.34	3.01	2.49	1.99	1.79	2.09	1.73	1.45
74	1983	3.95	3.16	2.97	2.46	1.97	1.73	1.65	1.42	1.17
75	1984	4.93	3.99	3.30	2.69	2.11	1.90	2.33	1.90	1.63
76	1985	4.31	3.42	3.07	2.55	2.02	1.79	2.43	1.98	1.71
77	1986	4.18	3.31	2.98	2.48	1.93	1.73	2.33	1.89	1.62
78	1987	3.75	3.02	2.81	2.40	1.91	1.67	2.00	1.64	1.36
79	1988	3.03	2.56	2.54	2.24	1.86	1.61	1.67	1.43	1.18
80	1989	3.61	2.89	2.75	2.36	1.90	1.67	2.17	1.78	1.51
81	1990	4.42	3.56	3.18	2.61	2.05	1.86	2.62	2.14	1.86
82	1991	4.95	4.02	3.32	2.65	2.08	1.88	2.48	1.99	1.74
83	1992	3.46	2.71	2.61	2.30	1.85	1.60	2.11	1.74	1.45
84	1993	3.68	2.96	2.79	2.36	1.89	1.65	2.34	1.90	1.64
85	1994	4.77	3.84	3.28	2.69	2.13	1.94	3.31	2.59	2.32
86	1995	4.68	3.76	3.20	2.61	2.03	1.85	2.30	1.87	1.57
87	1996	5.53	4.57	3.60	2.93	2.28	2.01	2.39	1.93	1.67
88	1997	4.57	3.58	3.11	2.56	2.02	1.83	2.98	2.29	2.09
89	1998	3.04	2.52	2.46	2.23	1.80	1.54	1.96	1.62	1.35
90	1999	4.00	3.22	2.98	2.50	1.97	1.71	2.58	2.06	1.80
91	2000	5.68	4.71	3.65	2.91	2.31	2.28	4.22	3.29	2.72
92	2001	5.17	4.28	3.49	2.81	2.20	2.10	3.02	2.43	2.20
93	2002	5.22	4.32	3.49	2.86	2.28	2.12	3.10	2.50	2.25
94	2003	4.29	3.38	3.04	2.51	2.00	1.74	2.00	1.67	1.38
95	2004	4.66	3.78	3.28	2.66	2.12	1.86	2.37	1.92	1.62
96	2005	4.67	3.80	3.31	2.70	2.14	1.92	2.56	2.02	1.74
97	2006	4.37	3.44	3.12	2.56	2.04	1.82	2.60	2.08	1.84

Appendix 2 Direct flood damages (VND mln at current price)

	Year and categories	Chau Phu	Long Xuyen	Tan Hong	Tam Nong	Sa Dec	Cai Be
	Flood 2000	**41,742**	**79,384**	**78,438**	**126,253**	**36,402**	**388,437**
1	Direct damages on Housing	5,071	6,492	12,654	16,950	13,309	21,347
2	Direct damages on Agriculture	1,636	1,322	31,273	70,052	11,612	305,622
3	Direct damages on Infrastructure	30,413	55,312	27,038	31,780	11,189	61,408
4	Relief & emergency	4,622	16,259	7,472	7,472	292	61
	Flood 2001	**10,512**	**8,288**	**32,020**	**36,737**	**15,143**	**73,291**
1	Direct damages on Housing	3,126	2,973	18,113	17,150	6,132	15,442
2	Direct damages on Agriculture	16	143	2,124	4,044	5,765	44,768
3	Direct damages on Infrastructure	6,106	4,670	9,739	13,786	3,247	13,081
4	Relief & emergency	1,265	502	2,044	1,757	0	0
	Flood 2002	**10,038**	**3,350**	**8,231**	**8,245**	**5,687**	**29,166**
1	Direct damages on Housing	2,546	255	3,067	3,791	4,100	12,857
2	Direct damages on Agriculture	40	36	0	0	61	46
3	Direct damages on Infrastructure	7,453	3,059	4,238	3,956	1,522	16,264
4	Relief & emergency	0	0	926	498	4	0
	Flood 2003	**0**	**0**	**0**	**252**	**0**	**0**
1	Direct damages on Housing	0	0	0	93	0	
2	Direct damages on Agriculture	0	0	0	0	0	
3	Direct damages on Infrastructure	0	0	0	159	0	
4	Relief & emergency	0	0	0	0	0	
	Flood 2004	**1,499**	**952**	**2,553**	**567**	**332**	**0**
1	Direct damages on Housing	376	128	53	419	0	
2	Direct damages on Agriculture	0	6	0	0	0	
3	Direct damages on Infrastructure	1,123	818	2,500	148	332	
4	Relief & emergency	0	0	0	0	0	
	Flood 2005	**1,161**	**261**	**1,878**	**317**	**265**	**0**
1	Direct damages on Housing	122	61	0	0	0	
2	Direct damages on Agriculture	0	0	306	36	0	
3	Direct damages on Infrastructure	1,039	200	1,572	281	233	
4	Relief & emergency	0	0	0	0	32	
	Flood 2006	**43**	**250**	**3,399**	**1,850**	**29**	**0**
1	Direct damages on Housing	43	0	1,080	1,280	20	
2	Direct damages on Agriculture	0	0	0	0	0	
3	Direct damages on Infrastructure	0	250	2,279	530	0	
4	Relief & emergency	0	0	40	40	9	
	Flood 2007	**37**	**450**	**534**	**1,837**	**43**	**0**
1	Direct damages on Housing	0	0	25	165	20	
2	Direct damages on Agriculture	0	0	0	0	23	
3	Direct damages on Infrastructure	37	450	509	1,672	0	
4	Relief & emergency	0	0	0	0	0	
	Flood 2008	**9,090**	**1,528**	**0**	**0**	**0**	**0**
1	Direct damages on Housing	0	0	0	0	0	
2	Direct damages on Agriculture	9,090	1,528	0	0	0	
3	Direct damages on Infrastructure	0	0	0	0	0	
4	Relief & emergency	0	0	0	0	0	

Source: Provincial Department Natural Disaster Mitigation & Management

Appendix 3 Flood damage in six selected districts

CHAU PHU, AG

Potential Risk (:	Potential flood risk (US$/year/ha)						
T (year)	100	50	25	20	10	5	2
P(%)	1%	2%	4%	5%	10%	20%	50%
Infrastructure	155	140	112	98	47	3	0
Housing	102	95	82	75	49	15	2
Agriculture	0	0	0	0	0	0	0
TOTAL	12	11	9	8	4	1	0

LONG XUYEN, AG

Potential Risk (:	Potential flood risk (US$/year/ha)						
T (year)	100	50	25	20	10	5	2
P(%)	1%	2%	4%	5%	10%	20%	50%
Infrastructure	494	428	331	295	197	158	76
Housing	51	45	36	32	17	1	0
Agriculture	1	1	1	0	0	0	0
TOTAL	76	66	51	46	29	21	10

TAM NONG, DT

Potential Risk (:	Potential flood risk (US$/year/ha)						
T (year)	100	50	25	20	10	5	2
P(%)	1%	2%	4%	5%	10%	20%	50%
Infrastructure	147	134	109	97	54	8	0
Housing	612	572	500	465	329	155	49
Agriculture	4	3	2	1	0	0	0
TOTAL	27	24	20	18	11	4	1

TAN HONG, DT

Potential Risk (:	Potential flood risk (US$/year/ha)						
T (year)	100	50	25	20	10	5	2
P(%)	1%	2%	4%	5%	10%	20%	50%
Infrastructure	150	136	111	99	56	18	5
Housing	365	344	305	287	212	112	31
Agriculture	4	3	2	1	0	0	0
TOTAL	32	29	24	22	14	6	2

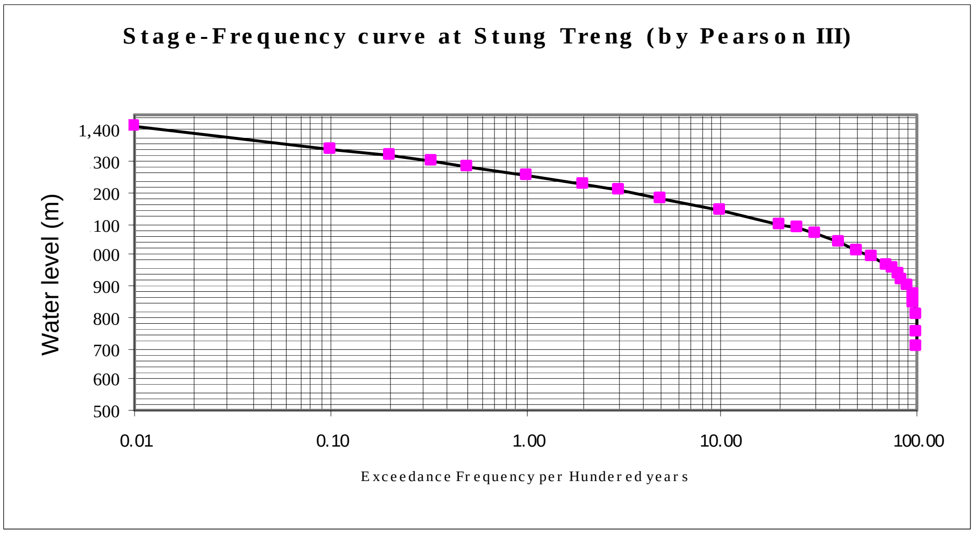
SA DEC, DT

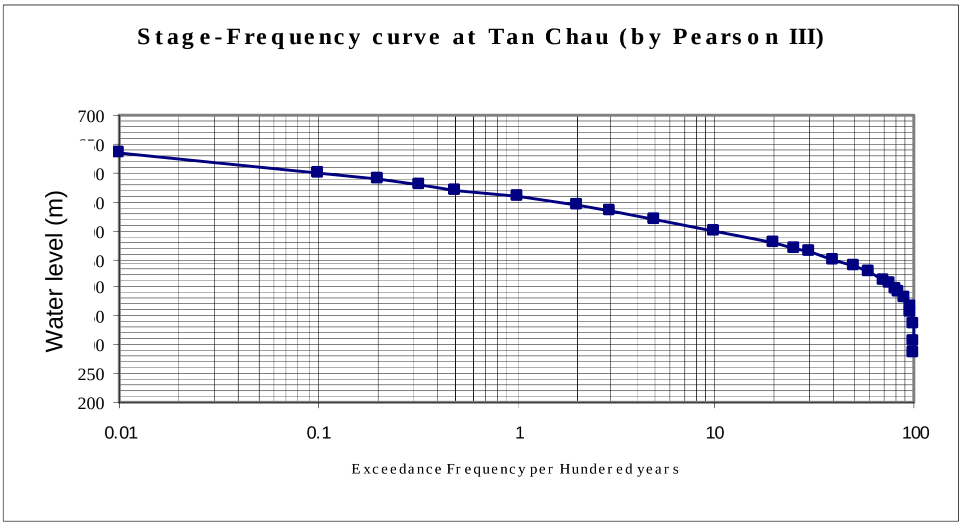
Potential Risk (:	Potential flood risk (US$/year/ha)						
T (year)	100	50	25	20	10	5	2
P(%)	1%	2%	4%	5%	10%	20%	50%
Infrastructure	184	166	136	123	70	8	2
Housing	426	388	323	296	178	27	0
Agriculture	27	25	22	20	13	4	0
TOTAL	87	79	66	61	37	7	0

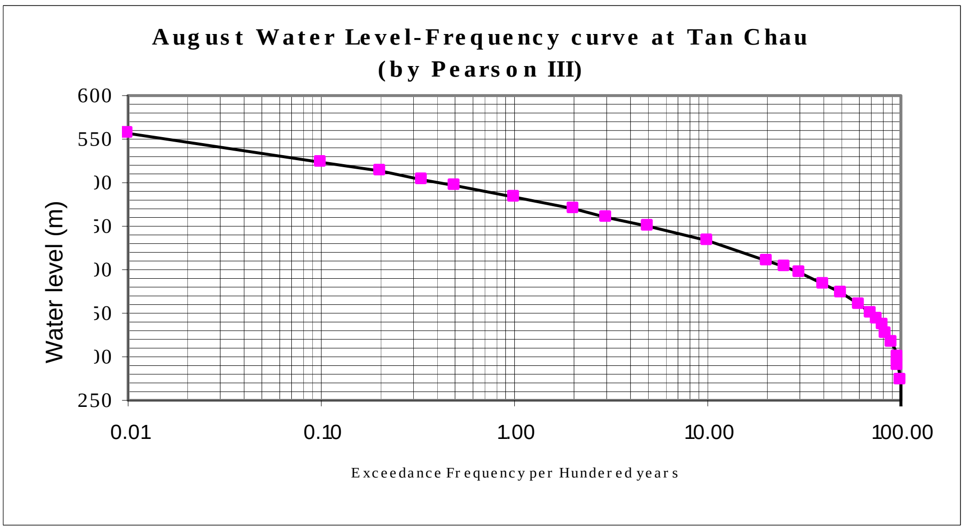
CAI BE, TG

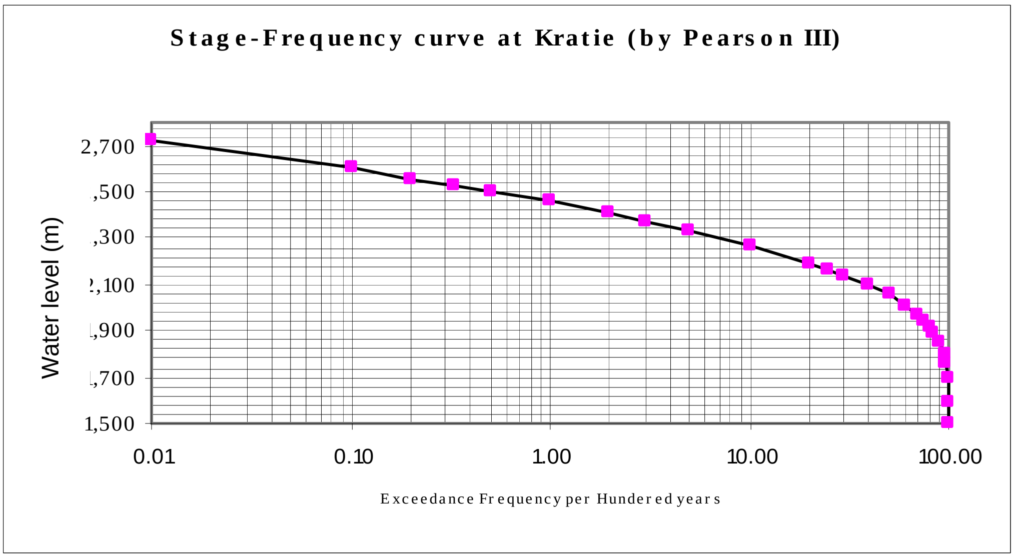
Potential Risk (:	Potential flood risk (US$/year/ha)						
T (year)	100	50	25	20	10	5	2
P(%)	1%	2%	4%	5%	10%	20%	50%
Infrastructure	182	152	109	91	48	36	18
Housing	255	230	189	171	101	24	2
Agriculture	34	28	20	16	5	0	0
TOTAL	51	43	31	26	11	3	1

Appendix 4 Stage Discharge Relations








Stage-Frequency curve at Kratie (by Pearson III)
Water level (m)
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,300
2,100
,900
,700
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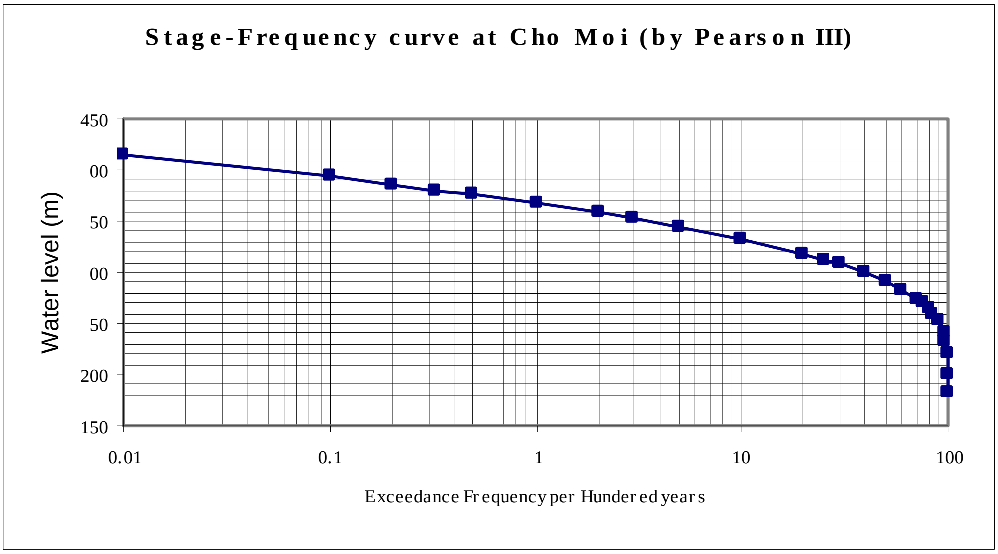
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


Stage-Frequency curve at Cho Moi (by Pearson III)
Water level (m)
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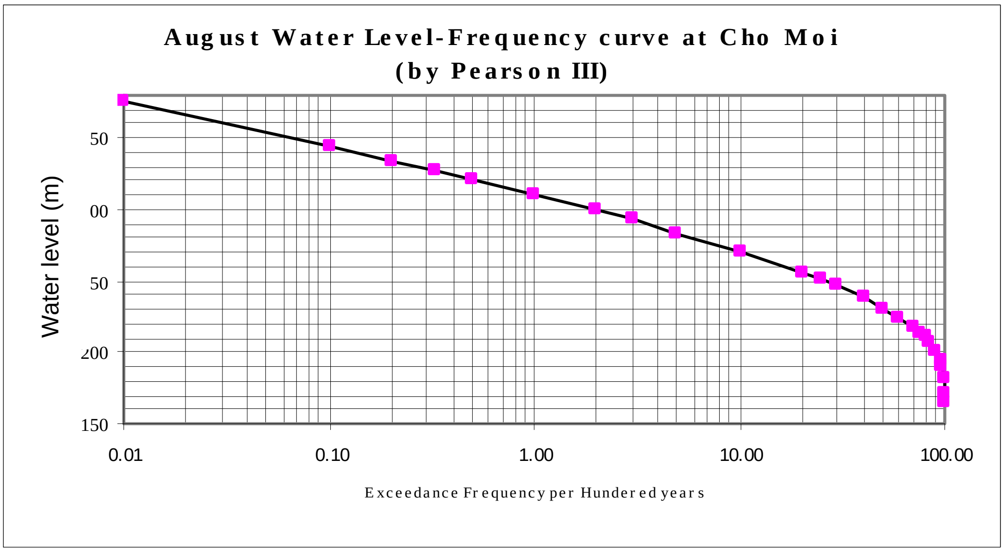
00
50
00
50
200
150
0.01
0.1
1
10
100
Exceedance Frequency per Hundered years


August Water Level-Frequency curve at Cho Moi
(by Pearson III)
Water level (m)
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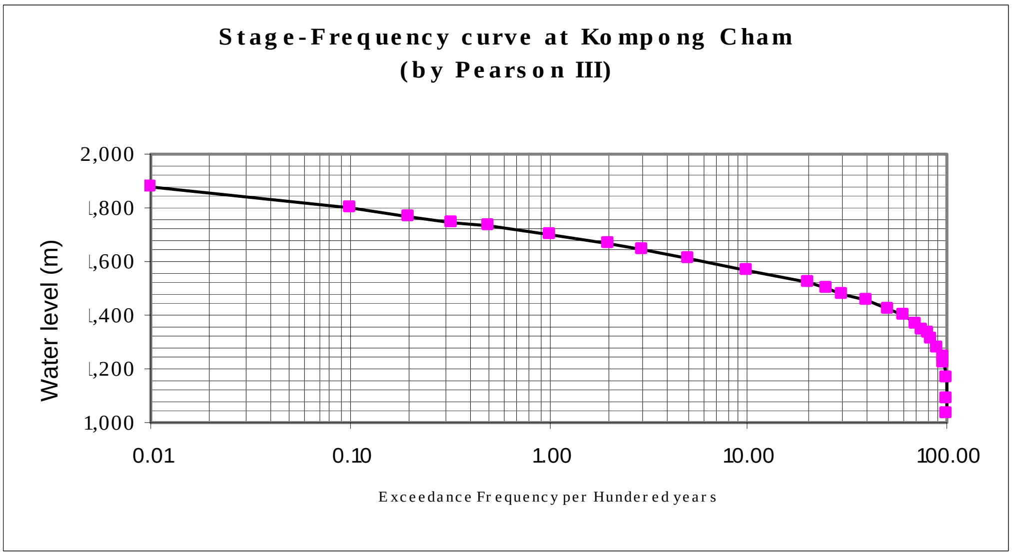
00
50
200
150
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


Stage-Frequency curve at Kompong Cham
(by Pearson III)
Water level (m)
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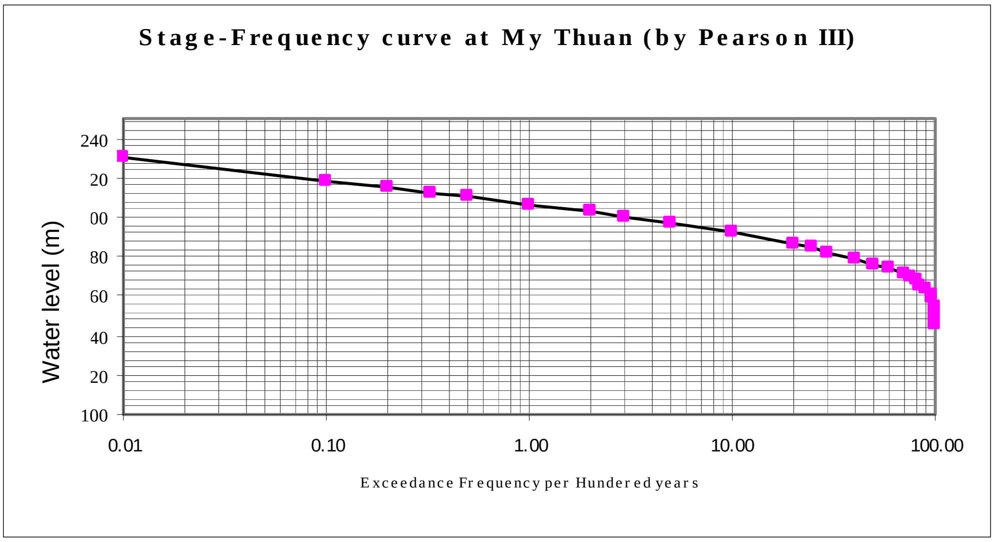
,600
,400
,200
1,000
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


Stage-Frequency curve at My Thuan (by Pearson III)
Water level (m)
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20
00
80
60
40
20
100
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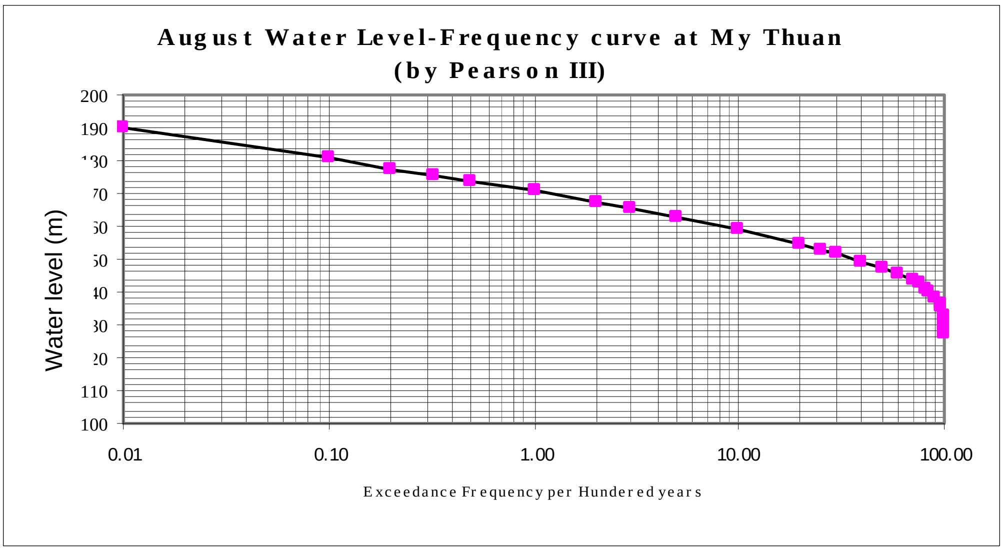
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


August Water Level-Frequency curve at My Thuan
(by Pearson III)
Water level (m)
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110
100
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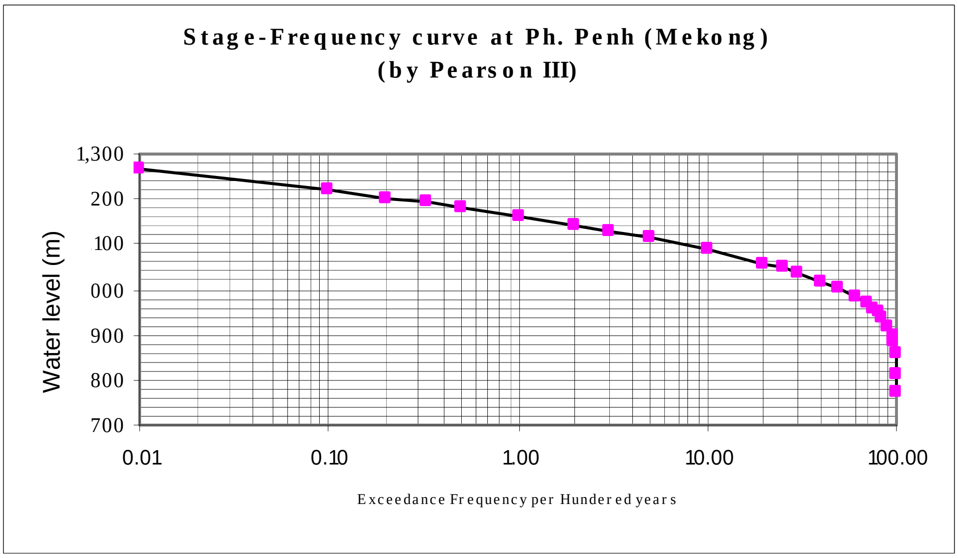
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


Stage-Frequency curve at Ph. Penh (Mekong)
(by Pearson III)
Water level (m)
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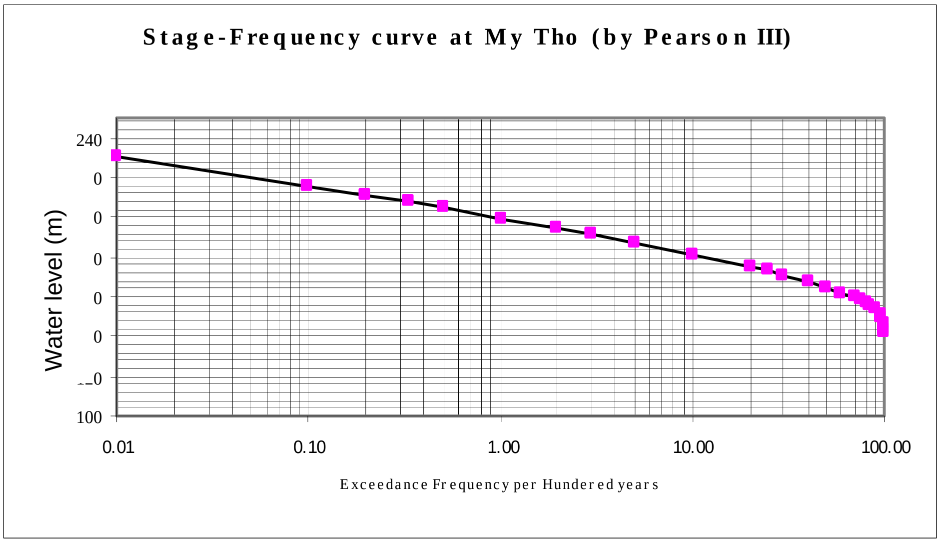
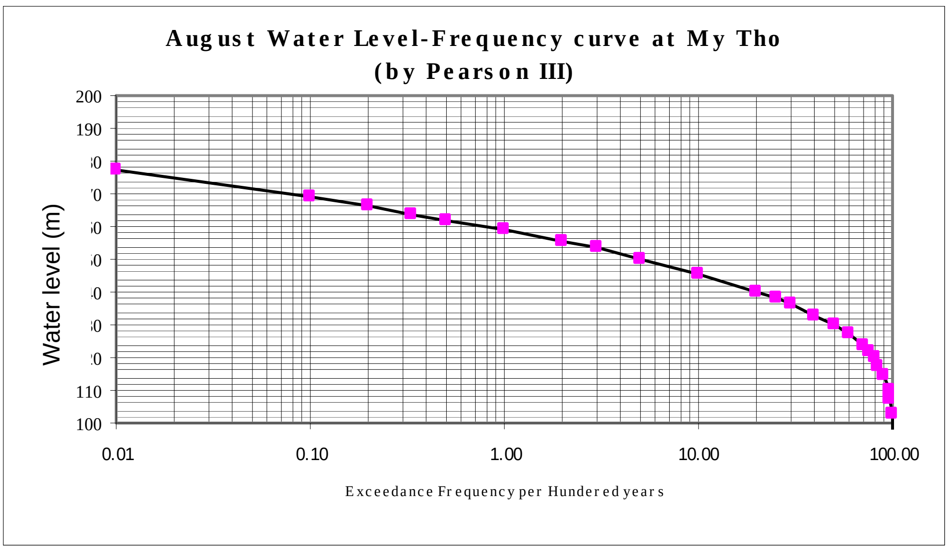
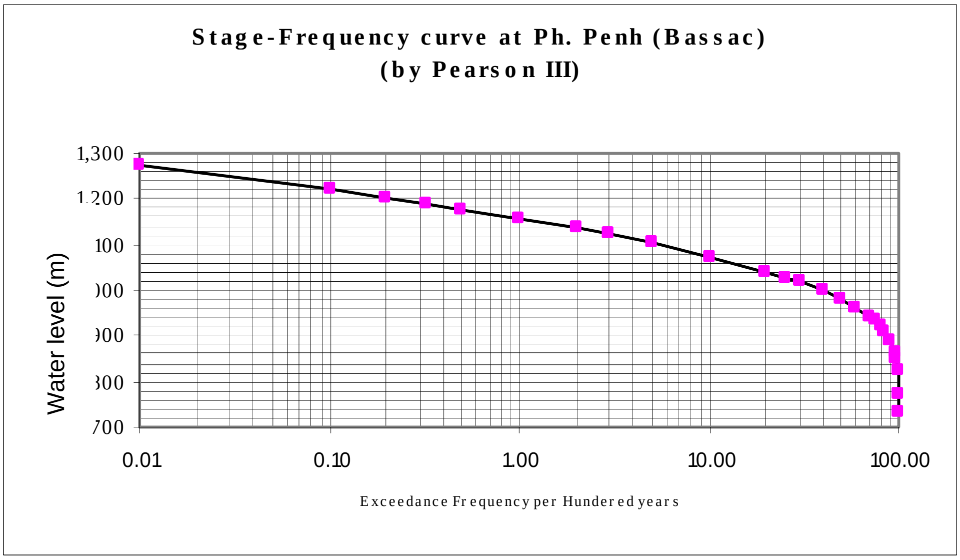
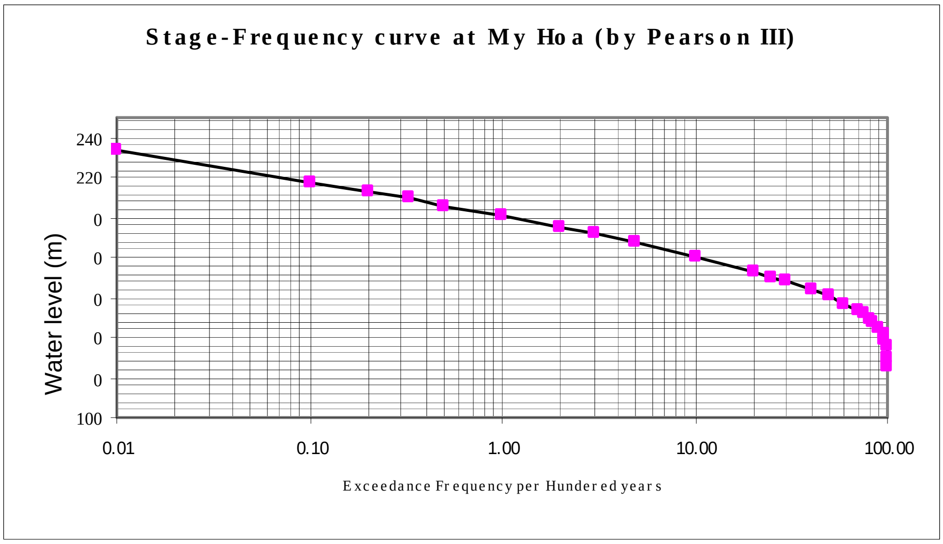
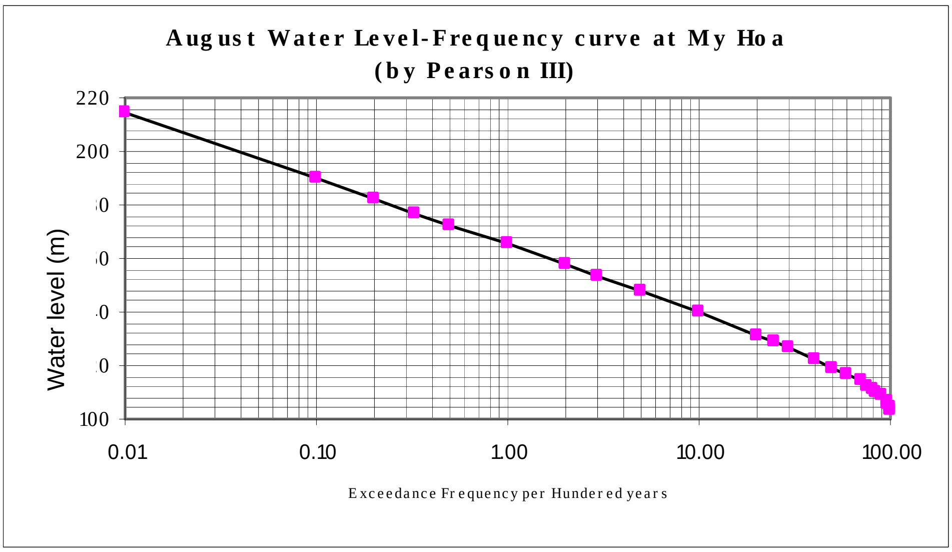
100
000
900
800
700
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

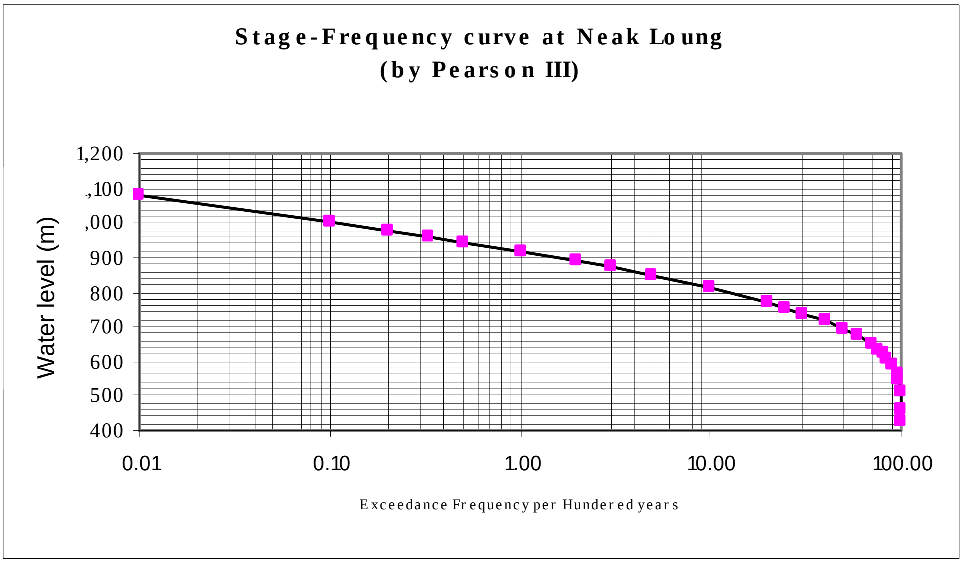

Stage-Frequency curve at My Tho (by Pearson III)
Water level (m)
240
100
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

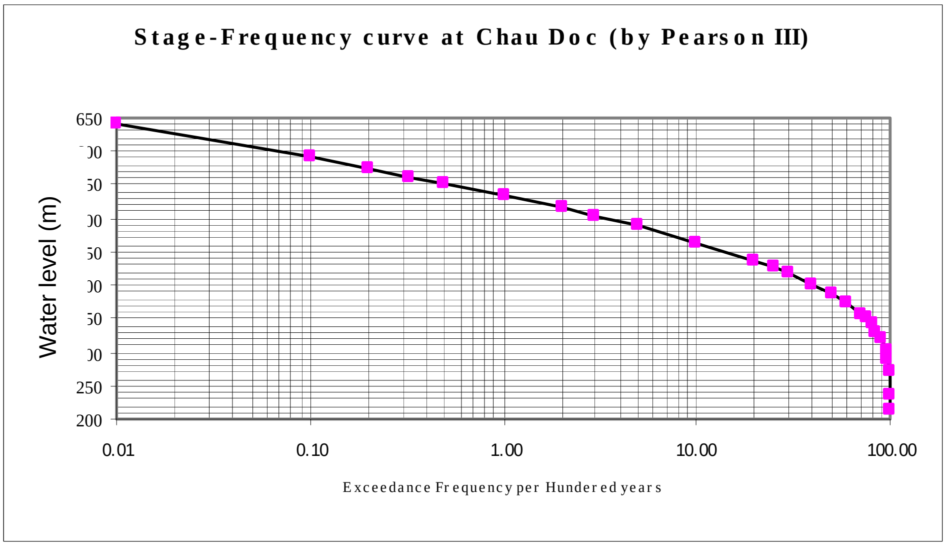

August Water Level-Frequency curve at My Tho
(by Pearson III)
Water level (m)
200
190
110
100
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

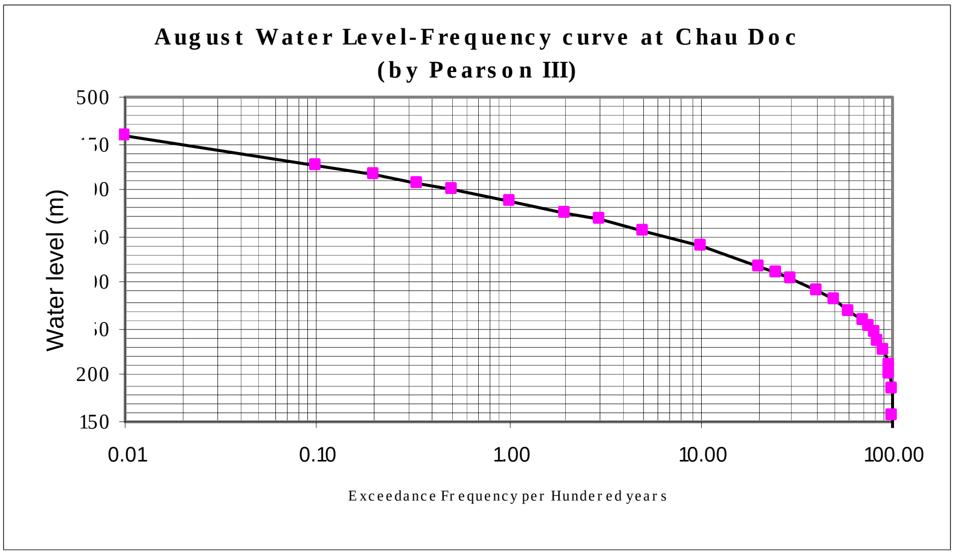

Stage-Frequency curve at Ph. Penh (Bassac)
(by Pearson III)
Water level (m)
1,300
1,200
100
)00
)00
300
700
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

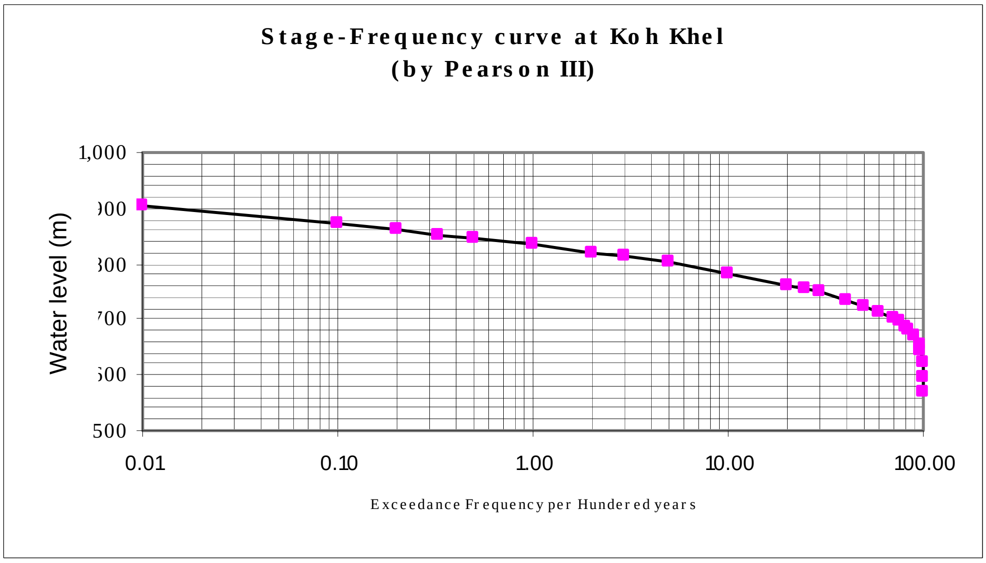

Stage-Frequency curve at My Hoa (by Pearson III)
Water level (m)
240
220
100
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

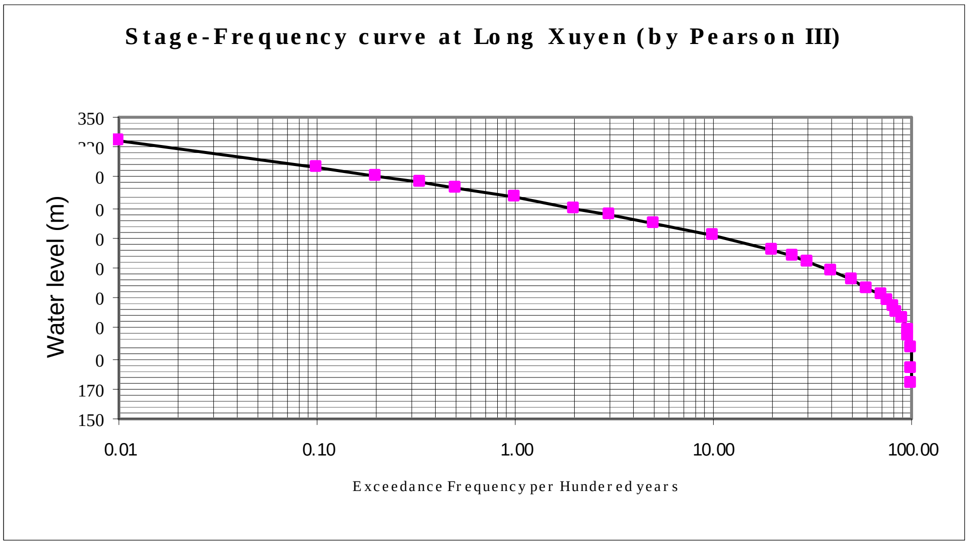

August Water Level-Frequency curve at My Hoa
(by Pearson III)
Water level (m)
220
200
100
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

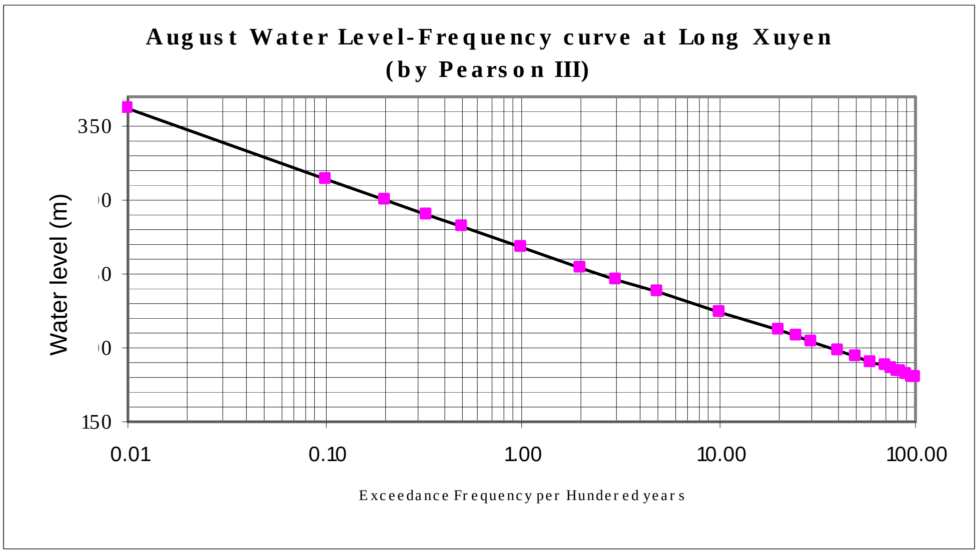

Stage-Frequency curve at Neak Loung
(by Pearson III)
Water level (m)
1,200
,100
,000
900
800
700
600
500
400
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

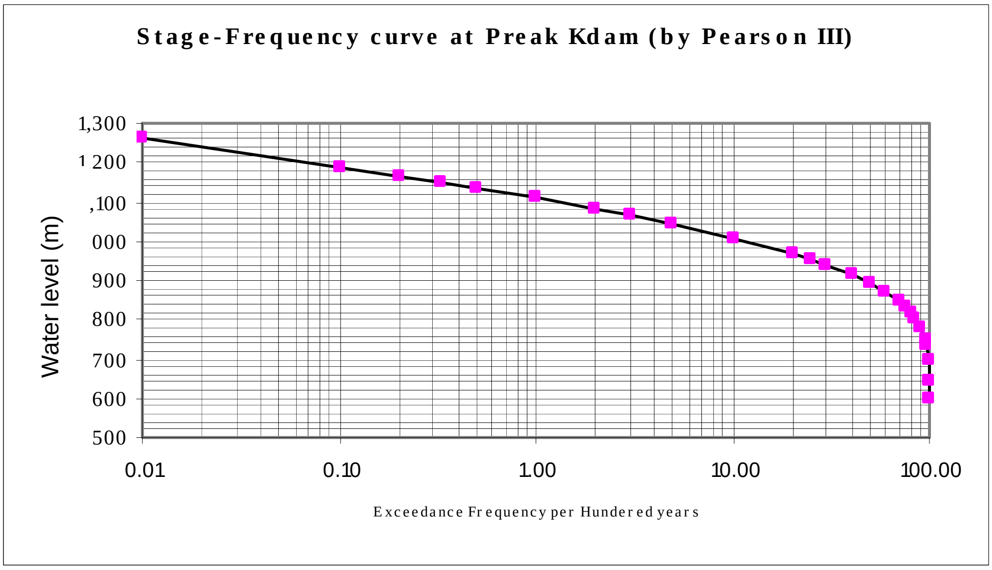

Stage-Frequency curve at Chau Doc (by Pearson III)
Water level (m)
650
250
200
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

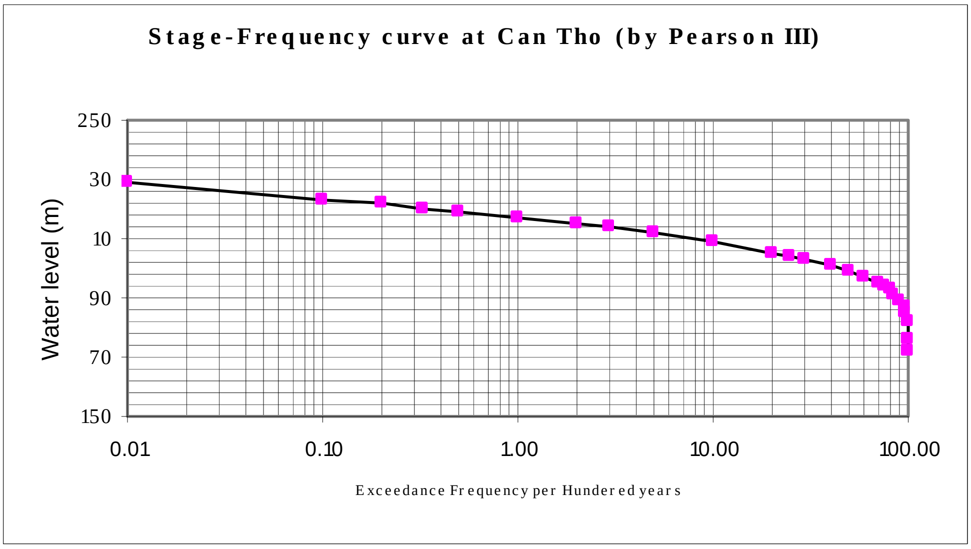

August Water Level-Frequency curve at Chau Doc
(by Pearson III)
Water level (m)
500
200
150
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

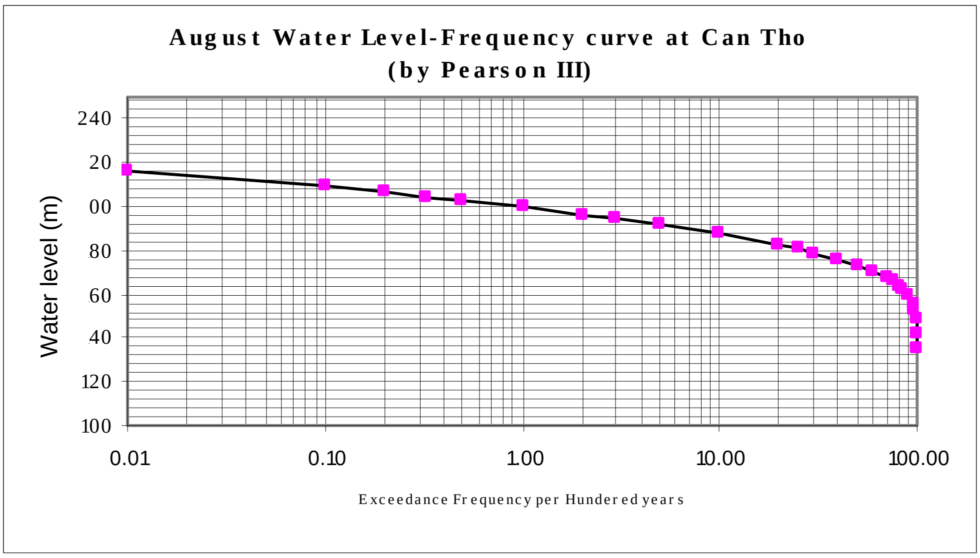

Stage-Frequency curve at Koh Khel
(by Pearson III)
1,000
500
Water level (m)
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

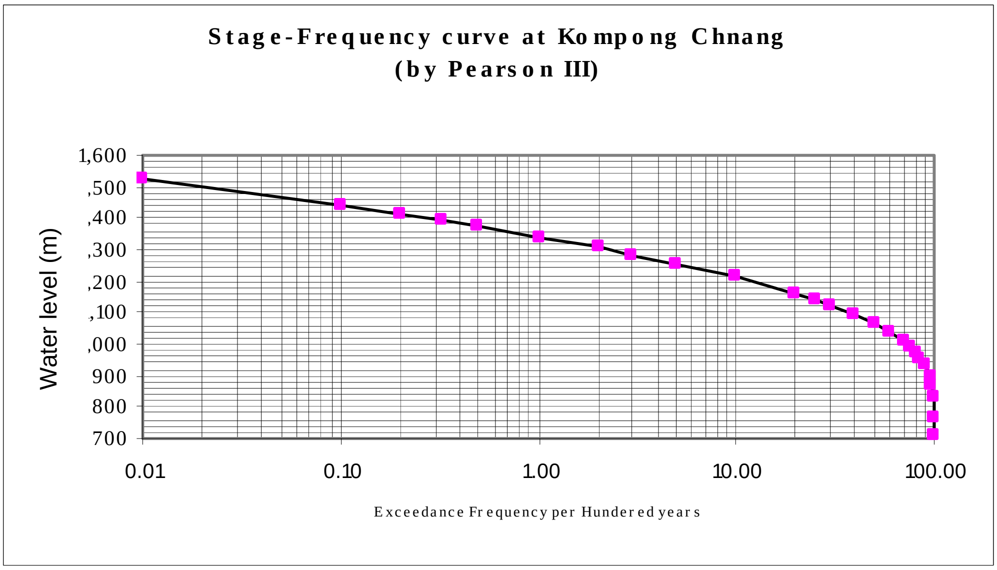

Stage-Frequency curve at Long Xuyen (by Pearson III)
350
170
150
Water level (m)
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

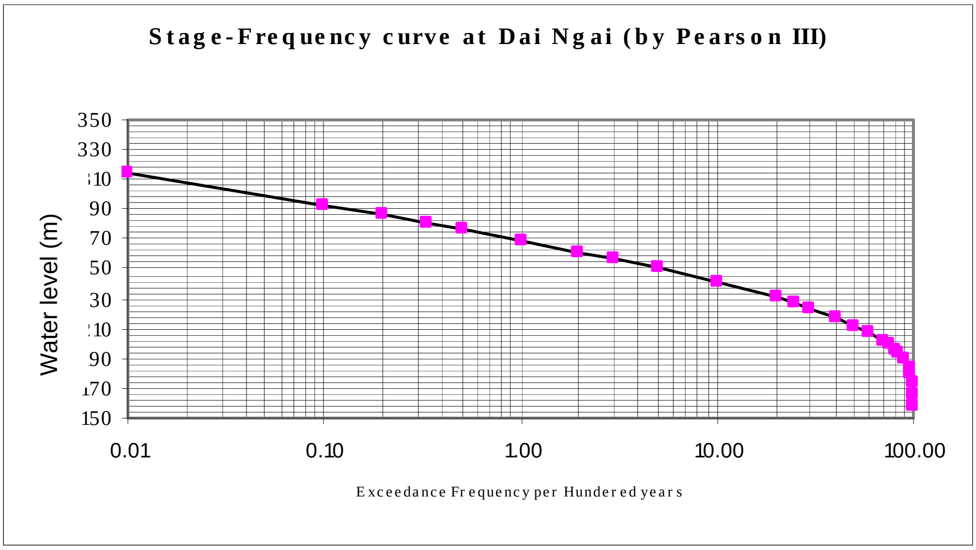

August Water Level-Frequency curve at Long Xuyen
(by Pearson III)
350
150
Water level (m)
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

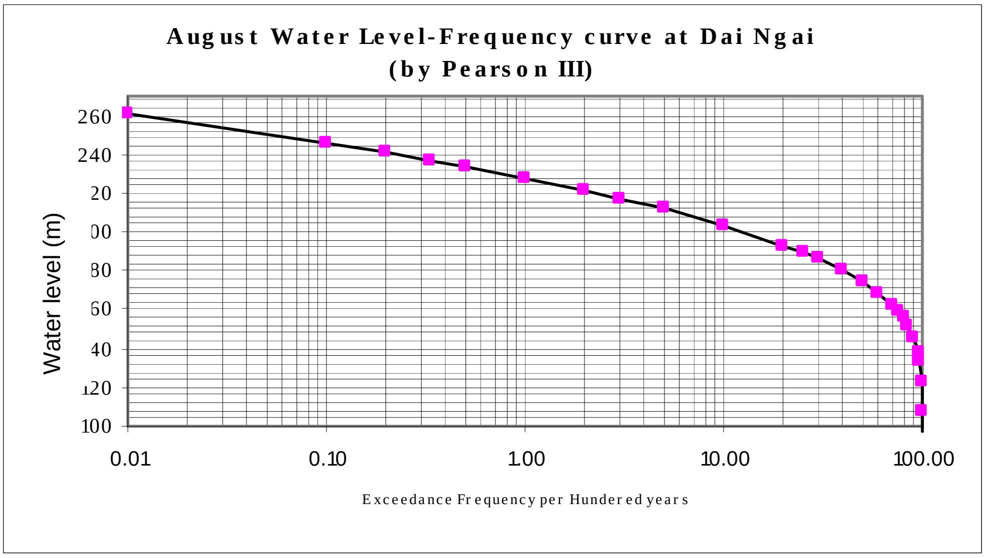

Stage-Frequency curve at Preak Kdam (by Pearson III)
Water level (m)
1,300
1 200
,100
000
900
800
700
600
500
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

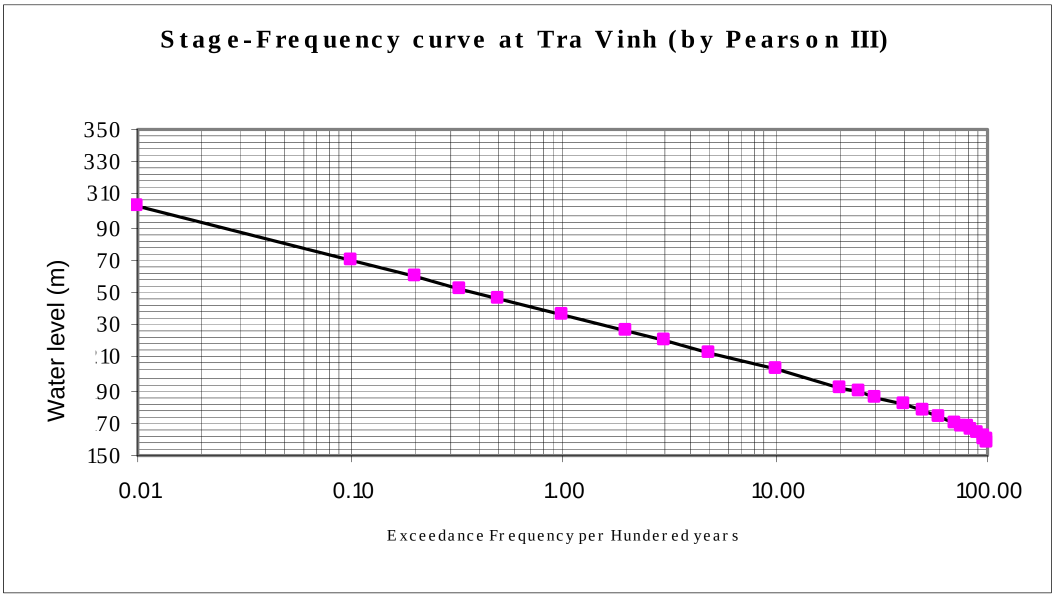

Stage-Frequency curve at Can Tho (by Pearson III)
Water level (m)
250
30
10
90
70
150
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

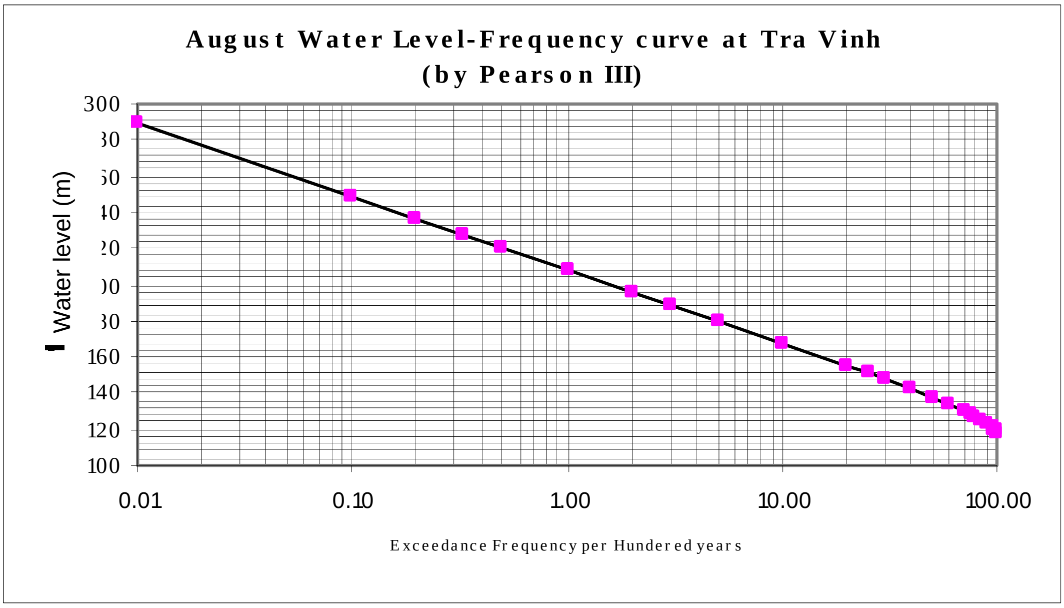

August Water Level-Frequency curve at Can Tho
(by Pearson III)
Water level (m)
240
20
00
80
60
40
120
100
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


Stage-Frequency curve at Kompong Chnang
(by Pearson III)
Water level (m)
1,600
,500
,400
,300
,200
,100
,000
900
800
700
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


Stage-Frequency curve at Dai Ngai (by Pearson III)
Water level (m)
350
330
10
90
70
50
30
10
90
70
150
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


August Water Level-Frequency curve at Dai Ngai
(by Pearson III)
Water level (m)
260
240
20
00
80
60
40
120
100
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


Stage-Frequency curve at Tra Vinh (by Pearson III)
Water level (m)
350
330
310
90
70
50
30
10
90
70
150
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years


August Water Level-Frequency curve at Tra Vinh (by Pearson III)
Water level (m)
300
160
140
120
100
0.01
0.10
1.00
10.00
100.00
Exceedance Frequency per Hundered years

Appendix 5 Unit rates

1. Concrete unit cost

STT	Cost items	Symbol	Calculation Formula	Results
I.	**Direct cost**	T	VL + NC + M + TT	2,025,246
1	Material	M		1,586,201
2	Labour	NC	NC x 1.44	346,765
3	Machine	M	MTC x 1.14	62,350
4	Other direct cost	TT	1.5% (VL+NC+M)	29,930
	Total direct cost	T	VL + NC + M + TT	2,025,246
II.	Common cost	C	5.5% x T	111,389
III.	Income before tax	TL	5,5% (T+C)	117,515
	Cost before tax	G	T + C + TL	**2,254,149**
IV.	VAT	GTGT	10% x G	225,415
	Cost after tax	GXD	G + GTGT	**2,479,564**
V.	Cost for set up tent	GxDNT	G x 1% x 1.1	24,796
	Sum	GXD	GXD + GXDNT	**2,504,360**
	Total	G	GXD x30%	**3,255,668**

2. Components of 1 m^3 concrete

	Beton 200#	m^3		1
	Sand	m^3		0.45
	Rock 1x2 cm	m^3		0.866
	Frest water	m^3		0.195
	Cement	kg		361

3. Unit cost for earth digging

STT	Cost items	Symbol	CalculationFormula	Results
I.	**Direct cost**	T	VL + NC + M + TT	4,423
1	Material	VL		0
2	Labour	NC	NC x 1.44	368
3	Machine	M	MTC x 1.14	3,990
4	Other direct cost	TT	1.5% (VL+NC+M)	65
	Total direct cost	T	VL + NC + M + TT	4,423
II.	Common cost	C	5.5% x T	243
III.	Income before tax	TL	5,5% (T+C)	257
	Cost before tax	G	T + C + TL	**4,923**
IV.	VAT	GTGT	10% x G	492
	Cost after tax	G^{XD}	G + GTGT	**5,416**
V.	Cost for set up tent	G_{xDNT}	G x 1% x 1.1	54
	Sum	G_{XD}	$G^{XD} + G_{XDNT}$	**5,470**
	Total	G	G^{XD} x30%	**7,111**

4. Unit cost for embankment

STT	Cost items	Symbol	CalculationFormula	Results
I.	**Direct cost**	T	VL + NC + M + TT	4,807
1	Material	VL		0
2	Labour	NC	NC x 1.44	368
3	Machine	M	MTC x 1.14	4,367
4	Other direct cost	TT	1.5% (VL+NC+M)	71
	Total direct cost	T	VL + NC + M + TT	4,807
II.	Common cost	C	5.5% x T	264
III.	Income before tax	TL	5,5% (T+C)	279
	Cost before tax	G	T + C + TL	**5,350**
IV.	VAT	GTGT	10% x G	535
	Cost after tax	G^{XD}	G + GTGT	**5,885**
V.	Cost for set up tent	G_{xDNT}	G x 1% x 1.1	59
	Sum	G_{XD}	$G^{XD} + G_{XDNT}$	**5,944**
	Total	G	G^{XD} x30%	**7,727**

5. Unit cost of pump

Item	Unit	Unit		Unit cost
Pump	no.	1		1,250,000,000

Appendix 6 Cost estimates

	Sample areas	Symbol	Area	Length			Note
			(ha)	Total	New make	Retaining wall	
I	AN GIANG		499	21,060	15,370	5,690	
1	LONG XUYÊN 1	LX1	198	6,240	3,750	2,490	
2	LONG XUYÊN 2	LX2	170	7,460	5,990	1,470	
3	LONG XUYÊN 3	LX3	76	4,260	3,480	780	
4	LONG XUYÊN 4	LX4	55	3,100	2,150	950	
II	VNĐỒNG THÁP		706	14,335	7,980	6,355	
5	TAM NÔNG	TN	336	7,980	7,980	-	
6	SA Déc	SD	370	8,145	-	6,355	Road No80 1,790m

	Areas	Symbol	Hpmax (cm)				
			1%	2%	5%	10%	20%
I	AN GIANG						
1	LONG XUYÊN 1	LX1	297	290	280	271	261
2	LONG XUYÊN 2	LX2	297	290	280	271	261
3	LONG XUYÊN 3	LX3	297	290	280	271	261
4	LONG XUYÊN 4	LX4	297	290	280	271	261
II	VNĐỒNG THÁP						
5	TAM NÔNG	TN	480	470	465	430	415
6	SA Déc	SD	240	236	230	225	219

	Areas	Symbol	Crest level (cm)				
			1%	2%	5%	10%	20%
I	AN GIANG						
1	LONG XUYÊN 1	LX1	397	390	380	371	361
2	LONG XUYÊN 2	LX2	397	390	380	371	361
3	LONG XUYÊN 3	LX3	397	390	380	371	361
4	LONG XUYÊN 4	LX4	397	390	380	371	361
II	VNĐỒNG THÁP						
5	TAM NÔNG	TN	580	570	565	530	515
6	SA Déc	SD	340	336	330	325	319

	Areas	Unit	Frequencies				
			1%	2%	5%	10%	20%
I	AN GIANG	1,000VND	123,668,391	118,327,568	110,810,510	104,581,205	97,571,450
1	LONG XUYÊN 1	1,000VND	45,030,375	42,925,650	39,970,068	37,531,222	34,799,735
1.1	Dyke paramettes		197,764	190,139	179,339	170,201	159,682
	Length	m	3,750	3,750	3,750	3,750	3,750
	Surface elevation	m	1.50	1.50	1.50	1.50	1.50
	Crest elevation	m	3.97	3.90	3.80	3.71	3.61
	Heigth of dyke	m	2.47	2.40	2.30	2.21	2.11
	Cross section	m^2	23.97	23.05	21.74	20.63	19.36
	Earth volume	m^3	89,893	86,427	81,518	77,364	72,583
	Dig volume	m^3	107,871	103,712	97,821	92,837	87,099
1.2	Concrete	m^3	7,895	7,450	6,826	6,312	5,737
1.2.1	Retaining wall		6,225	5,827	5,271	4,816	4,309
	Length	m	2,490	2,490	2,490	2,490	2,490
	Road elevation	m	2.97	2.97	2.97	2.97	2.97
	Retainingwall ELV	m	3.97	3.90	3.80	3.71	3.61
	Heigth of retaing wall	m	1.00	0.93	0.83	0.74	0.64
	Cross section	m^2	2.50	2.34	2.12	1.93	1.73
	Volume	m^3	6,225	5,827	5,271	4,816	4,309
1.2.2	Cover dyke slope		1,670	1,623	1,555	1,496	1,427
	Length	m	3,750	3,750	3,750	3,750	3,750
	Heigth of dyke	m	2.47	2.40	2.30	2.21	2.11
	Cross section	m^2	0.45	0.43	0.41	0.40	0.38
	Volume	m^3	1,670	1,623	1,555	1,496	1,427
1.3	Drainage pump						
	Areas	ha	198	198	198	198	198
	Number of pump	HTD2400	4	4	4	4	4
1.4	Cost	1,000VND	45,030,375	42,925,650	39,970,068	37,531,222	34,799,735
	Dig	1,000VND	767,066	737,492	695,603	660,157	619,359
	Earth	1,000VND	694,573	667,793	629,864	597,767	560,825
	Concrete	1,000VND	25,702,915	24,255,894	22,224,581	20,550,092	18,676,769
	Pump	1,000VND	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
	Construstion cost	1,000VND	32,164,554	30,661,178	28,550,049	26,808,016	24,856,954
	Compensation and resettlement	40% XL	12,865,822	12,264,471	11,420,019	10,723,206	9,942,781
	Cost/ha	1,000d/ha	227,426	216,796	201,869	189,552	175,756

	Areas	Unit			Frequencies		
			1%	2%	5%	10%	20%
2	LONG XUYÊN 2	1,000VND	39,176,226	37,638,709	35,470,110	33,665,950	31,626,992
2.1	Dyke parametters						
	Length	m	5,990	5,990	5,990	5,990	5,990
	Surface elevation	(m)	1.50	1.50	1.50	1.50	1.50
	Crest elevation	m	3.97	3.90	3.80	3.71	3.61
	Heigth of dyke	m	2.47	2.40	2.30	2.21	2.11
	Cross section	m^2	23.97	23.05	21.74	20.63	19.36
	Earth volume	m^3	143,588	138,052	130,211	123,576	115,939
	Dig volume	m^3	172,306	165,663	156,253	148,291	139,127
2.2	Concrete	m^3	6,342	6,033	5,596	5,233	4,824
2.2.1	Retaining wall	m^3					
	Length	m	1,470	1,470	1,470	1,470	1,470
	Road elevation	m	2.97	2.97	2.97	2.97	2.97
	Retainingwall ELV	m	3.97	3.90	3.80	3.71	3.61
	Heigth of retaing wall	m	1.00	0.93	0.83	0.74	0.64
	Cross section	m^2	2.50	2.34	2.12	1.93	1.73
	Volume	m^3	3,675	3,440	3,112	2,843	2,544
2.2.2	Cover dyke slope						
	Length	m	5,990	5,990	5,990	5,990	5,990
	Heigth of dyke	m	2.47	2.40	2.30	2.21	2.11
	Cross section	m^2	0.45	0.43	0.41	0.40	0.38
	Volume	m^3	2,667	2,592	2,484	2,390	2,280
2.3	Drainage pump						
	Areas	ha	170	170	170	170	170
	Number of pump	HTD2400	4	4	4	4	4
2.4	Cost	1,000VND	39,176,226	37,638,709	35,470,110	33,665,950	31,626,992
	Dig	1,000VND	1,225,260	1,178,020	1,111,111	1,054,491	989,323
	Earth	1,000VND	1,109,464	1,066,688	1,006,102	954,834	895,825
	Concrete	1,000VND	20,648,295	19,640,084	18,218,580	17,037,783	15,705,560
	Pump	1,000VND	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
	Construstion cost	1,000VND	27,983,019	26,884,792	25,335,793	24,047,107	22,590,708
	Compensation and resettlement	40% XL	11,193,207	10,753,917	10,134,317	9,618,843	9,036,283
	Cost/ha	1,000đ/ha	230,448	221,404	208,648	198,035	186,041
3	LONG XUYÊN 3	1,000VND	21,349,882	20,510,495	19,325,962	18,339,549	17,223,593
3.1	Dyke parametters						
	Length	m	3,480	3,480	3,480	3,480	3,480
	Surface elevation	(m)	1.50	1.50	1.50	1.50	1.50
	Crest elevation	m	3.97	3.90	3.80	3.71	3.61
	Heigth of dyke	m	2.47	2.40	2.30	2.21	2.11
	Cross section	m^2	23.97	23.05	21.74	20.63	19.36
	Earth volume	m^3	83,420	80,204	75,649	71,794	67,357
	Dig volume	m^3	100,104	96,245	90,778	86,152	80,828
3.2	Concrete	m^3	3,500	3,331	3,094	2,897	2,675
3.2.1	Retaining wall		1,950	1,825	1,651	1,509	1,350
	Length	m	780	780	780	780	780
	Road elevation	m	2.97	2.97	2.97	2.97	2.97
	Retainingwall ELV	m	3.97	3.90	3.80	3.71	3.61
	Heigth of retaing wall	m	1.00	0.93	0.83	0.74	0.64
	Cross section	m2	2.50	2.34	2.12	1.93	1.73
	Volume	m^3	1,950	1,825	1,651	1,509	1,350
3.2.2	Cover dyke slope		1,550	1,506	1,443	1,389	1,325
	Length	m	3,480	3,480	3,480	3,480	3,480
	Heigth of dyke	m	2.47	2.40	2.30	2.21	2.11
	Cross section	m^2	0.45	0.43	0.41	0.40	0.38
	Volume	m^3	1,550	1,506	1,443	1,389	1,325
3.3	Drainage pump						
	Areas	ha	76	76	76	76	76
	Number of pump	HTD2400	2	2	2	2	2
3.4	Cost	1,000VND	21,349,882	20,510,495	19,325,962	18,339,549	17,223,593
	Dig	1,000VND	711,837	684,392	645,520	612,626	574,766
	Earth	1,000VND	644,563	619,712	584,514	554,728	520,446
	Concrete	1,000VND	11,393,515	10,846,250	10,074,225	9,432,324	8,707,355
	Pump	1,000VND	2,500,000	2,500,000	2,500,000	2,500,000	2,500,000
	Construstion cost	1,000VND	15,249,916	14,650,354	13,804,259	13,099,678	12,302,566
	Compensation and resettlement	40% XL	6,099,966	5,860,141	5,521,704	5,239,871	4,921,027
	Cost/ha	1,000đ/ha	280,920	269,875	254,289	241,310	226,626

	Areas	Unit	Frequencies				
			1%	2%	5%	10%	20%
4	LONG XUYÊN 4	1,000VND	18,111,907	17,252,714	16,044,369	15,044,483	13,921,131
4.1	Dyke paramettersm						
	Length	m	2,150	2,150	2,150	2,150	2,150
	Surface elevation	(m)	1.50	1.50	1.50	1.50	1.50
	Crest elevation	m	3.97	3.90	3.80	3.71	3.61
	Heigth of dyke	m	2.47	2.40	2.30	2.21	2.11
	Cross section	m^2	23.97	23.05	21.74	20.63	19.36
	Earth volume	m^3	51,538	49,551	46,737	44,355	41,614
	Dig volume	m^3	61,846	59,462	56,084	53,226	49,937
4.2	Concrete	m^3	3,332	3,154	2,903	2,695	2,462
4.2.1	Retaining wall	m^3	2,375	2,223	2,011	1,837	1,644
	Length	m	950	950	950	950	950
	Road elevation	m	2.97	2.97	2.97	2.97	2.97
	Retainingwall ELV	m	3.97	3.90	3.80	3.71	3.61
	Heigth of retaing wall	m	1.00	0.93	0.83	0.74	0.64
	Cross section	m^2	2.50	2.34	2.12	1.93	1.73
	Volume	m^3	2,375	2,223	2,011	1,837	1,644
4.2.2	Cover dyke slope	m^3	957	930	892	858	818
	Length	m	2,150	2,150	2,150	2,150	2,150
	Heigth of dyke	m	2.47	2.40	2.30	2.21	2.11
	Cross section	m^2	0.45	0.43	0.41	0.40	0.38
	Volume	m3	957	930	892	858	818
4.3	Drainage pump						
	Areas	ha	55	55	55	55	55
	Number of pump	HTD2400	1	1	1	1	1
4.4	Cost	1,000VND	18,111,907	17,252,714	16,044,369	15,044,483	13,921,131
	Dig	1,000VND	439,784	422,828	398,813	378,490	355,099
	Earth	1,000VND	398,222	382,868	361,122	342,720	321,540
	Concrete	1,000VND	10,849,071	10,267,671	9,450,329	8,774,850	8,017,025
	Pump	1,000VND	1,250,000	1,250,000	1,250,000	1,250,000	1,250,000
	Construstion cost	1,000VND	12,937,077	12,323,367	11,460,264	10,746,060	9,943,665
	Compensation and resettlement	40% XL	5,174,831	4,929,347	4,584,106	4,298,424	3,977,466
	Cost/ha	1,000d/ha	329,307	313,686	291,716	273,536	253,111

	Areas	Unit			Frequencies		
			1%	2%	5%	10%	20%
II	VNĐỒNG THÁP	1,000VND	111,017,879	107,682,786	103,946,730	97,825,974	93,438,550
5	TAM NÔNG	1,000VND	47,112,411	46,100,619	45,596,859	42,110,423	40,637,600
1.1	Dyke paramettersLength						
	Length	m	7,980	7,980	7,980	7,980	7,980
	Surface elevation	(m)	1.50	1.50	1.50	1.50	1.50
	Crest elevation	m	5.80	5.70	5.65	5.30	5.15
	Heigth of dyke	m	4.30	4.20	4.15	3.80	3.65
	Cross section	m^2	53.54	51.66	50.73	44.46	41.88
	Earth volume	m^3	427,209	412,247	404,855	354,791	334,232
	Dig volume	m^3	512,651	494,696	485,826	425,749	401,079
1.2	Cover dyke slope		6,186	6,042	5,970	5,467	5,251
	Length	m	7,980	7,980	7,980	7,980	7,980
	Heigth of dyke	m	4.30	4.20	4.15	3.80	3.65
	Cross section	m^2	0.78	0.76	0.75	0.69	0.66
	Volume	m3	6,186	6,042	5,970	5,467	5,251
1.3	Drainage pump						
	Areas	ha	336	336	336	336	336
	Number of pump	HTD2400	5	5	5	5	5
1.4	Cost	1,000VND	47,112,411	46,100,619	45,596,859	42,110,423	40,637,600
	Dig	1,000VND	3,961,100	3,822,367	3,753,833	3,289,633	3,099,014
	Earth	1,000VND	3,300,916	3,185,306	3,128,194	2,741,361	2,582,512
	Concrete	1,000VND	20,139,706	19,671,341	19,437,158	17,797,880	17,095,332
	Pump	1,000VND	6,250,000	6,250,000	6,250,000	6,250,000	6,250,000
	Construstion cost	1,000VND	33,651,722	32,929,013	32,569,185	30,078,873	29,026,857
	Compensation and resettlement	40% XL	13,460,689	13,171,605	13,027,674	12,031,549	11,610,743
	Cost/ha	1,000d/ha	140,216	137,204	135,705	125,329	120,945
6	SA ĐÉC	1,000VND	63,905,468	61,582,167	58,349,871	55,715,551	52,800,950
6.1	Retaining wall						
6.1.1	Length	m	6,355	6,355	6,355	6,355	6,355
6.1.2	Road elevation	m	2.70	2.70	2.70	2.70	2.70
6.1.3	Retainingwall ELV	m	3.40	3.36	3.30	3.25	3.19
6.1.4	Heigth of retaing wall	m	0.70	0.66	0.60	0.55	0.50
6.1.5	Cross section	m^2	1.84	1.76	1.65	1.56	1.46
6.1.6	Volume	m^3	11,717	11,207	10,498	9,920	9,281
6.2	Pumping station						
	Areas	ha	370	370	370	370	370
	Number of pump	HTD2400	6	6	6	6	6
6.3	Kinh phí		63,905,468	61,582,167	58,349,871	55,715,551	52,800,950
	Concrete	1,000VND	38,146,763	36,487,262	34,178,479	32,296,822	30,214,964
	Pump	1,000VND	7,500,000	7,500,000	7,500,000	7,500,000	7,500,000
	Construstion cost	1,000VND	45,646,763	43,987,262	41,678,479	39,796,822	37,714,964
	Compensation and resettlement	40%XL	18,258,705	17,594,905	16,671,392	15,918,729	15,085,986
	Cost/ha	1,000VND/ha	172,717	166,438	157,702	150,583	142,705

	Areas	Unit			Frequencies		
			1%	2%	5%	10%	20%
7	CÁI BÈ						
7.1	Dyke parametters						
	Length	m	14,000	14,000	14,000	14,000	14,000
	Surface ELV	(m)	1.00	1.00	1.00	1.00	1.00
	Crest ELV	m	3.25	3.15	3.10	3.05	3.00
	Average cross section	m^2	8.52	7.67	7.25	6.84	6.44
	Earth volume	m^3	119,280	107,380	101,500	95,760	90,160
	Dig volume	m^3	143,136	128,856	121,800	114,912	108,192
7.2	Cost	1,000VND	2,838,652	2,555,453	2,415,520	2,278,918	2,145,648
	Earth	1,000VND	921,640	829,693	784,260	739,908	696,639
	Dig	1,000VND	1,105,968	995,631	941,112	887,890	835,967
	Construstion cost	1,000VND	2,027,609	1,825,324	1,725,371	1,627,799	1,532,606
	Compensation and resettlement	40%XL	811,043	730,130	690,148	651,119	613,042
	Cost/ha	1,000VND/ha	2,839	2,555	2,416	2,279	2,146
8	TÂN HỒNG						
8.1	Dyke parametters						
	Length	m	14,000	14,000	14,000	14,000	14,000
	Surface ELV	(m)	2.00	2.00	2.00	2.00	2.00
	Crest ELV	m	4.80	4.40	4.20	4.00	3.90
	Average cross section	m^2	13.26	9.34	7.59	5.93	5.15
	Earth volume	m^3	185,640	130,760	106,260	83,020	72,100
	Dig volume	m^3	222,768	156,912	127,512	99,624	86,520
	Cost	1,000VND	4,417,902	3,111,856	2,528,799	1,975,729	1,715,852
	Earth	1,000VND	1,434,384	1,010,343	821,039	641,470	557,095
	Dig	1,000VND	1,721,261	1,212,411	985,246	769,764	668,514
	Construstion cost	1,000VND	3,155,644	2,222,754	1,806,285	1,411,235	1,225,609
	Compensation and resettlement	40%XL	1,262,258	889,102	722,514	564,494	490,243
	Cost/ha	1,000VND/ha	4,418	3,112	2,529	1,976	1,716
9	CHÂU PHÚ						
9.1	Dyke parametters						
	Length	m	14,000	14,000	14,000	14,000	14,000
	Surface ELV	(m)	1.50	1.50	1.50	1.50	1.50
	Crest ELV	m	3.70	3.40	3.20	3.10	3.00
	Average cross section	m^2	9.46	7.03	5.56	4.86	4.2
	Earth volume	m^3	132,440	98,420	77,840	68,040	58,800
	Dig volume	m^3	158,928	118,104	93,408	81,648	70,560
	Cost	1,000VND	3,151,837	2,342,221	1,852,454	1,619,231	1,399,336
	Earth	1,000VND	1,023,324	760,461	601,446	525,724	454,330
	Dig	1,000VND	1,227,988	912,554	721,735	630,869	545,196
	Construstion cost	1,000VND	2,251,312	1,673,015	1,323,181	1,156,594	999,525
	Compensation and resettlement	40%XL	900,525	669,206	529,272	462,637	399,810
	Cost/ha	1,000VND/ha	3,152	2,342	1,852	1,619	1,399

Total volumes of works at Hpmax frequency

	Vùng bao	Unit	Frequency Hmax				
			1%	2%	5%	10%	20%
1	Long Xuyen City	m^3	714,929	687,127	647,758	614,466	576,178
1.1	Earth	m^3	368,440	354,234	334,115	317,089	297,493
1.2	Dig	m^3	442,128	425,081	400,937	380,507	356,991
1.3	Concrete	m^3	21,069	19,968	18,419	17,138	15,698
1.4	Pump HTD 2400	no.	11	11	11	11	11
1.1	LX 1						
1.1.1	Earth	m^3	89,893	86,427	81,518	77,364	72,583
1.1.2	Dig	m^3	107,871	103,712	97,821	92,837	87,099
1.1.3	Concrete	m^3	7,895	7,450	6,826	6,312	5,737
1.1.4	Pump HTD 2400	no.	4	4	4	4	4
1.2	LX 2						
1.2.1	Earth	m^3	143,588	138,052	130,211	123,576	115,939
1.2.2	Dig	m^3	172,306	165,663	156,253	148,291	139,127
1.2.3	Concrete	m^3	6,342	6,033	5,596	5,233	4,824
1.2.4	Pump HTD 2400	no.	4	4	4	4	4
1.3	LX 3						
1.3.1	Earth	m^3	83,420	80,204	75,649	71,794	67,357
1.3.2	Dig	m^3	100,104	96,245	90,778	86,152	80,828
1.3.3	Concrete	m^3	3,500	3,331	3,094	2,897	2,675
1.3.4	Pump HTD 2400	no.	2	2	2	2	2
1.4	LX 4						
1.4.1	Earth	m^3	51,538	49,551	46,737	44,355	41,614
1.4.2	Dig	m^3	61,846	59,462	56,084	53,226	49,937
1.4.3	Concrete	m^3	3,332	3,154	2,903	2,695	2,462
1.4.4	Pump HTD 2400	no.	1	1	1	1	1
2	Tam Nông						
2.1	Earth	m^3	427,209	412,247	404,855	354,791	334,232
2.2	Dig	m^3	512,651	494,696	485,826	425,749	401,079
2.3	Concrete	m^3	6,186	6,042	5,970	5,467	5,251
2.4	Pump HTD 2400	no.	5	5	5	5	5
3	Sa Déc						
3.1	Earth	m^3	-	-	-	-	-
3.2	Dig	m^3	-	-	-	-	-
3.3	Concrete	m^3	11,717	11,207	10,498	9,920	9,281
3.4	Pump HTD 2400	no.	6	6	6	6	6
4	Cái bè						
4.1	Earth	m^3	119,280	107,380	101,500	95,760	90,160
4.2	Dig	m^3	143,136	128,856	121,800	114,912	108,192
4.3	Concrete	m^3	-	-	-	-	-
5	Tân Hồng						
5.1	Earth	m^3	185,640	130,760	106,260	83,020	72,100
5.2	Dig	m^3	222,768	156,912	127,512	99,624	86,520
5.3	Concrete	m^3	-	-	-	-	-
6	Châu Phú						
6.1	Earth	m^3	132,440	98,420	77,840	68,040	58,800
6.2	Dig	m^3	158,928	118,104	93,408	81,648	70,560
6.3	Concrete	m^3	-	-	-	-	-

Investment cost for sample areas correlative with frequencies

	Areas	Unit	Frequencies				
			1%	2%	5%	10%	20%
1	Tp. Long xuyên	1,000VND	123,668,391	118,327,568	110,810,510	104,581,205	97,571,450
1.1	*LX 1*	*1,000VND*	*45,030,375*	*42,925,650*	*39,970,068*	*37,531,222*	*34,799,735*
1.2	*LX 2*	*1,000VND*	*39,176,226*	*37,638,709*	*35,470,110*	*33,665,950*	*31,626,992*
1.3	*LX 3*	*1,000VND*	*21,349,882*	*20,510,495*	*19,325,962*	*18,339,549*	*17,223,593*
1.4	*LX 4*	*1,000VND*	*18,111,907*	*17,252,714*	*16,044,369*	*15,044,483*	*13,921,131*
2	Tam Nông	1,000VND	47,112,411	46,100,619	45,596,859	42,110,423	40,637,600
3	Sa Déc	1,000VND	63,905,468	61,582,167	58,349,871	55,715,551	52,800,950
4	Cái bè	1,000VND	2,838,652	2,555,453	2,415,520	2,278,918	2,145,648
5	Tân Hồng	1,000VND	4,417,902	3,111,856	2,528,799	1,975,729	1,715,852
6	Châu Phú	1,000VND	3,151,837	2,342,221	1,852,454	1,619,231	1,399,336

Unit investment cost correlative with frequencies

	Vùng	Unit	Frequencies				
			1%	2%	5%	10%	20%
1	TP.Long Xuyên	1,000VND/ha	247,832	237,129	222,065	209,582	195,534
1.1	*LX1*	*1,000VND/ha*	*227,426*	*216,796*	*201,869*	*189,552*	*175,756*
1.2	*LX2*	*1,000VND/ha*	*230,448*	*221,404*	*208,648*	*198,035*	*186,041*
1.3	*LX3*	*1,000VND/ha*	*280,920*	*269,875*	*254,289*	*241,310*	*226,626*
1.4	*LX4*	*1,000VND/ha*	*329,307*	*313,686*	*291,716*	*273,536*	*253,111*
2	Tam Nông	1,000d/ha	140,216	137,204	135,705	125,329	120,945
3	Sa Déc	1,000VND/ha	172,717	166,438	157,702	150,583	142,705
4	Cái bè	1,000VND/ha	2,839	2,555	2,416	2,279	2,146
5	Tân Hồng	1,000VND/ha	4,418	3,112	2,529	1,976	1,716
6	Châu Phú	1,000VND/ha	3,152	2,342	1,852	1,619	1,399
1	TP.Long Xuyên	USD/ha	14,578	13,949	13,063	12,328	11,502
1.1	*LX1*	*USD/ha*	*13,378*	*12,753*	*11,875*	*11,150*	*10,339*
1.2	*LX2*	*USD/ha*	*13,556*	*13,024*	*12,273*	*11,649*	*10,944*
1.3	*LX3*	*USD/ha*	*16,525*	*15,875*	*14,958*	*14,195*	*13,331*
1.4	*LX4*	*USD/ha*	*19,371*	*18,452*	*17,160*	*16,090*	*14,889*
2	Tam Nông	USD/ha	8,248	8,071	7,983	7,372	7,114
3	Sa Déc	USD/ha	10,160	9,790	9,277	8,858	8,394
4	Cái bè	USD/ha	167	150	142	134	126
5	Tân Hồng	USD/ha	260	183	149	116	101
6	Châu Phú	USD/ha	185	138	109	95	82

Mekong River Commission
www.mrcmekong.org

Office of the Secretariat in Phnom Penh (OSP)
576 National Road, #2, Chak Angre Krom,
P.O. Box 623, Phnom Penh, Cambodia
Tel: (855-23) 425 353.
Fax: (855-23) 425 363

Office of the Secretariat in Vientiane (OSV)
Office of the Chief Executive Officer
184 Fa Ngoum Road,
P.O. Box 6101, Vientiane, Lao PDR
Tel: (856-21) 263 263.
Fax: (856-21) 263 264

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