Hợp tác Đức
DEUTSCHE ZUSAMMENARBEIT

Co-financed by
Australian Aid

ICMP

DIKE SURVEY REPORT
Results of an initial dike inspection in the Ca Mau Province

Published by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Published by
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany

Integrated Coastal Management Programme (ICMP)

9th floor, the Landmark, 5B, Ton Duc Thang, Dist 1,
Ho Chi Minh City, Viet Nam
T + 84 838239811
F + 84 838239813
I www.giz.de/viet-nam
http://daln.gov.vn/icmp-cccep.html

As at
January 2014

Author
Babette Scheres

Editing
Stefan Groenewold

Printing

Graphic & Design
Golden Sky Co.,ltd
5th Floor, No. 06 Nguyen Cong Tru St., Hanoi., Vietnam

Photo credits
© GIZ

On behalf of
German Federal Ministry for Economic Cooperation and Development (BMZ) and Australian Government Department of Foreign Affair and Trade (DFAT)

Publishing licence number: No:..1871-2015/CXBIPH/25-154/LĐ and 698/QĐ-NXBLĐ issue on 15 July 2015

DIKE SURVEY REPORT
Results of an Initial Dike Inspection in the Ca Mau Province

GIZ in Vietnam

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH has been working in Viet Nam for more than 20 years. We currently have around 250 specialised staff deployed across the country, including national and international personnel, Development Advisors and CIM experts.

On behalf of the German Government, GIZ provides advisory services to the Government of Viet Nam and is currently engaged in three priority areas: (i) Vocational training; (ii) Environmental policy and sustainable natural resource use; and (iii) Energy.

GIZ Viet Nam's main commissioning party is the German Federal Ministry for Economic Cooperation and Development (BMZ). Other commissions come from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry of Finance (BMF). GIZ Viet Nam is also engaged in various projects co-funded by the Australian Government (Department of Foreign Affairs and Trade – DFAT) and the European Union and cooperates closely with the German development bank KfW.

The Integrated Coastal Management Programme (ICMP) is being co-financed by the German and Australian Governments. In order to strengthen resilience and to reduce vulnerabilities to climate change impacts, the ICMP Programme supports Viet Nam in sustainably managing coastal ecosystems of the Mekong Delta affected by climate change. The Programme is being implemented by GIZ in close collaboration with the Ministry of Agriculture and Rural Development (MARD), as well as several departments of the five programme provinces An Giang, Bac Lieu, Ca Mau, Kien Giang and Soc Trang of the Mekong Delta.

For further information, please visit www.giz.de/viet-nam, and http://daln.gov.vn/icmp-cccep.html.

Contents

List of Figures

List of Tables

01 Introduction

Due to its geographical boundary conditions, Cà Mau province, the southernmost province of Vietnam, is regarded to be extremely vulnerable to climate change, especially to the impacts of sea level rise. The province is in the East, South and West surrounded by the sea (West Sea and East Sea) resulting in a coastline of 254 km in total. 87 estuaries are leading to the sea including 7 major estuaries (Ganh Hao, Bo De, Rach Goc, Ong Trang, Cai Doi Vam, Song Doc, Khanh Hoi). Altogether over 10.000 km of river, ditches and channels exist that are influenced by the tides of the East and West Sea. Furthermore, the whole province lies only a few meters above sea level; large parts even only 1 or 2 m above sea level. The combination of these and further facts result in a great vulnerability of the Cà Mau province against climate change.

The sea dike system of the Cà Mau province is projected to consist of two sections – the East-Sea dike and the West-Sea dike. The project to build the East-Sea dike (from Ganh Hao river to Bay Hap river) has been approved and currently the site clearance takes place. A total dike length of 76 km with a dike crest height of 3.20 m is aimed at. The West-Sea dike has been constructed years ago. A current project works on upgrading the dike and is in the site clearance planning phase. As defined in the project, the West-Sea dike reaches from the Bay Hap river to the Tieu Dua river with a total dike length of 108 km and a planned dike crest height of 3.00 m.

Besides the sea dike system, the Cà Mau province has three grades of river dikes: River dikes at large rivers that are funded by the government, river dikes at smaller channels owned by the districts/communes and private embankments at the rivers to protect aquaculture farms. In this report, only the river dikes nearby the Song Cua Lon channel are discussed.

Strong winds and big waves caused by storms and tropical depressions lead to severe erosion of the protection forests in front of the sea dikes or, if the protection forest is already not able to fulfill its task, to erosion of the dike. Additionally, further factors, such as human impacts or vegetation on the dike, can be a threat to the dike system.

Yet, no map of the current dike system of the Cà Mau province exists and the exact position of existing dikes (GPS-based) is not available. Furthermore, the status and condition of the dikes is often unclear or not documented. To improve this situation and to provide information that are necessary for the prioritization of dike enhancements and dike constructions, a method to inspect the dikes of the Cà Mau province was developed and applied at several sites. The approach of the developed dike inspection and results of an initial dike inspection are presented in the following.


TONS/FT² & KG/CM²
POCKET PENETROMETER
CL-700
SOILTEST INC.

02 Approach and method of the initial dike inspection

2.1 The method in general

On the purpose of analyzing the current status of the dike system in the Cà Mau province, a simple, but efficient dike inspection method had to be developed. Main features of this inspection method had to be:

- Collect relevant information on the geometry and condition of existing dikes
- Quick, simple and cost-effective
- Easy to learn, also for staff without much technical expertise
- Adapted to the circumstances in the Cà Mau province

Finally, an approach was worked out that helps to get an overview of the dike system by considering the following facts:

- At the moment the dike system in the Cà Mau province cannot be divided into sections as its characteristics change at least every few hundred meters
- Yet the dikes are not repaired and maintained on a regular basis and smaller damages or further threats (break outs, diggings) can be found every few meters. Especially erosion damages and plants are not only scattered on the dike, but continue over longer distances.

For these reasons an inspection method was developed that consists of investigations of the dike in pre-defined distances using check-lists. A dike inspection, during which every single observation is reported on, is actually not feasible and not recommended for the Cà Mau province considering the current status of the dike system.

The developed dike inspection method includes visual analyses of the dike and the documentation of their results, photo documentations and geological field tests. The approach is easy to learn and

practice, also for staff without much technical knowledge or experience. Three different report forms exist that are used to analyze and assess the dike system:

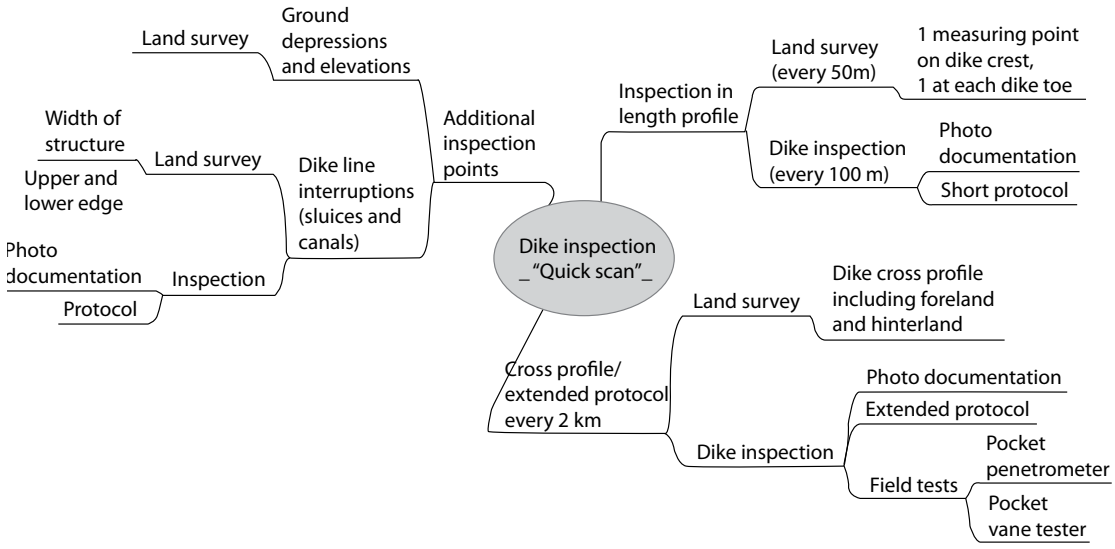
- Dike inspection report – cross profile report (every 2km) [see Annex A]
- Dike inspection report – short protocol (every 100m) [see Annex B]
- Dike inspection report – dike line interruptions [see Annex C]

These report forms include general information on the survey conditions and survey team, check-lists that help to assess and report on the dike condition, the documentation of field test results (only in the cross profile report) and further observations or remarks. They are used in the field combined with a photograph documentation. A digitalization of the results is aimed at by means of incorporating the results into GIS and creating maps of e.g. dike erosion or vegetation hot spots.

2.2 Details on how to conduct the dike inspection

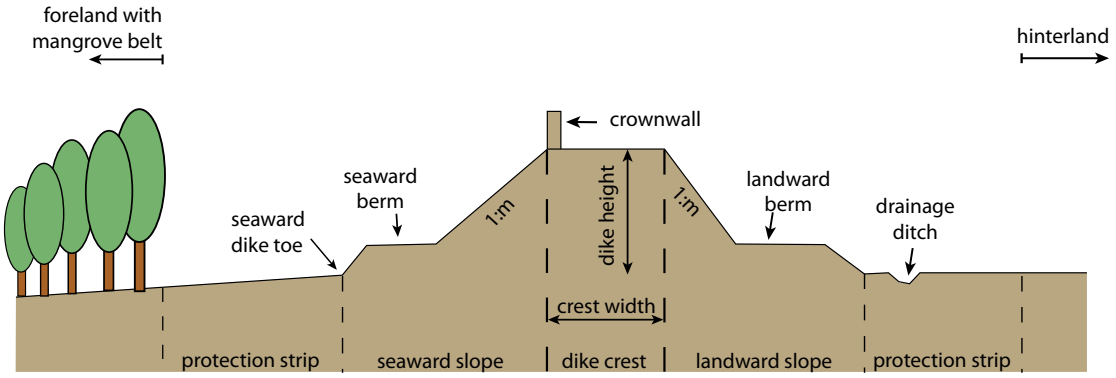
The short protocol is filled out every 100 m, the cross profile report every 2 km. The report form for dike line interruptions is e.g. used in the case of sluice gates or open channels. The choice of this approach is linked to the topographic dike survey that was planned for the near future. According to the national Vietnamese standards TCVN 8481:2010 "Dyke work – Demand for element and volume of topographic survey", a topographic survey of the dike system consists of a cross profile every 2 km and 3 additional survey points every 50 m (one on the dike crest, one at each dike toe). Adapting the dike inspection method to these standards allows combining the dike inspection with the topographic survey. A short protocol has been chosen for survey points every 100 m and a detailed report form for the cross profiles in order to adapt the expenditure of inspection time to the terrestrial survey. Figure 1 illustrates the structure of the developed dike inspection method.

Figure 1: Structure of the dike inspection method



In the following, more detailed explanations referring to the inspection report forms are given. Relevant definitions and terms used for the dike inspection are illustrated in Figure 2.

Figure 2: Definitions and terms for the dike inspection



Necessary devices for the dike inspection are: GPS instruments, a camera (if possible with GPS), a measuring tape, pocket penetrometer and pocket vane tester, a shovel, dike survey protocols (3 types), spare paper and pens.

2.2.1 General information and inspection conditions

Each protocol form includes the general information and inspection conditions. This section helps to document:

- the surveyor's name(s) and the institution/function of the surveyor(s) in case of questions afterwards
- the date and time of the inspection (important to match the photos if they are mixed up), the number of the protocol

- the geographical position of the site: GPS data central on the dike crest e.g. 8°55'10"N, 105°22'32"E or UTM format 541288.18, 985967.18; The coordinates are given in WGS84, UTM Zone 48N (EPSG: 32648)
- the weather during the inspection at this position (only in cross profile report); important as the weather might influence the field tests
- whether site photos are taken or not as a reminder to complete the photograph documentation

The very first photo should show the GPS instrument giving the actual GPS position to facilitate the correlation of photos afterwards. Further photos should be taken in the middle of the dike crest towards each direction, i.e. starting with the view towards the sea and then continuing clock-wise with a photo shot after each 90° rotation. Consequently, 5 photos will be taken per site. Try to avoid people on the photos. The photograph documentation allows to have a look at the visited site afterwards and check on e.g. the extent of vegetation. For dike line interruptions (sluice gates, open channels) two photos should be taken (see for example Figure 16): one towards the sea (i.e. behind the structure), one towards the hinterland (i.e. the front of the structure). All photos should be taken without using the zoom.

2.2.2 Visual assessment (short and cross profile report)

Relevant basic information on the dike condition and the dike's surroundings are collected within the visual assessment. A check-list leads the survey team through the different points that have to be analyzed. To avoid missing observations, the dike crest, dike slopes and transitions should be analyzed by looking at each part in detail (avoid to stand only in the middle of the dike crest!). No evaluation of damages is included in the report forms as professional knowledge and experience is required to complete the task of e.g. assessing the hazard of existing cracks or erosion. The following aspects are analyzed on existence and their position is documented:

- Erosion/break outs (cf. Figure 4 and Figure 20): Erosion and break outs may occur on the seaward slope as well as on the dike crest or landward dike slope. They can have different reasons such as erosion due to rain or floods or break outs due to uprooted trees or dike instabilities.
- Plants growing in/on the dike (cf. Figure 28): Plants can have negative influences on the dike stability and their presence on the dike should be assessed critically. All plants (trees, bushes, flowers, high grass, … except for short grass and small intermixed weeds) should be reported on.
- Roots in the dike material (only in cross profile report): Roots in the dike material can best be observed in fresh break outs or diggings (e.g. in the small excavations created for the field tests)
- Animal borrowing: Animals, such as rats, may borrow into the dike, dig holes and that way decrease the dike stability. A detailed check of the whole dike is necessary to detect animal borrowing.
- Dike cover/revetment (cf. Figure 3): Common dike covers are e.g. rubble mound layers and concrete or steel slabs. Also maintained grass protects the dike from erosion and is defined as a dike cover/revetment.
- Toe protection (cf. Figure 4): e.g. rip rap covering, wood pilling or emergency repair with plastic pilling
- Structure on the dike crest (only in cross profile report): e.g. crownwall
- Trench parallel to the dike (cf. Figure 15 right): Taking material from the foreland to construct the dike often leads to a trench parallel to the dike. Erosion effects can be increased due to this trench.
- Use of the dike: as a road, for houses or other uses
- Land in front of dike: mangroves, bare land, houses, aquaculture or other uses
- Unauthorized human impacts: private plantations, diggings or other impacts

Furthermore, the following geometrical values are measured/estimated:

- Dike crest width: measured with a measuring tape
- Distance between seaward dike toe and mangrove belt (only in cross profile report): estimated
- Distance between landward dike toe and land use (only in cross profile report): estimated

Figure 3: Highly damaged dike revetment (left) and dike revetment with concrete slabs (right) [Heiland & Schüttrumpf, 2009]

Figure 4: Toe protection with wood pilling. Yellow arrow: Gap in revetment due to further erosion [Albers & Von Lieberman, 2011]

2.2.3 Dike material – field tests (cross profile report)

Every 2 km (so for each cross profile report) field tests should be performed to determine soil-mechanical parameters of the dike material and receive information about its strength. The pocket penetrometer and pocket vane tester are used for these tests. The tests shall be conducted on the dike crest or, if not possible there, on the landward dike slope. Choose the measuring position with care to avoid gravel or other disturbed areas that would influence the measurement. Measurements have to be conducted in „fresh" samples or cut surfaces as the drying of the soil will influence the results, i.e. dig a hole of at least 10 cm depth if there are no fresh break outs. The test area has to be smooth. After the inspection, close and compact all holes created.

Pocket penetrometer tests (determination of the unconfined compression strength [kg/cm^2]): Move the red reading ring back to the position against the penetrometer body (towards the lowest reading on the scale). Hold the device firmly and push it with a smooth constant force into the soil up to the calibration groove which is located 6.35 mm (¼") from the tip. Read the unconfined compression strength [kg/cm^2] directly on the lower load side of the red ring closest to the top of the handle.

Pocket vane tester (determination of the shear strength [kg/cm^2]): Move the pointer counter-clockwise to zero to reset the device. Choose a reasonably flat surface (at least 25 mm in diameter). Use the large vane (0.2 kg/cm^2) for e.g. pliable/soft samples, the small vane (2.5 kg/cm^2) for stiff clays or similar. Push the vane vertically into the soil to the depth of the blade. Rotate it clockwise with a constant vertical pressure so that the failure occurs within 5 to 10 seconds (vane keeps on rotating as the soil fails). Take care that the pointer is not influenced by your rotation. Take the reading value from the pointer (the pointer will remain in the measuring position until it is manually repositioned). The shear strength [kg/cm^2] is determined with conversion charts given enclosed to the measuring device. Note down the adapter no., reading value and shear strength.

Figure 5: Pocket vane tester with adapter CL 102 (left) and pocket penetrometer (right)

2.2.4 Dike line interruptions

Dike line interruptions can be weak points of the dike system and need special attention. Most common dike line interruptions in the Cà Mau province are sluice gates and open channels. For the purpose of mapping the dike system, the position and condition of dike line interruptions is of interest. Therefore, the dike inspection includes one report form to collect information on dike line interruptions. This report form distinguishes between installations in/on the dike and open canals through the dike and includes the following points to check on:

For installations in/on the dike:

- type: sluices, outlets, pumping stations, ...
- width of installation: measured
- visible damages?
- visible scour holes?
- channel exit berm strongly eroded?
- protection measures installed?

For open canals through the dike:

- width of canal: estimated
- channel exit berm strongly eroded?
- protection measures installed?

2.2.5 Further observations/remarks

A section for further observations and remarks is included in each protocol. There relevant information about the dike and its surroundings that are not covered by the protocol should be noted down, such as

- erosion or vegetation patterns, potential uprooting
- specifications on the use of the dike or foreland (e.g. aquaculture embankment on top of the dike)
- if the trench in front of the dike is used as a canal or for aquaculture
- assessments of the dike material (finger test, observed cracks and their depth, …)
- information received by local people
- problems during the dike inspection (e.g. reasons if field tests were not possible, if the dike crest width could not be measured, …)

03 Initial dike inspection in Cà Mau Province and its results

Several sites of the Cà Mau province were visited to carry out an initial dike inspection and to use the dike inspection method presented in chapter 2 where possible. Table 1 gives an overview of the visited areas, the date and participants. A map with marks of the visited sites is given in Annex D.

Table 1: Sites of the initial dike inspection in the Cà Mau province

District	Commune	Date	Protocol number(s)	Participants
District	Commune	Date	Protocol number(s)	Participants
U Minh	Khanh Tien	27.11.2013	-	SIWRP, SubFipi, DARD, GIZ Cà Mau
Dam Doi	Nguyen Huan	02.01.2014	-	DARD , GIZ Cà Mau
Nam Can	Lam Hai	03.01.2014	#1 - #4	DARD[1], GIZ Cà Mau
	Tam Giang	03.01.2014	#5 - #12	DARD[1], GIZ Cà Mau
	Dat Moi	03.01.2014	-	DARD[1], GIZ Cà Mau
Tran Van Thoi	Song Doc	06.01.2014	#1 - #6	DARD[1], GIZ Cà Mau
Phu Tan	Cai Doi Vam	06.01.2014	#7 - #10	DARD[1], GIZ Cà Mau
Tran Van Thoi	Khanh Binh Tay	20.01.2014	#1 - #6	DARD[2] , GIZ Cà Mau

[1] Mr. Thoi (Technician of Dike Management Unit – Irrigation Branch), Mr. Dien (Technician of Irrigation Branch)
[2] Mr. Dien (Technician of Irrigation Branch)

The visited sites and results from the dike inspection are described in the following sections. The results in form of reports (cf. Annex A to C) have been digitalized using Microsoft Excel tables including the exact GPS-positions of the sites. The photograph documentation has been post-processed and stored with regard to the protocol number. An incorporation of the results into GIS is aimed at.

3.1 U Minh district (Khanh Tien commune) - dike survey on 27.11.2013

The visited dike section in the Khanh Tien commune lies a bit northern of Hoang Mai and is part of the West-Sea dike. The dike inspection of this site was carried out with a larger team including a land survey team and technicians to take soil samplings. Figure 6 (left) pictures the dike. The dike crest is not paved or covered with grass/plants. Vegetation can be found on the seaward and landward dike slope and trees exist at the transition from the slopes to the dike crest. In front of the dike one can see scattered households and a big trench that was created due to the excavation of dike material and is now used as a channel for boats (see Figure 6 right). A mangrove forest exists between this trench and the sea. The hinterland is used by private aquaculture farms that lie directly at the toe of the dike.

Figure 6: View along the dike (left) and dike foreland (right)

Following the dike line a few hundred meters, the dike's appearance changes and becomes less ordered (see Figure 7). There, vegetation can also be found on the dike crest and the transition from the dike crest to the slopes is harder to define.

Figure 7: View along the dike

The terrestrial survey was carried out according to Vietnamese national standards by a land surveyor and assistants. The cross-profile of the inspected site was measured. A nearby national benchmark helped to refer the measured elevations to the reference height. Furthermore, dike material samplings were taken to analyze those in the laboratory according to Vietnamese national standards. Figure 8 shows the land survey of the cross-profile (left) and the process of taking a soil sampling (right). First results of the terrestrial survey illustrated that the dike crest settled for about 1 m (design height was 2.5 m, now the dike crest lies at about 1.5 m). The detailed results are presented in the related report of the Southern Institute for Water Resources Planning (SIWRP). A finger test on the dike material has been carried out by an expert and showed that proper material was used for the dike construction (appropriate mixture of clay, silt and sand). The exact grain size distribution and further soil-mechanical parameters, such as the Atterberg limits of dry density, are given in the report of SIWRP.

Figure 8: Land survey (left) and soil sampling (right)

Besides the described dike section, a sluice gate closing the channel R. Huong Mai was visited (see Figure 9 left). This sluice gate is connected to the dike line and therefore helps to protect the hinterland from floods. However, the dike section next to the sluice has settled so that water flowed over the dike during recent times (see SIWRP report for the results of the terrestrial survey around the sluice gate). A new sluice gate is under construction more inland (see Figure 9 right). This sluice gate is not connected to the dike line yet.

Figure 9: Sluice gate connected to the dike line (left) and sluice gate further inland (right)

3.2 Dam Doi district (Nguyen Huan commune at border to Tam Giang Dong commune) - dike survey on 02.01.2014

No sea dike exists in the Dam Doi district yet. A wide mangrove belt (about 3 km) that is zoned into protected mangroves (aquaculture and harvesting permitted) and critical mangroves (no people living, harvesting forbidden) can be found. The border between both zones is marked by milestones (ca. every 500 m, picture see Figure 10 left, GPS data and a map available at DARD). About 1 km of mangrove forest is in front of the milestone line. It is suggested to build a dike inland from the milestone line; the cutting of the mangroves that exist there would be accepted. Dike construction material would be taken from nearby areas (e.g. dried soil from dredging channels). The milestone line is covered by mangroves and hard to access; further investigations (especially field tests) will not give much more information at the moment or may not be possible.

Figure 10: Milestone at N 08°49'38.6" E 105°18'37.0" (left) and view along milestone line (right)

A hydraulic construction in front of the protection forest is aimed at by DARD to prevent erosion and support mangrove rehabilitation. Still, a lot of cutting takes place in the mangroves. Floods occur regularly (approx. 2 times a year).

Nearby the visited site, an open channel (Song Ho Gui) with a width of more than 20 m can be found (see Figure 11). As there is no sluice gate closing this channel, a flood could move inlands unhindered even if a dike existed.

Figure 11: Estuary of Song Ho Gui (open channel) leading to the sea

3.3 Nam Can district – River dikes (Tam Giang, Dat Moi and Lam Hai commune)

3.3.1 Lam Hai commune (dike survey 03.01.2014 #1 - #4)

In a distance of 200 to 300 m from the channel Song Cua Lon, the river dike in the Lam Hai commune can be found nearby the bridge that is momentarily constructed to connect Ngoc Hien with the rest of the Cà Mau province. In some parts much vegetation can be found on the dike crest (see Figure 12); in other parts aquaculture embankments cover the dike crest (see Figure 13 right). A trench (not used) exists in front of the dike, followed by mangroves (see Figure 13 left).

Figure 12: View along the dike line (03.01.2014 #2)

Figure 13: View from the dike crest towards the channel Song Cua Lon (left) and view along the dike line (right) (03.01.2014 #4)

The dike shows very steep slopes as a result of erosion. Embankments that were constructed on top of the dike are not compacted and show very deep cracks (at least up to 30 cm). The material consists of blackish silty clay with many roots in it. No people are living in front of the dike. Aquaculture ponds exist directly behind the dike. There are no sluice gates of the aquaculture farms interrupting the dike line as these are built towards another smaller channel in the hinterland. Towards the bridge, the dike is under construction and enhanced to build a street on top of the dike (see Figure 14).

Figure 14: Dike construction works nearby the bridge to build a road on the dike

3.3.2 Tam Giang commune (dike survey 03.01.2014 #5 - #12)

An about 7 – 8 km long river dike exists in the Tam Giang province. This dike's geometry differs a lot from one survey position to the next due to the influence and impact of human activities (see Figure 15). Single plants cover the dike slopes, especially at the transition to the aquaculture ponds. A trench can be found in front of the dike due to excavated soil material, partly filled with water, partly without. For the purpose of aqua farming, the dike toe was stabilized with wood pilings on a small section of the visited site (cf. Figure 15 right).

Figure 15: View along the dike line (03.01.2014 #10 left and #12 right)

People are living in front of the dike next to the channel Song Cua Lon. The distance between the dike and the channel is about 50m and a small mangrove strip exists. The hinterland is used by aquaculture.

The dike line is often interrupted by sluice gates from adjoining aquaculture farms. Due to the more seaward construction of these sluice gates, the dike line meanders. Existing sluice gates do not show major damages, but the channel exits are affected by erosion and scour holes can be found.

Figure 16: Sluice gate photographed from front (left) and back (right) (03.01.2014 #9)

3.3.3 Dat Moi commune (dike survey 03.01.2014)

Yet no river dike has been built in the Dat Moi commune. However, construction preparations were undertaken by placing milestones ca. every 300 m. Some of these milestones are now already partly covered by constructions of the local people (see Figure 17 left). The distance between the channel and milestones is about 50 to 100 m. It is planned to build a dike along the milestones. The line of milestones leads through aquaculture ponds, houses and further obstacles (see Figure 17).

Figure 17: Milestone at N 08°45'18.1" E 104°57'09.2" and surroundings houses (left), nearby aquaculture farms (right)

Several houses, a school and an embankment with a small road on top can be found in front of the milestone line. The embankment with the road on top (see Figure 18) was built closer to the channel and is not planned to be increased due to too high costs and the destruction of the road system. Furthermore, the dike is planned to be constructed more inland to consider the occurrence of erosion.

Figure 18: Embankment with road in front of the milestone line next to the channel

3.4 Tran Van Thoi district (Song Doc and Khanh Binh Tay commune)

3.4.1 Song Doc commune - dike survey 06.01.2014 #1 - #6

The visited dike section in the Tran Van Thoi commune was built in 1997 (information given by local people) and is part of the 90 km long West-Sea Dike. Due to a quite clear structure of the dike elements, the dike crest and dike slopes can be identified in general (see Figure 19). In average, the dike crest is between 5.50 to 6.50 m wide and used as a road for motorbikes and pedestrians. Single small buildings can be found on the dike crest and/or seaward slope. Inland households of local people adjoin directly to the dike or are built on the former landward dike slope. Partly it seems as if dike material was excavated to use it for private purposes. Many trees can be found on the dike slopes and the transition to the dike crest, which were planted during a previous project in order to prevent erosion.

Figure 19: View along the dike line (06.01.2014 #1 left and #5 right)

Although this site is not influenced by floods yet, the dike is eroding a lot due to rainfalls that wash away the dike material. Consequently, huge erosion can be found especially between the trees on the dike slopes. Furthermore, the roots of the trees have become visible and the stability of the trees decreased. Big break outs on the dike slopes can already be found, most probably as a result of fallen trees (see Figure 20).

Figure 20: Tree on dike slope with exposed roots (left) and break out on dike slope (right)

About 1 km of critical mangrove forest can be found in front of the dike at the visited site. Further north the mangrove belt is narrowed down; only a few meters of mangrove forest exist 5 km northern (information given by local people). Dike material was excavated from the seaside which resulted in a big trench in front of the dike. This trench is now used for aquaculture (see Figure 21).

Figure 21: Aquaculture pond and mangrove belt in front of the dike

The dike material consists mostly of very compacted silt and brownish clay with many roots in it. Cracks with a depth of about 2 cm were found on the dike crest. Besides missing erosion protection and an increased risk of dike failure due to trees on the dike, this part of the dike is especially endangered by human impacts and the lack of maintenance/repair.

Towards the channel Song Ong Doc, that interrupts the dike line, the dike ends all at once leaving houses and people next to it without any flood protection (see Figure 22).

Figure 22: End of the dike (left) and house without flood protection (right)

3.4.2 Khanh Binh Tay commune - dike survey 20.01.2014 #1 - #6

In the Khanh Binh Tay commune near the Hon Da Bac island, a 1.2 km long dike with convex corners in the dike line (bend to the seaside) can be found. Construction works of this dike section began in 2009 according to the design plans and were finished at the end of 2011. The seaward dike slope as well as the dike crest and landward slope are covered with interlocking concrete slabs which were produced by a factory in the Cà Mau province. Additives to make the concrete resistant against saline influences were used. The dike shows regular slopes, respectively a stepped slope in some parts, and a seaward berm in cross-profile. Figure 23 pictures the existing dike.

Figure 23: View along the dike line (20.01.2014 #2 left and #4 right)

A seaward toe protection has been constructed and furthermore a breakwater in form of concrete piles and gabions was installed in front of the dike to decrease the forces of incoming waves (see Figure 24).

Figure 24: View towards the sea (20.01.2014 #3)

In order to increase the friction and consequently increase the wave energy loss during wave run-up on the seaward dike slope, different kinds of concrete slabs were used for the dike construction: Compared to the concrete slabs that are used for the dike crest and landward slope, the concrete slabs for the seaward slope show additional roughness elements (see Figure 25 left). Some slabs of the seaward slope are already missing these additional roughness elements (see Figure 25 right). It is assumed that the concrete slabs with missing additional roughness elements were not produced in one piece. Rather these roughness elements were added manually and the bond failed due to too high stress.

Figure 25: Concrete slab revetment on dike crest and seaward slope (left) and missing roughness elements on the seaward slope (right)

Due to settled or washed out dike material, settlements of single stones and also settlements of larger areas can be observed (see Figure 25 left and Figure 26).

Figure 26: Settlements of the seaward berm filled with standing water

Both ends of the dike show an abrupt border and no connection to further flood protection measures. The sluice that closes the channel has been constructed a few hundred meters more inland and is not connected to the existing dike (see Figure 27 left). Along the coastline (see Figure 27 right), a wave breaker (2 rows of piles with stones in between, see Annex G) follows the described dike. In case of a flood, the water could flow along the borders of the dike into the hinterland.

Figure 27: Ends of the dike construction near Hon Da Bac island

Two years after the construction of the visited dike section, no tremendous damages were visible during the site inspection. Furthermore, this construction represents a milestone in the design and construction of dikes in the Cà Mau province. Still, future maintenance is required to prevent the progression of smaller damages mentioned above and a concept has to be developed to connect the dike to further flood protection measures.

3.5 Phu Tan district (Cai Doi Vam commune) - dike survey 06.01.2014 #7 - #10

As part of the 90 km long West-Sea dike, the visited dike section in Cai Doi Vam shows a great variability of plants on top of the dike crest and dike slopes. Due to human impacts and missing maintenance, this dike section has lost the typical and aspired appearance of a dike. No paths are available and the dike crest is sometimes hard to pass (see Figure 28). Transitions between the dike crest, dike slope and surroundings land cannot be defined precisely. On top of the dike a fruit plantation, which is managed by the household living nearby, and further plants can be found.

Figure 28: View along the dike line (06.01.2014 #9 left and #7 right)

A big trench that is now used as a shallow channel was created due to the excavation of material in front of the dike. However, the dike is situated a few meters away from the channel and erosion did not affect the seaward dike slope in such a great extent yet. Mangroves can be found in front of the channel. The hinterland is used by households and their aquaculture. Recent floods reached only up to the dike toe and did not endanger the households. The material of the dike crest is very compacted and contains many roots.

04 Conclusions and recommendations

After developing a dike inspection method that is adapted to the boundary conditions of the Cà Mau province and undertaking several field trips to different sites, an overview of the province's dike system has been gained. The dike geometry, condition and surroundings differed from site to site and in some places no dike has been built yet. Erosion damages exist at most of the visited dike sections. All sites – except for the dike in the Khanh Binh Tay commune – have in common that a lot of vegetation can be found on the dike; partly planted on purpose (public or private), partly as a consequence of uninfluenced natural processes. Still, one of the biggest hazards seems to be the lack of maintenance and repair as well as the human impacts on the dike, which are connected to the excavation of dike material or unauthorized constructions in/or the dike.
The developed dike inspection method offers a concept for future GPS-based dike mapping and initial site evaluations. During the site visits, staff of the provincial DARD has been introduced to the developed dike inspection method and their assistance in assessing the sites has been appreciated. Future work on the dike system in the Cà Mau province can go into different directions: Continue gathering information on the dike system and develop a digital information system including GIS-based maps or start improving the dikes and their management based on the achieved information.

The following is recommended for further dike inspections:

- The provincial DARD can and should be integrated in further dike inspections
- An expert or intensive trainings are necessary to do detailed observations and assessments
- With regard to the results of already undertaken inspections, special attention has to be paid to the hazards caused by unauthorized human impacts
- Local people may have interesting information and should be interviewed during the dike inspection (occurrence of floods, details concerning the dike construction, …)
- Data digitalization and processing is required after the inspection. A digital information system showing the positions and results of visited sites is aimed at. Using this information system, it

should be possible to develop maps showing erosion/vegetation/human impact hot spots, the crest width along the dike line or sites with e.g. an already existing dike revetment.

- If the inspection of single sites is considered instead of inspecting the whole dike system, the following places should be visited additionally: the transition from Bac Lieu province to Cà Mau province, the transition from Kien Giang province to Cà Mau province, the southern tip of the West-Sea Dike, Khanh Binh Tay Bac commune, Phu Tan commune and Khanh Hoi commune

Possible next steps to improve the dikes and the dike management in the Cà Mau province are:

- Work on cost-effective and applicable measures to stop/prevent dike erosion (e.g. a grass cover). Start a pilot project to test and monitor this measure at an appropriate site (Tran Van Thoi district – Song Doc commune?)
- Awareness rising of local people, especially households living behind the dike, with the objective to decrease the number of human impacts on the dike and to increase the motivation of maintaining the dikes
- Give support in establishing a regular dike survey/dike control program at the provincial DARD to guarantee that changes of the dike condition are notified, documented and reported instantly and threats are prevented. Therein the local people should also be hindered from using the dike for private purposes and informed about possible consequences of their impacts

The development of knowledge and awareness may be a major issue currently as the functionality of the dikes depends on regular repair and maintenance activities as well as on the absence of unauthorized human impacts. Without the necessary awareness and regular supervision, a newly built or enhanced dike will lose its implemented design quite fast.

As soon as the dikes in the Cà Mau province are enhanced, repaired and/or maintained regularly, the dike survey method should be adapted to this improved situation. Possible ways to do a dike survey on maintained dikes are for instance described in "BC Ministry of Environment, Lands and Parks – Water Management Branch (2000): Flood Protection Works Inspection Guide" or "Pilarczyk, K.W. (2003): Management and Maintenance of Dikes and Banks".

References

Albers, T., Von Lieberman, N. (2011): Current and Erosion Modelling Survey. Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

BC Ministry of Environment, Lands and Parks – Water Management Branch (2000): Flood Protection Works Inspection Guide

Heiland, M., Schüttrumpf, H. (2009): Sea dyke rehabilitation in Kien Giang Province, Viet Nam. Published by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

Pilarczyk, K.W. (2003): Management and Maintenance of Dikes and Banks. Published by Rijkswaterstaat-DWW

Southern Institute for Water Resources Planning (SIWRP) (2014): Report concerning the dike inspection in the Khanh Tien commune, U Minh district, Cà Mau province (in progress)

Appendix A: Dike inspection report – cross profile report (every 2 km)

Dike inspection report – cross profile report (every 2 km)

Province: **District:** **Commune:**

General information and inspection conditions:

Name(s) of observer(s) & Institution/function: _____

1.2 Date: _____ 1.3 Time: _____ 1.4 No.:___

1.5 Geographical Position: _____

1.6 Weather: ☐ Heavy rain ☐ Cloudy ☐ Little rain ☐ Sunny

1.7 Site photos taken: ☐ yes ☐ no

Dike material - field tests:

Measuring position	2.1 Pocket Penetrometer	2.2 Pocket Vane Tester		
	Unconfined compression strength [kg/cm^2]	Adapter size/no.	Reading value	Shear strength [kg/cm^2]
dike crest				

Visual assessment:

3.1 Erosion/break outs: ☐ none ☐ seaward slope ☐ dike crest ☐ landward slope

3.2 Plants growing in/on the dike: ☐ none ☐ seaward slope ☐ dike crest ☐ landward slope

3.3 Roots in the dike material: ☐ yes ☐ no

3.4 Animal borrowing: ☐ none ☐ seaward slope ☐ dike crest ☐ landward slope

3.5 Dike cover/revetment: ☐ none ☐ seaward slope ☐ dike crest ☐ landward slope

type: _____

visible damages: ☐ yes ☐ no

3.6 Toe protection (stone rip rap, wood pilling, ...): ☐ yes ☐ no

type: _____

visible damages: ☐ yes ☐ no

3.7 Structure on the dike crest (crownwall): ☐ yes ☐ no

type: _____

visible damages: ☐ yes ☐ no

3.8 Trench parallel to the dike (material taken from foreland)? ☐ no ☐ yes

3.9 Use of the dike: ☐ none ☐ road ☐ settlements ☐ other

3.10 Land in front of dike: ☐ mangroves ☐ bare land ☐ settlements ☐ aquaculture ☐ other

3.11 Dike crest width: ____ m (with measuring tape)

3.12 Distance between seaward dike toe and mangrove belt: approximately ____ m

3.13 Distance between landward dike toe and land use: approximately ____ m

3.14 Unauthorized human impacts: ☐ none ☐ plantation ☐ diggings ☐ other

Further observations/remarks:

Appendix B: Dike inspection report – short report (every 100 m)

Dike inspection report – short report (every 100 m)

Province: **District:** **Commune:**

General information and inspection conditions:
Name(s) of observer(s) & Institution/function: _____

1.2 Date: _____ 1.3 Time: _____ 1.4 No.:___

1.5 Geographical Position: _____

1.6 Site photos taken: ☐ yes ☐ no

Visual assessment:

2.1 Erosion/break outs: ☐ none ☐ seaward slope ☐ dike crest ☐ landward slope

2.2 Plants growing in/on the dike: ☐ none ☐ seaward slope ☐ dike crest ☐ landward slope

2.3 Animal borrowing: ☐ none ☐ seaward slope ☐ dike crest ☐ landward slope

2.4 Trench parallel to the dike (material taken from foreland)? ☐ no ☐ yes

2.5 Use of the dike: ☐ none ☐ road ☐ settlements ☐ other

2.6 Land in front of dike: ☐ mangroves ☐ bare land ☐ settlements ☐ aquaculture ☐ other

2.7 Dike crest width: ___ m (with measuring tape)

2.8 Unauthorized human impacts: ☐ none ☐ plantation ☐ diggings ☐ other

2.9 Dike cover/revetment: ☐ none ☐ seaward slope ☐ dike crest ☐ landward slope

2.10 Toe protection (stone rip rap, wood pilling, ...): ☐ yes ☐ no

Further observations/remarks:

Appendix C: Dike inspection report – dike line interruptions

Dike inspection report – dike line interruptions

Province: **District:** **Commune:**

General information and inspection conditions:
Name(s) of observer(s) & Institution/function: _____

1.2 Date: _____ 1.3 Time: _____ 1.4 No.:___

1.5 Geographical Position: _____

1.6 Site photos taken: ☐ yes ☐ no

Dike line interruptions:

2.1 Installations in/on the dike (sluices, outlets, pumping stations, ...): ☐

type: _____

width of installation [m]: _____ ☐ measured ☐ estimated

visible damages: ☐ yes ☐ no

visible scour holes: ☐ yes ☐ no

channel exit berm strongly eroded: ☐ yes ☐ no

protection measures installed: ☐ yes ☐ no

or

2.2 Open canals through the dike:

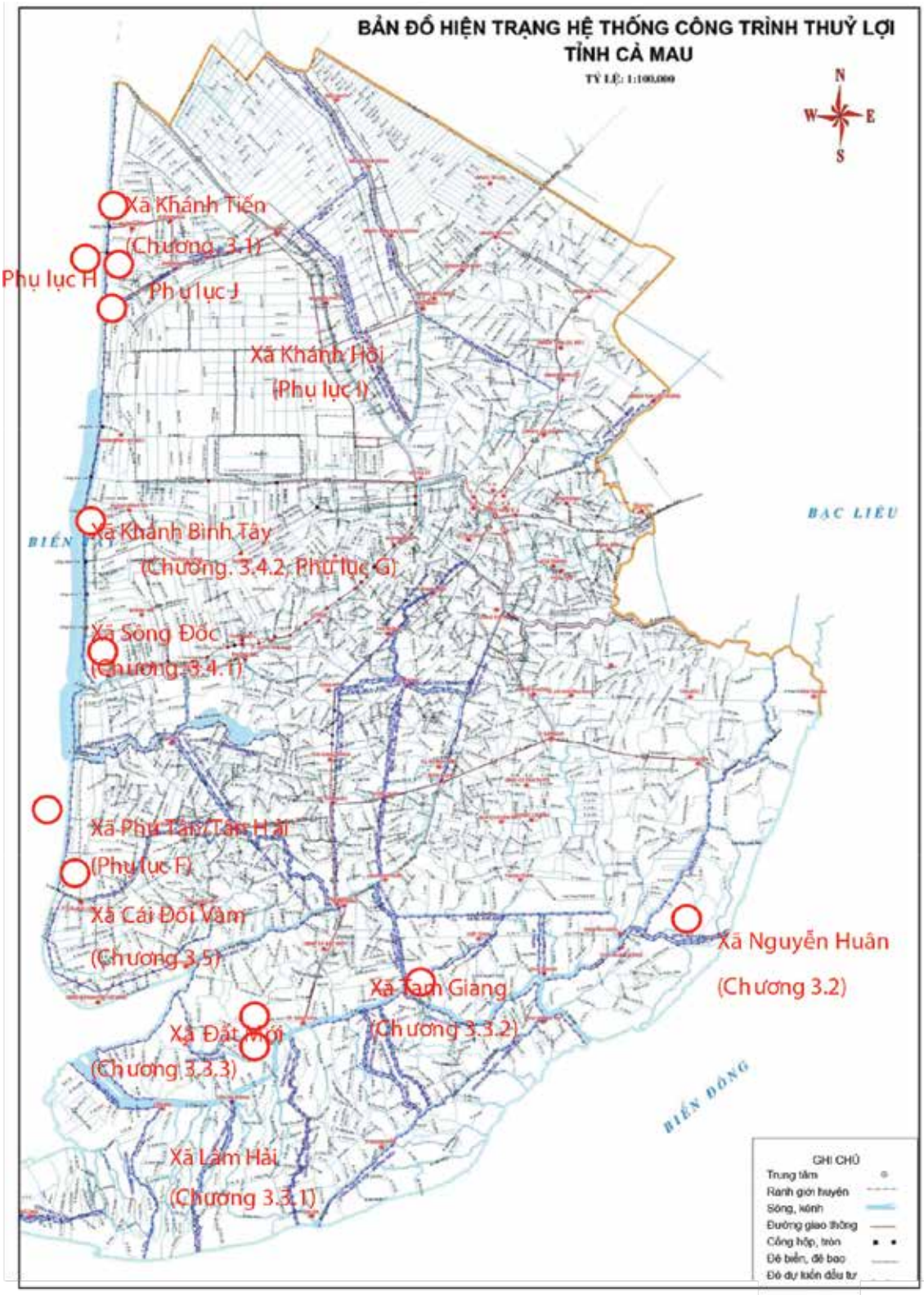
width of canal: ☐ <2m ☐ 2-5m ☐ 5-10m ☐ 10-20m ☐ >20m

channel exit berm strongly eroded: ☐ yes ☐ no

protection measures installed: ☐ yes ☐ no

Further observations/remarks:

Appendix D: Visited sites 11/2013 – 01/2014



Appendix E: Overview of visited sites during the initial dike inspection

Table 2: Visited sites during the initial dike inspection in the Cà Mau province

District	Commune	Date	GPS position	Protocol number	Site
U Minh	Khanh Tien	26.11.2013	?	-	Breakwater (Annex H)
	Khanh Hoi/ Khanh Tien	26.11.2013	?	-	Sluice gate & gabions (Annex I)
	Khanh Hoi	26.11.2013	?	-	Sluice gate (Annex J)
U Minh	Khanh Tien	27.11.2013	cf. SIWRP report	-	Dike
				-	Sluice gate
Dam Doi	Nguyen Huan	02.01.2014	N 08°49'38.6" E 105°18'37.0"	-	Milestone
			N 08°49'27.6" E 105°18'13.3"	#1	Open channel
Nam Can	Lam Hai	03.01.2014	N 08°44.138' E 104°57.804'	#1	Dike (short protocol)
			N 08°44.088' E 104°57.800'	#2	Dike (short protocol)
			N 08°44.034' E 104°57.794'	#3	Dike (short protocol)
			N 08°43.976' E 104°57.773'	#4	Dike (cross profile protocol)
	Tam Giang	03.01.2014	N 08°46.904' E 105°05.029'	#5	Dike (short protocol)
			N 08°46.907' E 105°04.998'	#6	Dike line interruption
			N 08°46.921' E 105°04.984'	#7	Dike (cross profile protocol)
			N 08°46.923' E 105°04.965'	#8	Dike line interruption
			N 08°46.936' E 105°04.943'	#9	Dike line interruption
			N 08°46.942' E 105°04.932'	#10	Dike (short protocol)
			N 08°46.948' E 105°04.902'	#11	Dike line interruption
			N 08°46.971' E 105°04.875'	#12	Dike (short protocol)
	Dat Moi	03.01.2014	N 08°45'18.1" E 104°57'09.2"	-	Milestone
			N 08°45'14.7" E 104°57'22.5"	-	Milestone
Tran Van Thoi	Song Doc	06.01.2014	N 09°02.781' E 104°48.776'	#1	Dike (short protocol)
			N 09°02.719' E 104°48.826'	#2	Dike (short protocol)

			N 09°02.669' E 104°48.855'	#3	Dike (short protocol)
			N 09°02.610' E 104°48.875'	#4	Dike (cross profile protocol)
			N 09°02.549' E 104°48.891'	#5	Dike (short protocol)
			N 09°02.491' E 104°48.907'	#6	Dike (short protocol)
Phu Tan	Phu Tan/ Tan Hai	06.01.2014	N 08°55'44.3" E 104°47'56.9"	-	Breakwater (Annex F)
Phu Tan	Cai Doi Vam	06.01.2014	N 08°52.176' E 104°48.013'	#7	Dike (short protocol)
			N 08°52.116' E 104°48.008'	#8	Dike (short protocol)
			N 08°52.063' E 104°48.003'	#9	Dike (cross profile protocol)
			N 08°52.031' E 104°47.999'	#10	Dike (short protocol)
Tran Van Thoi	Khanh Binh Tay	20.01.2014	N 09°10'32.8" E 104°48'31.9"	#1	Dike (short protocol)
			N 09°10'35.0" E 104°48'20.1"	#2	Dike (short protocol)
			N 09°10'37.9" E 104°48'29.1"	#3	Dike (short protocol)
			N 09°10'40.2" E 104°48'30.8"	#4	Dike (cross profile protocol)
			N 09°10'40.7" E 104°48'34.4"	#5	Dike (short protocol)
			N 09°10'41.6" E 104°48'38.1"	#6	Dike (short protocol)
			near N 09°10'32.8" E 104°48'31.9"	-	Breakwater (Annex G)

Appendix F: Breakwater in Phu Tan/Tan Hai commune (at channel exit of K. Tan Bien)

At the channel exit of K. Tan Bien between Phu Tan and Tan Hai commune (N 08°55'44.3" E 104°47'56.9"), a breakwater was constructed to prevent erosion and increase sedimentation. This breakwater was constructed in 2012 with two rows of concrete piles and stones in between. The construction covers both sides of the channel exit, leaving a gap of about 30 m between the two sections to allow boats passing through. The following pictures give an overview of the construction and its surroundings.

Figure 29: Breakwater at the channel exit of K. Tan Bien between Phu Tan and Tan Hai commune

Figure 30: Surroundings of breakwater at the channel exit of K. Tan Bien between Phu Tan and Tan Hai commune

Appendix G: Breakwater in Khanh Binh Tay commune (near Hon Da Bac island)

Next to the visited dike section in Khanh Binh Tay commune (see chapter 3.4.2, near 20.01.2014 #1, N 09°10'32.8"E 104°48'31.9"), a breakwater was constructed to prevent erosion and increase sedimentation. This breakwater was constructed with two rows of concrete piles and stones in between. The following pictures give an overview of the construction and its surroundings.

Figure 31: Breakwater in Khanh Binh Tay commune near Hon Da Bac island

Figure 32: Surroundings of breakwater in Khanh Binh Tay commune near Hon Da Bac island

Appendix H: Breakwater in Khanh Tien commune

In Khanh Tien commune (see Annex D for map), a breakwater was constructed to prevent erosion and increase sedimentation. This breakwater was constructed with two rows of concrete piles and stones in between. The following pictures give an overview of the construction and its surroundings.

Figure 33: Breakwater in Khanh Tien commune

Figure 34: Surroundings of breakwater in Khanh Tien commune

Appendix I: Sluice gate and gabion protection in Khanh Tien/ Khanh Hoi commune

In Khanh Tien/Khanh Hoi commune (see Annex D for map), a sluice gate was constructed. The channel exits outside the sluice gate are on both sites protected by gabions to prevent erosion. At one side a breakwater is connected to the gabions (see Figure 37). The following pictures give an overview of the constructions and their surroundings.

Figure 35: Sluice gate in Khanh Tien/ Khanh Hoi commune: inland view (left) and seaside view (right)

Figure 36: Gabion protection at sluice gate in Khanh Tien/ Khanh Hoi commune

Figure 37: Gabion protection at sluice gate in Khanh Tien/ Khanh Hoi commune and connected breakwater

Appendix J: Sluice gate in Khanh Hoi commune

The sluice gate existing in Khanh Hoi commune (see Annex D for map) is shown in the following figures.

Figure 38: Sluice gate in Khanh Hoi commune: inland view

Figure 39: Sluice gate in Khanh Hoi commune

Department of Agriculture and
Rural Development of
Ca Mau Province