THE SOCIALIST REPUBLIC OF VIETNAM

Data Collection Survey on Basin-based Comprehensive Sediment Management in River Systems of the Central Region in Vietnam

FINAL REPORT

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Japan International Cooperation Agency (JICA)
Transport Engineering Design Inc. (TEDI)
Oriental Consultants Global Co., Ltd. (OCG)
Pacific Consultants Co., Ltd. (PCKK)

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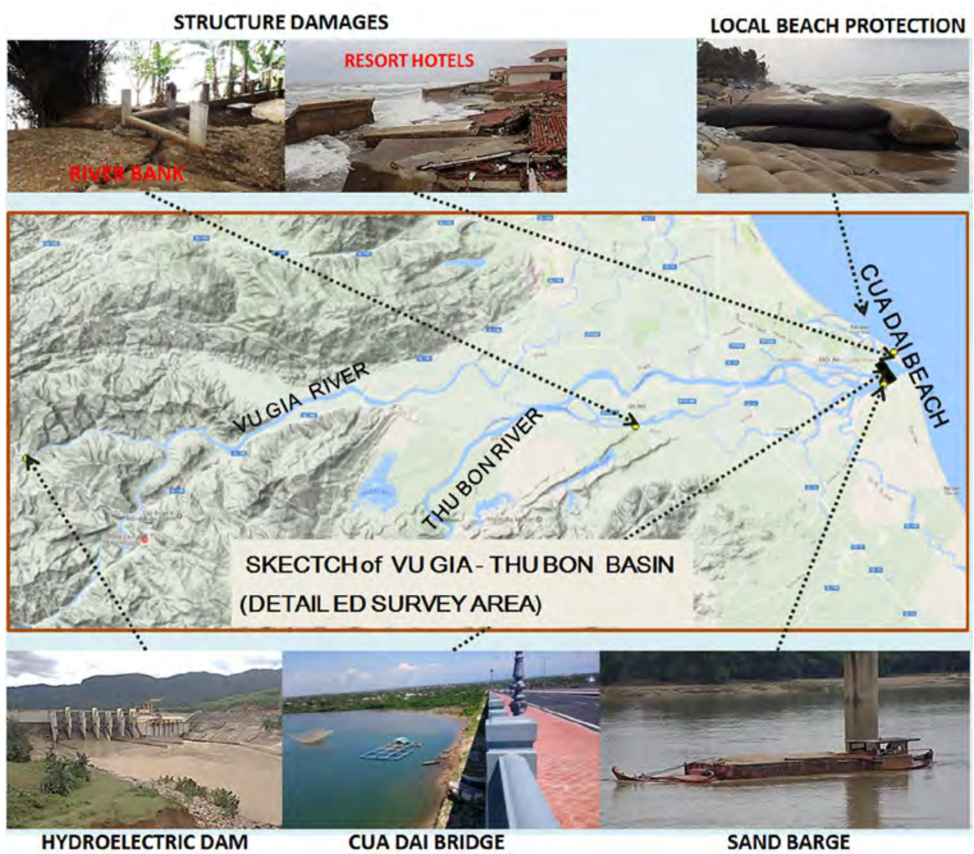
Abbreviations and Acronyms

CSM	Comprehensive Sediment Management
DARD	Department of Agriculture and Rural Development
DONRE	Department of Natural Resources and Environment
DOC	Department of Construction
EIA	Environment Impact Assessment
JICA	Japan International Cooperation Agency
MARD	Ministry of Agriculture and Rural Development
MOC	Ministry of Construction
MONRE	Minister of Natural Resources and Environment
MOT	Ministry of Transport
MOIT	Ministry of Industry and Trade
PPC	Provincial People Committee
RBOs	River Basin Organization
SEA	Strategic environmental Assessment

1. Introduction

1.1 Background

In recent years, coastal erosion has been amplified in many areas in Vietnam causing serious adverse impacts to dense inhabitants as well as rich ecological values along the shore. Of possible causes, a reduction of river-supplied sediment and changes of a longshore sediment transport pattern could be considered as chief culprits. The former is often caused by surface water diversion, soil reservoir storage, dam building and sand mining. Whereas, construction of man-made structures along the beach could disturb the along shore sediment transport flows, and accordingly, it affects the position and shape of coastal lines. However, these issues are not well recognized and addressed properly in Vietnam. And as a result, to cope with coastal retreat issues, ad hoc hard counter measures are often implemented locally without any consideration of coastal sediment transport regime. The construction of coastal revetments or groins to stop beach erosion in Cua Dai beach of Hoi An, for example, do not help to stabilize the foreshore but in contrast, erosion still develops with increasing magnitude over the last few years (**Fig 1.1.1**). The lack of scientific evidences and solid understandings about changes of sediment transport in river systems and coastal areas attributes to this trend. In fact, recent lessons from coastal research community in Japan prove that coastal retreat problems could not be solved effectively without a proper and comprehensive consideration of sediment-related issues arising in various forms at the areas of mountain / foot of mountain, alluvial plain, and river mouth /coast in accordance with a so-called "flow of sediment".



Source: JICA Study Team

Figure 1.1.1 Study Area of the Project and that of the Current Situation

1.2 Objective(s) of the Survey[1]

In line with previous support from JICA for Vietnam to develop basin based plans for flood management ("Integrated Flood Management Plans (IFMPs" [2]) in the central region, it is expected that a similar concept with IFMP, namely "Comprehensive Sediment Management (CSM)"[3], can be effectively applied to deal with issues related to changes of sediment transport in river systems and coastal areas and it serves as the context for this survey. To support for the formulation of CSM, this survey project aims at 1) providing quantitative evidence of the changes of sediment transport in river system and coastal areas in center Vietnam; 2) identifying the cause that triggers the serious coastal erosion problems directly related to "sediment management" issues; and 3) proposing possible solutions as well recommendation for the establishment of CSM's framework so as to solve these problems in an effective and sustainable way. Outputs that are expected by the consultancy are as below:

(1) Present status and problems related to the changes in sediment transport regime in river systems and coastal areas in Vietnam are clarified with appropriate evidence. Including:

- Present status of coastal erosion in Vu Gia-Thu Bon River Basin (*Page 2-8～2-11*)
- Coastal erosion due to reduction of sediment supply from river (*Page 2-11～2-40*)
- Causes of reduction of sediment supply from river (*Page 2-40～2-62*)
- Coastal erosion due to interruption of longshore sediment transport (*Page 2-62～2-65*)
- Present status of river erosion (*Page 2-66～2-73*)
- Present status of coastal erosion in other area (*Page 2-74～2-87*)

(2) Necessary data and information for developing integrated sediment management plan in the Vu Gia – Thu Bon river basin are collected. Including:

- Human activities in river basin (*Page 2-2 ～ 2-8*)
- Long-shore shoreline change (*Page 2-17 ～ 2-27*)
- Wind and wave data (*Page 2-27 ～ 2-30*)
- Water discharge, water level (*Page 2-44*)
- Cross-sections: Coastal area (*Page 2-30*) and river area (*Page 2-46 ～ 2-53*)
- River bed material (*Page 2-54 ～ 2-55*)
- Legal framework regarding management of sediment transport issues in river basin (Page *3-1 ～3-18*)

(3) A participatory framework is proposed for developing and implementing integrated sediment management plan in the Vu Gia –Thu Bon river basin including steady implementation of basic data and information management. Including:

- Development and implementing of legal and institutional (*Page 4-3 ～ 4-4*)
- Development and implementing of technical issues: Data collection and design standards (*Page 4-4～4-7*)

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[1] Data Collection Survey on Basin-based Comprehensive Sediment Management in River Systems of the Central Region, Term Of Reference, Feb 2017, JICA

[2] The project for building disaster resilient societies in central region in Vietnam Final report, Mar 2012, JICA

[3] The concept of "Comprehensive Sediment Management" includes data and information management, coordination with diverse stakeholders and comprehensive planning of human activities which directly or partly affects to "flow of sediment"

(4) A proposal for policy development and legal and institutional arrangement necessary for appropriate sediment management in Vietnam is formulated (*Page 4-1 ～ 4-2; Page 4-7～4-10*).

1.3 Survey Area

The targeted area covers the six provinces in the central coastal region of Vietnam, such as Quang Tri, Thua Thien Hue, Quang Nam, Quang Ngai, Binh Dinh, and Phu Yen where serious coastal erosion problems are being faced. (**Fig 1.3.1**), which concentrates on Vu Gia-Thu Bon River Basin including Cua Dai Beach located at its river mouth.

Source: JICA Study Team

Figure 1.3.1 Target Area

2. Current status of coastal erosion issues, their causes and impacts

2.1 Chapter Summary

Field survey as well as hearing survey at MARD, MONRE, PPCs, DARDs, DONREs were carried out to collect data and information on coastal erosion and other issues related to the change of sediment transport in river systems and coastal areas in targeted provinces. The results show that erosion occurred in many areas near to the river mouths along the central coast. River mouth is well known as the exit gate of the river sediment transportation processes and sediment supplied from river play as important sources of beach formation. Therefore, coastal erosion found near the river mouth are the consequences of human activities on river basin which lead to the decrease of sediment amount transported to river mouths such as dam and infrastructures construction, and sand mining. Moreover artificial structures such as anti-sedimentation jetties for inland waterway (Ex: Cua Tung Beach), resort's seawall (Ex: Hoi An Beach) which interrupted the natural long-shore sediment transport route, and bridges on the river mouth (Ex: Cua Dai Bridge) which changed the direction of sediment transport toward the coast, also altered the natural balance of sediment transportation and made the coastal erosion more serious.

Erosion of river banks also an issue that needs attention in the central provinces. According to local people, river bank erosion usually occurs after large floods. This means that the analysis of river erosion requires the data of river cross-section before and after the flood or satellite images data. However, those river cross-section data have not been measured in the past and filed survey of cross-sections was conducted only one time in the dry season due to the limited budged and time. Moreover, large area of satellite images data also could not obtained due to limited budget. So the quantitative and qualitative analysis of river bank erosion is not possible within this project.

The quantitative analysis of coastal erosion was conducted to understand the mechanism of sediment transport in Vu Gia Thu Bon River basin, which is the basis input data for investigate the anti-erosion measures in the next step. In detail, the quantitative changes of sediment transport due to following causes were investigated:

- Coastal erosion due to reduce of sediment discharge to river mouth
- Coastal erosion due to interruption of longshore sediment transport

Coastal erosion due to reduce of sediment discharge to river mouth:
Calculation process is done separately for river area (extending form upstream to river mouth) and coastal area (extending from river mouth to adjacent coastal zone). The sediment transport rate obtained from calculation process for river basin was utilized as an input data for calculation of sediment transport in coastal area.

As for quantitative analysis in river area: annual sediment discharge from river is estimated and compared for the period before and after dam construction (1997 and 2017), considering the impact effects of sand mining. In which:

- Effect of dam construction is considered by setting the amount of sediment output behind the dam equal to zero after the construction of the dam
- To account the effect of sand mining, the data provided by Quang Nam Province about the annual dredged volume between calculation points has been used. The dredged volume has been deducted from the amount of annual sediment discharge at the calculation point.

As for quantitative analysis in coastal area: The shoreline change was analyzed using the satellite images to understand the long-term change of shoreline. Then the sediment transport in coastal area was analyzed using 1-line model to understand the current mechanism sediment transport.

The results of the quantitative analysis show that:

- The advance and retreat of sand bar in front of Cua Dai estuary appears to be closely related to erosion in Cua Dai coast. Following the decay of sand bar happened since 1993, the erosion is observed clearly. In the first phase, from 1973 to 1992, the coastline near the Thu Bon River mouth had advanced 1000m. During this time, it's estimated that the Thu Bon River could have supplied the abundant sediment volume. In the second phase, from 1993 to 2017, the coastline had retreated 200m and it's presumed that the sediment supply from the river decreased due to sand mining and dam constructions

- During 1973-1992, the northward sediment transport is larger than southward sediment transport. However, this trend is reversed in 1992-2017. Additionally, the sediment supply from river decreased in the period of 1992-2017.
- The sediment supply to Cua Dai estuary has decreased by 40% according to the results from 1997 and 2017. In which the sediment discharge has reduced by 14% due to dam construction and by 24% due to sand mining activities.

Coastal erosion due to interruption of longshore sediment transport

Impact of structures such as groins, steel sheet pile, etc.., have been implemented using google images.

Impact of construction of groin: In 2015, a system of groins, using geotextile, was implemented in front of Victoria Resort to stop the erosion. However, the analyzed results of shoreline change and topographic change indicates that erosion still keeps progressing to the adjacent areas even after the construction

Impact of construction of steel sheet pile: In Feb 2017, the construction of steel sheet pile in the right northern site of this estuary had prevented the sediment from being transported to the northern site and aggravated the coastal erosion in the North side of the steel sheet pile.

2.2 Current Status of Human Activities Affecting Sediment Transport in Vu Gia-Thu Bon River Basin

According to a global scale study[4], coastal retreat is directly influenced by the reduction of river-supplied sediment. The increase of human activities such as dams/reservoirs construction, sand mining or construction of infrastructures that diverse river flow has caused various problems on coastal erosion by reducing the amount of sediment supply of rivers, blocking the movement of drift sand, and changing the direction of sediment flow. These intensive activities are also observed at Vu Gia – Thu Bon basin during the survey

2.2.1 Sand mining

Sediment supply from river systems is one of the most important sediment sources for the formation of beaches. Therefore, loss of sediment due to sand mining in upstream and middle stream area may result in the erosion of riverbeds, which will in turns reduce the flow velocity and then reduce the sediment discharge to coastal areas, as a consequence. Basically, mineral resources such as sand and gravel are managed by the Department of Natural Resources and Environment (DONRE). DONRE manages and licenses the operation of sand mining on rivers. However, the management of exploiting sand activities after being licensed are not controlled properly. Thus, several hundred thousand m3/year of sand have been dredged in each province. **Table 2.2.1** shows the actual condition of sand mining in the targeted provinces

Most sand mining activities are conducted in middle stream of the basin (**Fig 2.2.1**). According to data received from Quang Nam's DONRE (2017), approximately 10 million m^3 of sand has been mined from river channels since 2008, however the actual mining volume cannot be estimated because most of sand mining has been done illegally.

4 Syvitski, J.P.M., Vorosmarty, C.J., Kettner, A.J. and Green, P., 2005. Impact of humans on the flux of terrestrial sediment to the global coastal ocean. Science, 308(5720): 376-380

Table 2.2.1 Sand Mining in Targeted Provinces

No	Province	River / site	Volume of sand mining	Planning for mining	Remarks
1	Quang Tri	· Thach Han River · Ben Hai River	-	-	· There are two companies in the Ben Hai River area qualified for exploiting sand. · There are many sand sucking boats illegally operating to extract sand.
2	Hue	· Huong River · Bo River	40.27 million tons reserved	Existing	· There are five white sand mining projects licensed by the Ministry of Natural Resources and Environment. · The illegal white sand mining operations are still occurring.
3	Quang Nam	Vu Gia - Thu Bon River basin 85sites	443milion m^3 reserved	-	· According to information collected from the Department of Environment and Natural Resources, Quang Nam Province, there are about 85 sand mining sites in the province from 1990 to 2007
4	Quang Nagi	Tra Khuc River	-	Existing	· Quang Ngai properly manages and controls the illegal exploitation of sand on rivers.
5	Binh Dinh	Lai Giang River Kon River La Tinh River Ha Thanh River	-	Existing	· Sand mining is under the management the Department of Natural Resources and Environment. · The management of exploiting sand activities after licensing has not been properly cared for.
6	Phu Yen	Ba River Ky Lo River	100,000-150,000m^3/y dredged (Statistics) 759,826m^3 reserved	Existing	· Phu Yen Department of Construction has set up "Planning for exploration, mining, processing, and utilization of minerals as common building materials and peat coal in Phu Yen province until 2020 and orientation to 2030 approved by the provincial People's Committee under Decision No. 3237/QD-UBND dated 30/12/2016.

Source: JICA Study Team – Data collected during interview survey

Source: JICA Study Team

Figure 2.2.1 Location of Sand Mining in Quang Nam Province (Red Marks)

2.2.2 Dam Construction

Dam construction is considered to be one of the main contributing factors to reduce the sediment discharge to the river mouth due to sediment retention which preventing the sediment transport from upstream to coastal reaches of rivers. The current condition of dams and hydropower plants in central regions are shown in **Table 2.2.2**. Most of the dams and reservoirs had been constructed in the 2000s and will continue to have a huge influence on the sediment transport of river basin in the central region and then aggravate the river and coastal erosion in the future. In the rivers of Vietnam, the mountainous area occupies a large proportion of the topography and the catchment area of dams built in many rivers accounts for a large proportion of the entire water system. This indicates that dam construction may have a big influence on the amount of sediment supply in the whole water system.

Table 2.2.2 Dams and Hydropower plants in Targeted Provinces

No	Province	River	Dam and Hydropower plant (Completion year)
1	Qunag Tri	Thach Han River Ben Hai River Lau River	There are not many hydropower plants built in Quang Tri province. The most notably, Quang Tri Hydropower Plant was built on Rao Quan River, a large tributary of Thach Han River.
2	Hue	Huong River Bo River	· A Luoi (2012); Binh Dien (2009); Huong Dien (2013), etc.
3	Quang Nam	Vu Gia River Thu Bon River	· A Vuong (2008); Song Con 2 (2009); Song Tranh 2 (2011); Dak Mi 4 (2012); Song Bung 4 (2014) · Song Bung 2 (2014); Song Bung 5 (2012) · Song Bung 6 (2012)
4	Quang Ngai	Tra Khuc River	· Son Tra (2018); Song Lien 1; Dak Re
5	Binh Dinh	Lai Giang River Kon River La Tinh River Ha Thanh River	The Ministry of Industry and Trade has planned 14 hydropower plants on this river with total capacity of 312.1 MW. Among them, there are 11 hydropower plants located in Vinh Thanh district (Binh Dinh). Tra Xom; Vinh Son 5; Tien Thuan; Van Phong Ken Lut Ha; Vinh Son 4, etc.
6	Phu Yen	Ba River Ky Lo River	· Ba Ha River (2009); Hinh River (2001); La Hieng River (2015); Krong H'Nang (2011)

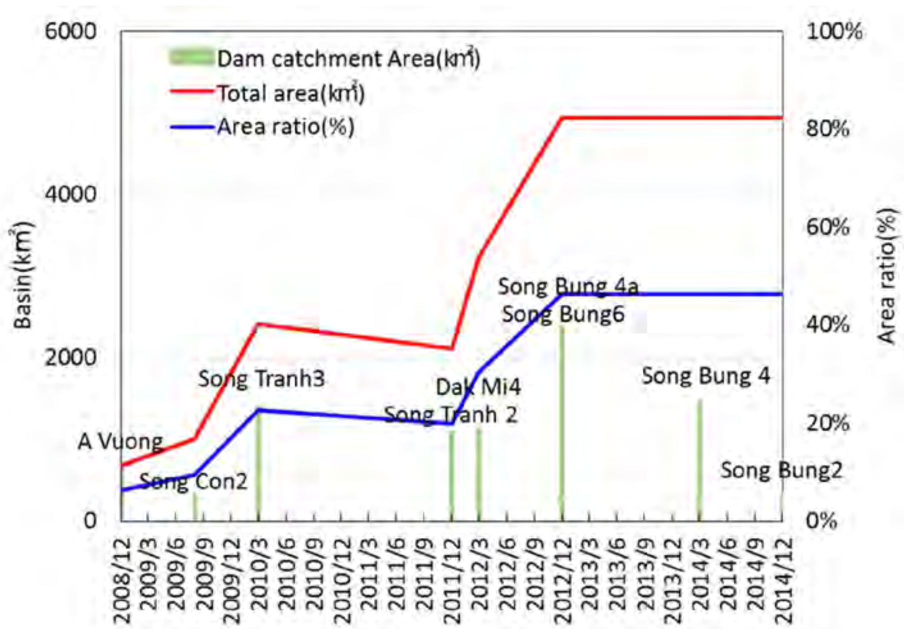
Source: JICA Study Team – Data collected during interview survey

As for Quang Nam Province, 42 hydropower plant projects had been approved with a total capacity of 1,606.76 MW. Among that there are ten terraced hydropower projects approved by MOIT with a total capacity of 1,156MW and 32 medium- and small-sized hydropower projects approved by the PPC with a total capacity of 450.76MW. Location and capacity of main hydropower plants are shown in **Fig 2.2.2**. Example of dam structure is shown in **Fig 2.2.4**. The catchment area of dams is occupying nearly 50% the entire catchment (**Fig 2.2.3**).

Hydropower project	Design capacity (MW)	Year of commencement	Year of completion
A Vuong	210	8/2003	12/2008
Song Con 2	63	11/2005	8/2009
Song Tranh 2	190	quarter I/2006	quarter IV/2011
Dak Mi 4	190	quarter II/2007	quarter I/2012
Song Bung 4	156	quarter II/2010	quarter I/2014
Song Bung 2	100	quarter IV/2011	quarter IV/2014
Song Bung 5	57	quarter IV/2009	quarter IV/2012
Song Bung 6	29	quarter III/2010	quarter IV/2012

Source: JICA Study Team

Figure 2.2.2 Location of Hydropower Plants in Quang Nam Province



Source: JICA Study Team

Figure 2.2.3 Dam Catchment Areas and Ratio

Source: JICA Study Team

Figure 2.2.4 Song Bung 5 Hydropower Dam

2.2.3 River flow diversion

Construction of infrastructures along the river may result in changes of flow regime (i.e, changes of flow direction, run-off timing and run-off discharge volume) which in turn bring a negative effect on sediment transport processes in rivers and coastal areas. Some major structures that seem to have negative impacts on sediment transports in Quang Nam Province are as follows:

- **Dai Loc Weir:**

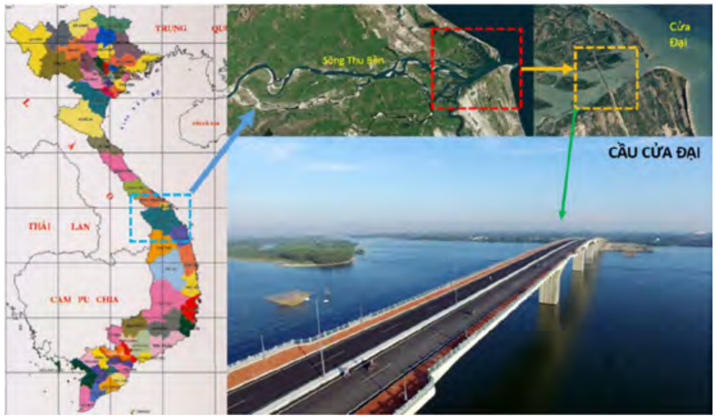
Dai Loc Weir was constructed in 2009 at a point where water is diverted from Vu Gia River to Thu Bon River to ensure enough water discharge to Han River (downstream part of Vu Gia River, See **Fig 2.2.5**). This artificial structure has changed the timing of run-off, i.e, reduces the discharge volume to Thu Bon River during dry season but it has caused overflow and increased water supply to this tributary during flood season. As the nature of sediment movement, most of fluvial sand is carried to the coast during the flood season, one part (finer bodies) is transported further offshore, but the other part (coarser sand) will be kept at the estuary in the form of sandbars. The migration of these sand bars down along the coast under wave actions during winter/summer times might protect the beach from erosion. The significant increase of flood discharge might wash away the nearshore sandbars to offshore area and therefore put the beach at Cua Dai under a vulnerable situation.

Source: JICA Study Team

Figure 2.2.5 Dai Loc Weir

- **Cua Dai Bridge**

Cua Dai Bridge crosses Thu Bon River at 1.5 km upstream of the estuary, and has an abutment on the left bank that has been partially reclaimed (**Fig 2.2.6**). Since the river cross-section is narrowed down on the left due to construction of this abutment, river main stream might have been diverted to the right bank. As a consequence, it could lead to a reduction of sediment supplied to the left coast of Cua Dai while sediment volume distributed to that of the right side could increase significantly.



Source: JICA Study Team

Figure 2.2.6 Cua Dai Bridge

2.2.4 Longshore sediment transport disturbance structures

Part of coastal morphodynamics processes is sediment transport. The changes of gradients in sediment transport rates lead to erosion or accretion, which in turn alternate the nearshore morphology. For practical approaches, littoral sediment movement in the nearshore zones is usually divided into a cross-shore and alongshore process. Alongshore sediment transport is generally associated with alongshore currents which are induced by oblique incident waves. It is considered as a chief mechanism causing long term evolution of beach. Whereas, short term seasonal changes (i.e, scale of few days or weeks) are closely resulted by cross-shore sediment transport as a consequence of wave orbital motions and cross shore currents.

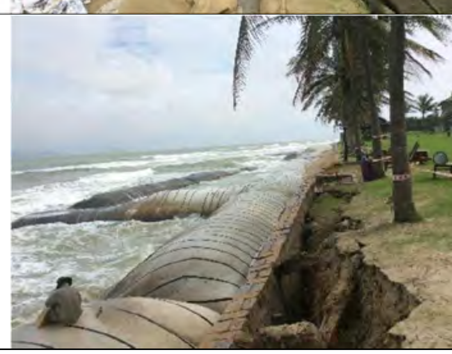
In the Cua Dai coastal area, erosion prevention measures, such as sea dikes, revetments or groins, etc.., have been implemented for the past few years. According to the report on the policy of investing the construction of coastal protection and rehabilitation of the beach of Golden Sand Resort & Spa[5] of TEDI Port, in storm season, a series of five-star resorts along nearly 10km long of Cua Dai coast has experienced severe landslides. In order to protect their property, owners of the resorts (Victoria, Golden Sand, and Sunrise Resort- **Fig 2.2.7**) have spent up to hundreds of billions VND to construct locally prevention structures while waiting for the local functional sectors seeking a synchronized solution (**Table 2.2.3**). Additionally, in 2015, a system of groins, which uses geotextile, was built in front of several resorts to mitigate the erosion. However, the erosion prevention structures as well as the resorts themselves are disturbing the longshore sediment transport, and then aggravating the coastal erosion. Qualitative analysis for destructive mechanism of coastal erosion due to these man-made structures along the Cua Dai beach will be discussed in detail in Part 2.4.3.

[5] Port & Waterway Engineering Consultant Joint Stock Company, "Report proposed investment policy construction of coastal protection works and restore the beach landscape resort Golden Sand Resort & Spa," C Port & Waterway Engineering Consultant Joint Stock Company, Hanoi, 2016.

Source: JICA Study Team

Figure 2.2.7 Resorts on Cua Dai Beach

Table 2.2.3 Embankment Protection the North Side of Cua Dai

Region	Structure	Image
Golden Sand Resort	Rock formations for tiled roofs	
Victoria Resort	Shore and geotextile shore protection (Geotube)	
Palm Resort	Geotextile protection works (Geotube)	

2.3 Current status of Severe Coastal Erosion on Vu Gia-Thu Bon River Basin's beaches

According to the report "Current situation on management and construction of agricultural and rural development project in Vu Gia - Thu Bon Basin" received from Quang Nam Province on March 2017, some coastal landslides have occurred as follows:

- Cua Dai, Hoi An City: the northern coast of Cua Dai (Dien Ban and Hoi An) have continuously eroded for a long time. The eroded area is about 8 km long with an average width of 80m and a maximum width of 200m

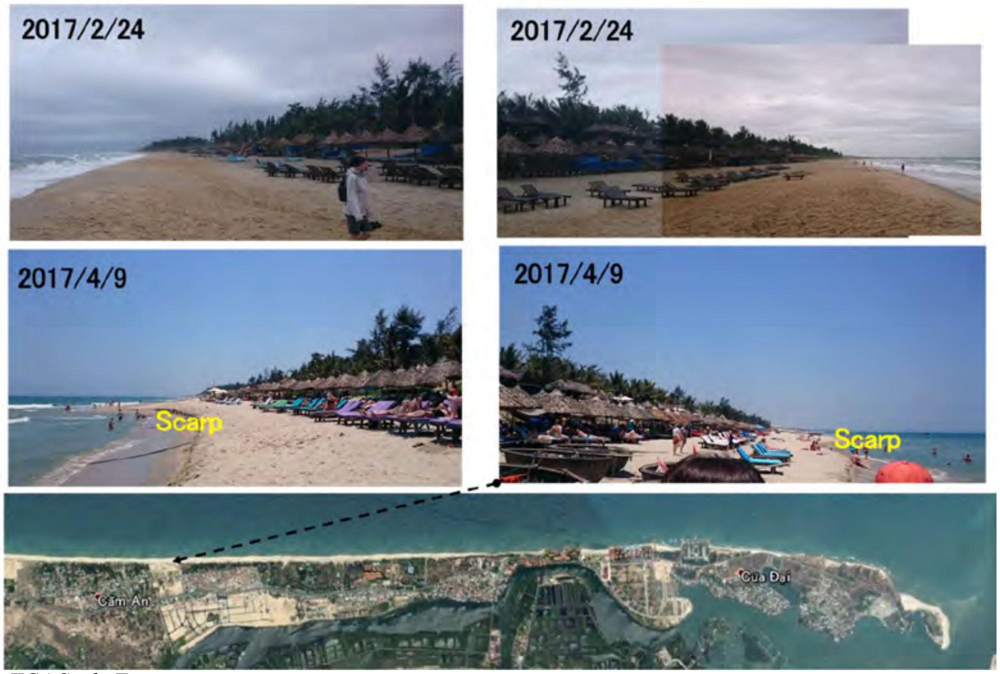
- Cua Lo - Nui Thanh District: The landslide length is over 2km, extending over villages 1, 4 and 5 of Tam Hai commune. Yearly average speed is about 30m to 40m. The erosion caused the loss of residential land and the production of pine forest 5 and more than 300 households to be relocated. At present, the risk of losing land of pines forest 1 and 4, which covering 100 ~120 households, is obvious.

Results of satellite imagery analysis in 2011, 2012 and 2014 show that yearly average erosion speed are about of 30~80 m (**Fig 2.3.1**).

Source: JICA Study Team

Figure 2.3.1 Erosion of Cua Dai Beach from Satellite Images

<u>*Current situation of An Bang Beach:*</u>
The current situation An Bang Beach is shown in **Fig 2.3.2-3**. The photographs in the upper part were taken in Feb. 24th, 2017 and the photographs in the lower part were taken in Apr. 9th, 2017. In the lower photographs, the shoreline retreated and a small scarp occurred which point out that the erosion has been expanding to the north coast rapidly.



Source: JICA Study Team

Figure 2.3.2 Current situation of An Bang beach

In the vicinity of Palm Beach, the sandy beach recovers (factor confirmation required)

Source: JICA Study Team

Figure 2.3.3 Current Situation of Cua Dai Beach

<u>*Current situation of Thu Bon River estuary:*</u>

The current situation of Thu Bon River estuary is shown in **Fig 2.3.4**. New river mouth was formed in November 2016 and it still continues in April 2017. It is thought that the new river mouth will have a salutary effect on the sediment supply from Thu Bon River. However, the sheet piles were constructed after the flood of November 2016 and it has blocked the sediment transport from the river mouth to the north coast.

Source: JICA Study Team

Figure 2.3.4 Current Situation of Thu Bon River Estuary

2.4 Analysis the Impact of Human Activities on Erosion

2.4.1 Coastal Erosion due to Reduction of Sediment Supply from River

(1) Objectives of Analysis

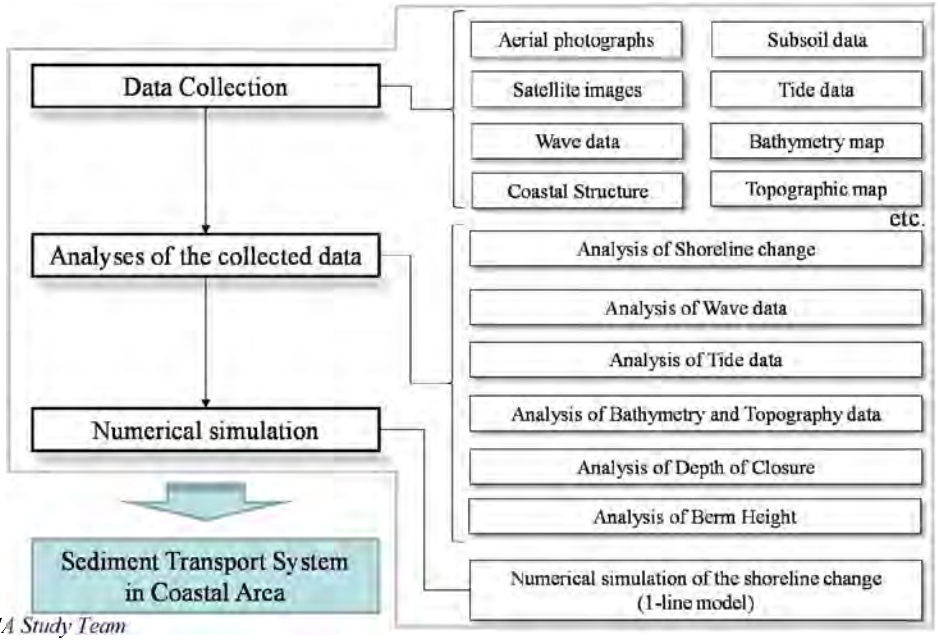
- To understand sediment transport system in coastal areas, quantitatively.
- To examine main effects to the coastal erosion in Cua Dai Beach.
- To investigate available countermeasures for the coastal erosion in Cua Dai Beach.

(2) Methodology of Analysis

- The extent of shoreline changes estimated by aerial photographs
- The mechanism of sediment transport will be investigated by the shoreline change analysis.
- Based on the results of shoreline change and sediment transport mechanism, the sediment transport maps will be created.
- The coastal sediment transport rate will be calculated by numerical simulation software.

1) Workflow

The workflow of quantitative analysis of sediment transport in coastal area is shown in **Fig 2.4.1**.



Source: JICA Study Team

Figure 2.4.1 Work Flow of sediment transport in coastal area

2) Data Collection:

The necessary data is listed in **Table 2.4.1**.

Table 2.4.1 Necessary data for quantitative analyses of Sediment transport in coastal area

DETAILED SURVEY		
CATEGORY	KEYWORDS	DETAIL
Basic data and information on coastal erosion and other issues related to the change of sediment transport in river system and coastal zone	Topographic, Bathymetric Map	Topographic data in coastal areas
		Depth contour diagram (for coastal analysis)
		Coast profile
	Marine chart	Marine chart of different years
	Tide	Tidal data of nearby tide station -Tide data (water level): tide data should be collected at the nearest station of Cua Dai Beach
	Subsoil	Soil Investigation data -Data of sediment grain size in coastal area
	Wind	Observed Wind Direction and Wind Speed Data at station nearest to Cua Dai Beach
	Wave	Wave height/ wave period/ wave direction 1. Offshore wave data of Cua Dai Beach (wave height, wave direction and wave period) ・Offshore waves should be observed or analyzed at water depth greater than depth of incident offshore waves (about 1/2 of offshore wave length) ・If possible, offshore waves should be analyzed based on probability statistics (probability of 50 years, 30 years and 10 years) using the record of typhoons.
	Typhoon/Monsoon	Typhoon data: Atmospheric pressure and tracking record

DETAILED SURVEY		
	Littoral Drift and Sedimentation	The data below is required for analysis of incident sediment amount and annual sediment transport rate ・Real time data of accreted sediment in dam reservoirs within Vu Gia- Thu Bon Basin. ・Turbidity data in the river area
	River discharge	Data is required for the analysis of sediment transported in river areas. Therefore, data should be collected in several stations along Thu Bon River and Vu Gia River (upstream site, middle stream site, and estuary)
	Satellite image Aerial photograph	Aerial photograph Data is required to analyze past shoreline change and past river estuary formation of Cua Dai Beach and Thu Bon river estuary. Therefore, data should be collected from past to now, as much as possible.
	Coastal Structure	Dike, groin, which include the geotube, etc. - Structure, length, width, time of construction

Analyses of Collecting Data: Several analyses in advance are carried out in order to get the information for numerical simulation. The input and output of each analysis are shown in **Table 2.4.2**.

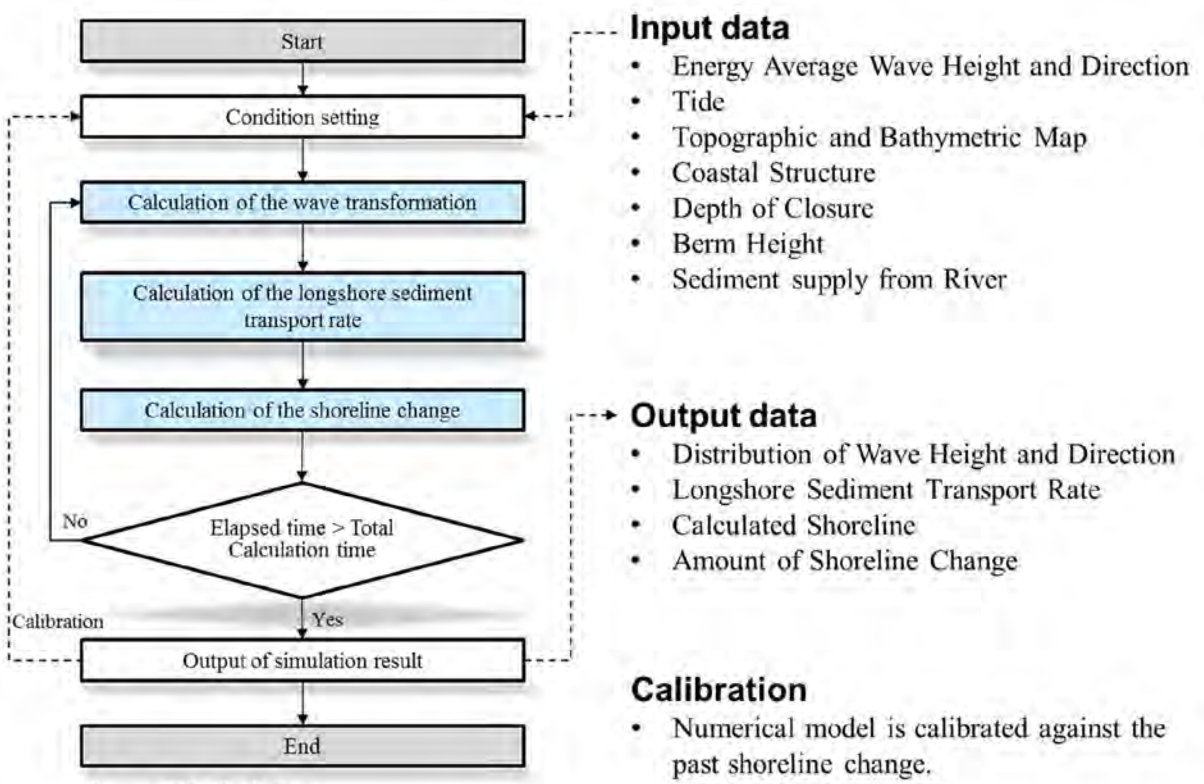
Table 2.4.2 Analyses of collecting data

ANALYSIS	INPUT	OUTPUT (PURPOSE OF THE ANALYSIS)
Analysis of Shoreline change	Aerial photographs, Satellite images	Shoreline change over time - The analysis of the shoreline change based on the satellite images and aerial photographs will be conducted to understand the direction and the amount of the sediment transport. - The mechanism of sediment transport will be investigated by the shoreline change analysis. Based on the results of shoreline change and sediment transport mechanism, the sediment transport maps will be created.
Analysis of Wave data	Wave data, Typhoon/Monsoon, Wind data	Wave characteristic - Energy average wave height and direction is used for numerical simulation.
Analysis of Tide data	Tide data	Characteristic tide level - High water level, Highest high water level (H.H.W.L) - Mean water level, Low water level
Analysis of Bathymetry and Topography data	Bathymetry map, Topographic map	Change of water depth over time, Average bottom slope - The analysis of the bathymetric data is carried out to grasp the amount of the sediment transport quantitatively.

ANALYSIS	INPUT	OUTPUT (PURPOSE OF THE ANALYSIS)
Analysis of Depth of Closure	Bathymetry map, Marine chart, Coast profile, Subsoil data (grain size)	Depth of Closure - It is used for numerical simulation.
Analysis of Berm Height	Topographic map, Coast profile Subsoil data (grain size)	Berm Height - It is used for numerical simulation.

3) Theory of hindcasting model

Reconstruction by a model of the historical change is called hindcasting. The hindcasting model used in this study consists of two sub-models: wave field model for reproduction of the wave field in the targeted area and 1-line model for analyzing the shoreline changes. Details of simulation steps and the overview of the numerical simulation model are shown in **Fig 2.4.2**.



Source: JICA Study Team

Figure 2.4.2 Simulation steps

Wave Field Model

Deep ocean incident wave data of 27 years (1988 - 2014) were reproduced using the observed wind data at an offshore point (N 16.00 E108.50) of Cua Dai Beach. Then, the wave in surf-zone were calculated from calculated deep ocean wave using wave deformation analysis considering all the factors that lead to changes in the wave characteristics (wave height, wave period and wave direction) such as wave decay, wave set-up, friction, refraction, dissipation of wave energy in the breaking process etc. Climatic conditions of this area are strongly characterized by monsoons, which results in the domination of southwest wind in summer and northeast wind in winter. To represent the transformation of incident wave in plane wave field due to these large-scale climatic changes, a model based on energy balance equation has been applied.
Breaker wave height and wave direction are needed as boundary conditions for the 1-line model. In this study, they were calculated by coupling a wave decay model (Isobe, 1986) in the energy balance equation. Karlsson function of wave energy balance is shown as below:

$$\frac{\partial}{\partial x}(DV_x)+\frac{\partial}{\partial y}(DV_y)+\frac{\partial}{\partial \theta}(DV_\theta)=\begin{cases}0 & (\gamma \le \gamma_b)\\ -\Phi_d & (\gamma > \gamma_b)\end{cases} \qquad (3.3.1)$$

$$V_x = C_g \cos\theta$$
$$V_y = C_g \sin\theta$$
$$V_\theta = \frac{C}{C_g}\left(\frac{\partial C}{\partial x}\sin\theta - \frac{\partial C}{\partial y}\cos\theta\right) \qquad (3.3.2)$$

Where, x, y: alongshore and offshore coordinate axis; D: spectrum density; C: wave velocity; Cg: group velocity; Φ_d: energy dissipation function due to wave breaking (wave breaking model of Isobe (1986)); γ : ratio between flow and wave velocity; γ_b : breaking limit at water depth of γ.

Basic assumption for this model

- Form of wave is unchanged for time.
- Partial wave period is unchanged.
- External energy is not considered.
-

Shoreline Change Model

In this study, a numerical model for analysis of shoreline change is developed based on the basic theory of 1-line model. In the 1-line model, longshore sediment transport is assumed to occur uniformly over the beach profile from the berm height down to the depth of closure (Hanson, 1989).
The overall equation of shoreline change was derived by considering the conservation of a control volume of sediment during an infinitesimal interval of time (**Fig 2.4.3**).

$$\frac{\partial y}{\partial t}+\frac{1}{D_s}\frac{\partial Q}{\partial x}=0 \qquad (3.3.3)$$

Where, y: shoreline position, x: longshore coordinate, t: time, D_s : depth of closure, Q : longshore sediment transport rate.
Breaker wave height and wave direction, which were already calculated by wave plain field model as explained above, were used to calculate rate of longshore sediment transport based on equation of Ozasa・Brampton (1979).

$$Q=\frac{(EC_g)_b}{(\rho_s-\rho)g(1-\lambda)}\left(K_1\sin\alpha_{bs}\cos\alpha_{bs}-K_2\cot\beta\cos\alpha_{bs}\frac{\partial H_b}{\partial x}\right)= \qquad (3.3.4)$$

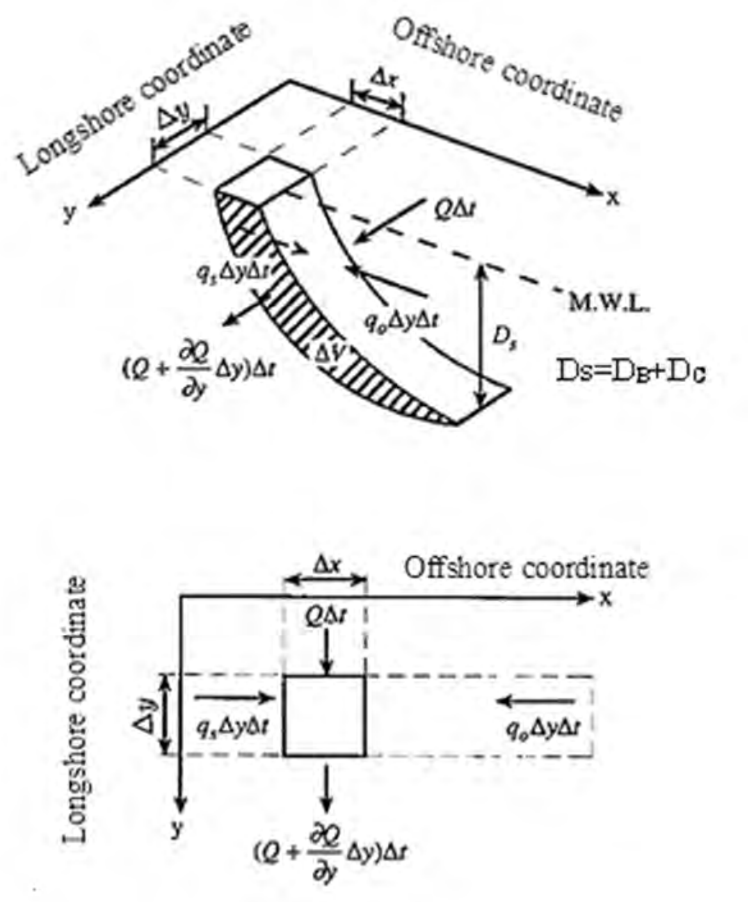
Where, E: wave energy density, C_g: wave group velocity, ρ, ρ_s : density of water and sand, λ: porosity of sand (=0.4), g: gravitational of acceleration (=9.8 m/s^2), K_1, K_2: non-dimensional parameter

(K_1=0.38, K_2=0.62), α_{bs}: angle between breaking wave crest and shoreline, cotβ: inverse of sea slope, H_b: breaker wave height.

In this study, depth of closure Ds was calculated after Hallermeiyer (1981).

$$D_s = \left(2.28 - 10.9 \frac{H_0}{L_0} \right) H_0 \qquad (3.3.5)$$

Where H_0, L_0 are offshore wave height and length, respectively.
Analysis result was confirmed with considered closure depth obtained based on grain size analysis.



Source: Horikawa (1985)

Figure 2.4.3 Theory of 1-line model

<u>Basic assumption for this model</u>

- Only longshore sediment transport causes shoreline change.
- Sediment is transported alongshore between two well-defined limiting elevations on the profile.
- The beach profile maintains an average shape, which represents characteristics of the study coast, except storm-induced extreme changes.

<u>Limiting elevation on the profile</u>

- DB: Average Berm Height (m)
- DC: Depth of Closure (m)

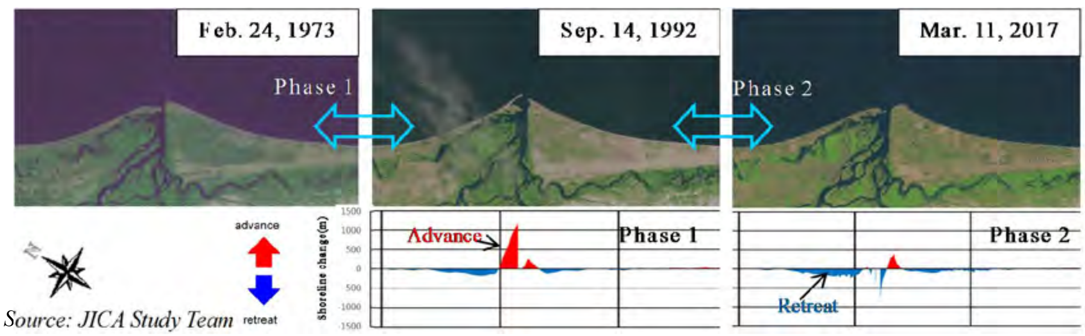
<u>Limiting elevation on the profile</u>

- Equilibrium beach slope: extracting from real beach profile

(3) Analysis of Collected Data

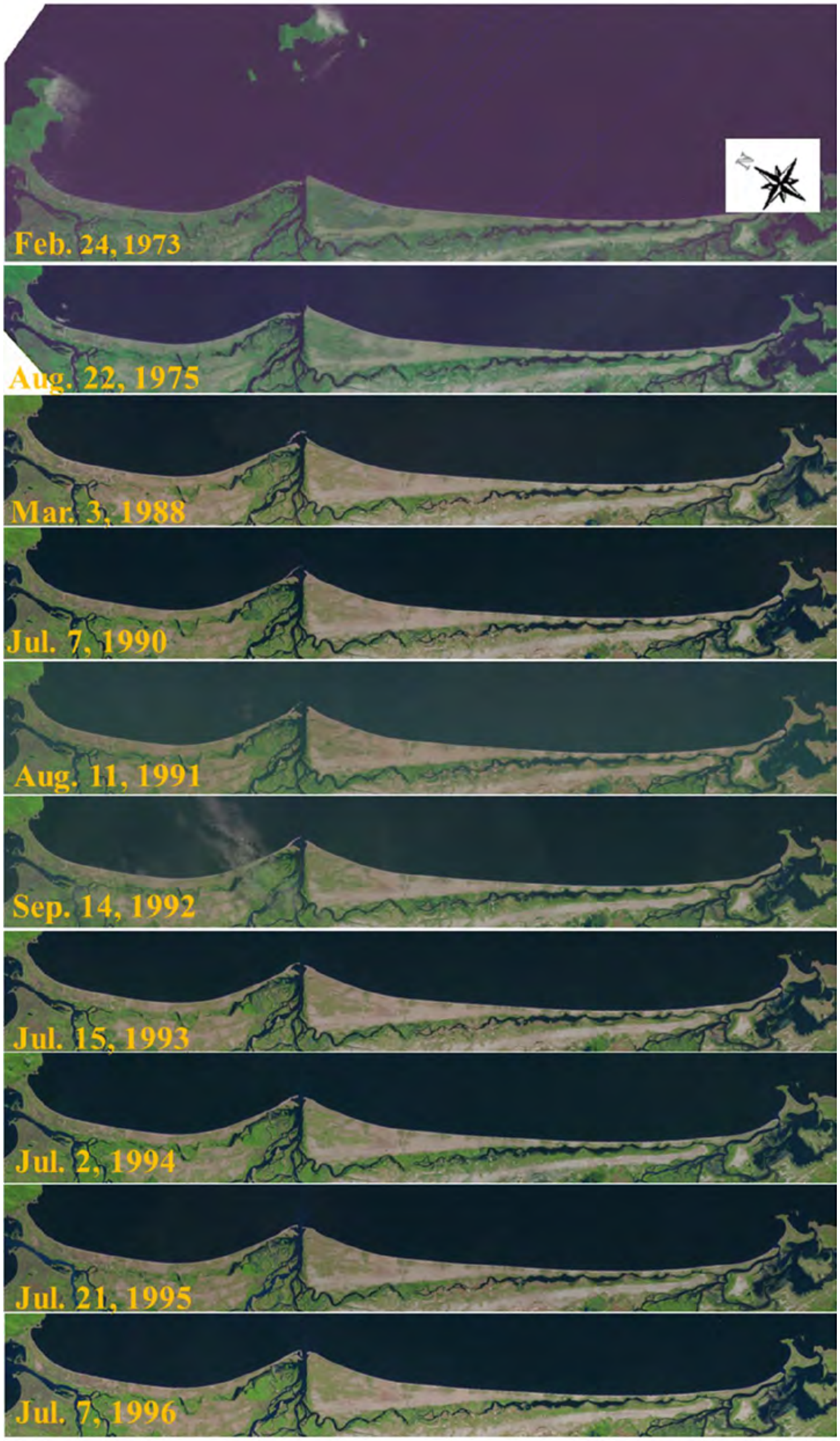
1) Analysis of shoreline change from Satellite Images

Satellite images captured during February 1973 to March 2017 of area from the Son Tra peninsula to Truong Giang river estuary (**Figure 2.4.5-7)** have been collected for analysis of the shoreline change. The analysis of long–term shoreline change has been conducted using Landsat images since it is difficult to obtain other high-resolution aerial photographs from the past to the present in Vietnam. Despite the low resolution, it is possible to obtain Landsat images from almost every year since 1973. In this study, 28 pieces of Landsat images from 1973 to 2017 were analyzed (**Fig 2.4.8-14**). The analysis result of long-term shoreline change is shown in **Fig 2.4.4**. There are two phases of shoreline change. In the first phase, from 1973 to 1992, the coastline near the Thu Bon River mouth had advanced. During this time, it's estimated that the Thu Bon River could have supplied the abundant sediment volume. In the second phase, from 1993 to 2017, the coastline had retreated and it's presumed that the sediment supply from the river decreased due to sand mining and dam constructions.



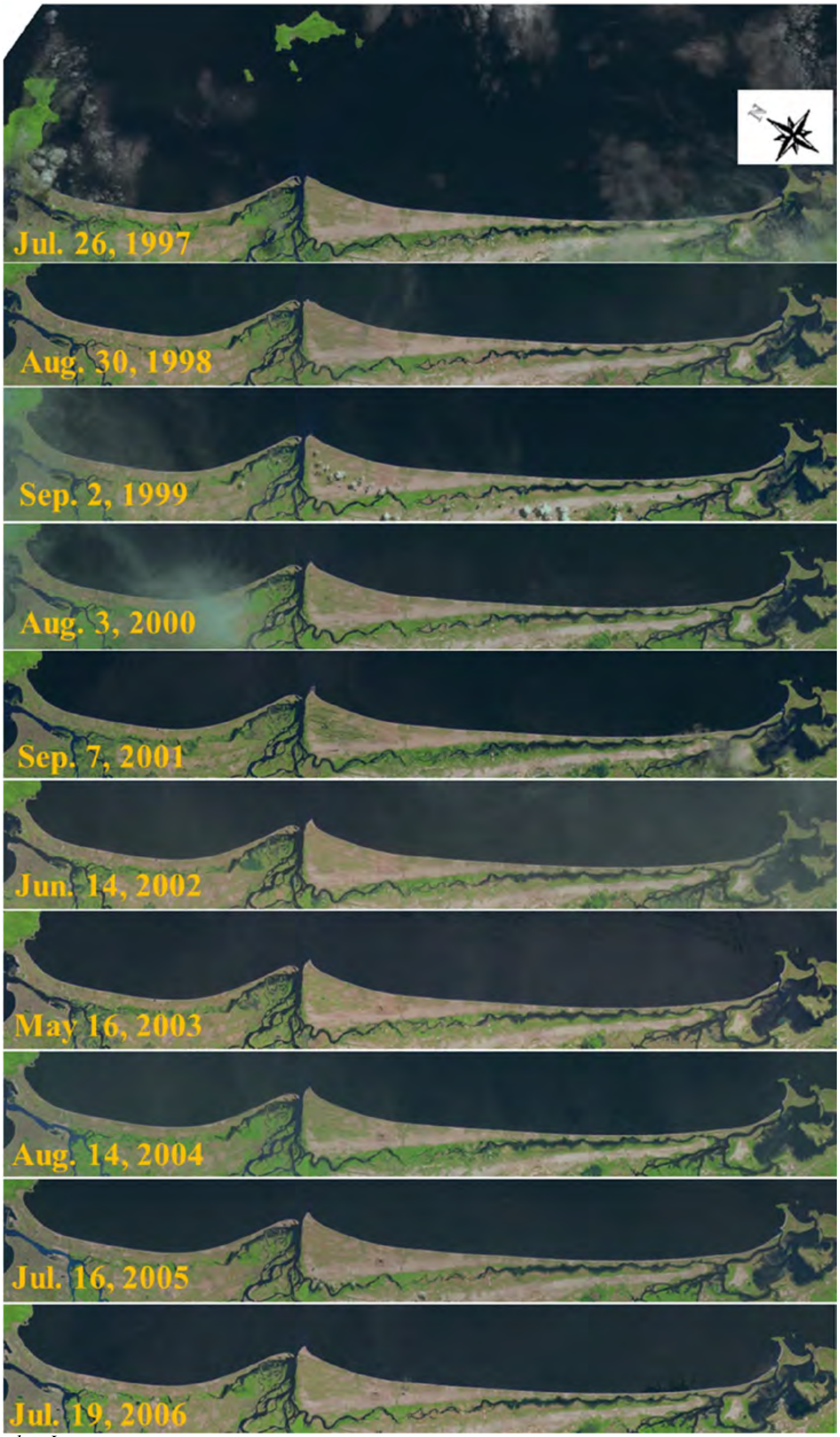
Source: JICA Study Team

Figure 2.4.4 Two Phases of Shoreline change (Reference year: 1973)



Source: Landsat Image

Figure 2.4.5 Satellite Image (1)

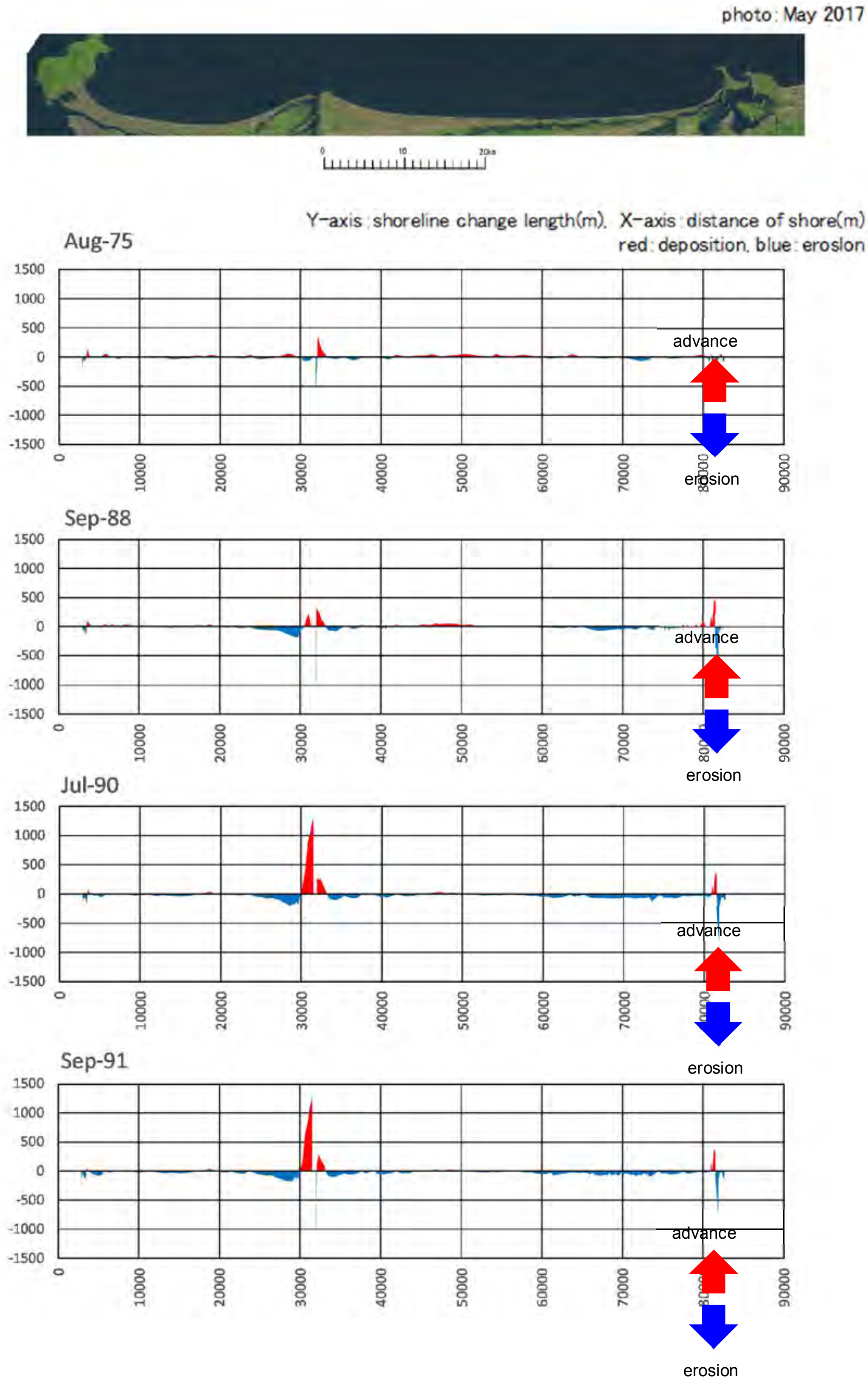


Source: Landsat Image

Figure 2.4.6 Satellite Image (2)

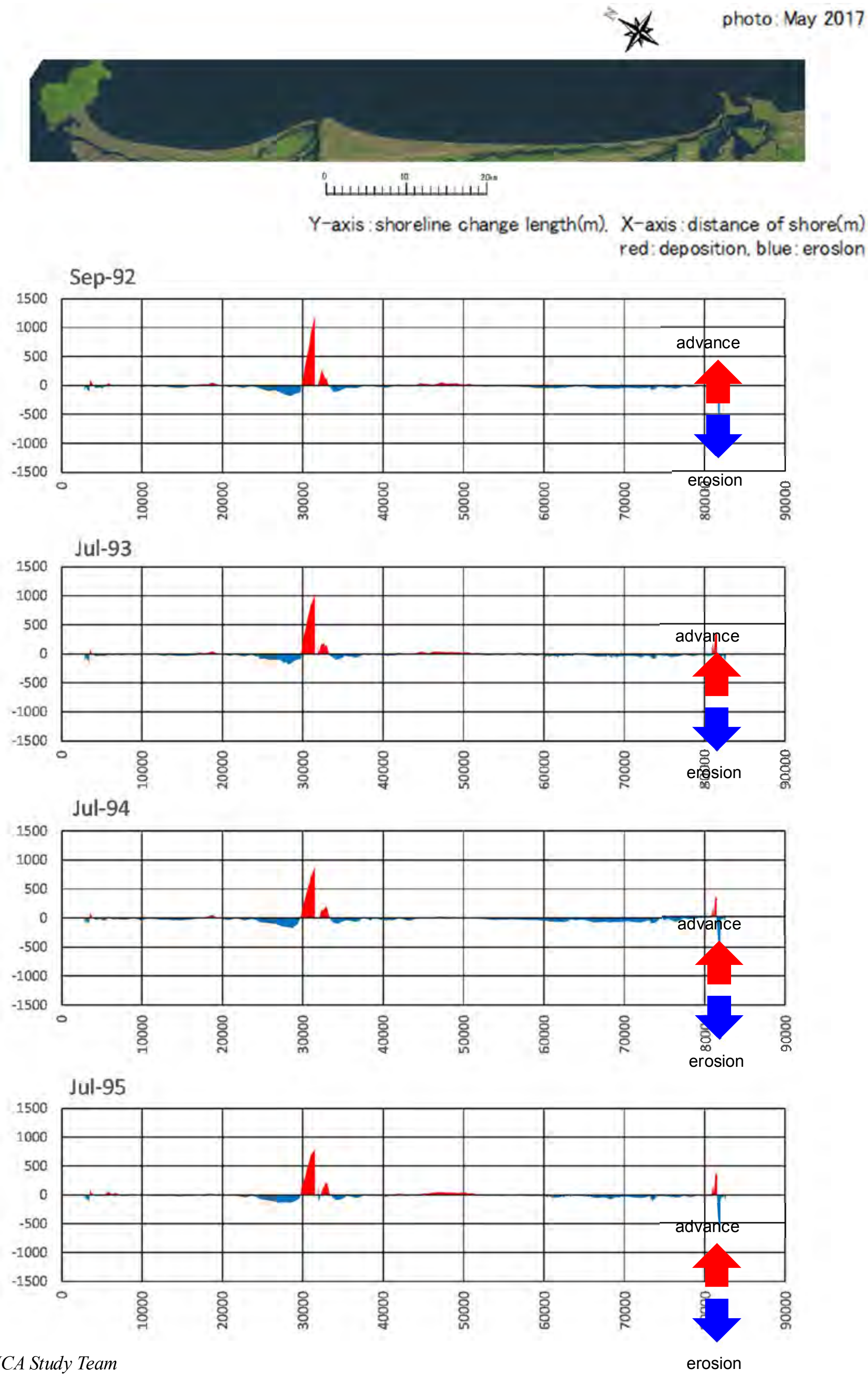
Source: Landsat Image

Figure 2.4.7 Satellite Image (3)



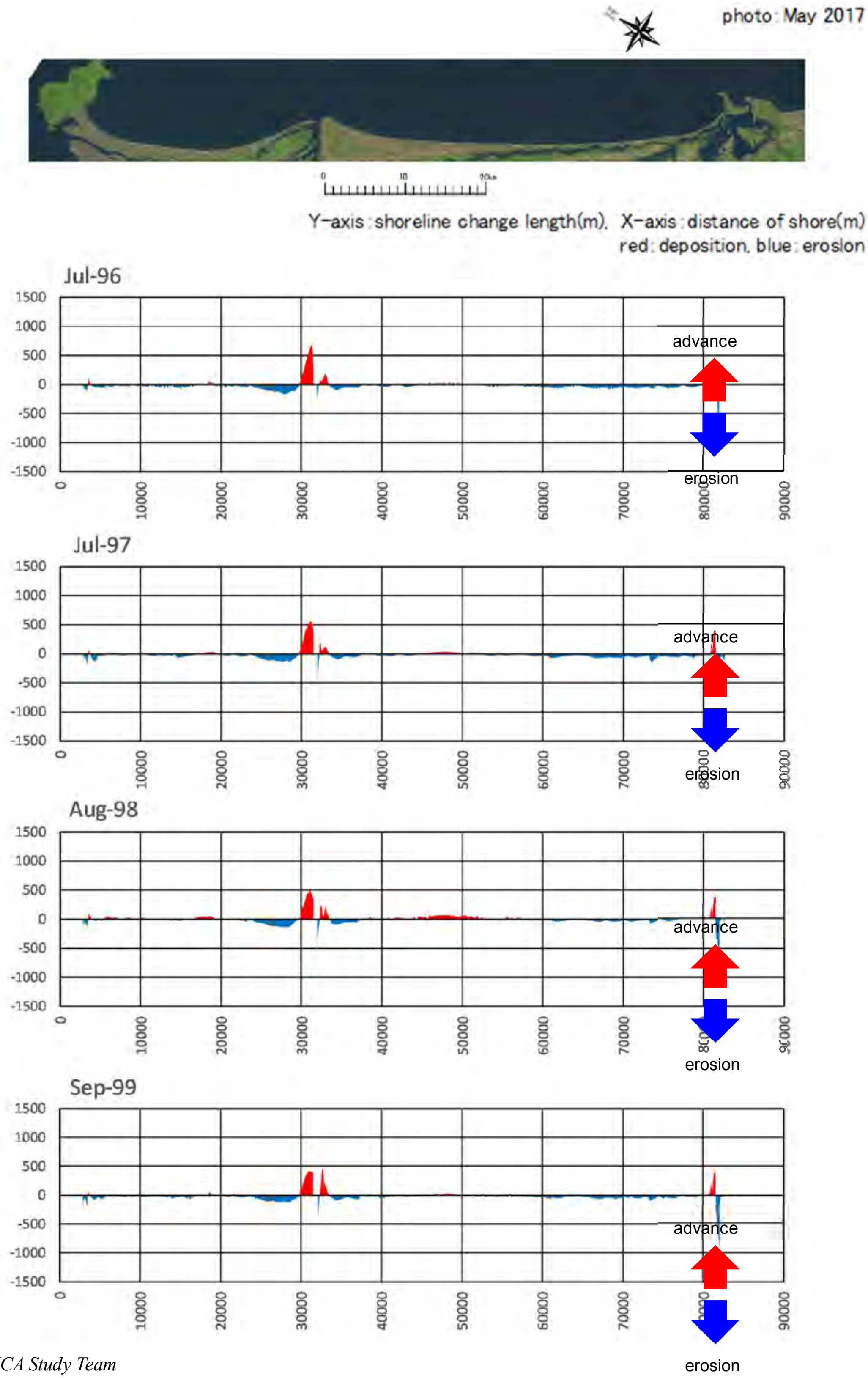
Source: JICA Study Team

Figure 2.4.8 Shoreline change extracted from satellite image (1)



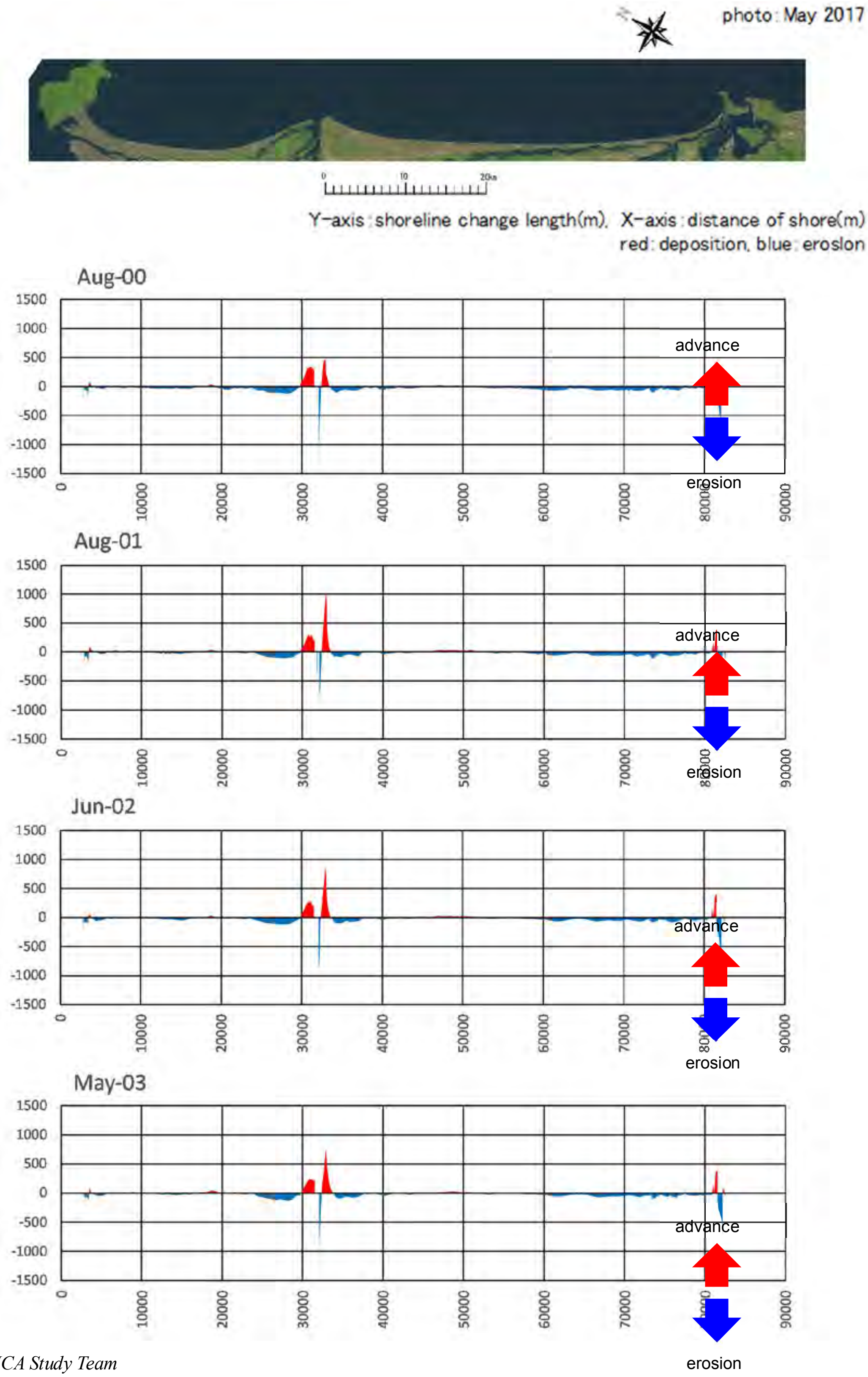
Source: JICA Study Team

Figure 2.4.9 Shoreline change extracted from satellite image (2)



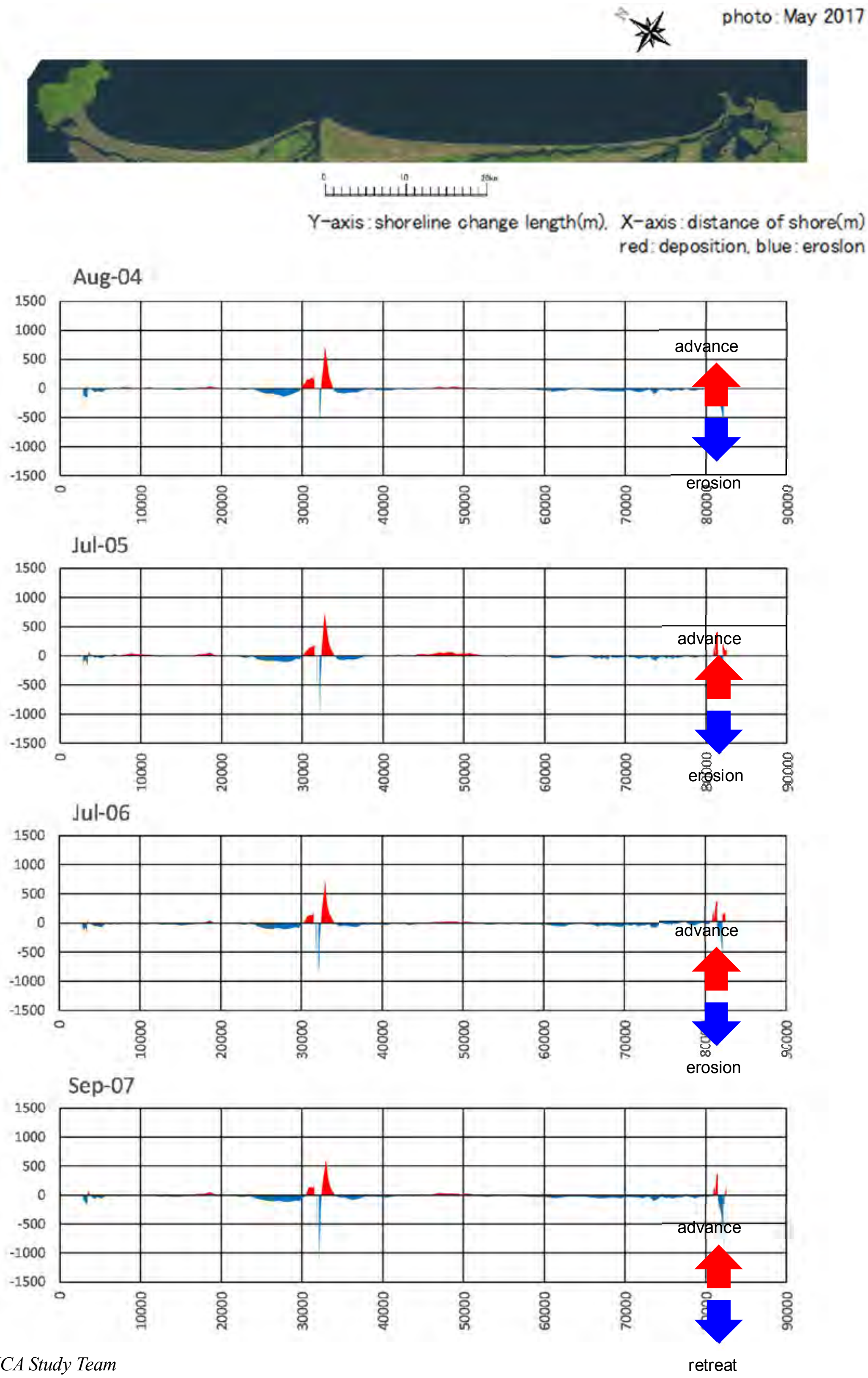
Source: JICA Study Team

Figure 2.4.10 Shoreline change extracted from satellite image (3)



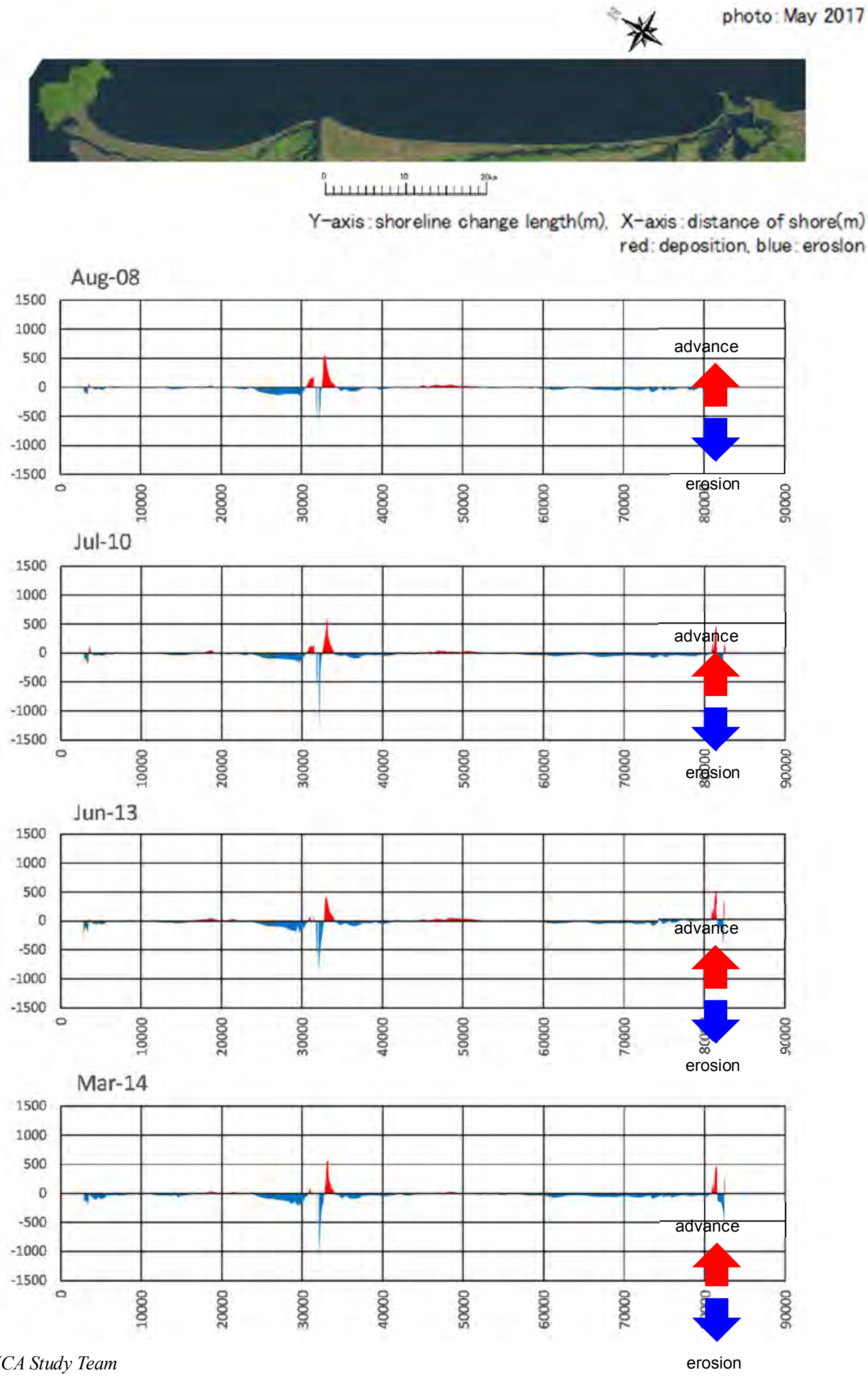
Source: JICA Study Team

Figure 2.4.11 Shoreline change extracted from satellite image (4)



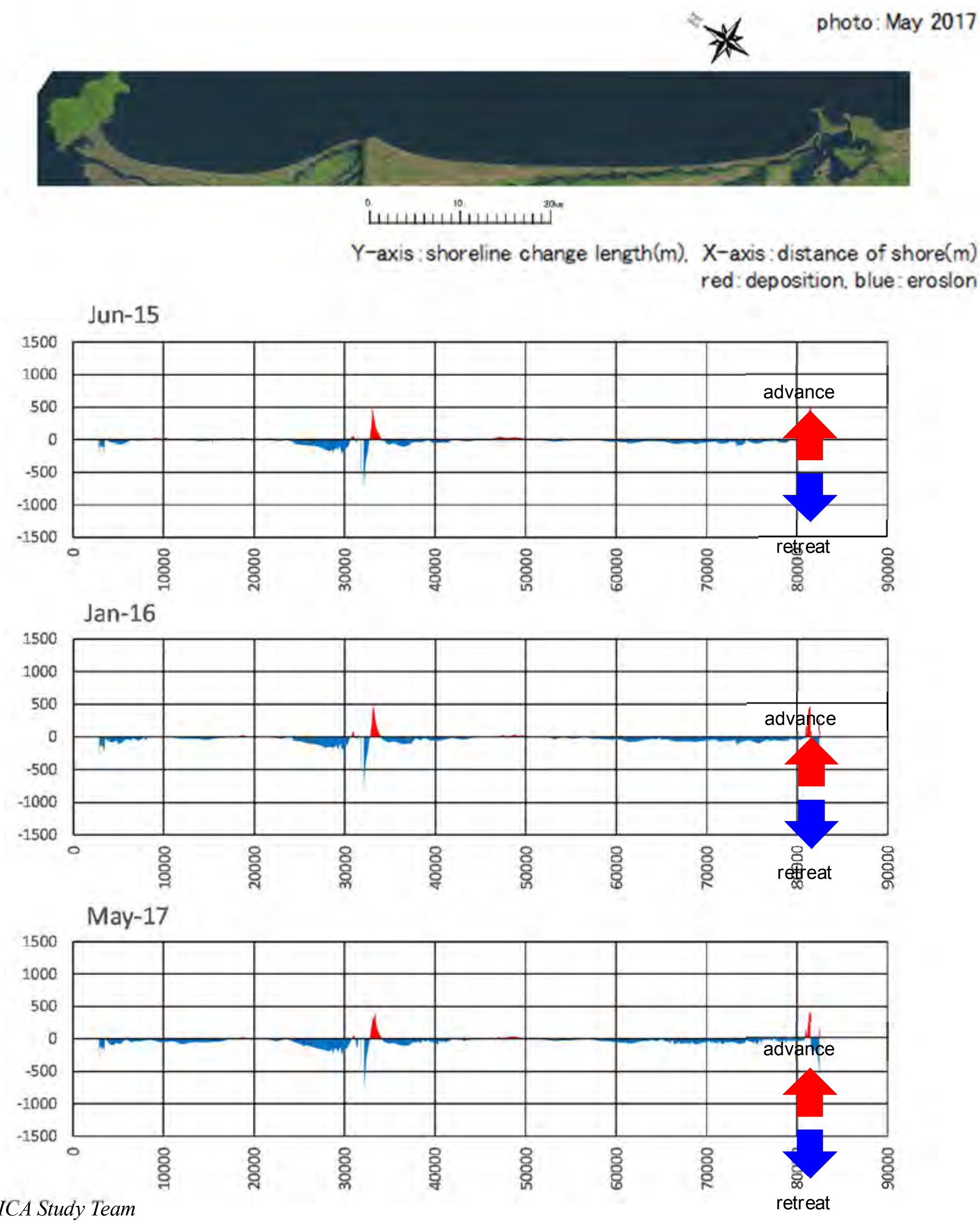
Source: JICA Study Team

Figure 2.4.12 Shoreline change extracted from satellite image (5)



Source: JICA Study Team

Figure 2.4.13 Shoreline change extracted from satellite image (6)

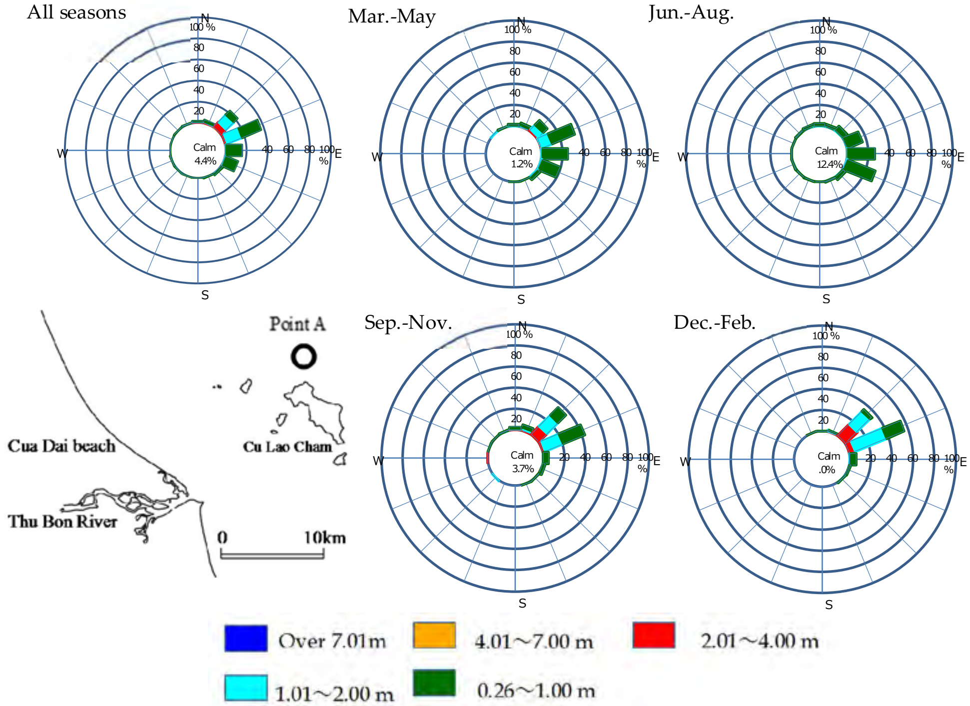


Source: JICA Study Team

Figure 2.4.14 Shoreline change extracted from satellite image (7)

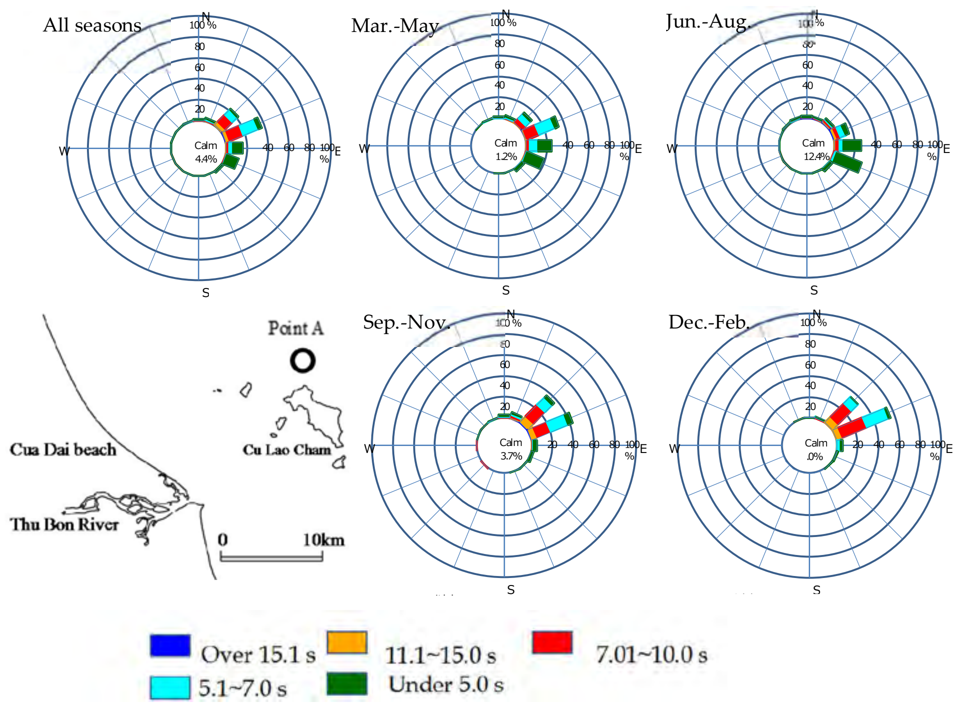
2) Analysis of wave data

The incident wave data of 27 years (1988 - 2014) has been reanalyzed from the observed wind data at a point (N 16.00 E108.50) offshore of Cua Dai Beach, Point A - **Fig 2.4.15**). The characteristic of wave condition of this area is shown in **Fig 2.4.15-16**. The dominant wave directions are NE, ENE and E. In summer, the wave height is less than 1.0m. In winter, occurrence frequency of wave height larger than 1.0m is considerably high. The average wave energy in this time period was estimated to be NE - ENE wave direction with 1.29 m of wave height and 7.46s of wave period.



Source: JICA Study Team

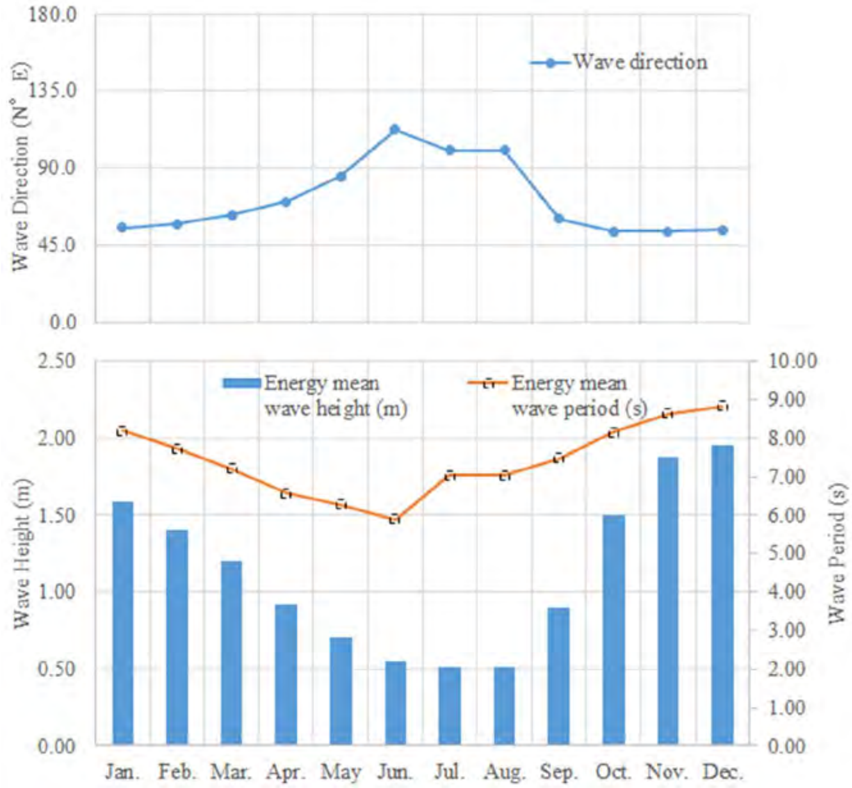
Figure 2.4.15 Distribution of Wave Height



Source: JICA Study Team

Figure 2.4.16 Distribution of Wave Period

The monthly mean wave energy are shown in **Fig 2.4.17**. And the simulation cases are shown in **Table 2.4.3**. As mentioned above, the summer wave differs from the winter wave. The mean wave energy of summer monsoon and winter monsoon are shown in **Table 2.4.4**.



Source: JICA Study Team

Figure 2.4.17 Monthly Mean Wave Energy at Point A

Case	Energy average wave height (m)	Energy average wave period (s)	Wave direction
All-Season	1.29	7.36	N58.0°E
Jan.	1.59	8.20	N55.0°E
Feb.	1.40	7.74	N57.3°E
Mar.	1.20	7.20	N62.4°E
Apr.	0.92	6.57	N70.2°E
May	0.71	6.29	N85.1°E
Jun.	0.55	5.89	N112.4°E
Jul.	0.51	7.03	N100.1°E
Aug.	0.51	7.03	N100.1°E
Sep.	0.90	7.49	N60.3°E
Oct.	1.50	8.15	N53.0°E
Nov.	1.88	8.65	N52.8°E
Dec.	1.95	8.84	N53.7° E

Table 2.4.3 Monthly Mean Wave Energy at Point A

Source: JICA Study Team

Table 2.4.4 Mean Wave Energy of Monsoon

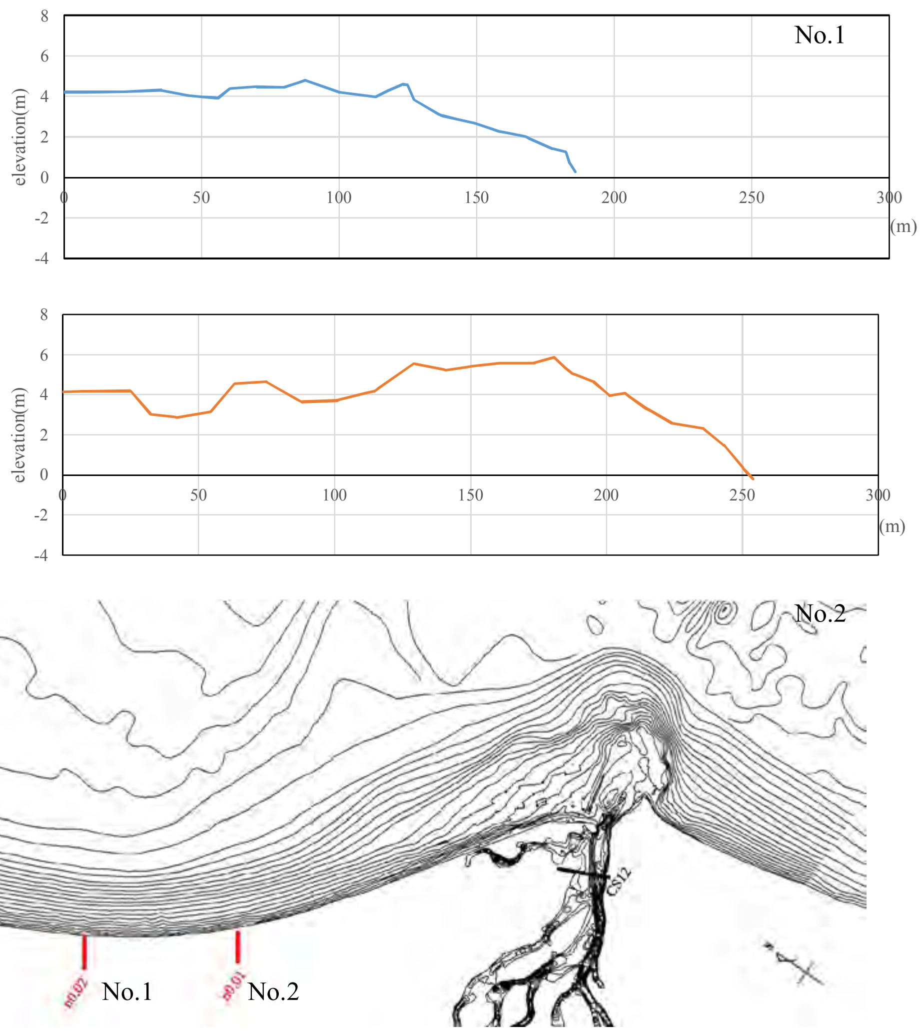
Case		Wave Height unit: m	Wave Period unit: s	Wave Direction unit: degree
Summer monsoon	May-Oct.	0.89	6.87	65.9
Winter monsson	Nov.-Apr.	1.57	7.86	55.8

Source: JICA Study Team

3) Analysis of Berm Height and Depth of Closure

The beach profile observed in field study is shown in **Fig 2.4.18**. Based on these data and sand sampling data, the berm height and depth of closure in Cua Dai Beach were determined.

- Berm Height: 1.8m (after Sunamura equation)
- Depth of Closure: -6m (after Hallermeiyer equation)



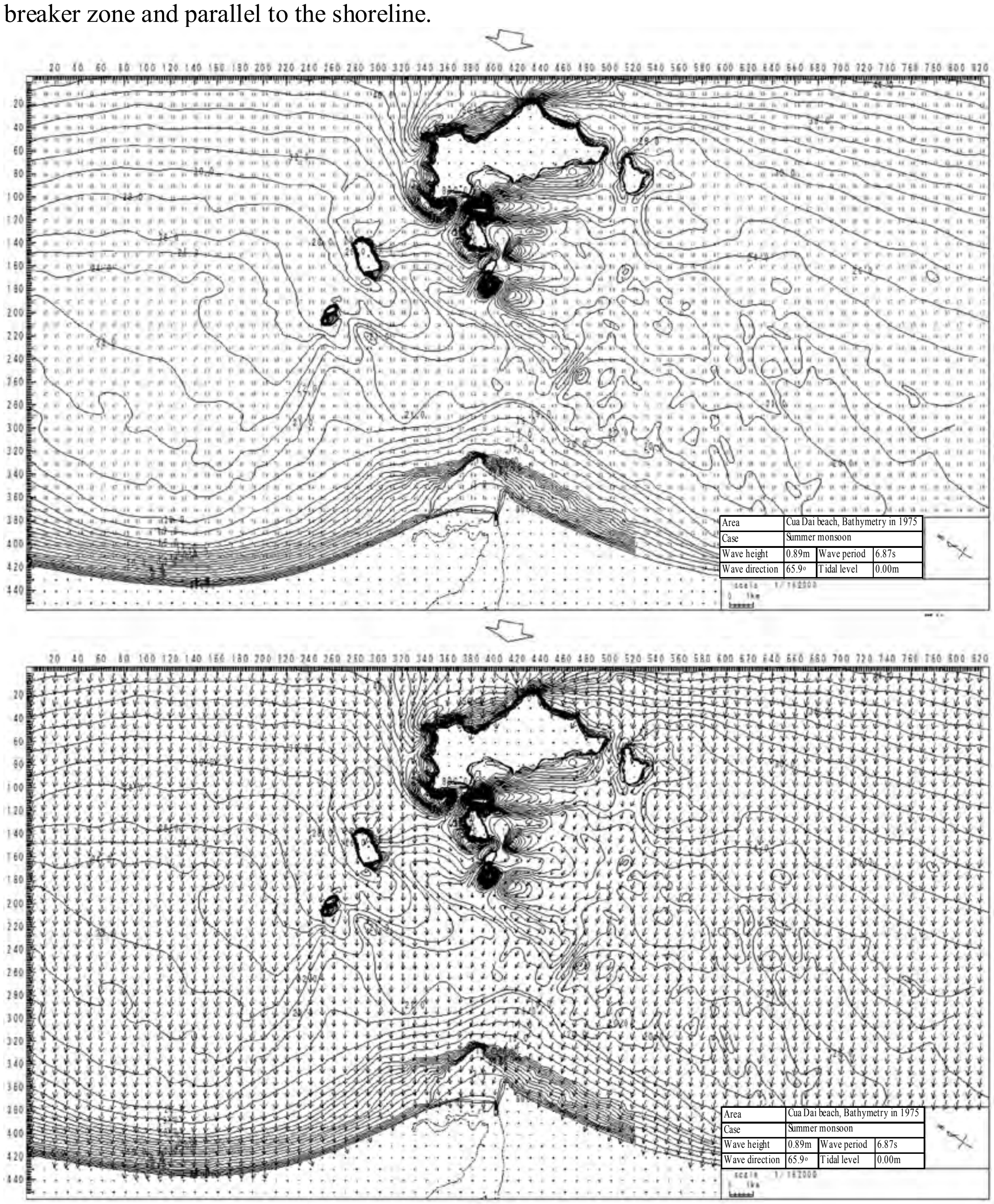
Source: JICA Study Team

Figure 2.4.18 Beach Profile

(4) Numerical Simulation

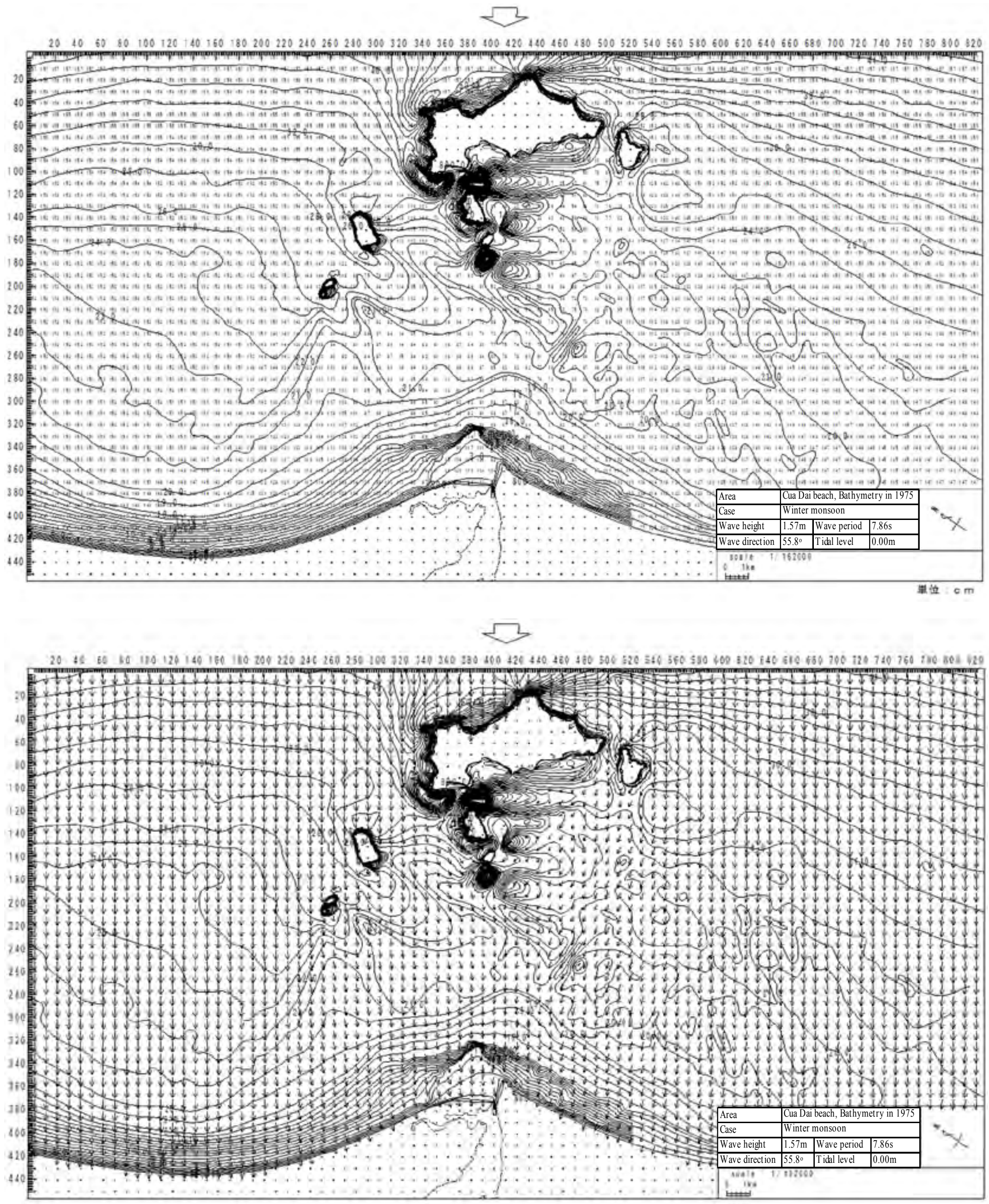
1) Calculation of Wave Transformation

The distributions of calculated wave height and wave direction are shown in **Figure 2.4.19-20.** Available data to study the characteristic of nearshore wave conditions are extracted from the area near breaker zone and parallel to the shoreline.



Source: JICA Study Team

Figure 2.4.19 Distribution of Calculated Wave Height and Wave Direction in Summer Monsoon



Source: JICA Study Team

Figure 2.4.20 Distribution of Calculated Wave Height and Wave Direction in Summer Monsoon

2) Analysis of Shoreline Change and Sediment Transport Rate

The numerical simulation model which can estimate the shoreline change has been developed. It is based on the basic theory of the 1-line model and it can predict the long-term change of shoreline due to longshore sediment transport. Two models were built to re-create the two phases of shoreline change described in the previous section.

Calculation Conditions: The calculation conditions are shown in **Table 2.4.5**.and **Table 2.4.6**

Table 2.4.5 Analysis Condition (CASE1)

Items	CASE1
Analysis range	Range：40km、 mesh size 50m
Incident wave	➢ Monsoon energy mean wave calculated from the offshore wave data Summer monsson (May-Oct.) 0.89m, 6.87s 65.9degree Winter monsoon (Nov.-Apr.) 1.57m, 7.86s, 55.8degree
Analysis period	May 1975 - May 1988, 14years (Phase1)
Shoreline data	Initial Shoreline：Apr. 1975 Landsat Image
	Coastal structures: -
Coefficient of Longshore sediment transport	K_1=0.011, K_2=0.009
Boundary of sediment transport	■ Berm height：1.8 m (calculated based on Sunamura equation)
	■ Closure Depth: -6.0 m (calculatted based on Hallermeiyer equation)
	■ Equilibrium slope: 1/170
Boundary conditions	Eastern side of longshore direction: open boundary
	■ Landside：No sediment transport
	■ Sediment supply from the river: 850,000 m^3/y = 550,000 m^3/y (Sediment supply from the river in Case2) +300,000m^3/y (Sand mining volume in Case2)
	■ Sand mining volume : 0m^3/y
	Western side of longshore direction: open boundary

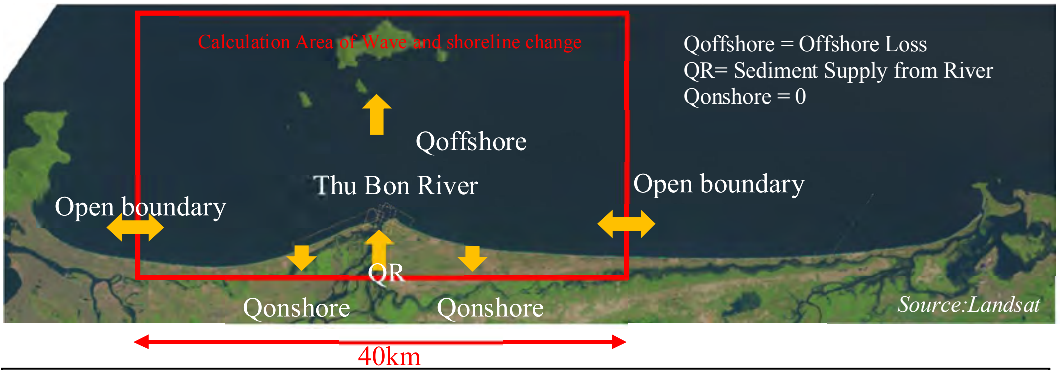
Table 2.4.6 Analysis condition (CASE2)

Items	CASE2
Analysis range	Range：40km、 mesh size 50m
Incident wave	➢ Monsoon energy mean wave calculated from the offshore wave data Summer monsson (May-Oct.) 0.89m, 6.87s 65.9degree Winter monsoon (Nov.-Apr.) 1.57m, 7.86s, 55.8degree
Analysis period	May 2001 - May 2017, 17years (Phase2)
Shoreline data	Initial Shoreline：Sep. 2001 Landsat Image
	Coastal structures: sea dike, groins, break water
Coefficient of Longshore sediment transport	K1=0.011, K2=0.009
Boundary of sediment transport	■ Berm height：1.8 m (calculated based on Sunamura equation)
	■ Closure Depth: -6.0 m (calculatted based on Hallermeiyer equation)
	■ Equilibrium slope: 1/170
Boundary conditions	Eastern side of longshore direction: open boundary
	■ Landside：No sediment transport
	■ Sediment supply from the river: 550,000 m^3/y Average value which were estimated in previous reserch
	■ Sand mining volume : 300,000m^3/y
	Western side of longshore direction: open boundary

Source: JICA Study Team

<u>Boundary Conditions</u>

The boundary conditions are set based on the terrain condition around the Cua Dai River mouth. The boundary conditions are shown in **Fig 2.4.21**.



CASE1
■ Sediment supply from the river: 850,000 m^3/year
= 550,000 m^3/y (Sediment supply from the river in Case2) +300,000m^3/y (Sand mining volume in Case2)
■ Sand mining volume and others : 0m^3/ year

CASE2
■ Sediment supply from the river: 550,000 m^3/ year
Average value which were estimated in previous research
■ Sand mining volume and others : 300,000m^3/ year

Source: JICA Study Team

Figure 2.4.21 Boundary Condition

Analysis Result of Shoreline Change and Sediment Transport Rate

【Case1】

Analysis results of shoreline change from 1975 to 1988 are shown in **Fig 2.4.22** which demonstrates an accretion trend in the northern area of Cua Dai estuary. Sediment transport rate are shown in **Fig 2.4.23**.

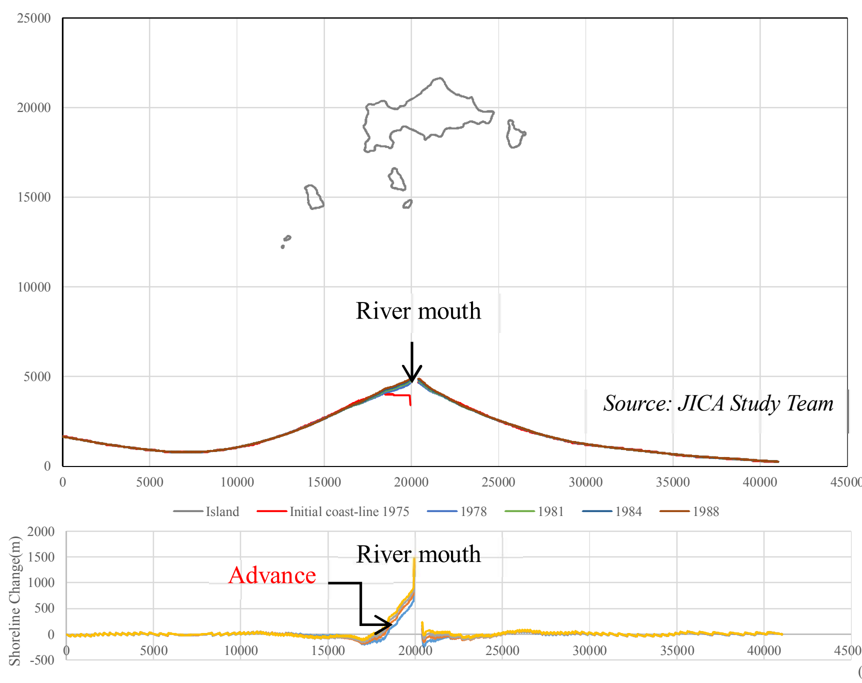
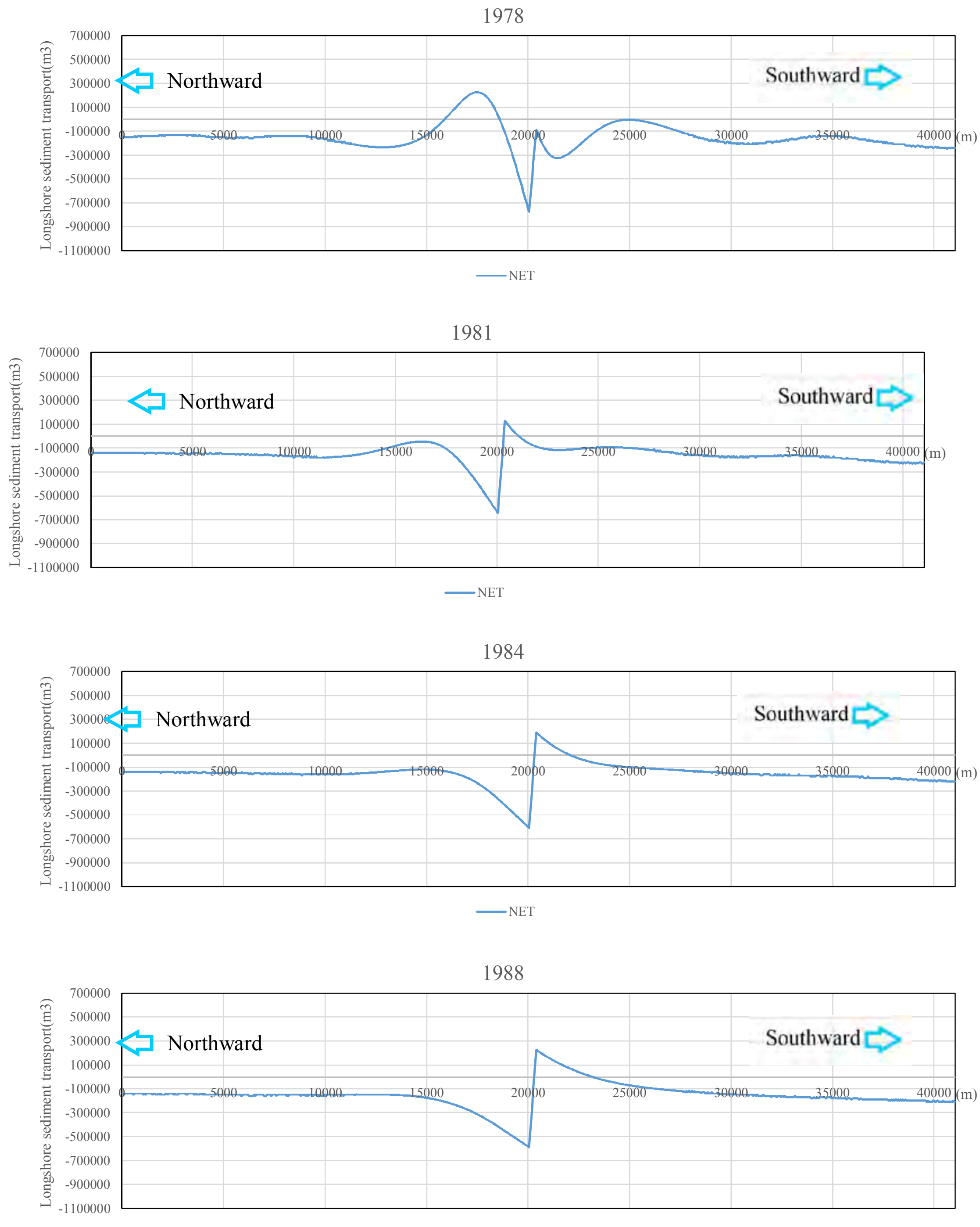


Figure 2.4.22 Analysis Result of Shoreline Change (CASE1)

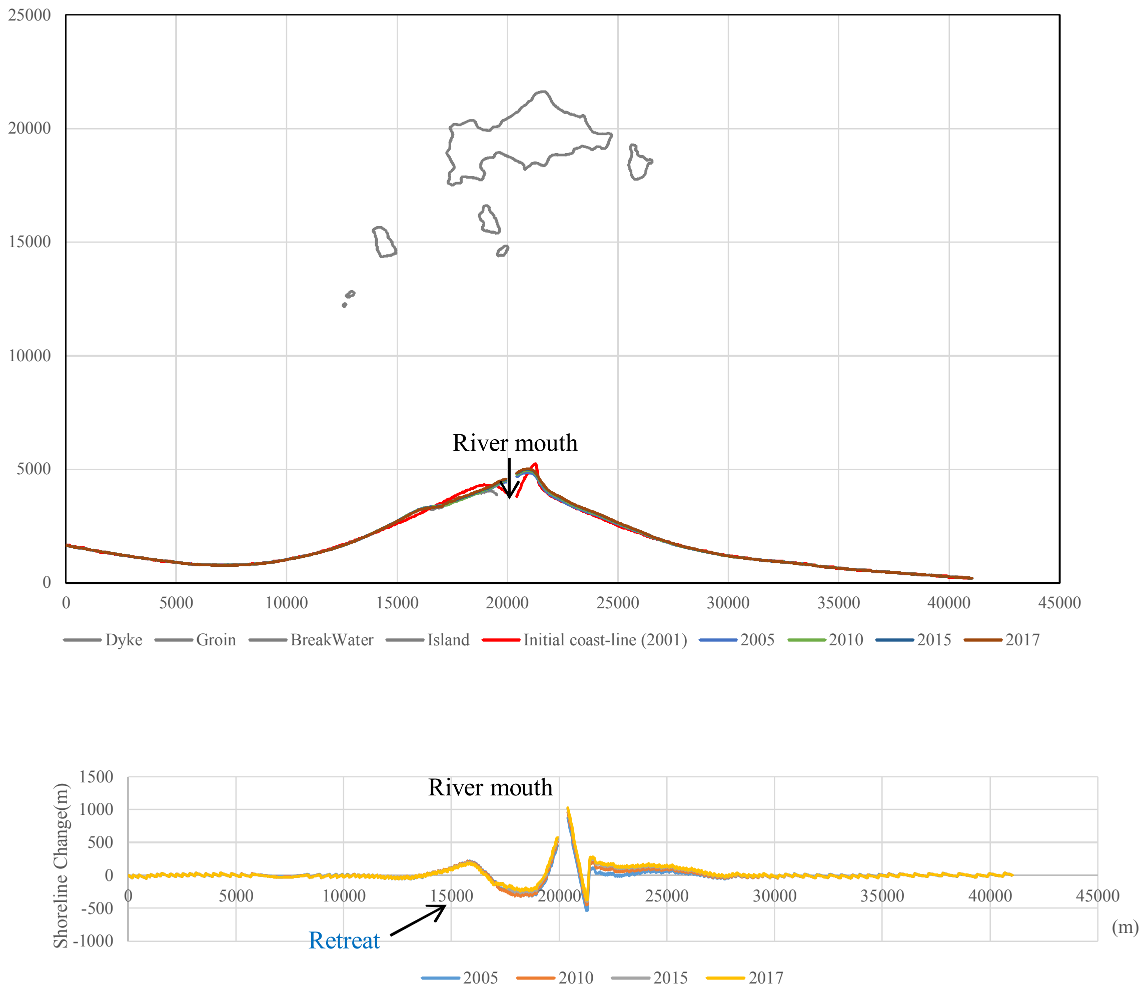


Source: JICA Study Team

Figure 2.4.23 Sediment Transport Rate (CASE1)

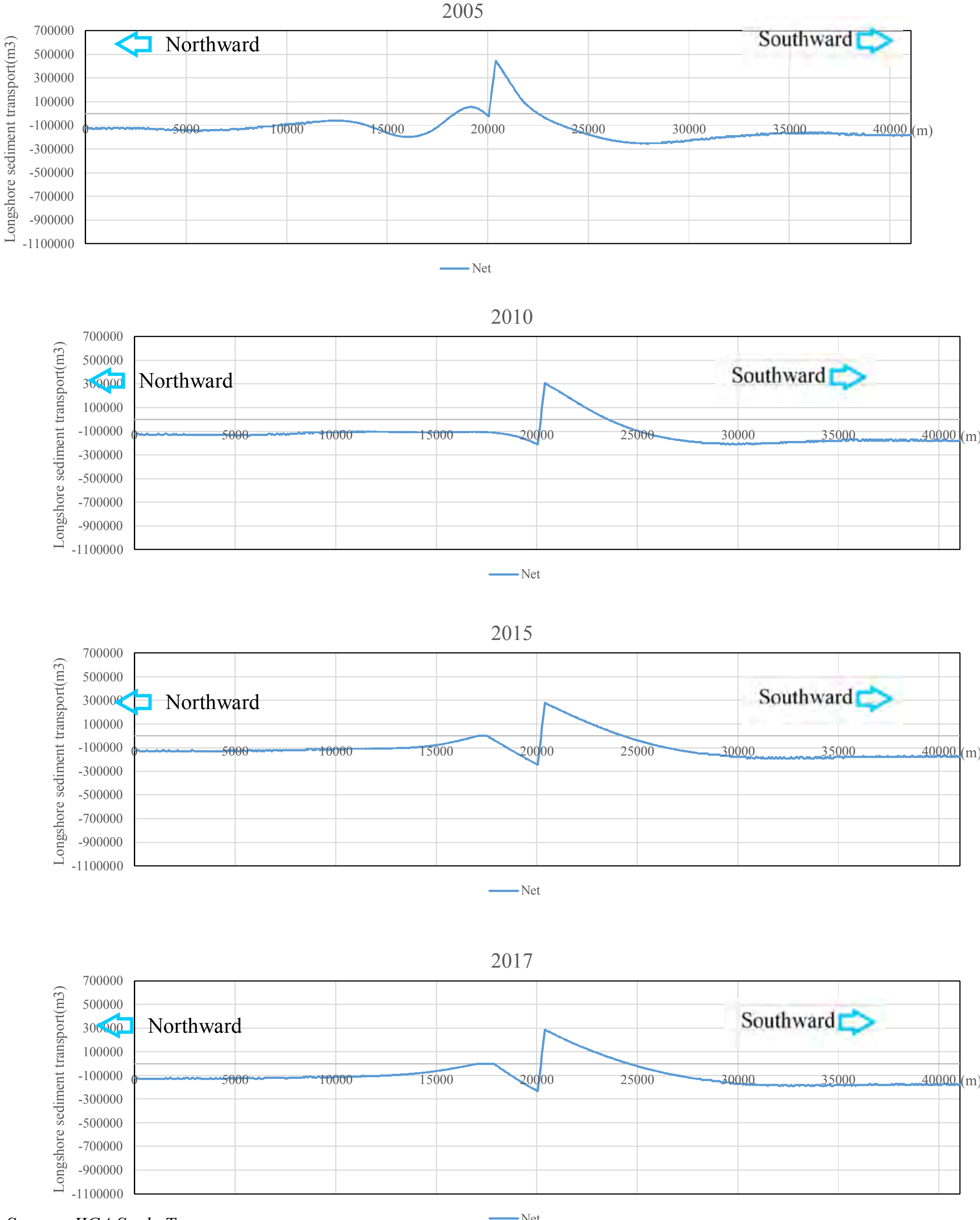
【Case2】

Analysis results of shoreline change from 2001 to 2017 are shown in **Fig 2.4.24**, which demonstrates an accretion trend in the southern area and an erosion trend in the northern area of Cua Dai estuary. And, the sediment transport rates are shown in **Fig 2.4.25**.



Source: JICA Study Team

Figure 2.4.24 Analysis Result of Shoreline Change (CASE2)

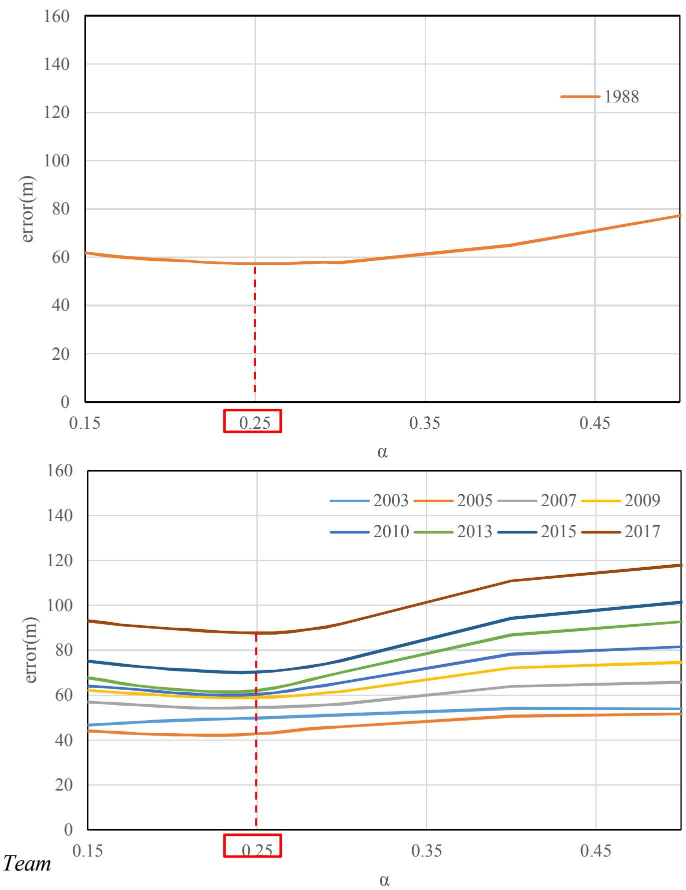


Source: JICA Study Team

Figure 2.4.25 Sediment Transport Rate (CASE2)

<u>Calibration</u>

Numerical models were calibrated based on data of past shoreline change. The coefficients for calibration are shown in **Fig 2.4.26**. The coefficient is determined to minimize the numerical errors between the calculated shoreline and the shoreline extracted from satellite image. The model using the coefficient α (=0.25) can explain the past shoreline change in this study.



Source: JICA Study Team

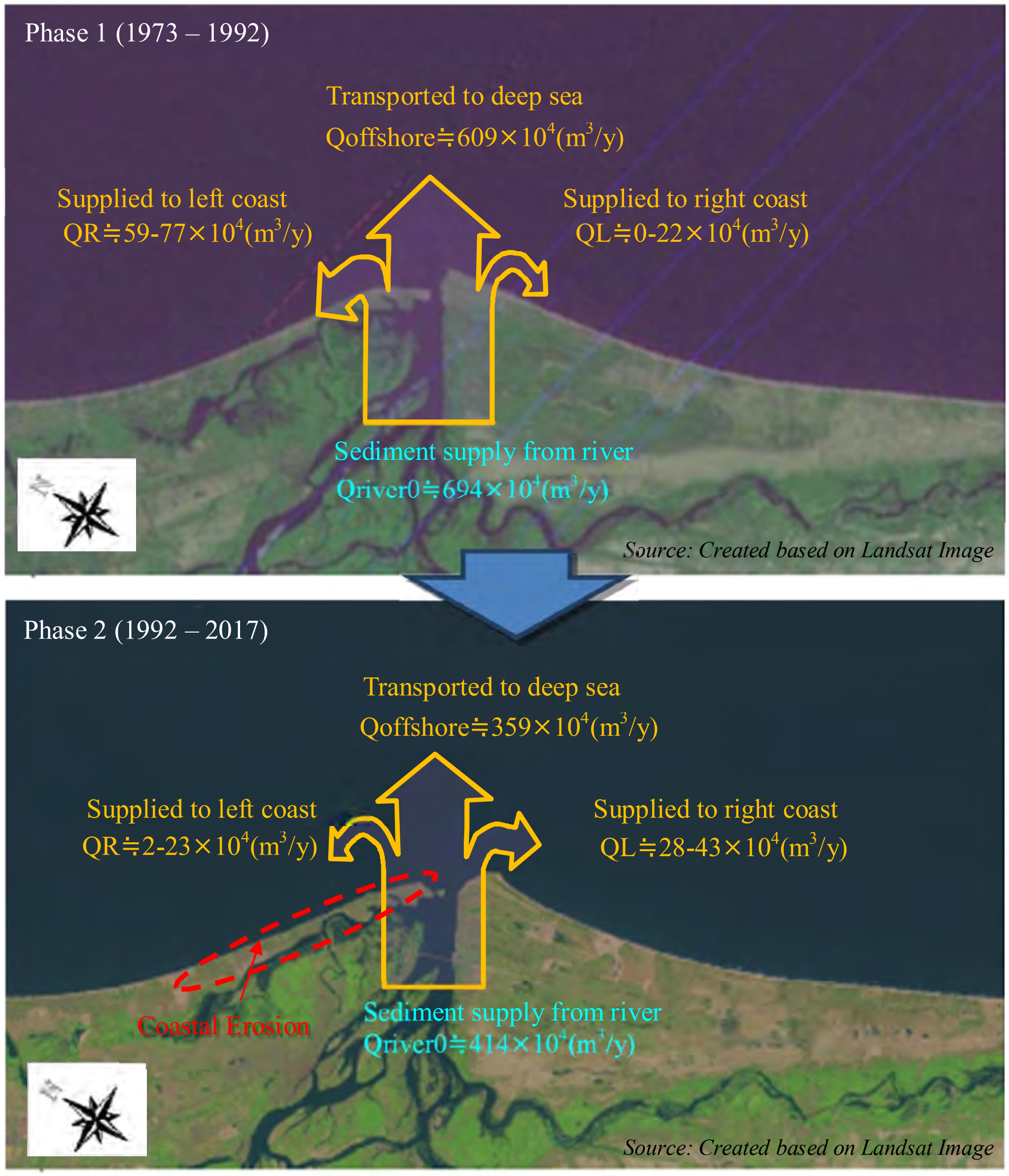
Figure 2.4.26 Calibration Coefficient

<u>Sediment Transport Map</u>

The sediment transport maps are shown in **Fig 2.4.27**. It shows the distribution rate of sediment supplied from the Thu Bon River mouth to offshore areas, the northern area, and the southern area. The balance of sediment supply northward and southward changed between Phase1 and Phase2. During Phase1 (1973-1992), the northward sediment transport is larger than southward sediment transport. However, this trend is reversed in Phase2 (1992-2017). Additionally, the sediment supply from river decreased in Phase2.

Therefore, the reproduction of the past shoreline changes by numerical simulation model (1-Line model) reveals that the main causes of severe erosion at Cua Dai beach are:

- Reduction of sediment supply from the river due to the dam constructions and sand mining
- Change in the directional distribution of the sediment supply from the river



Source: JICA Study Team

Figure 2.4.27 Sediment Transport Map

2.4.2 Causes of Reduction of Sediment Supply from River

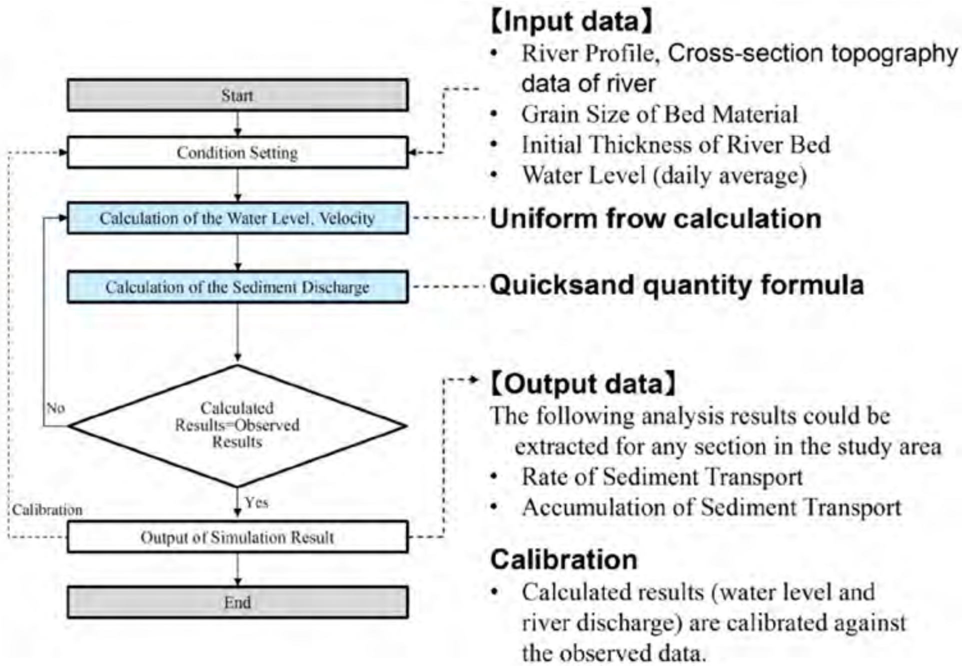
(1) Methodology of Analysis

Collected hydrological data, profile and bed materials of river basins and channels were used for quantitative analyses of sediment transport in river systems.

- **Analysis Policy**

Determine representative cross sections at about 10 to 15 points to calculate the amount of sediments that are transported through the cross sections. Based on the calculated results, evaluate the effect of dam construction or channel excavation on sediment transport.

- **Simulation Flow:** Calculation was conducted as flowchart in **Fig 2.4.28**



Source: JICA Study Team

Figure 2.4.28 Calculation Flow

Cross sections and discharges on the sections are used to conduct a uniform flow calculation and study hydraulic volumes. An equation of uniform flow is given below. In the case of the absence of measured discharges on the representative cross sections, measured discharges at other points, and information on basin areas at representative points and other points are used to establish discharge conditions.

$$u = \frac{1}{n} R^{2/3} I^{1/2} \qquad (2.1)$$

Where, u: Flow velocity $(=Q/A)$, Q: Discharge, A: Cross-sectional area of flow, n: Coefficient of roughness, R: Hydraulic radius, I: Bed slope
In order to obtain topographic features on the representative cross sections, past survey results, and survey results from the Project are used.

Analysis of sediment discharge
Hydraulic volumes from the uniform flow calculation and Ashida-Michiue Formula (*), an equation for sand carrying capacity to determine an amount of sediments. The Ashida-Michiue Formula is given below.

$$\frac{q_{bxk}}{\sqrt{sgD^3}} = 17\tau_*^{3/2}\left(1-\frac{\tau_{*c}}{\tau_*}\right)\left(1-\frac{u_{*c}}{u_*}\right) \qquad (2.2)$$

Where, q_{bkx} : Dimensionless sand drift volume, s: In-water gravity of bed material (=1.65), g : Gravity acceleration, D: Grain diameter, τ_*, τ_{*c}: Dimensionless tractive force and dimensionless critical tractive force, respectively, u_*: Friction velocity, u_{*c} : Critical friction velocity

Friction velocity u_* and dimensionless tractive force are calculated from the following equations, respectively.

$$u_*^2 = \frac{gn^2u^2}{R^{1/3}} \qquad (2.3)$$

$$\tau_* = \frac{u_*^2}{sgD} \qquad (2.4)$$

To calculate a critical friction velocity for transfer, Iwagaki formula has been applied with a grain diameter of 3.03mm or more. For reference, the units for u_* and D that are used in this equation are cm/s and cm, respectively.

$$u_{*c}^2 = 80.9D \quad (D \geq 0.303) \qquad (2.5)$$

Scenarios of calculation are shown in **Table 2.4.7.**

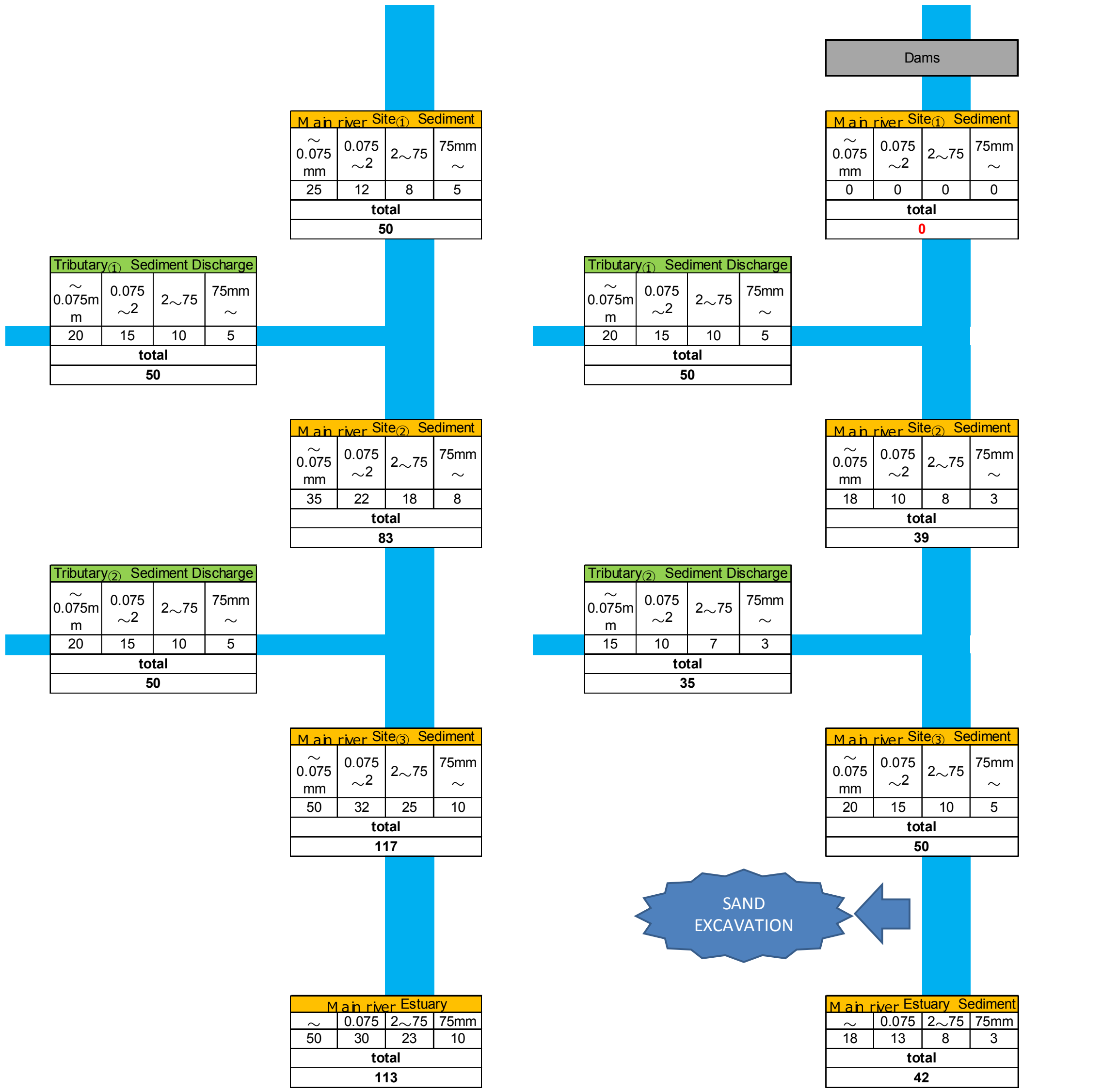
Table 2.4.7 Calculation Cases

<table>
<tr><th>Study CASE</th><th>Before dam construction</th><th>After dam construction
(Without dredging)</th><th>After dam construction
(With dredging)</th></tr>
<tr><td>Lateral profile</td><td>1997 and 2007 data</td><td colspan="2">2017 (the Project's) investigation data</td></tr>
<tr><td rowspan="2">Discharge</td><td>Before dam construction</td><td colspan="2">Recent</td></tr>
<tr><td colspan="3">Mean discharge over a given period (approximately 5 to 10 years)
* Apply a specific discharge value to each study point.</td></tr>
<tr><td>Bed material</td><td colspan="3">2017 (the Project's) investigation data</td></tr>
</table>

Source: JICA Study Team

- **Output Data**

As a result of the study, the amount of sediment that passes through each representative point is incorporated into a sediment balance diagram to determine the differences between the amount of sediment at the representative point and at the estuary (**Fig 2.4.29**).



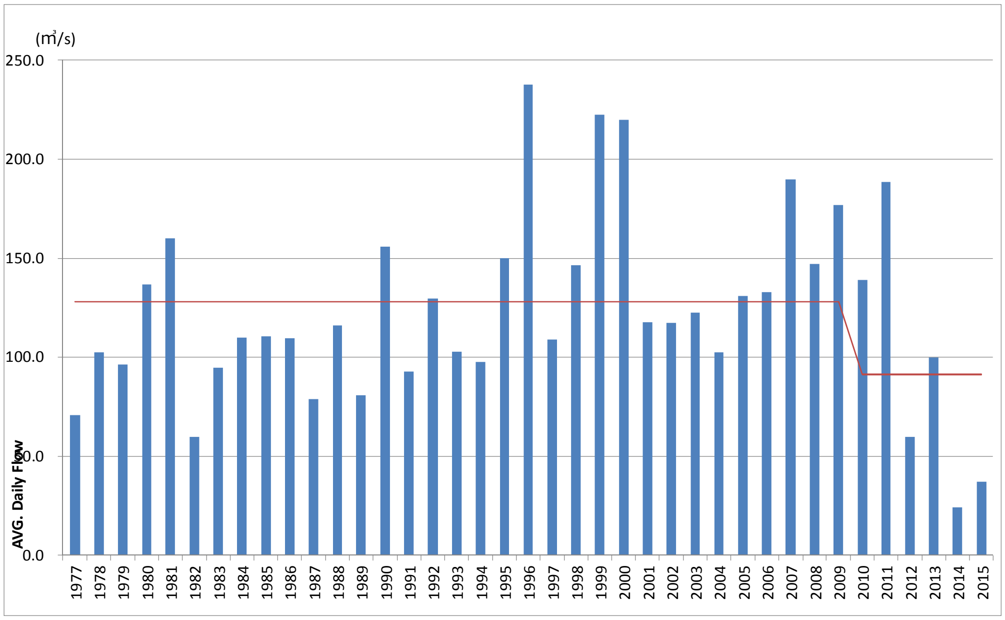
Source: JICA Study Team

Figure 2.4.29 Conceptual Diagram of Sediment Balance

(2) Results

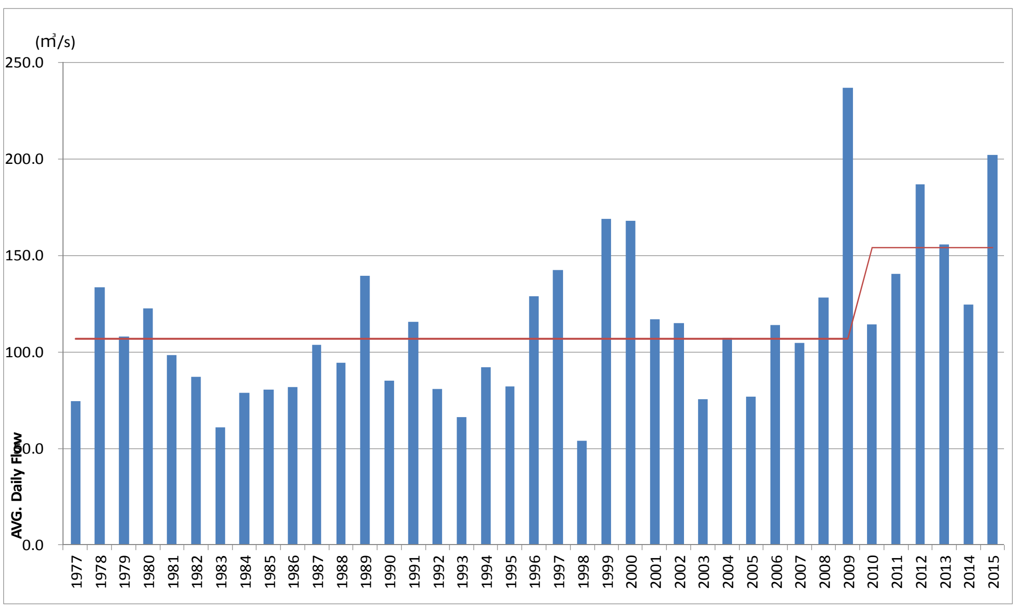
- **Water discharge**

Changes in the water discharge were analyzed using data of daily average water discharge observed at Nong Son Station and Thanh My Station during 1977~2015. Nong Son and Thanh My stations show a remarkable change on the annual water discharge after 2010 (**Fig 2.4.30-31**). At Thanh My Station which is located in Vu Gia River, annual water discharge has drastically decreased since 2012, while at Nong Son Station, which is located on Thu Bon River, annual water discharge has increased from 2012 onward. This is assumed to be caused by the operation of Dak Mi 4 hydropower plant (completed in 2012), which receives water from Vu Gia River but releases it to Thu Bon River for power generation (**Fig 2.4.32**).



Source: JICA Study Team-Created based on Quang Nam Province data

Figure 2.4.30 Annual Water Discharge of Thanh My Station



Source: JICA Study Team-Created based on Quang Nam Province data

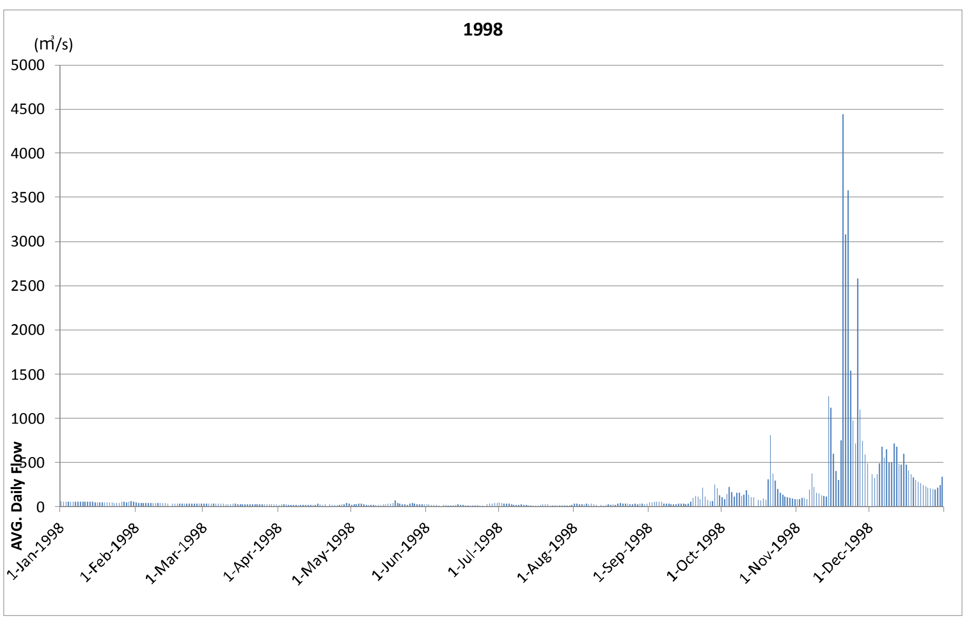
Figure 2.4.31 Annual Water Discharge of Nong Son Station

Source: JICA Study Team created by QGIS

Figure 2.4.32 Location of Thanh My Station, Nong Son Station and Dak Mi 4

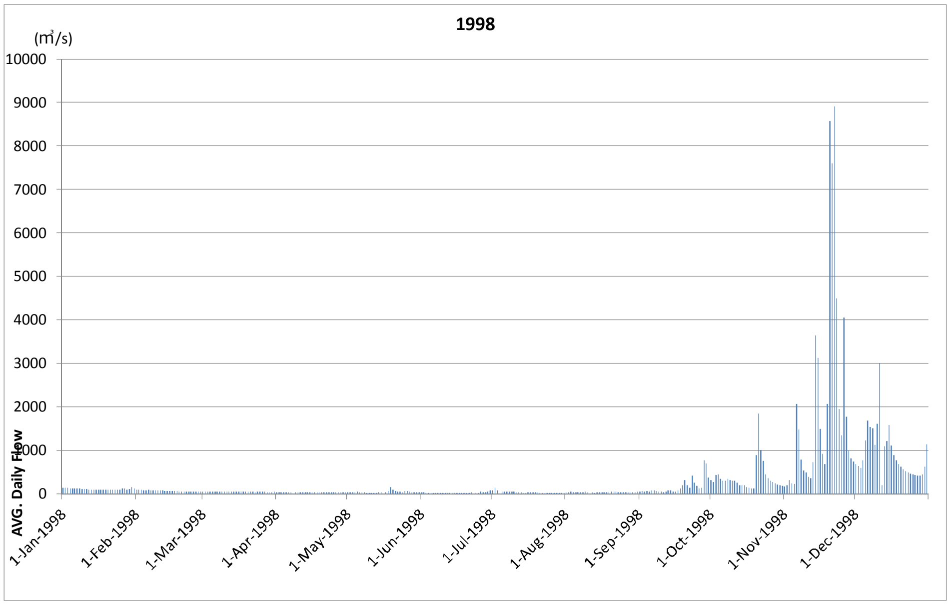
Peak discharge in the past

- NongSon: 1998/11/22 8, 920 m^3/s **(Fig 2.4.33)**
- ThanhMy: 1998/11/20 4,440 m^3/s **(Fig 2.4.34)**



Source: JICA Study Team-Created based on Quang Nam Province data

Figure 2.4.33 Daily water discharge in 1998 at Nong Son Station



Source: JICA Study Team-Created based on Quang Nam Province data

Figure 2.4.34 Daily Water Discharge in 1998 at Thanh My Station

- **River profile**

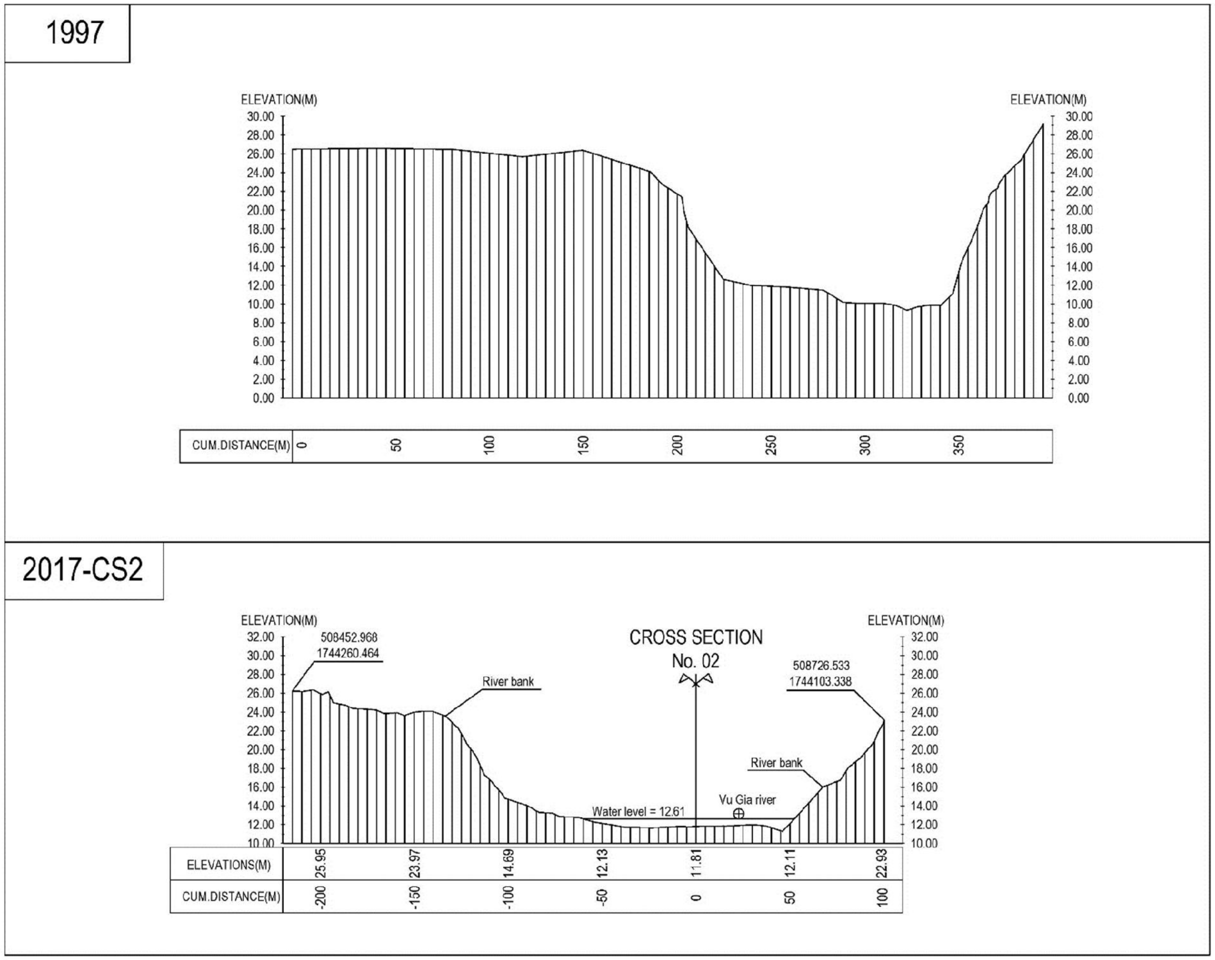
As for the cross section of the river channel, there is a large difference between the data collected in 1997 and the data collected by field measurement in 2017 (**Fig 2.4.35-42**). The reasons of the difference can be

- The riverbed change due to the change in the amount of sediment discharged
- The discrepancy of survey locations in 1997 and 2017.

This is a problem that needs to be addressed for the next stage of sediment management.

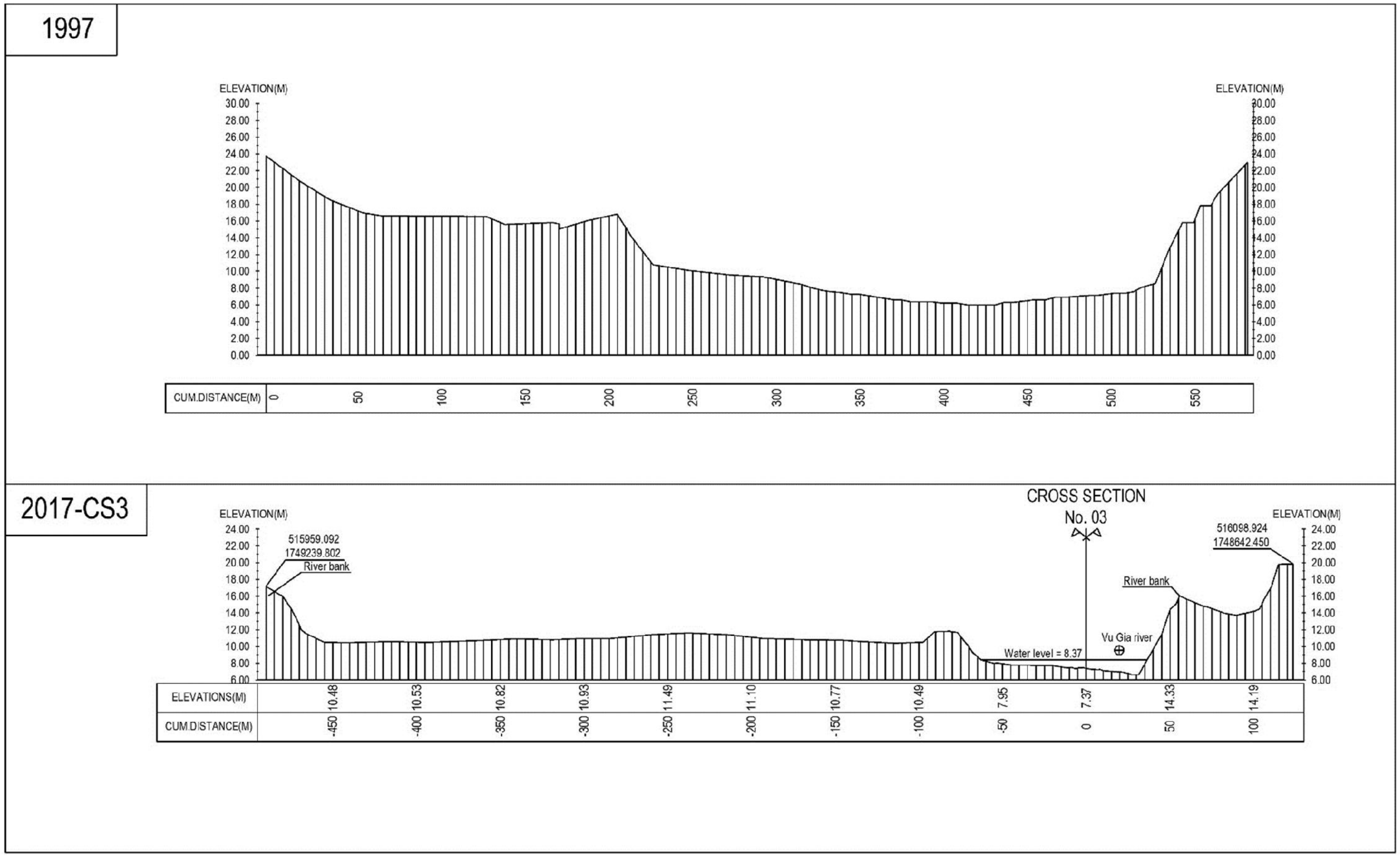
Source: JICA Study Team created based on Google Earth

Figure 2.4.35 Cross-section Measurement Points



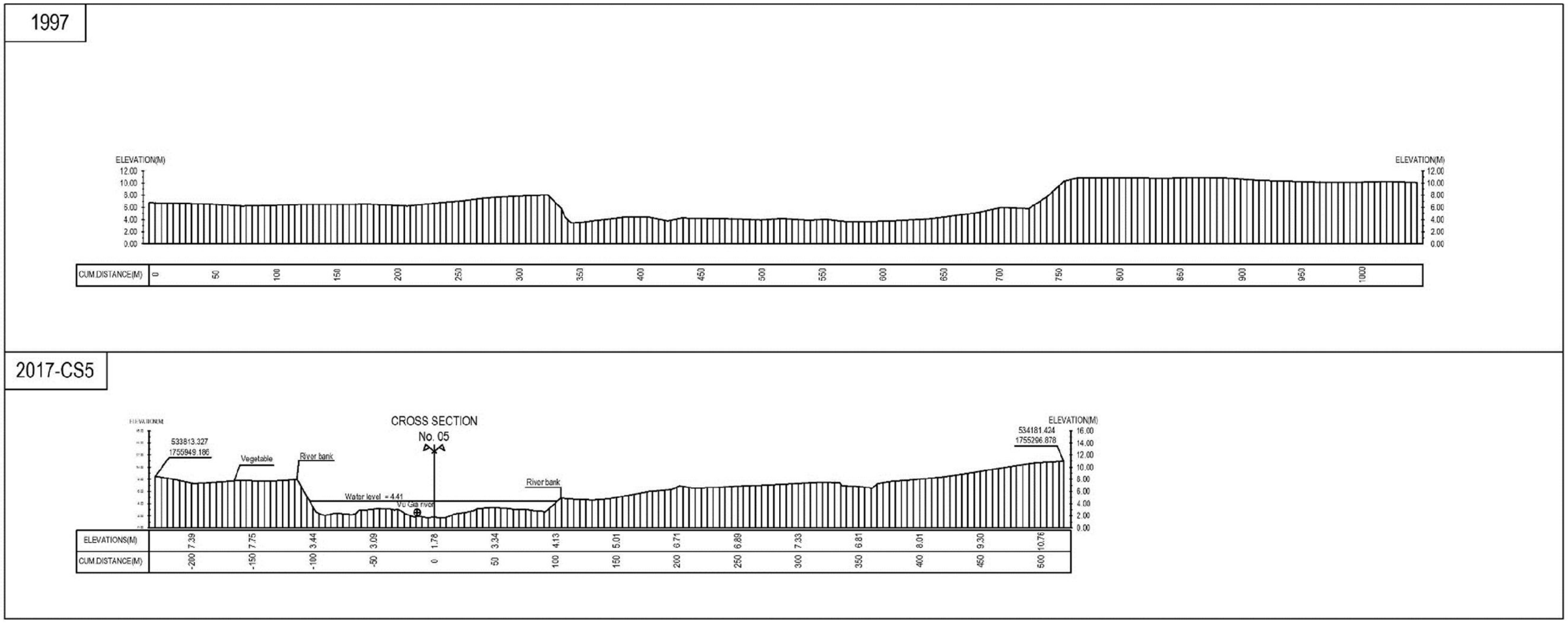
Source: JICA Study Team

Figure 2.4.36 Riverbed change CS2



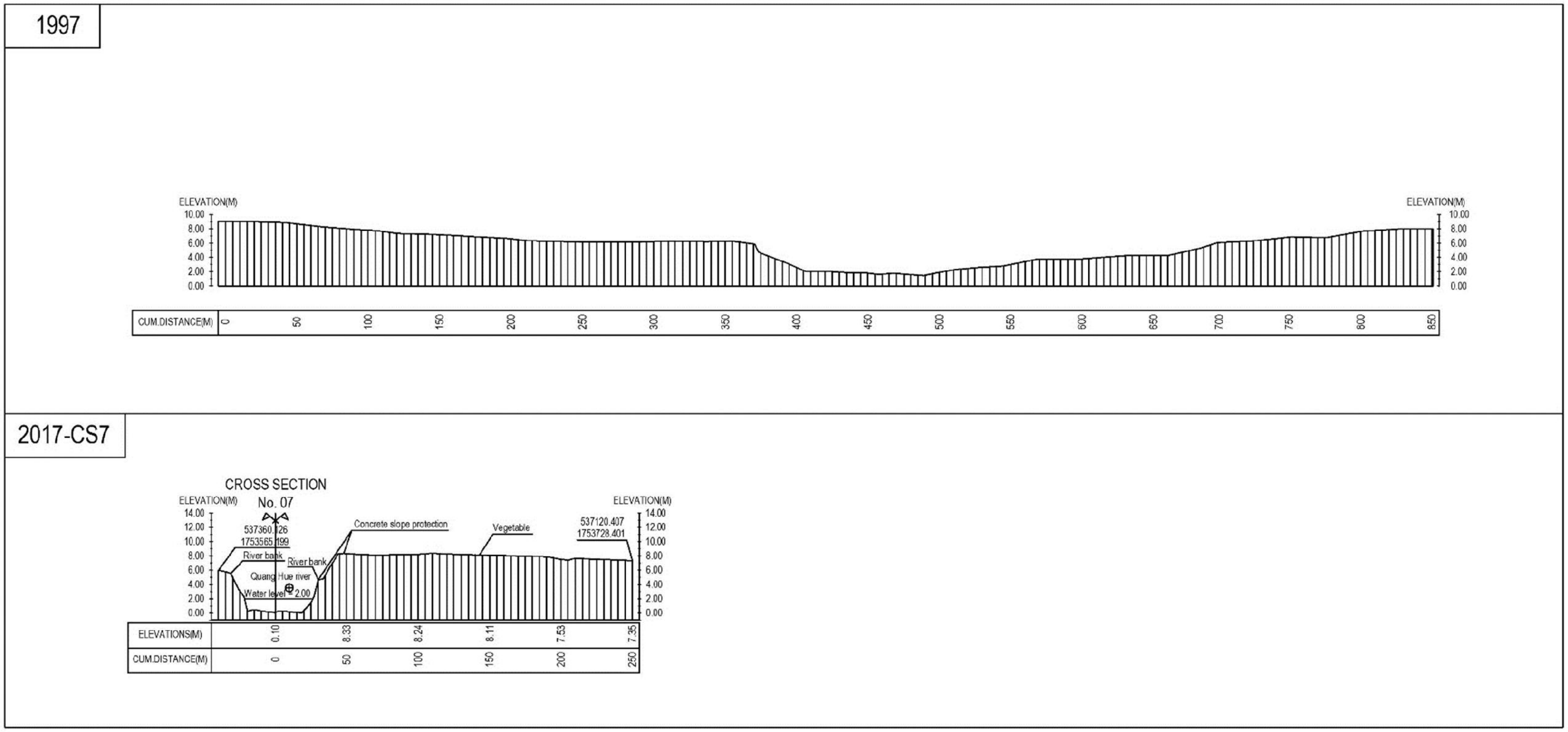
Source: JICA Study Team

Figure 2.4.37 Riverbed change CS3



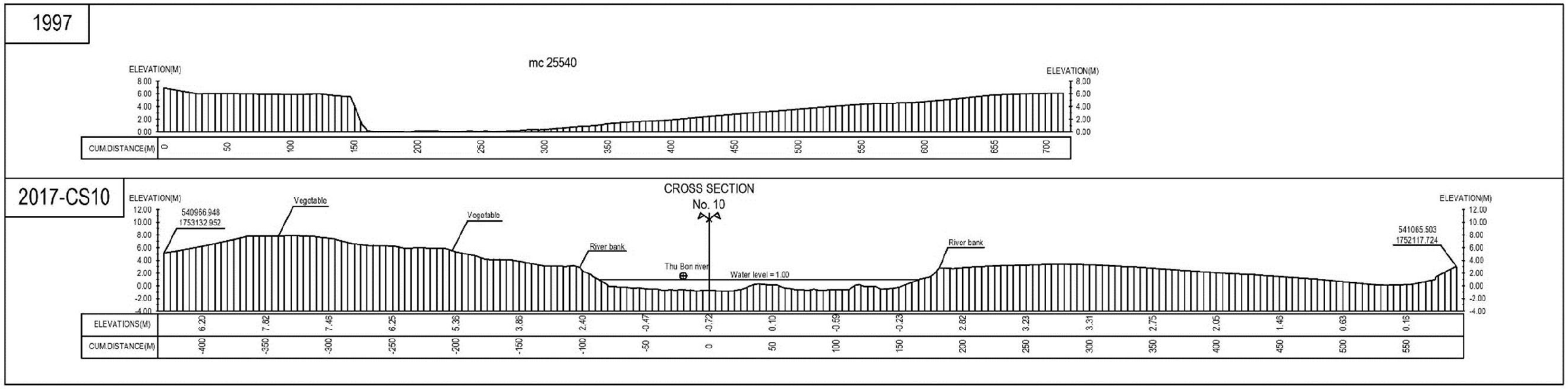
Source: JICA Study Team

Figure 2.4.38 Riverbed change CS5



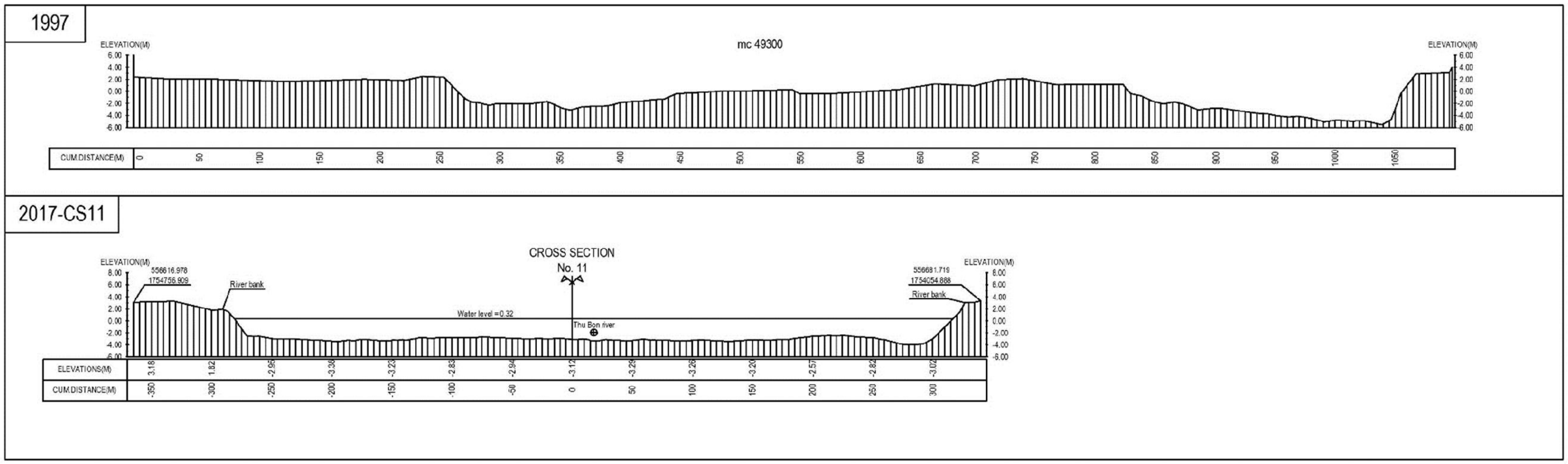
Source: JICA Study Team

Figure 2.4.39 Riverbed change CS7



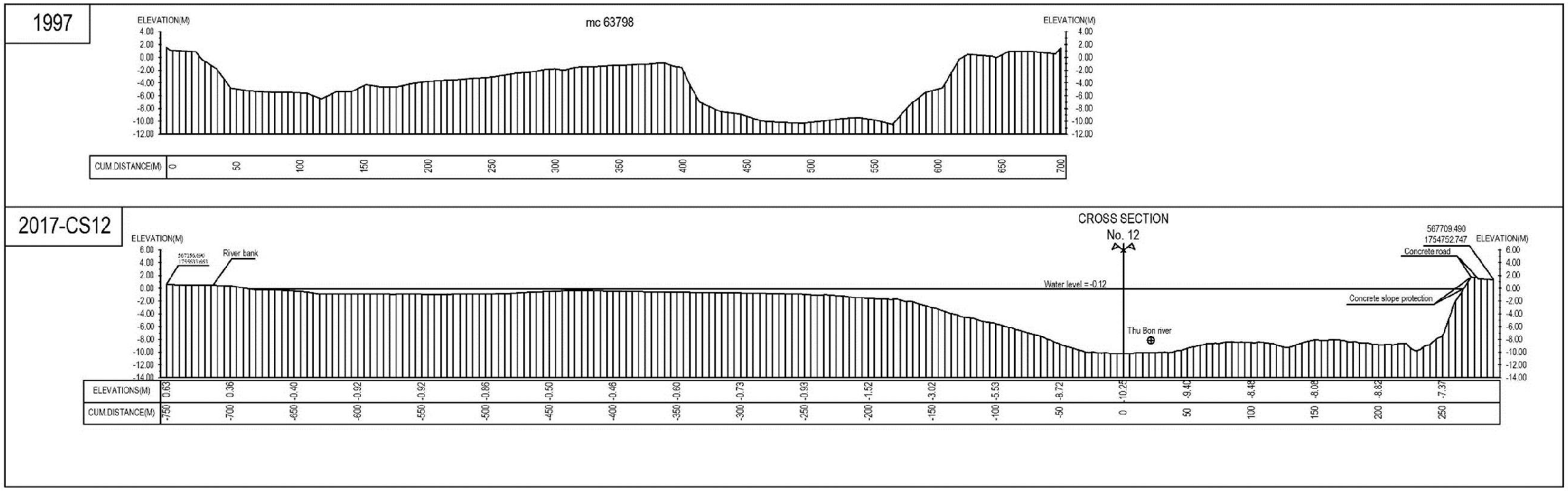
Source: JICA Study Team

Figure 2.4.40 Riverbed change CS10



Source: JICA Study Team

Figure 2.4.41 Riverbed change CS11

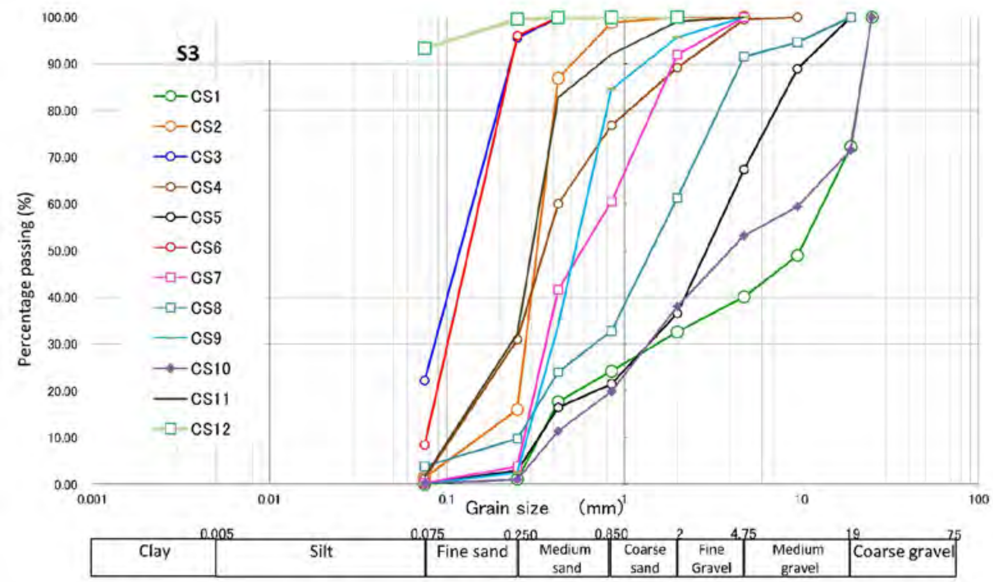


Source: JICA Study Team

Figure 2.4.42 Riverbed change CS12

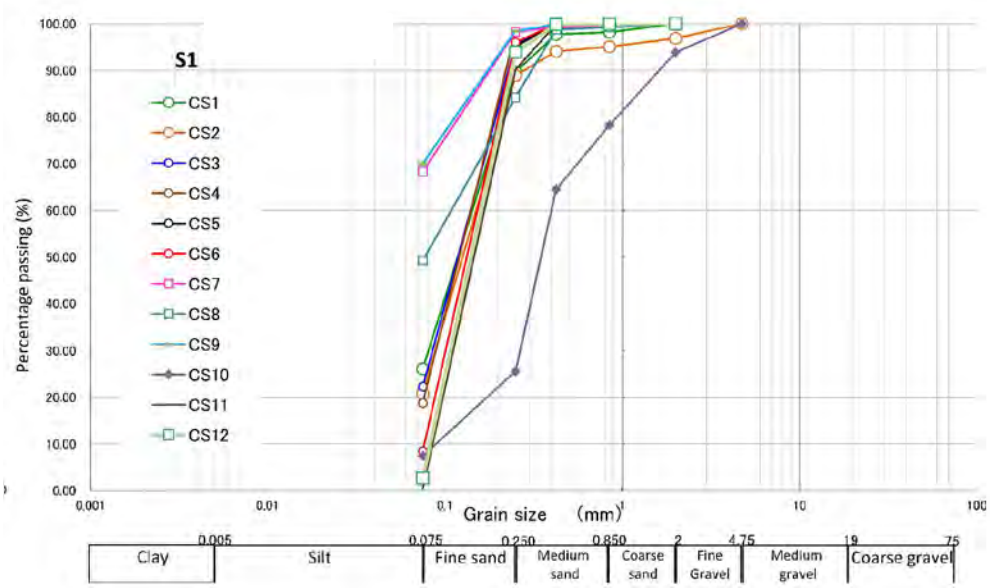
◆ **Riverbed materials**

There is a large difference in particle size group from point to point, and from upstream to downstream is small (**Figure 2.4.43-45**).



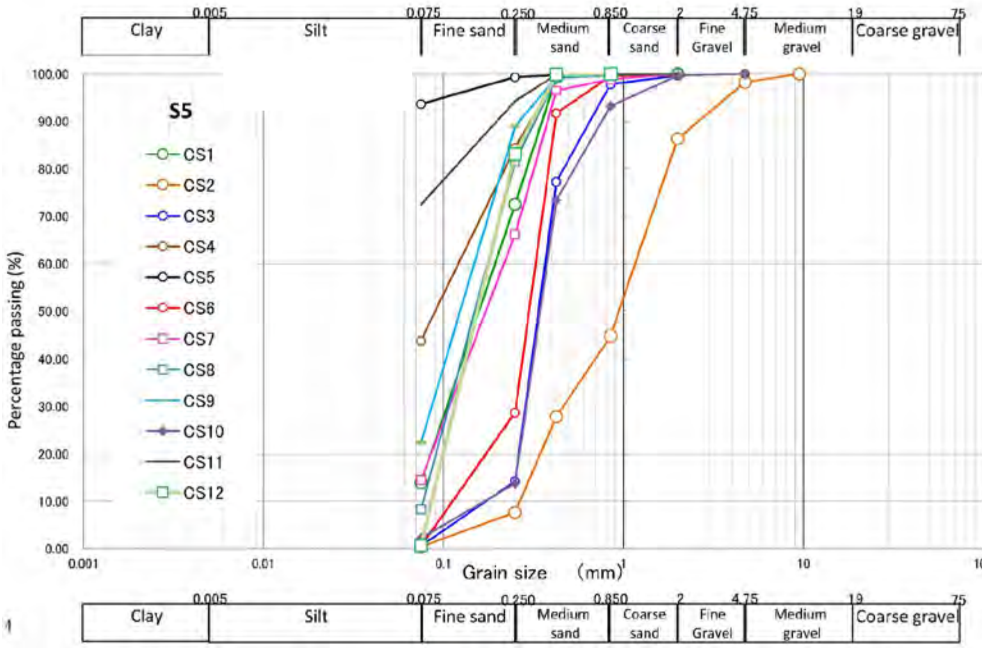
Source: JICA Study Team

Figure 2.4.43 Riverbed Particle Size in Center of the River



Source: JICA Study Team

Figure 2.4.44 Riverbed Particle Size at River Bank (1)



Source: JICA Study Team

Figure 2.4.45 Riverbed Particle Size at River Bank (2)

- **Change of sediment discharge**

After construction of dams, the volume of sediment discharge to the estuary has been reduced by 1.000×10^3(m^3/year) comparing with that before construction of dams. The reduced volume of sediment discharge value becomes 2.800×10^3(m^3/year) considering the effect of sand mining. Comparison of the effect of dam construction, sand mining and historical maximum flooding shows that sand mining has the most influential on the reduction in sediment discharge (**Table 2.4.8**).

・Influence of dams【963×10^3m^3】 ＜Influence of sand mining【$1,830\times10^3$m^3】

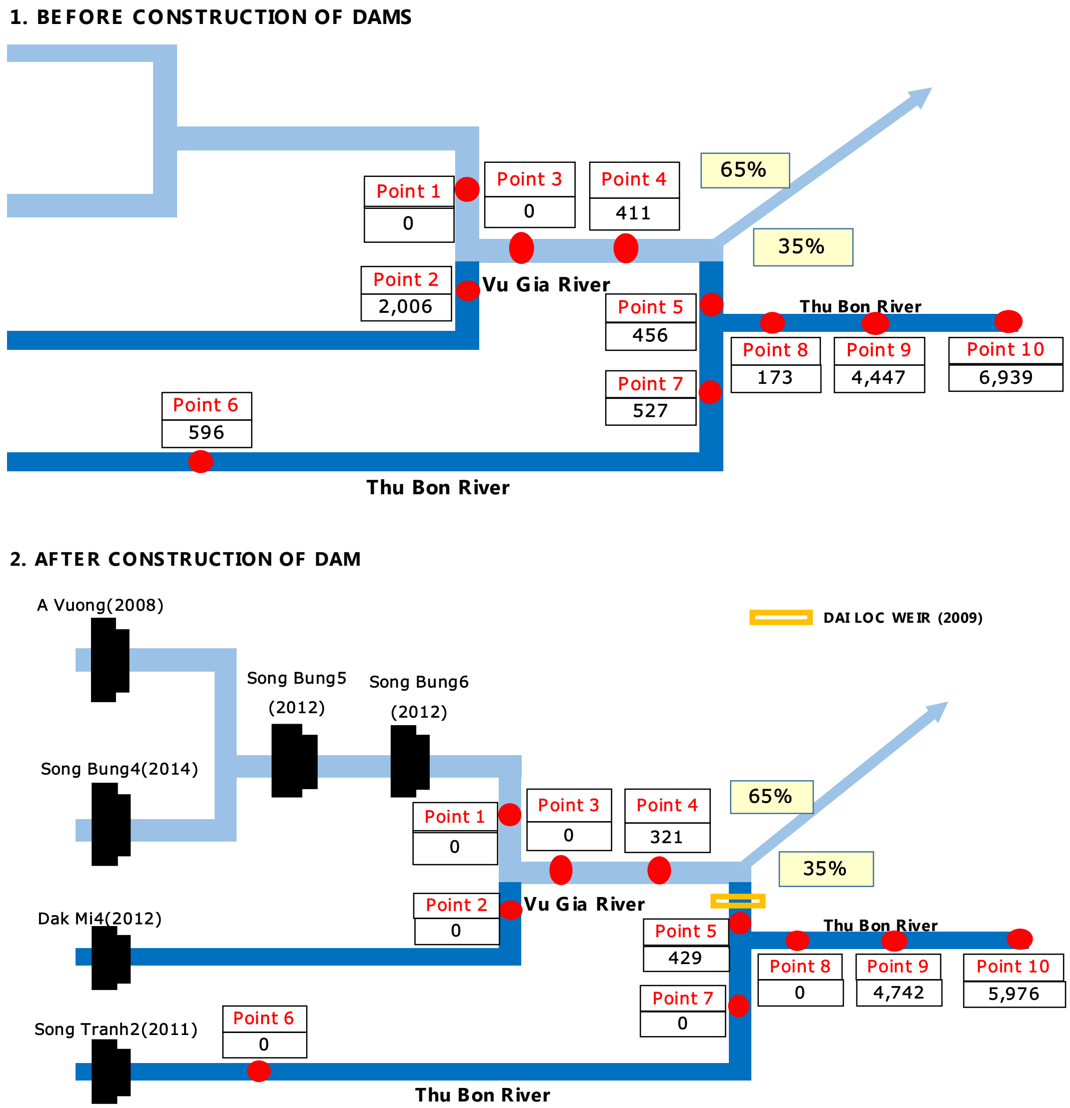
・ Influence of sand mining【$1,830\times10^3$m^3】＞Influence of flooding【$1,638\times10^3$m^3】

⇒ Sand mining has the most influence.

Table 2.4.8 Scenario and Relevant Results of River Sediment Transport Analysis

	Annual mean average runoff sediment volume	Maximum flow rate
	× 10^3m^3/annual	× 10^3m^3/1flowing out
①Before construction of Dams	6,939	1,638
②After construction of Dams	5,976	1,241
③After construction of Dam + Sand Mining	4,146	
Impact of Dam construction(① – ②)	963	397
Impact of Sand Mining(② – ③)	1,830	

Source: JICA Study Team



Source: JICA Study Team

Figure 2.4.46 Sediment Discharge Diagram

point2 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
97	461	1,001	159	202	72	13	0	0	0
Total									
2,006									

point6 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
75	152	128	33	74	93	16	26	0	0
Total									
596									

point6～point7 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-23	46	5	-85	6	78	16	26	0	0
Total									
69									

point7 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
98	106	123	118	68	15	0	0	0	0
Total									
527									

point5・point7～point8 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
171	175	192	146	132	23	-5	-9	-15	0
Total									
810									

point8 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
4	12	56	26	32	15	5	9	15	0
Total									
173									

point8～point9 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-1,123	-1,678	-1,180	-171	-156	7	5	9	15	0
Total									
-4,274									

Thu Bon River point9 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
1,127	1,690	1,236	198	188	8	0	0	0	0
Total									
4,447									

point9～point10 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-466	-1,899	-15	-97	-3	-12	0	0	0	0
Total									
-2,491									

Thu Bon River point10 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
1,593	3,589	1,251	295	191	20	0	0	0	0
Total									
6,939									

point1 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point1・point2～point3 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
97	461	1,001	159	202	72	13	0	0	0
Total									
2,006									

point3 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point3～point4 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-84	-91	-48	-16	-41	-69	-39	-23	0	0
Total									
-411									

point4 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
84	91	48	16	41	69	39	23	0	0
Total									
411									

point4～point5 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
8	9	-76	-39	-55	47	39	23	0	0
Total									
-45									

point5 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
76	81	125	55	96	22	0	0	0	0
Total									
456									

×10^{3}m^3/annual

Source: JICA Study Team

Figure 2.4.47 Sediment Flow Chart (Before Construction of Dam)

point2 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point6 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point6～point7 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point7 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point5・point7～point8 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
72	77	117	52	90	21	0	0	0	0
Total									
429									

point8 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point8～point9 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-1,202	-1,802	-1,318	-211	-200	-9	0	0	0	0
Total									
-4,742									

Thu Bon River point9 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
1,202	1,802	1,318	211	200	9	0	0	0	0
Total									
4,742									

point9～point10 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-170	-1,289	241	-43	36	-9	0	0	0	0
Total									
-1,234									

Thu Bon River point10 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
1,372	3,091	1,078	254	164	17	0	0	0	0
Total									
5,976									

point1 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point1・point2～point3 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point3 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0
Total									
0									

point3～point4 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-66	-71	-38	-12	-32	-54	-31	-18	0	0
Total									
-321									

point4 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
66	71	38	12	32	54	31	18	0	0
Total									
321									

point4～point5 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-6	-6	-79	-39	-59	33	31	18	0	0
Total									
-108									

point5 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
72	77	117	52	90	21	0	0	0	0
Total									
429									

×10³m³/annual

Source: JICA Study Team

Figure 2.4.48 Sediment Flow Chart (After Construction of Dam)

point2 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
0	0	0	0	0	0	0	0	0	0	0

point6 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
0	0	0	0	0	0	0	0	0	0	0

point6～point7 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
0	0	0	0	0	0	0	0	0	0	0

point7 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
0	0	0	0	0	0	0	0	0	0	0

point5．point7～point8 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
76	81	125	55	96	22	0	0	0	0	456

point8 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
0	0	0	0	0	0	0	0	0	0	0

point8～point9 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
-769	-1,154	-844	-135	-128	-5	0	0	0	0	-3,036

Thu Bon River point9 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
769	1,154	844	135	128	5	0	0	0	0	3,036

point9～point10 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
-182	-991	96	-41	14	-7	0	0	0	0	-1,110

Thu Bon River point10 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
951	2,144	748	176	114	12	0	0	0	0	4,146

point1 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
0	0	0	0	0	0	0	0	0	0	0

point1．point2～point3 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
0	0	0	0	0	0	0	0	0	0	0

point3 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
0	0	0	0	0	0	0	0	0	0	0

point3～point4 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
-84	-91	-48	-16	-41	-69	-39	-23	0	0	-411

point4 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
84	91	48	16	41	69	39	23	0	0	0

point4～point5 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
8	9	-76	-39	-55	47	39	23	0	0	-45

point5 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～	Total
76	81	125	55	96	22	0	0	0	0	0

×10³m³/annual

Source: JICA Study Team

Figure 2.4.49 Sediment Flow Chart (After Construction of Dam+ Sand Mining)

point1 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
0	0	0	0	0	0	0	0	0	0	0

point2 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
28	134	291	46	59	21	4	0	0	0	583

point1 ·point2～point3 Accumulated sediment volume

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
18	116	272	36	42	8	-1	-4	-7	0	479

point3 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
11	18	19	10	17	12	5	4	7	0	104

point3～point4 Accumulated sediment volume

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
-50	-47	-16	-1	-13	-37	-23	-12	7	0	-193

point4 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
61	66	35	11	29	50	28	16	0	0	297

point4～point5 Accumulated sediment volume

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
39	43	0	-4	2	44	28	16	0	0	168

point5 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
22	23	35	16	27	6	0	0	0	0	129

point6 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
33	68	57	15	33	41	7	11	0	0	265

point6～point7 Accumulated sediment volume

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
4	36	20	-21	12	37	7	11	0	0	105

point7 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
30	32	37	36	21	4	0	0	0	0	160

point5 ·point7～point8 Accumulated sediment volume

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
43	28	-53	-8	-23	-22	-11	-20	-33	0	-99

point8 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
8	27	126	59	71	32	11	20	33	0	387

point8～point9 Accumulated sediment volume

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
-335	-488	-251	-1	13	30	11	20	33	0	-968

Thu Bon River point9 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
343	515	377	60	57	2	0	0	0	0	1,356

point9～point10 Accumulated sediment volume

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
-33	-332	81	-9	12	-2	0	0	0	0	-283

Thu Bon River point10 Amount of sediment discharged

~0.075 (mm)	0.075~0.25	0.25~0.425	0.425~0.85	0.85~2	2~4.75	4.75~9.5	9.5~19	19~25	25~ (mm)	Total
376	848	296	70	45	5	0	0	0	0	1,638

$\times 10^3 m^3$/flood

Source: JICA Study Team

Figure 2.4.50 Sediment Flow Chart (Before Construction of Dam-1988 Flood)

point2 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0

Total: 0

point1 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0

Total: 0

point1・point2～point3 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0

Total: 0

point3 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0

Total: 0

point3～point4 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-42	-45	-24	-8	-20	-34	-20	-11	0	0

Total: -204

point4 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
42	45	24	8	20	34	20	11	0	0

Total: 204

point4～point5 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
26	28	-1	-3	1	30	20	11	0	0

Total: 111

point5 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
16	17	25	11	20	5	0	0	0	0

Total: 93

point6 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0

Total: 0

point6～point7 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0

Total: 0

point7 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0

Total: 0

point5・point7～point8 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
16	17	25	11	20	5	0	0	0	0

Total: 93

point8 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
0	0	0	0	0	0	0	0	0	0

Total: 0

point8～point9 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
-352	-528	-386	-62	-59	-3	0	0	0	0

Total: -1,389

Thu Bon River point9 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
352	528	386	62	59	3	0	0	0	0

Total: 1,389

point9～point10 Accumulated sediment volume

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
67	-114	162	9	25	-1	0	0	0	0

Total: 148

Thu Bon River point10 Amount of sediment discharged

～0.075 (mm)	0.075～0.25	0.25～0.425	0.425～0.85	0.85～2	2～4.75	4.75～9.5	9.5～19	19～25	25 (mm)～
285	642	224	53	34	4	0	0	0	0

Total: 1,241

$\times 10^3 m^3$/flood

Source: JICA Study Team

Figure 2.4.51 Sediment Flow Chart (After Construction of Dam-1988 Flood)

- **Comments on calculation results**

In the sediment flow charts (**Figure 2.4.46-51**), the sediment discharge at Point 8 is zero. The possible reason is that the particle size (D60) at this point is large. In addition, we have deducted the influence of the upstream dam and sediment dredging and then the sediment discharge became zero as a consequent. Therefore, the sediment discharge at Point 8 might be not consistent with actual conditions. Since the results of the previous survey could not be obtained, it is difficult to evaluate the validity of the sediment grain size obtained by this survey. However, the other points in downstream reach are consistent with the actual condition of the site.

In general, though there are singular values at some points on the sediment flow chart, which do not match the actual situation, but comparing with some rivers from Japan, it can be said that the results are in reasonable orders (**Fig 2.4.52**).

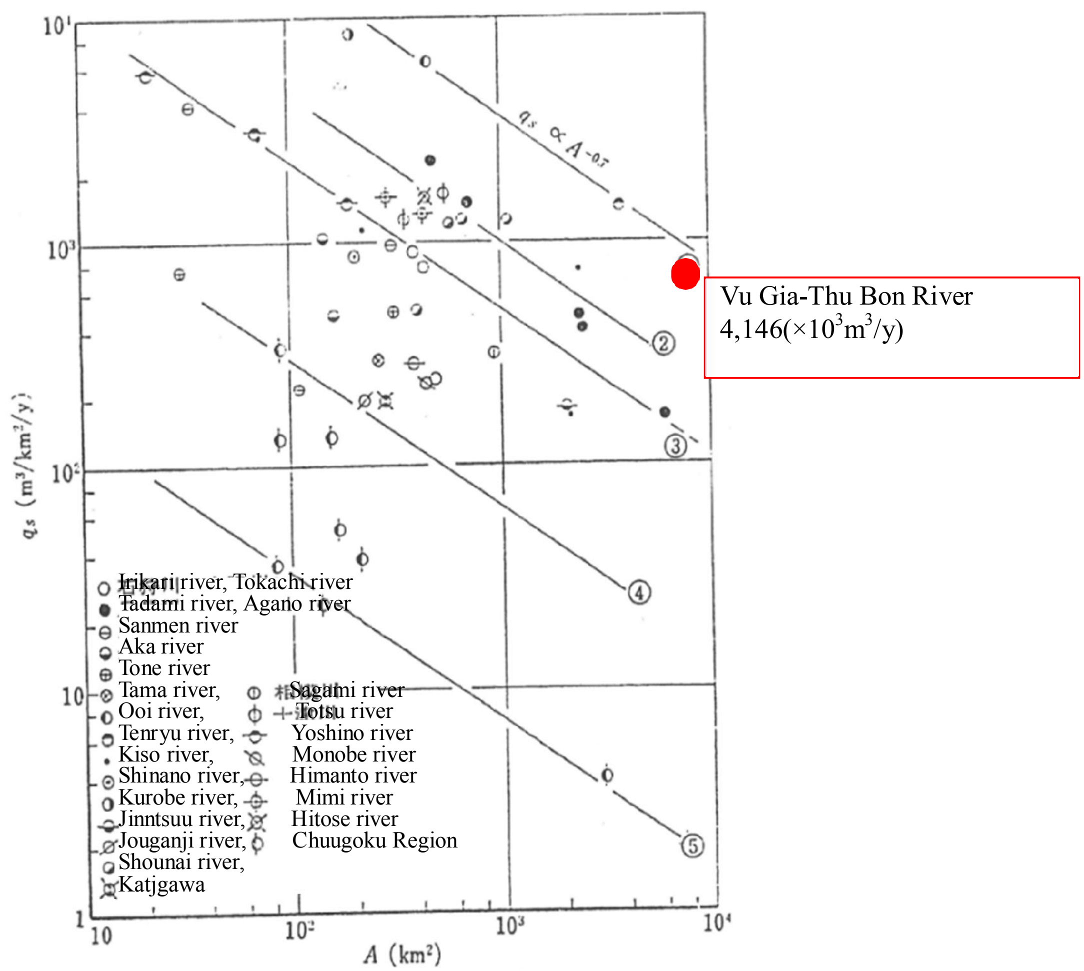
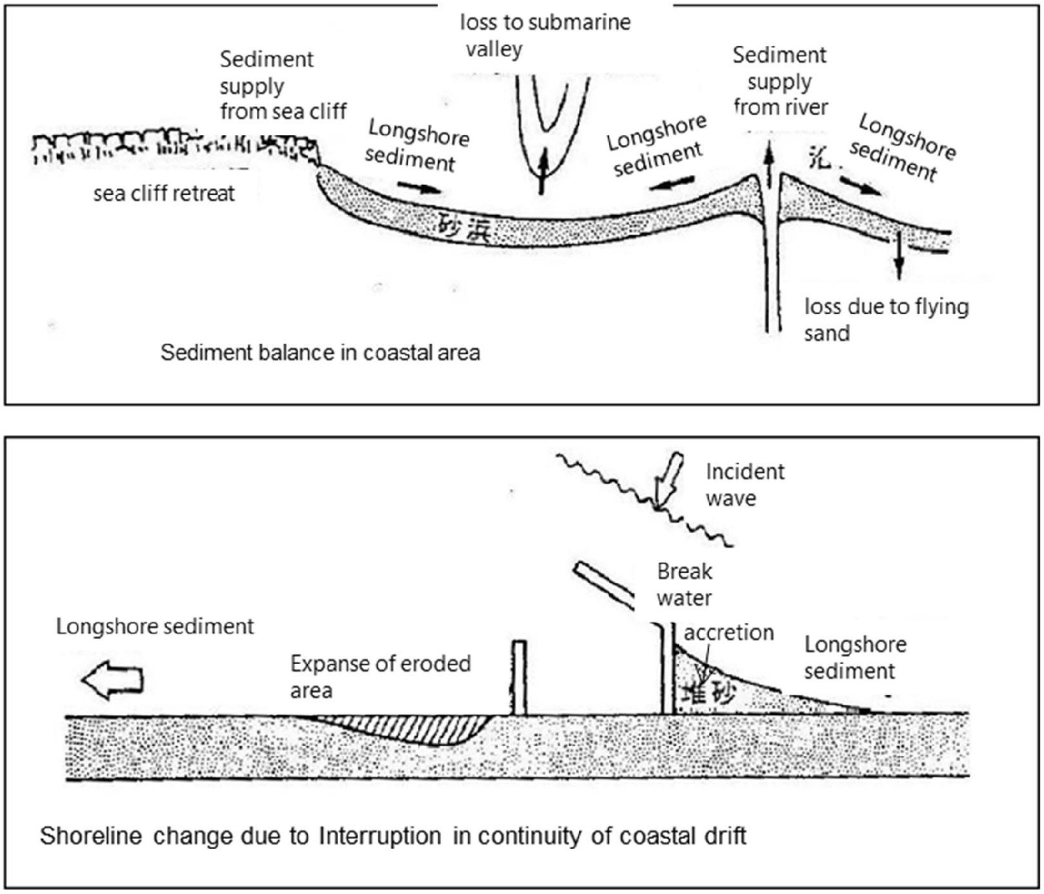


Figure 2.4.52 Relationship of Specific Sediment Discharge Volume and Catchment Area

2.4.3 Coastal Erosion due to Interruption of Longshore Sediment Transport

In coastal areas, where longshore sediment transport is prominent, the construction of structures, such as groins or breakwaters, may interrupt the natural sediment transport. These structures keep sediments on the up-drift side and concurrently inducing erosion on the down-drift side (**Fig 2.4.53**).



Source: Coastal Erosion in Japan (Uda, 1997)

Figure 2.4.53 Diagram of Longshore Sediment Transport

In the Cua Dai coastal area, erosion prevention measures, such as groins, steel sheet pile, etc.., have been implemented for the past few years (**Fig 2.4.54**). However, since these measures were designed without consideration of longshore sediment transport, they not only bring minor improvements but also cause adverse impacts on the adjacent areas.

Source: Created based on satellite image taken by GeoEye

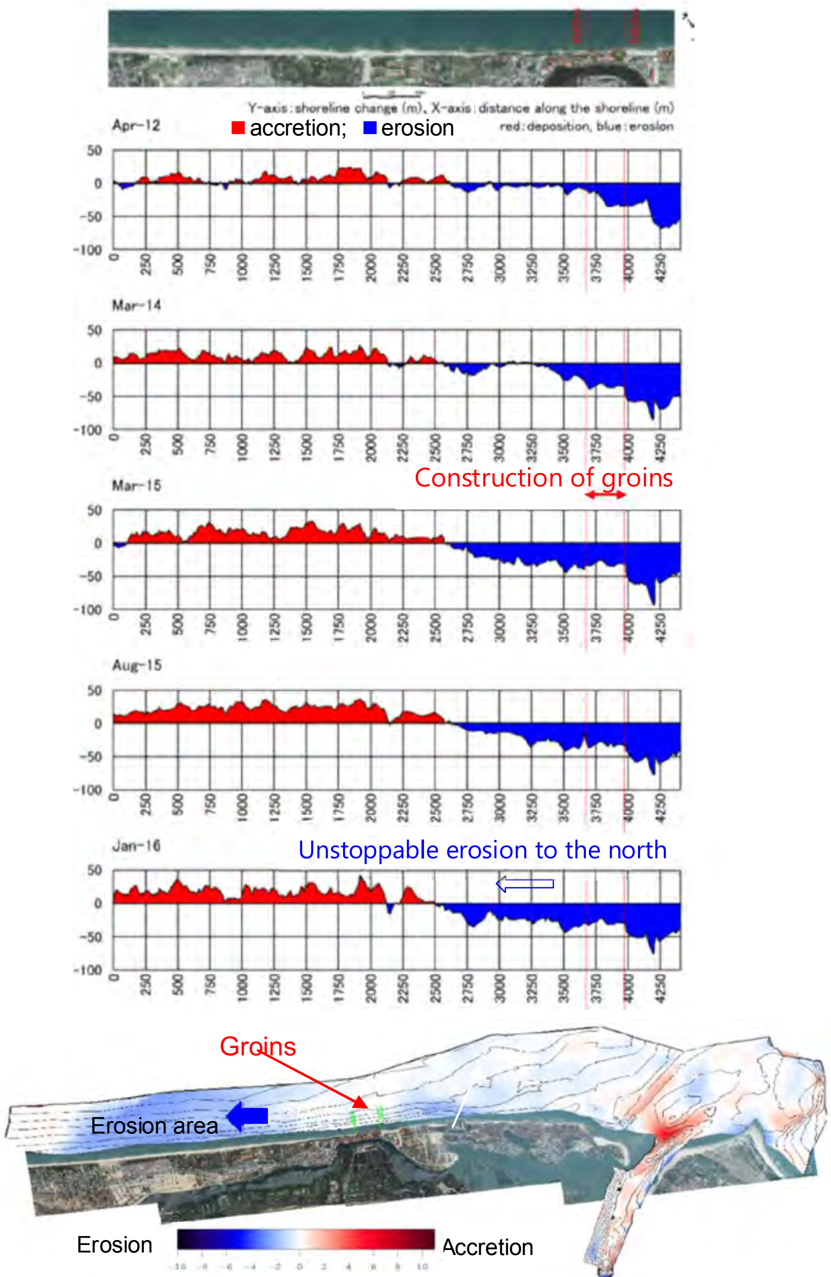
Figure 2.4.54 Erosion prevention measures implemented in Cua Dai coastal area

(1) Analysis of groin's effects

In 2015, a system of groins, using geotextile, was implemented in front of Victoria Resort to stop the erosion (**Fig 2.4.55**). However, the analyzed results of shoreline change and topographic change indicate that erosion still keeps progressing to the adjacent areas even after the construction (**Fig 2.4.56**).

Source: Created based on satellite image taken by GeoEye

Figure 2.4.55 Construction of Groins in front of Victoria Resort



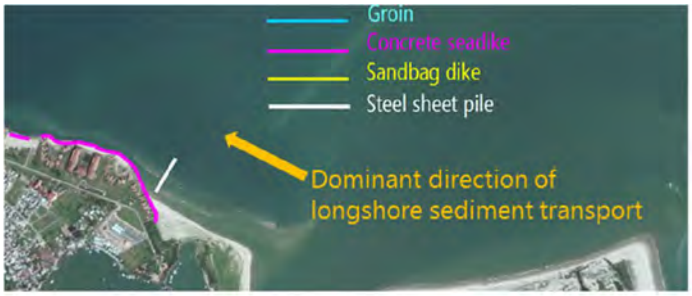
Source: JICA Study Team

Figure 2.4.56 Analysis of Shoreline Change from Apr 2012 to Jan 2016

(2) Analysis of steel sheet pile's effects

Due to high waves in December 2016, a new estuary was formed and it was expected to allow vast sediment transport toward the northern site.

However, the construction of steel sheet pile in the right northern site of this estuary has prevented the sediment from being transported to the northern site (**Fig 2.4.57**). Therefore, coastal erosion in Cua Dai Beach still continues (**Fig 2.4.58**).



Jan 1st 2017: Before construction

Apr 10th 2017: After construction

Figure 2.4.57 Construction of Steel Sheet Pile on the Northern Site of Cua Dai Estuary

Source: Created based on satellite image taken by GeoEye

Figure 2.4.58 Analysis of Shoreline Change before and after Construction of Steel Sheet Pile

2.5 Current Status of River Erosion and Coastal Erosion in Other Areas

2.5.1 River Area

Summary of current situation of river erosion in central region are shown in **Table 2.5.1**

Table 2.5.1 Summary of Current situation of River Erosion in Central Region

		Quang Tri	**Thua Thien hue**	**Quang Nam**	**Quang Ngai**	**Binh Dinh**	**Phu Yen**
Basic data on situation of erosion	**Location**	Ben Hai River, Thanh Han River, O Lau River	Bo River, Huong River, Truoi River,	Dai Loc, Dien Ban, Hoi An, Duy Xuyen, Nong Son district	Tra Bong River, Tra Khuc River, Ve River, Tra Cau River	Hoai Nhon, Phu My, Phu Cat	Phu Loc, Phu Hoa
	Length (km)	104.452	66.700	-	163.650	-	35.300
	Speed (m/year)	-	-	-	5-10 (in some area up to 30)	-	-
	Level - Distance (km)	① 16.952 ② 47.82 ③ 39.68		-	① 3.800 ② 103.717 ③ 56.133	-	-
Situation of hinterland (land use)	**Tourism**	×	◎	×	×	×	×
	Agriculture	◎	◎	◎	◎	◎	◎
	Aquaculture	◎	◎	◎	◎	◎	◎
	Industry	×	▲	▲	▲		▲

		Quang Tri	Thua Thien hue	Quang Nam	Quang Ngai	Binh Dinh	Phu Yen
	Resident (household)	No info	・relocated: 508 ・effected: 2419	over 7000	・relocated: 2804 ・affected: 6192		1000 (directly effected)
Causes of erosion		No relating survey or research	No data	・Dam construction in upstream area ・Deforestation	PPC's opinion: ・Increasingly complicated weather conditions ・Flooding and torrential rain ・Storm surge	PPC's opinion: ・Deforestation ・Occurrence of torrential rain ・Uncontrollable sand mining ・River channel burial (due to planting)	PPC's opinion: ・Difference in river flow between dry season and rain season ・Deforestation ・Effects of typhoon and wave ・Effect of flooding ・Economical activities in river area
Current Countermeasures	**Contents**	・Groins (43.888km) ・concrete revetment (114.06km)	・anti-erosion measure (70.1km, including dike, revetment and groins)	・Revetment with root consolidation ・Turing and planting bamboos ・dike (65km, including concrete dike and stone bag dike) ・dredging in river area for channel adjustment	・30 projects of constructing anti-erosion measure from 2008 to 2016	・Groin (850m) in Thien Chanh estuary for preventing accretion in estuary	・dike (cost: about 2.1 million USD/km)

		Quang Tri	Thua Thien hue	Quang Nam	Quang Ngai	Binh Dinh	Phu Yen
	Effects	No comment from PPC	No comment from PPC	No comment from PPC	No comment from PPC	・ineffective	・Partial measures only for extremely serious effected area due to limited cost

Source: JICA Study Team created based on interview results

(1) Quang Tri Province

Due to the short and steep rivers, the water level increases very rapidly, (flooding can rise up to 3-4m a day); then the high current velocity hits the weak river banks causing erosion. The rate of erosion varies with locations. The lowest erosion speed is 1-3m per year observed in O Lau, and Ma Waterfall, Nhung. The highest erosion speed is 3-5m/year observed in Thach Han, Ben Hai, and Hieu Rivers. Since 2013, in the rainy season, serious river bank erosion has continued to occur threatening human life and infrastructure such as the Thach Han section which is 1.5 km long, O Lau River section, 2.5km long, Hieu River section 1km long, and Ho Xa River which is 1km long.

- Erosion level: 104.5 km is a very dangerous area: 17 km, dangerous 47.8 km, and normal 39.7 km.
- The erosion in recent years has threatened human lives, infrastructure works, cultural and historical relics, and farming lands. Some places have lost much of their residential area such as Trung Yen, and Tan Dinh (Trieu Phong District)

(2) Hue Province

According to data, the province has 84 erosion sites with a total length of 66.7 km, mainly in key rivers including Huong River: 15.5 km, Bo River: 10.5km, Truoi River: 2.5km, Nong River: 1.5km, Cau Hai River: 3.5km, Bu Lu River: 1.8km, Nuoc Ngot 3.0km, O Lau 0.3 km, Khe Tre 1.1km, and Ta Rinh 2.4km; affecting 2,419 householders' lives, and forcing over 508 households to relocate. According to local authority's opinions, the cause of river bank erosion is due to:

- The rivers are short and steep, water level between the flood season and the dry season makes river banks unstable.
- Geologic riverside is soft and weak, prolonged heavy rain and high flow rates lead to erosion.
- Uncontrolled exploitation of sand on the river
- Construction of upstream reservoirs, the imbalance of muddy sand causes shore erosion.

Erosion on Huong River: **Fig 2.5.1-2**

Source: Hue Province

Figure 2.5.1 Some Images of Erosion of River Banks in Huong River (1)

Erosion at Huong river bank passed by Huong Tho commune

Erosion at Huong river bank passed by Huong Ho ward

Source: Hue Province

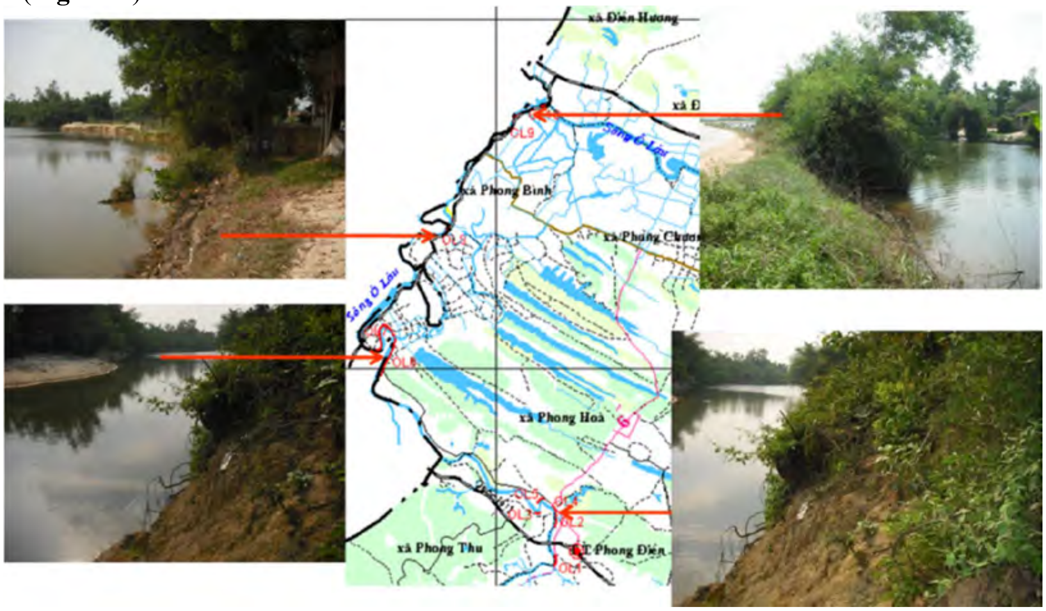
Figure 2.5.2 Some Images of Erosion of River Banks in Huong River (2)

<u>*Erosion of Bo River:*</u> Currently, there are 16 erosion points with total length of 10.5 km at Bo River (**Fig 2.5.3**).

Source: Hue Province

Figure 2.5.3 Erosion of Bo River Bank in Huong Xuan Commune, Huong Tra Town

Erosion of O Lau River: Currently, there are 10 erosion points with a total length of 3km at O Lau River (**Fig 2.5.4**)



Source: Hue Province

Figure 2.5.4 Erosion of O Lau River Bank

Erosion of Truoi River: Currently, there are 5 erosion points with total length of 2.5 km at Truoi River (**Fig 2.5.5**).

Source: Hue Province

Figure 2.5.5 Erosion of Truoi River Bank

<u>Erosion of Bu Lu River:</u> mainly in Loc Vinh Commune, Phu Loc District with length about 1.8 km (**Figure 2.5.6**).

Source: Hue Province

Figure 2.5.6 Erosion of Bu Lu River Bank

(3) Quang Nam Province

According to the report on Vu Gia - Thu Bon basin landslide of the project management unit of construction projects for agricultural and rural development, river erosion is obvious in many locations as shown **Fig 2.5.7**. Erosion areas are summarized in **Table 2.5.2**.

Table 2.5.2 Erosion Areas in Vu Gia Thu Bon River System

Commune/District/City	River erosion occured areas
Nong Son Commune	Trung Phuoc, Que Trung Commune
Hoi An City	Thanh Nam Tay, Cam Nam Ward
	Thanh Nam Dong, Cam Nam Ward
	Thanh Nam, Cam Nam Ward
	Village 2, Cam Thanh Commune
	Dong Hiep, Minh An Ward
	Thanh Ha embankment, Thanh Ha warddegraded
	Pottery Village, Thanh Ha Ward
Duy Xuyen Commune	Village 18 to 19, Duy Thanh Commune
	My Phuoc - Trieu Chau, Duy Phuoc Commune
	Thach Xuyen - PhuDa 1, Duy thu Commune
Dien Ban Town	Con Toi, Dien Hoa
	Van Ly embankment, Dien Hongdamaged
	Thanh Dong canal, Dien Hong
	Van Ly – Ky Lam, Dien Quang
	Thanh Quyt, Dien Thang Nam
Dai Loc Commune	Hoi Ong Minh, Ap Bac, Dai Minh
	Quang Dai 1, Dai Cuong

Commune/District/City	River erosion occured areas
	Bai Qua village, Dai Son
	Dai My, Dai Hung
	Ha Vy, Dai Hong

Source: Quang Nam Province

Source: JICA Study Team created based on Quang Nam Province data

Figure 2.5.7 Erosion Points in Vu Gia – Thu Bon River Basin (Red marks)

(4) Quang Ngai Province

River bank erosion has been occurring over the years. There are 153 erosion points with total erosion length of 163.6 km. The erosion rates average 5-10m/year, with some places up to 30m / year. Some areas are seriously eroded after the 2016 flood such as:

- Erosion on the bank of Tra Cau River passing through Kim Giao Village, Pho Thuan Commune and passing through Dong Quang Village, Pho Van Commune, Duc Pho District: erosion length about 1,000m.
- Erosion on the bank of Tra Bong River crossing Dong Min Village, Binh Duong District, Binh Son District: erosion length about 750m.
- Ve River bank erosion crossing Van Xuan 2 and Phu Lam Tay Commune, Hanh Tin Dong Commune, Nghia Hanh District: the length of erosion is about 900m.
- Ve River bank erosion passing Thanh Long Hamlet Duc Thang Commune, Mo Duc District: erosion length about 500m.

(5) Binh Dinh Province

The erosion has become serious since 1990, and now occurs in all 4 major river basins in the province. After the floods in 2016, local authorities reported that there were 50 particularly dangerous sites, with a total length of 78 km. Some areas of serious erosion include:

- Upstream of Luat Le Dieu Tri Bridge, Tuy Phuoc, L = 300m
- Dap Bridge to Ngo La Bridge, Canh Vinh, Van Canh, L = 500m
- Hoa Trung-Hoa Lac, Binh Tuong, Tay Son, L = 600m
- Phu Tho, Tay Phu, Tay Son, L = 500m
- An Thai - Phu Ngoc, Nhon Phuc, An Nhon, L = 1,000 m
- Dinh Nhon Son, An Nghia, and Hoai An, L = 200m

River bank erosion is threatening agricultural production by losing land for agricultural production and transportation. In addition, erosion is also threatening the lives and property.

Sedimentation phenomenon:
Sedimentation is also a concern in coastal estuarine areas. Typically in the Tam Quan fishing port, the channels have been seriously accreted, fishing vessels have run aground, and are damaged. More than half of the area of the storm shelter has been heavily filled, and when the tide is down, fishing vessels are often heeled over, which is not safe. Streams in Quy Nhon and De Gi fishing ports are also being narrowed and the vessels coming and leaving the port are facing many difficulties. At present, the maintenance work is still done every year, but its effect is not as much as expected.

(6) Phu Yen Province

River erosion has become serious since 2012 with 19 erosion points, with the length of 35.3 km, especially in Phu Loc Village, Hoa Thang Commune, Phu Hoa District with 2km long. In addition, areas such as Phong Nien Village, Hoa Thang Commune, Phu Hoa District, the banks of the Ky Lo River across the Ngan Son Bridge have also begun to erode and need to be protected as soon as possible.
River erosion directly affects people's lives and property (with more than 1000 affected households), in addition to a large area of agricultural land. Waterfront trading is also affected.

2.5.2 Coastal Erosion

Summary of current situation of coastal erosion in central region is shown in **Table 2.5.3**

Table 2.5.3 Summary of Current Situation of Coastal Erosion in Central Region

		Quang Tri	Thua Thien hue	Quang Nam	Quang Ngai	Binh Dinh	Phu Yen
Basic data on situation of erosion	**Location**	Vinh Thai commune, Cua Tung Beach	Phong Dien, Quang Dien, Huong Tra, Thuan An, Phu Vang, Phu Loc	Cua Dai beach	Binh Son, Duc Pho	Hoai Nhon, Phu My, Phu Cat	Xom Ro, Tuy Hoa
	Length km)	6.000	34.000	7000.000	33.436	28000.000	13.600
	Speed (m/year)	-	-	10-30	10-30	-	18
	Level - Distance (km)	-	-		① 3.790 ② 29.646 ③ 56.133	-	-
Situation of hinterland (land use)	**Tourism**	◎ ・Resort hotel: 2	◎	◎ ・Resort hotel: 378 (6881 rooms)	◎ ・Resort hotel: 10		◎ ・Resort hotel: 10
	Agriculture	◎	◎	-	◎	◎	◎
	Aquaculture	◎	◎	-	◎	◎	◎
	Industry	×	-	-	▲		▲

		Quang Tri	Thua Thien hue	Quang Nam	Quang Ngai	Binh Dinh	Phu Yen
	Resident (household)	No info	378217 (33% of population living in terrace area)	2000 (directly effected)	・relocated: 514 ・affected: 1165		1600 (directly effected)
Causes of erosion		No relating survey or research	No data	・Reduction of sediment supply from river system ・Reduction of sediment supply in coastal system	No relating survey or research	No relating survey or research (PPC's opinion: currently coastal erosion is not serious problem in comparison with estuary accretion)	No relating survey or research (PPC's opinion: mainly due to storm surge, climate change, sea level rise, economical activities nearby coastal area)
Current Countermeasures	**Conte nts**	・Groins (0.8km) ・sea dike (3.8m in Vinh Thai beach)	・Thuan An estuary adjustment (phase1, cost: 6.8 million USD) ・Hai Duong urgent anti-erosion measure (cost: 2.1 million USD) ・Revetment in An Duong commune (cost: 1.8 million USD) ・Revetment in Quang Dien commune (cost: 6.8 million USD) ・Groins in Phu Thuan commune ((cost: 0.6 million USD)	・Geo-tube, sea dike, beach nourishment (partial and in small scale)	・6 projects of constructing anti-erosion measure from 2008 to 2016	Sea dike, revetment	・dike (cost: about 4.5 million USD/km)

		Quang Tri	Thua Thien hue	Quang Nam	Quang Ngai	Binh Dinh	Phu Yen
	Effects	・temporary level and unable to protect inland area in typhoon season	No comment from PPC	・having effect for local area but causing minus effect for adjacent area	No comment from PPC	No comment from PPC	・Partial measures only for extremely serious effected area due to limited cost

Source: JICA Study Team created based on interview results

(1) Quang Tri Province

The Quang Tri coast is 75km long; spreading across the districts of Vinh Linh, Gio Linh, Trieu Phong and Hai Lang. Quang tri locates in the North Central Coast region, subject to the lunar semi-diurnal tide. The largest tidal range in September reached 2.35 m. The shoreline in the rainy season is severely eroded annually, such as the coastline in Mac Nuoc Village, Dong Luat, Vinh Thai Commune, where at some locations, about 100m width of shore have been eroded (**Fig 2.5.8**).

Source: JICA Study Team

Figure 2.5.8 Location Map of Eroded Coasts in Quang Tri Province

Erosion of Cua Tung Beach:

Cua Tung Beach is located in Vinh Linh District, Quang Tri Province. It was named as "Queen of the beaches" with green water, and silky sand. Since ten years ago, the beach has been eroding (**Fig 2.5.9**). About a width of 100m of the beach was lost during this time.

Source: JICA Survey Team

Figure 2.5.9 The Change of Cua Tung Beach over 10 years

The Southern jetty in **Fig 2.5.10** was constructed in 2004 in order to prevent the river channel from accretion due to sediment transport from south to north. However, the jetty also impedes the transport of white sand from the southern area to the northern area. Then, the width of Cua Tung Beach has gradually decreased and the "Queen beach" no longer exists.

Source: JICA Study Team

Figure 2.5.10 Current Situation of Cua Tung Beach

In order to reduce the influence of coastal erosion on the businesses of the local peoples, a coastal dike was constructed at the northern beach. Moreover, a northern jetty with 90m length was constructed in 2012 to prevent the river channel from sedimentation due to sediment transport in the north-south direction.

However, the length of that northern jetty is said to be too short and sedimentation still occur on the river channel. According to Quang Tri PC, they have to conduct dredging twice every year to deepen the river channel. Until the end of 2016 the dredging cost was covered by the "Saline sand recovery project". However, from this year, they have to find another fund for annually dredging.

Cua Viet Beach: Thach Han River has the two jetties at the river mouth which had constructed from 2010 to 2014 to prevent the estuary to a closure by littoral drift. Due to the construction of these jetties and groin, there is a decline of sandbar in front of the estuary. However, the coastal erosion around the river mouth has not been confirmed until now (**Fig 2.5.11**). Generally, training jetty decreases the sediment supply from river to coast. Therefore, continuous monitoring of the shoreline change near the river mouth is recommended.

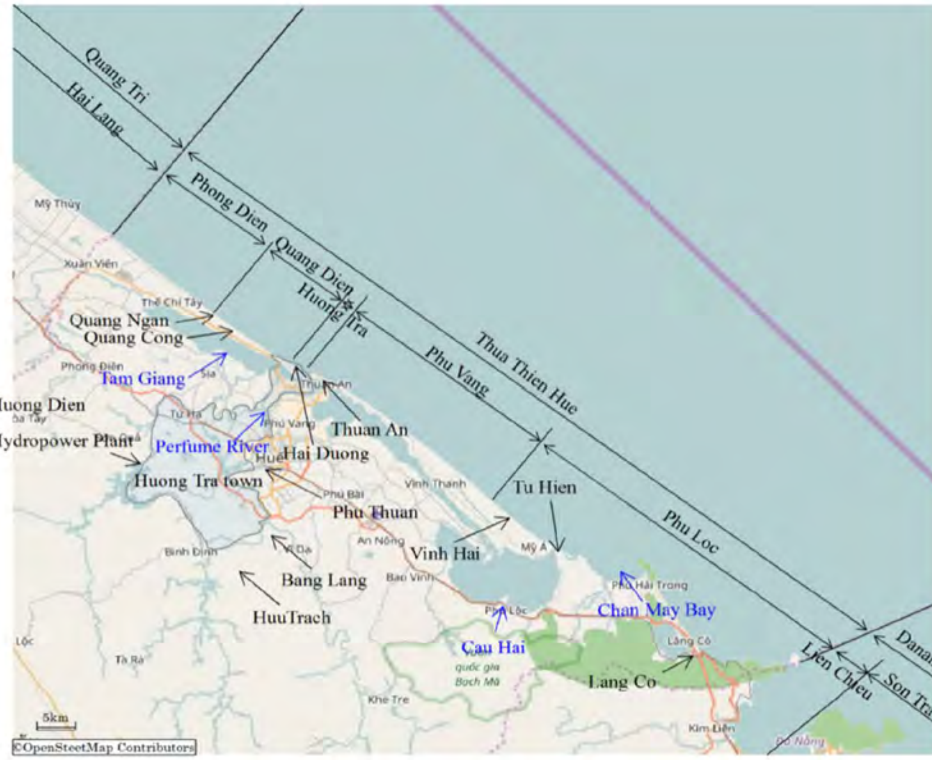
Source: JICA Study Team

Figure 2.5.11 Current Situation of Cua Viet Beach

(2) Hue Province

In recent years, typhoons, floods, tropical depressions and monsoons have caused severe erosion over a total length of 34km including ten critical points, threatening the lives and the property of more than a million households in the area. The serious areas are: Phong Hai- Phong Dien District, Quang Cong-Quang Ngan- Quang Dien District, Hai Duong - Huong Tra District, Thuan An Town, Phu Thuan District, Phu Hai District, Phu Vang District, Vinh Hai, Vinh Dien, La Giang Lagoon, and Phu Loc District (**Fig 2.5.12**).

The erosion rates have been increasing rapidly since 2015, especially in 2016 due to huge waves, tides, and storm surges which have caused a substantial erosion along more than 8.5 km of shoreline, eroding into the mainland as much as 15-20m concentrating on the communes of Quang Dien, Phu Vang and Phu Loc districts (**Fig 2.5.13**) ... Especially, the coastal region through Village 4, Vinh Hai Commune, Phu Loc District has opened a new 30 meter sea estuary and lead to the risk of further expansion.



Source: JICA Study Team

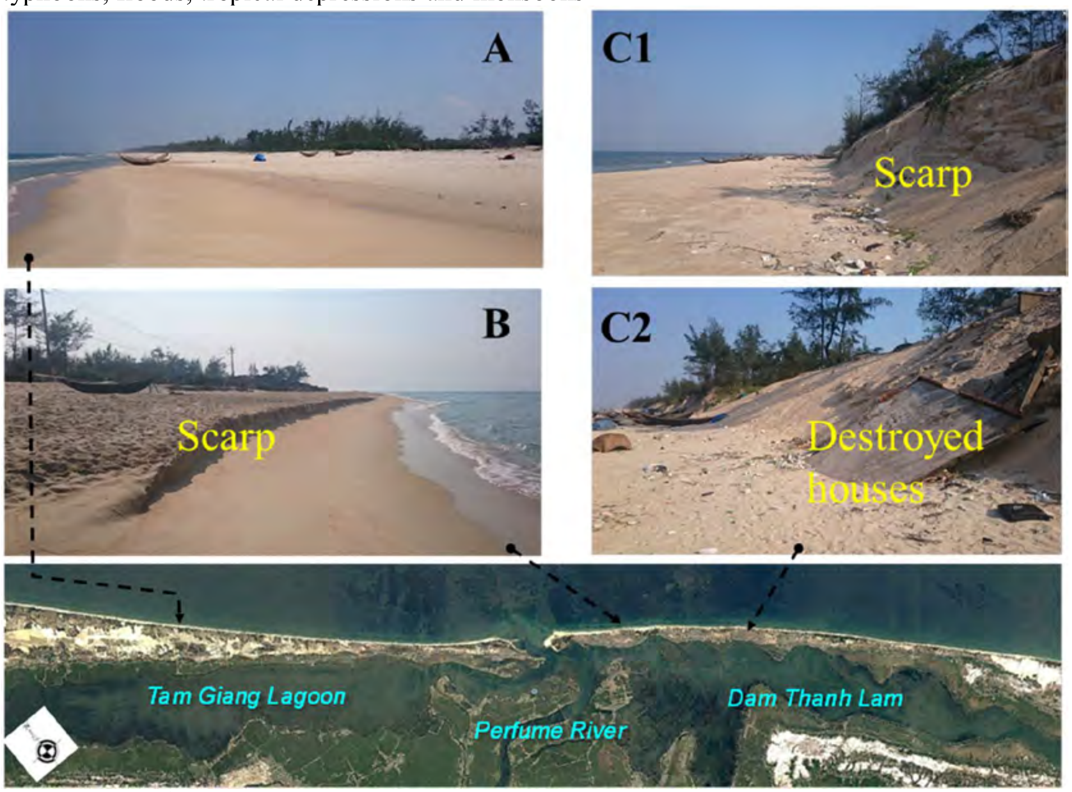
Figure 2.5.12 Location Map of Eroded Coasts in Hue Province

Source: JICA Study Team

Figure 2.5.13 Coastal Erosion in Recent Years

Coastal Erosion of Quang Dien – Phu Vang District:

The current situation of the coast between Quang Dien District and Phu Vang District is shown in **Fig 2.4.14**. The photograph “A” shows the beach of Quang Ngan, Quang Dien District. This beach has about 50m width sandy beach and the evidence of the past erosion could not be found. The photograph "B" shows the Phu Thuan Beach in Phu Vang District. From the photograph, the foreshore slope is steeper than that of Quang Ngan Beach and the scarp can be confirmed, which means that the beach has been eroded in recent days. The photograph "C" shows Phu Dien Beach. A big scarp and destroyed houses due to the erosion were found. It is thought that the coast line have retreated rapidly in recent years. It is considered that the coast line in front of the sand dune had been kept by the balance between the sediment supply from the river and the longshore sediment transport due to the waves generated by typhoons and monsoons. However, the balance has been changed because of the construction of groins at the estuary of Perfume River in 2007-2008, the dam construction and the dredging. Thus, the change of sediment supply should be observed in addition to the effects of typhoons, floods, tropical depressions and monsoons

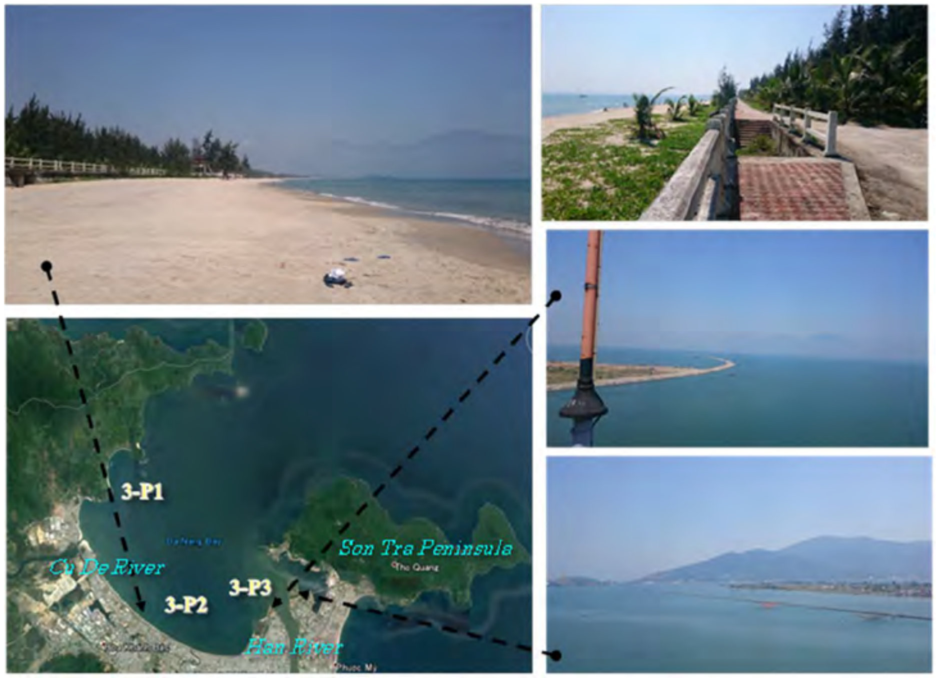


Source: JICA Study Team

Figure 2.5.14 Current Situation of the Coast between Quang Dien and Phu Vang District

(3) Da Nang City

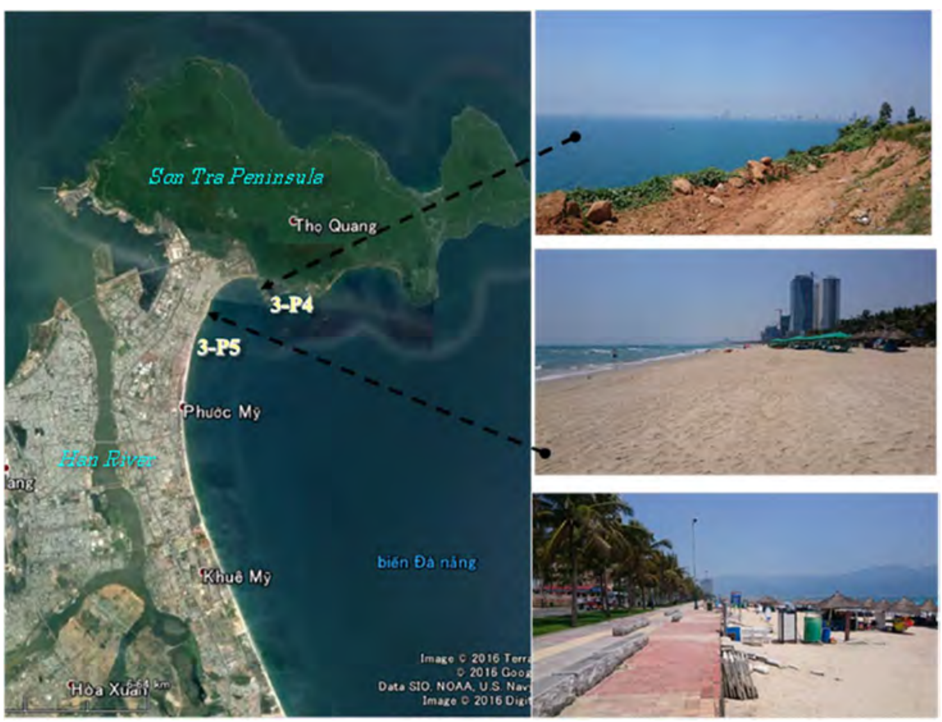
Da Nang beach is a pocket beach surrounded by a cape, so it is stable (**Fig 2.5.15**). The resort development in the estuary part changes the balance and there is a possibility of future erosion.



Source: JICA Study Team

Figure 2.5.15 Current situation of Da Nang Western Coast

It is the terminal part of the drift sand which continues from Cua Dai and it is stable since it is the part of the peninsula which is shielded against waves (**Fig2.5.16**)



Source: JICA Study Team

Figure 2.5.16 Current Situation of Da Nang Eastern Coast

(4) Quang Ngai Province

Coastal erosion has been complicated since 2007 with nineteen erosion points, and a total length of 33.3 km (**Fig 2.5.17**). The average erosion speed is about 5-10m/year, with some places up to 30m/year. Seriously eroded areas are:

- An Cuong Hamlet, Binh Hai Commune, Binh Son District: erosion length around 1,000m, width of 15-30m (including 640m severe erosion).
- Phuoc Thien Hamlet, Binh Hai Commune, Binh Son District: landslide length 2,500m, average width 19.2m.
- Nghia An Commune, Quang Ngai City: 800m erosion length, average width 20m.
- Thanh Duc Village, Pho Thanh Commune, Duc Pho District: erosion 800m length, average width 15m.

Source: JICA Study Team

Figure 2.5.17 Location Map of Eroded Coasts in Quang Ngai Province

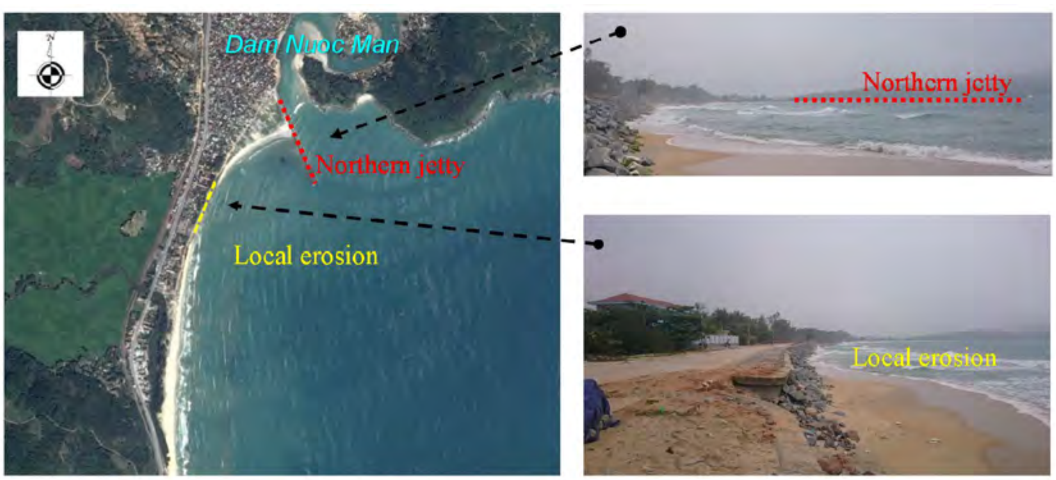
Coastal Erosion of Nghia An District:

The current situation of the coast between Tra Khuc River and Ve River in Nghia An District is shown in **Fig 2.5.18**. This coast has been eroded in recent years. Photograph “A” shows the sheet pile to protect the coast near the Tra Khuc River mouth. Especially, the center of the coast between two rivers has been eroded seriously, and the scarp developed along the beach and roots of trees have been exposed (See Photograph “B”).

Source: JICA Study Team

Figure 2.5.18 Current Situation of Nghia An Coast

<u>*Coastal Erosion of Thanh Duc Village coast*</u>:
The current situation of Thanh Duc coast is shown in **Fig 2.5.19**. A specific part of the coast does not have a beach and the dike was collapsed due to storm surge in 2016. The northern jetty was built in 2002. After that, the coastline near the jetty has advanced and the adjacent beaches have retreated. Therefore, the construction of the jetty is suspected of contributing to the local erosion and the destruction of the sea dike.



Source: JICA Study Team

Figure 2.5.19 Current Situation of Thanh Duc Coast

(5) Binh Dinh Province

Coastal erosion has become serious in the past ten years, occurring on the entire coast of the province at different levels. Comparison of satellite images from 1973 show that the coast has lost 1-2 m width of shore, even 5-6 m of shore at some locations. Some areas have seriously eroded such as Tam Quan, Hoai Huong, Hoai Hai, Hoai Nhon District; My Thanh, My Duc, Phu My District; De Gi (Cat Khanh), Trung Luong (Cat Tien) Phu Cat District; Nhon Ly, and Nhon Hai Quy Nhon City. The total length of the above eroded areas is 28 km (**Fig 2.5.20**).

Coastal erosion is threatening people's lives and assets, affecting the tourism, fishing industry and employment of the people.

Source: JICA Study Team

Figure 2.5.20 Location Map of Eroded Coasts in Binh Dinh Province

<u>*Coastal Erosion of Thien Chanh coast:*</u>

The current situation of Thien Chanh coast in Hoai Nhon District is shown in **Fig 2.5.21** "A". A part of the coast has been eroded and the scarp can be confirmed in the photograph. The northern jetty was built in 1999. After that, the coastlines near the jetty have advanced and the adjacent beach have retreated. Therefore, the construction of the jetty is suspected of contributing to the local erosion.

<u>*Coastal Erosion of De Gi coast:*</u>

The current situation of De Gi coast in Phu Cat District is shown in **Fig 2.5.21** "B" and "C". The beach near the jetty has been eroded and the scarp can be confirmed in the photograph. In addition, the coastal forest behind the beach has been destroyed. The eroding areas concentrate on the local beach near the jetty. Thus, the cause of erosion might be concerned with the impeded sediment supply or the reflected wave from the jetty.

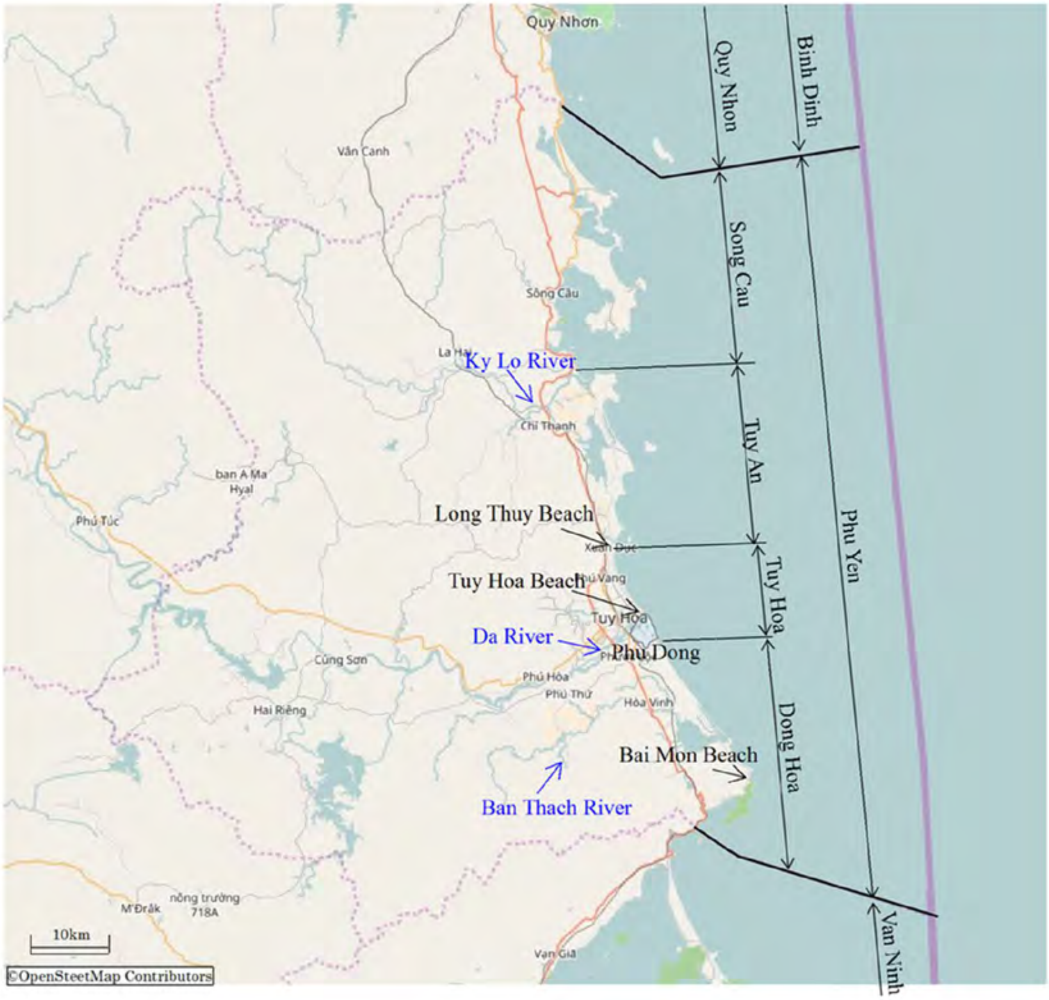
Source: JICA Study Team

Figure 2.5.21 Current Situation of Thien Chanh Coast and De Gi Coast

(6) Phu Yen

Coastal erosion has become a serious problem since 2012 and continues to date. According to statistics, there are 15 erosion sites in the whole province with the length of 13.6 km. Especially, the area of Ro village, Phu Dong ward, Tuy Hoa city demonstrates an erosion length of about 1 km, and width of 45m. At some other areas, such as the mouth of the Ban Thach River, the Da River, and the Ky Lo River, the erosion problem is now becoming more serious and needs protection (**Fig2.5.22**).

The phenomenon of erosion has a significant impact on the life and property, especially, the area near the site of the erosion; in addition, boat anchorage activities, fishing and seafood are also affected. Typically, Tuy An district has about 1,600 affected households.



Source: JICA Study Team

Figure 2.5.22 Location map of the eroded coasts in Phu Yen Province

Coastal Erosion near the Estuary of Da Rang River:

The current situation of the coast near the estuary of Da Rang River in Tuy Hoa district is shown in **Fig 2.5.23.** This coast has been eroded in recent years. Photograph "A" shows the beach located in the left bank of Da Rang River. The steep foreshore slope indicates that the beach has been eroded. And, the stone Dike has been constructed behind the beach as shown in photograph "B". It points out that the high wave can overtop the sand dune and reach the residential area because of the reduction of beach width. On the other hand, photograph "C" and "D" shows the situation of the coast on the left bank of Da Rang River, in front of Ro village. As mentioned above, the coast has already been protected by the see Dike and the groins because the shoreline have retreated seriously in recent years.

The causes of severe erosion are estimated to be the reduction of sediment supply from Da Rang River because of the retreat of the sandbar. And, this phenomenon is quite similar to erosion in Cua Dai beach. Additionally, the effect of these countermeasures can be referenced for considering countermeasure in Cua Dai beach.

Source: JICA Study Team

Figure 2.5.23 Current Situation of Coast Near the Estuary of Da Rang River

3. Legal, Administrative and Organizational aspects of sediment management

The quantitative analysis from the previous chapter clearly shows that the severe coastal retreat in the center provinces of Vietnam is mainly due to the intensified human activities that disturb the nature of sediment flow not at local but rather at a river basin scale. In this part, current issues with River Basin-based Sediment Management in Vietnam will be discussed which includes current status of: 1) coordination among related stakeholders to tackle with coastal erosion problems, 2) planning issue considering to the disturbance of sediment movement, 3) management of necessary data and information for erosion prevention measures.

3.1 Legal and Institutional Issues

3.1.1 Coordination among Related Stakeholders to tackle with Coastal Erosion Problems

Comprehensive sediment management in river systems and coastal regions is a fairly new issue in Vietnam. There is no specialized agency dealing with integrated sediment management. On the other hand, the changes in sediment transport in river systems and coastal regions of Vietnam have closely linked to the operation and management of dams/reservoirs as well as man-made constructions; management of sand mining. Therefore, the management of the mentioned activities was investigated as an indirect method of analysis of the integrated sediment management in river basins and coastal regions. Currently, different kinds of organizations at various levels are getting involved in the planning, implementation, and management of human activities in river basins. In general, institutions at the central government level are primarily responsible for the legal framework, establishment of national master plan, and coordination among local ministries while provincial institutions are in charge of the formulation of the planning of the administrative units under their management based on a master plan regulated by relevant ministries; direct implementation activities inspection; budget allowance for project implementation. .

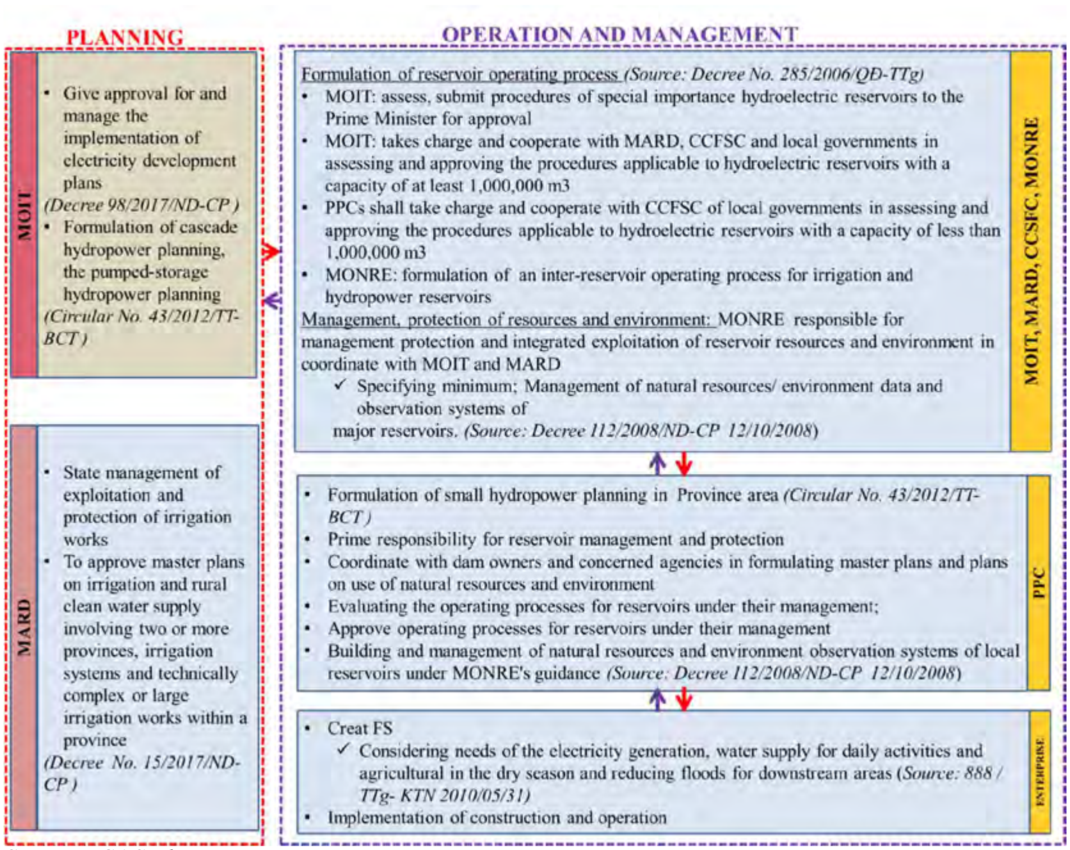
(1) Management of Hydropower Dam Planning and Operation

As shown in the previous chapter, dams/reservoirs construction has been increased from the 2000s. Common to most of them is the sediment trapping in reservoirs, the reduction of flow, and therefore, reduction of sediment supply from the river, then, result in gradually increasing of river erosion and coastal erosion. Current legal documents stipulate that MOIT shall be responsible for approval and manage the implementation of a master plan of hydropower dam development (Decree No.98/2017/ND-CP[6]) while MARD takes the prime responsibility for the master plan of irrigation reservoirs development (Decree No. 15/2017/ND-CP[7]). The master plan is publicized for receiving comments from the relevant ministries such as MONRE, MARD, MOC, MOT, Ministry of National Defense, PPCs of project area and other relevant agencies before approved (**Fig 3.1.1**).

Operation and management of dam and reservoirs involves many stakeholders as follows:

[6] Decree No.98/2017/ND-CP dated 2017/08/18 on "Defining The Functions, Tasks, Powers And Organizational Structure Of Ministry Of Industry And Trade" (Article 2-6: Tasks and powers Regarding energy)

[7] Decree No.15/2017/ND-CP on "defining the functions, tasks, powers and organizational structure of the ministry of agriculture and rural development" (Article 2-13: Article 2. Tasks and powers Regarding irrigation)



Source: JICA Study Team

Figure 3.1.1 Roles of Relevant Ministries and PPCs in Dam/Reservoirs Management

Table 3.1.1 Legal Document of Dam/ Reservoir Planning and Management

Legal document regarding management of dam		Details contents
PLANNING, INVESTMENT CONSTRUCTION Circular No.: 43/2012/TT-BCT Ha Noi, Dec 27, 2012 Regulation on management of planning, investment and construction of hydropower project and operation of hydropower works	Authority of organization of formulation of hydropower planning	• Cascade hydropower planning, the pumped-storage hydropower planning in the country: General Department of Energy • Small hydropower planning in the area: PPC • For small hydropower project located in two or more provinces: arrangement between Provinces is required In case the Provincial People's Committees do not agree with one another, the Provincial People's Committee where the power plant is expected to be located shall send a written report to MOIT for consideration and settlement.
	Content and dossier of hydropower planning.	• Assessing the conformity and impact of the hydropower projects proposed planning and other related projects in the basin. • Assessing the strategic environment under the provisions of Decree No. 29/2011/ND-CP and Decree No. 29/2011/ND-CP). • Surveying and preliminarily assessing the impact of the projects with proposed planning for population, land, extraction, and use of water needs in the lowlands. • Preliminary assessing and proposing solutions to minimize the negative impact of the project on the environment – society such as minimally discharging of flow to lowlands; compensation, support, relocation, and resettlement; plantation to recover forest area for converted purpose use of the projects.
	Appraisal and approval of hydropower planning	The agencies and units concerned gathered opinions about hydropower planning including: • For the cascade hydropower planning and Pumped-storage hydropower planning: MONRE, MARD, MOC, MOT, MOF, PPCs of project area and other related agencies and units (if necessary). • For small hydropower planning: MONRE, MARD, and other related units (if necessary).
	Formulation of investment project in hydropower works construction	Contents of FS : • Updating the present condition and planning the extraction and use of related water resources in the basin, as a basis for calculation for determining the design hydrological characteristics and the relationship between flow and water levels in study lines. • Calculating and determining the minimum flow specified in Decree No. 112/2008/ND-CP • Assessing the project's impact on safety, output power, extraction capacity of the adjacent works and projects in the basin that have been approved by the competent authority. • Carefully assessing the impact of the project on the environment in the area in accordance with Decree No. 29/2011/ND-CP (residential land, rice land, cropland, protection forest land, specialized land, production forest land, etc.) • Assessing other combining effects of projects such as flood reduction, water supply for lowlands; development of tourism, water transportation, aquaculture; labor force employed in the process of investment, construction and operation of the project

Table 3.1.2 Legal Document of Dam/ Reservoir Planning and Management (cont)

Legal document regarding management of Hydropower dam		Details contents
PLANNING, INVESTMENT AND DAM CONSTRUCTION No. 15/2017/ND-CP Hanoi, February 17, 2017 Decree on Defining the functions, tasks, powers and organizational structure of the ministry of agriculture and rural development	13. Regarding irrigation:	a/ To perform tasks of state management of exploitation and protection of irrigation works in accordance with law b/ To direct, guide and examine basic surveys, strategies, master plans, plans, programs, schemes, projects, policies and laws on irrigation and rural clean water; investment in the construction, repair and upgrade of irrigation and clean water works in rural areas; and operation of irrigation reservoirs and works in accordance with law; c/ To direct, guide and examine the elaboration, approval and implementation of irrigation master plans for agriculture and for multiple socio-economic purposes in accordance with law; d/ To approve master plans on irrigation and rural clean water supply involving two or more provinces, irrigation systems and technically complex or large irrigation works within a province to serve water supply and drainage; prevention and control of drought and saltwater intrusion; soil improvement and anti-desertification; and rural water supply in accordance with law; dd/ To direct, guide and examine technical processes and policies on irrigation and drainage; irrigation and drainage management, management of exploitation of irrigation works; to guide and inspect the implementation of regulations on discharge of wastewater into irrigation works; / To direct, guide and examine plans on protection of irrigation works and scope of protection of irrigation works; i/ To direct, guide and examine the elaboration of plans on construction, management of exploitation, use and protection of rural water supply and drainage works; k/ To perform tasks of state management of dam and irrigation reservoir safety in accordance with law; to perform the tasks under the Ministry's state management as prescribed in the Law on Water Resources and other laws.
PROCEDURES FOR OPERATING HYDROELECTRIC RESERVOIR SYSTEM No. 285/2006/QĐ-TTg Ha Noi, December 25, 2006 Decision on authority to promulgate and implement procedures for operating hydroelectric reservoir system	Power to approve the procedures	1. The Prime Minister shall approve the procedures applicable to hydroelectric reservoirs with special importance that the reservoir regulation gives a great impact on dike system and socio-economic activities of central-affiliated cities and provinces or neighboring countries. The Ministry of Industry shall assess and submit the said procedures to the Prime Minister for approval. 2. The Ministry of Industry shall take charge and cooperate with the Ministry of Agriculture and Rural development, National steering committee of prevention and control of flood and hurricanes and relevant ministries and local governments in assessing and approving the procedures applicable to hydroelectric reservoirs with a capacity of at least one million cubic meters (1,000,000 m3), excluding reservoirs specified in Clause 1 of this Article. 3. The People's Committees of provinces and central-affiliated cities shall take charge and cooperate with relevant ministries and National steering committee of prevention and control of flood and hurricanes of local governments in assessing and approving the procedures applicable to hydroelectric reservoirs with a capacity of less than one million cubic meters (1,000,000 m3). The decision on approval and procedures shall be sent to the Ministry of Industry for consolidation.

Table 3.1.3 Legal Document of Dam/ Reservoir Planning and Management (cont)

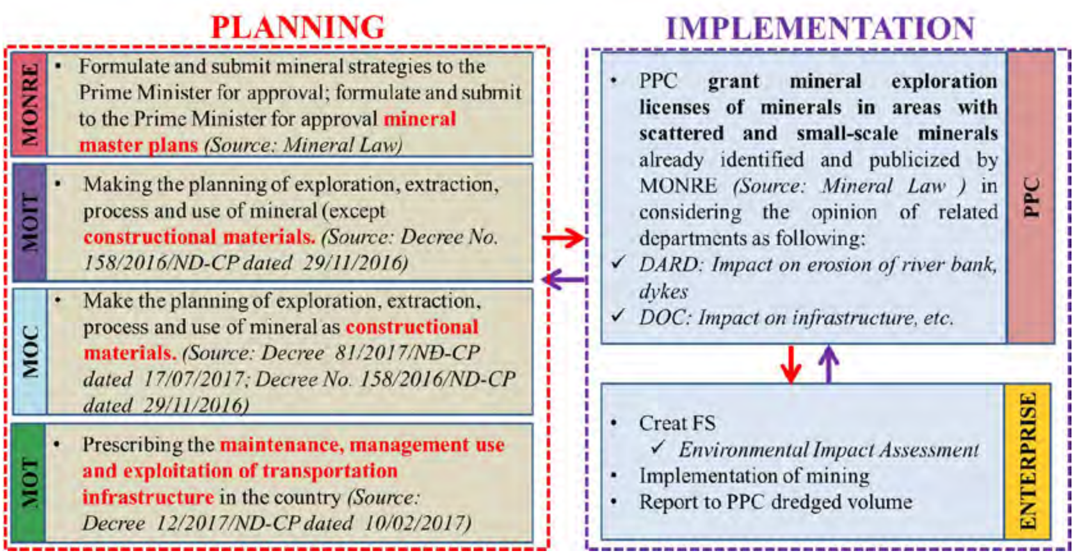
Legal document regarding management of dam		Details contents
PROCEDURES FOR OPERATING RESERVOIR SYSTEM No. 85/2006/QĐ-TTg	Contents of procedures3. Specific regulations of procedures:	a) Regulations on anti-flooding task - Early flood, main flood, and late flood periods; - Water level in reservoir in the following periods: early flood, main flood, and late flood; - Regularly preventing flooding and reducing heavy flooding for downstream areas. - Control gate manual for safe operation, ensuring that the water level in the reservoir does not exceed the prescribed level - Rules for coordination between flood-reduction and flood-division works (if any). b) Regulations on power generation - Working regime of hydroelectric plants in the system; - Requirements for water flows flushed downstream to ensure the ecological flows (if any); - Rules for coordination between power generation and other tasks (if any).
MANAGEMENT, PROTECTION AND INTEGRATED EXPLOITATION OF RESOURCES AND ENVIRONMENT Decree No. 112/2008/ND-CP Hanoi, Oct 20, 2008 On management, protection and integrated exploitation of resources and environment of hydropower and irrigation reservoirs	Responsibilities of relevant ministries	<u>MONRE</u> • To submit to the Government or the Prime Minister for promulgation, or promulgate according to its competence, legal documents on management protection and integrated exploitation of reservoir resources and environment. • To assume the prime responsibility for. and coordinate with concerned ministries, branches and localities in, specifying minimum flow requirements for reservoir lowlands • To direct the establishment and perform the unified management of natural resources and environment data and observation systems of major reservoirs. • To synthesize and determine water use needs of branches, localities and economic organizations in reservoir lowlands and supervise the assurance of provision of hydro meteorological and water resource information, data and forecasts for reservoirs. • To assume the prime responsibility for and coordinate with MOIT and MARD in formulating inter-reservoir water regulation plans for reservoirs of national importance and submit them to the Prime Minister for decision when serious drought, water shortage or water source contamination, or other serious environmental incidents or disasters occur in the river basin. • To submit to the Prime Minister for approval a list of irrigation and hydropower reservoirs in the river basin required of an inter-reservoir operating process. • To direct and coordinate with concerned ministries, branches, localities and investors in formulating an inter-reservoir operating process for irrigation and hydropower reservoirs <u>MOIT and MARD</u> • To direct the formulation, coordinate with the MONRE and concerned ministries, branches and localities in. evaluating reservoir or inter-reservoir (if any) operating processes under their state management; to approve according to their competence reservoir or inter-reservoir (if any) operating processes under their state management or submit them to the Prime Minister for approval according to law. • To direct the elaboration of reservoir water regulation plans; to direct water regulation for reservoirs under their state management when serious drought, water shortage or water source contamination.

(2) Management of Sand Mining Planning and Implementation

Sand mining from river channels reduces the amount of sediment supply which can result in a deepening of the channel as well as coastal erosion. Interview survey results expose that location and scale of mining field are proposed based on the required amount for economic activities and ad-hoc capacity of the target river without concrete scientific investigation on the influence of sand mining on downstream sediment flow.

At present, several ministries are involved in the planning of sand mining. From these ministries, MONRE is responsible for formulating and submitting the mineral strategies and mineral master plans to the Prime Minister for approval (Mineral Law[8]); MOIT takes primary responses for making the planning of exploration, extraction, process and use of mineral, except constructional materials while MOC makes the planning of exploration, extraction, process and use of minerals as constructional materials (Decree No. 158/2016/ND-CP[9]). In addition, MOT is assigned for maintenance, management use and exploitation of transportation infrastructure in the country (Decree 12/2017/ND-CP dated 10/02/2017[10]) that means MOT should make a response for the making and implementation of river channel dredging planning (**Fig 3.1.2**).

PPCs are engaged in direct activities such as grant permission for sand mining, budget allowance, and inspection of mining activities. Interview results indicate that mining areas are selected based on the approved master plans and evaluation of related departments. For example, DARD gives opinion regarding the impacts of sand mining on safety of river bank and dikes; DOC assesses the negative impact on infrastructures. Detailed content of relevant legal document are summarized in **Table 3.1.6.**



Source: JICA Study Team

Figure 3.1.2 Roles of Relevant Ministries and PPCs in Sand Mining Management

8 No. 60/2010/QH12 dated November 17, 2010 Mineral law

9 Decree No.158/2016/ND-CP dated November 29, 2016 on Guidelines for the law on mineral

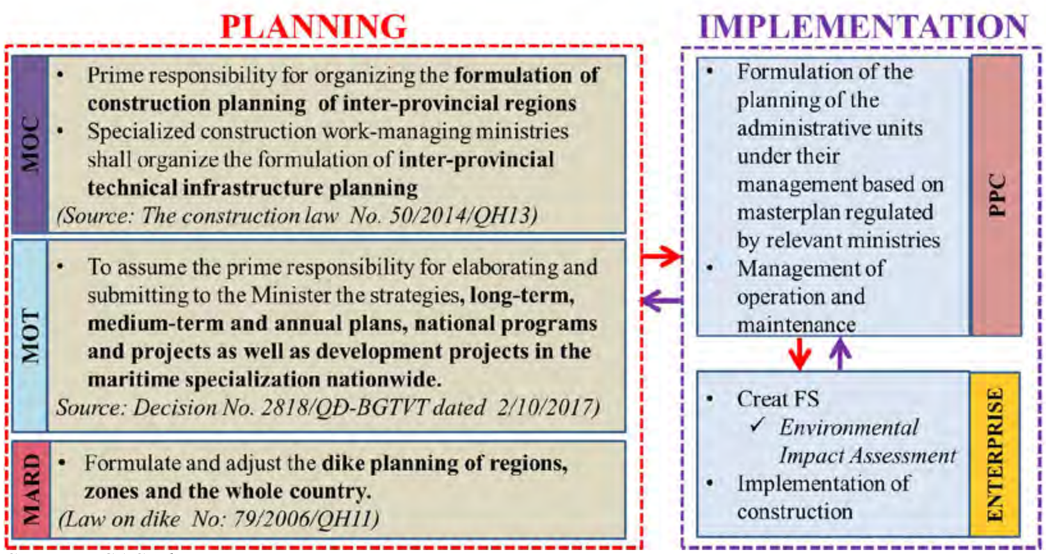
10 Decree No.12/2017/ND-CP dated February 10, 2017 on Defining the functions, tasks, powers and organizational structure of the ministry of transportation

Table 3.1.4 Legal Document of Sand Mining Planning and Management

Legal document regarding management of sand mining		Details contents
No. 60/2010/QH12 Nov 17, 2010 Mineral law	Responsibilities of the Government, ministries and ministerial-level agencies for state management of minerals	MONRE • Formulate and submit mineral strategies to the Prime Minister for approval; formulate and submit to the Prime Minister for approval mineral master plans as assigned by the Government • Identify and publicize mineral areas according to its competence; identify and submit to the Prime Minister for decision areas not subject to auction of the mining right according to its competence • Guide and organize the registration of geological baseline surveys of minerals; make statistics of and inventory mineral deposits • Summarize results of geological baseline surveys of minerals and mineral activities; manage geological and mineral information and specimens PPCs • Formulate and submit to competent state agencies for approval local master plans on exploration, mining and utilization of minerals under the Government's regulations • Recognize criteria for calculating mineral deposits; approve mineral deposits; make statistics of and inventory mineral deposits falling within their licensing competence • Report mineral activities in their localities to central state management agencies in charge of minerals
	Competence to grant mineral exploration licenses and mining licenses	• MONRE may grant mineral exploration licenses and mining licenses in cases other than those specified in Clause 2 of this Article. • PPCs may grant mineral exploration licenses, licenses for mining of minerals for use as common construction materials, peat, and minerals in areas with scattered and small-scale minerals already identified and publicized by MONRE; and licenses for salvage mining.
No. 158/2016/ND-CP Nov 29, 2016 Decree on guidelines for the law on mineral	Making and submitting for approval of the planning of mineral	Responsibility for making and presenting a planning for minerals to the Prime Minister for approval is prescribed in clause 3, Article 10 of the Law on minerals as follows: • MONRE will preside over to make the planning of geological baseline mineral survey • MOIT will take charge of making the planning of exploration, extraction, process and use of mineral • MOC will preside over to make the planning of exploration, extraction, process and use of mineral as constructional materials
	Planning for exploration, extraction and use of minerals in the centrally provinces and cities	The making of the planning for exploration, extraction and use of minerals in provinces and central-affiliated cities must ensure the following principles: • Consistent with the mineral strategy, mineral planning and the overall planning for socio-economic development of the province; land-use planning assessed and approved by competent authorities; guarantee of national defense and security in the administrative divisions; • Guarantee of the extraction and use of minerals rationally, economically and efficiently to serve the current needs in consideration of the scientific and technological development and mineral demand in the future; • Protection of the environment, natural landscape, cultural and historical monuments, famous landscape and other natural resources. The basis for making the planning for exploration, extraction and use of minerals in the centrally provinces and cities includes: • The overall planning of socio-economic development of the provinces, area planning and the mineral strategy; mineral planning • The mineral demand in the planning period; • Scientific and technological advances in mineral exploration and mining • Result of execution of the previous period planning.

(3) Management of other Infrastructures

Economic development is always accompanied by an increase in the construction of infrastructures such as roads, bridges, harbor structures (berth, revetment, and breakwater), river banks, and sea dikes. According to the Construction Law[11] MOC is allocated the prime responsibility for organizing the formulation of construction planning of inter-provincial regions. MOT is assumed the prime responsibility for elaborating and submitting to the Minister the strategies and development plan in maritime specialization nationwide (Decision No. 2818/QĐ-BGTVT[12]). Law on dike[13] stipulates that the formulation and adjustment of dike planning is allocated to MARD (**Fig 3.1.3**).



Source: JICA Study Team

Figure 3.1.3 Roles of Relevant Ministries and PPCs in Management of Infrastructures Constructions

3.1.2 Planning Issue Considering to the Disturbance of Sediment Movement

A modern approach for large infrastructure development plans often includes a Strategic Environmental Assessment (SEA) during the master plan phase and during the implementation period of the projects; Environmental Impact Assessment (EIA) should be carried out. The current environmental impact assessment procedures in Vietnam for all types of economic activities mainly concentrate on qualitative/quantitative assessment of air/water/soil pollution but not sediment issues. In addition, the contents of SEA and EIA do not specify or mention the evaluation items, criteria, and evaluation methods as well as requirement of assessment member for specific type of project. Detailed list of entities subject to SEA and EIA are shown in **Table 3.1.5 and Table 3.1.6**.

Table 3.1.5 List of Entities Subject to Strategic Environmental Assessment

4	*Strategies, planning, or plans for development of industries and fields having dramatic impacts on the environment*
4.1.2	Strategies or planning for development of electricity, hydroelectricity; exploration, mining and mineral processing
4.1.3	Strategies or planning for development of agriculture, forestry, aquaculture, irrigation, or animal husbandry

[11] No. 50/2014/QH13 dated June 18, 2014: The Construction Law
[12] Decision No. 2818/QĐ-BGTVT dated 2/10/2017: Decision on regulating the functions, tasks, powers and organizational structure of Vietnam Maritime Administration.
[13] No: 79/2006/QH11 dated November 29, 2006: Law on dikes

4.1.4	Strategies or planning for development of infrastructure in road traffic, railway traffic, sea traffic, river traffic, port traffic or air traffic
4.2	*Planning for development of inter-provincial and inter-regional industries and field*
4.2.2	Planning for development of irrigation
4.2.3	Planning for development of hydroelectricity
4.2.4	Planning for development of transport
4.2.6	Planning for extraction and processing of minerals

Table 3.1.6 List of Entities Subject to Environmental Impact Assessment

No.	Project	Scale
Projects under competence to decide investment policies of the National Assembly; or competence to decide investment approval of the Government or the Prime Minister		All
Construction projects		
13	Construction projects for sea encroachment	Coastal boundary length: at least 1,000 m; or encroachment area: at least 5 hectares
Transport projects		
22	Construction projects for road bridges or rail bridges	Length: at least 500 m (excluding feeder roads)
23	Construction projects for river and sea ports; asylum harbors; projects for dredging of navigable channels, inland waterway jet	River ports and seaports: Capable of receiving 1,000 DWT ships or larger;
		Dredging: at least 50,000 m³ per year
Projects for irrigation, forest extraction and cultivation		
30	Construction projects for water reservoirs	Reservoir volume: at least 100,000 m³
31	Construction projects for irrigation and water supply and drainage works for agricultural, forestry and fishery production	Irrigation and water supply and drainage work area: at least 500 hectares
32	Projects for dikes and sea and river embankments	Length: at least 1,000 m
Projects for mineral exploration, extraction and processing		
35	Projects for the extraction of sand, gravel, leveling materials	Crude sand or gravel: at least 50,000 m³ of per year
		Crude leveling materials: at least 100,000 m³ of per year

For example, SEA of the Vu Gia – Thu Bon River Basin Hydropower Plan (ADB 2008) and EIA of Song Bung 4 Hydropower Project, Phase II (ADB) focus on assessment of independent and cumulative impacts on Vu Gia-Thu Bon river basin through evaluation of soil, water and air pollution; hydrological factors (water discharge behind dam); erosion in vicinity of dam's downstream (qualitative) and sediments trapping in reservoirs (management of dam's capacity). Then, they provided enhancement measures and environmental management plan for such kind of issues.

The content of SEA and EIA are stipulated in Circular No. 27/2015/TT-BTNMT dated May 29, 2015. However, Vu Gia Thu Bon SEA report and Song Bung II EIA report reflect the fact that content of SEA and EIA are not specified the evaluation items, criteria, and evaluation method as well as requirement of assessment member for specific type of project. In addition, quantitative evaluation of river/coastal erosion is not mentioned in SEA and EIA.

Content of Assessment and predictions of environmental impact for project (EIA Chapter 3)
Affecting source related to waste : It is required to specify quantity, load and concentration of all specific waste parameters of the Project and compare with standards and technical regulations in force, specify waste generation space and time;
Affecting sources non-related to waste (slide, collapse, land subsidence, erosion of river, stream, lake, coast; silting of river-beds, streambed, lakebed, seabed; degradation of environmental physical, ect.)

Conditions and criteria for titles of the assessment council: *The president or the deputy president must be an environment specialist or a specialist in the field of the project and have at least 07 years' experience if he/she obtains a Bachelor's Degree, at least 05 years' experience if he/she obtains a Master Degree, at least 03 years' experience if he/she obtains a Doctor Degree or he/she is the head of the assessment authority or the standing assessment agency.*
(Circular No. 27/2015/TT-BTNMT dated May 29, 2015)

Therefore, it is advisable to include the detail specification and evaluation criteria as well require the involvement of specific environmental specialists in the evaluation of EIA and SEA for each specific type of economic activities. For instance, environmental regulations on hydropower dam construction project should include the impact assessment for changes of suspended sediment transport before and after dam construction and the evaluation process must be carried out by qualified river-basin sediment specialist(s)

3.2 Sediment Management Institution at the River Basin Level

As mentioned above, there is no specialized agency dealing with integrated sediment management at the river basin level. At the province-level, the People's Committees of provinces/cities are the leading agencies in the State management in the localities. People Committee regulates the organizational structure, duties and powers of professional affiliates of the province-level People's Committee[14]. There is a slight difference among provinces in task allocation for relative departments under their administration. However, most of cases the plans made by ministries are imposed on the provincial branches of the ministries. The management of issues regarding sediment transport in river basin and coastal areas involves DARDs, DONREs and some other Departments such as Department of Industry, Department of Health, Department of Transportation, Department of Construction, etc. These departments have functional units to help manage issues related to irrigation, hydropower, water resources management, mineral resources, disaster prevention, etc.

River basin management and coastal management in Vugia-Thu Bon River Basin:
According to Decision No.1989/QĐ-TTg[15] Vu Gia-Thu Bon belong to Group A - (Inter-provincial large river basin) spreading over Kon Tum, Thua Thien Hue, Da Nang, Quang Ngai, Quang Nam Province (**Table 3.2.1**).

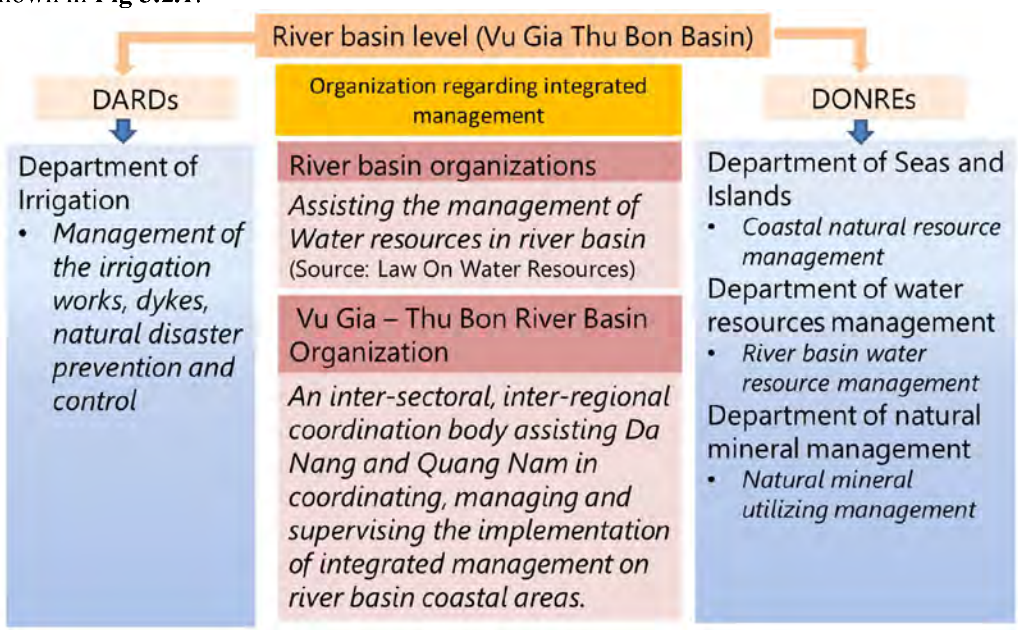
Table 3.2.1 Vu Gia-Thu Bon River Basin

No.	Name	Exit	Length (Km)	Catchment Area (Km^2)	Under the Province/ City of	Noted
	Vu Gia Thu Bon River System			10.035	Kon Tum, Thua Thien Hue, Da Nang, Quang Ngai, Quang Nam	Group A - (Inter-provincial large river basin)
1	**Vu Gia River**	**Thu Bon River**	**209**	**5.425**	**Kon Tum, Thua Thien Hue, Quảng Nam, Đa Nang**	**Area and length of main channel up to Giao Thuy**

[14] No. 77/2015/QH13 dated June 19, 2015: Law on organizing the local government- *Article 21. Duties and powers of the provincial-level People's Committee; Article 49. Duties and powers of the district-level People's Committee*
[15] Decision No: 1989/ QĐ-TTg dated November 1, 2010: Promulgating the list of Inter-provincial river basin

No.	Name	Exit	Length (Km)	Catchment Area (Km^2)	Under the Province/ City of	Noted
	Nuoc Che River	Vu Gia River	38	284	Kon Tum, Quang Nam	
	Thanh River	Vu Gia River	72	552	Kon Tum, Quang Nam	Other name: Đăks Peng River
	Con River	Vu Gia River	59	634	Thua Thien Hue, Quang Nam	Other name: Sông Con
	Vinh Dien River	Vu Gia River	23		Da Nang, Quang Nam	Other name: Đò Toản River
	Qua Giang River	Vinh Dien River	15		Quang Nam, Da Nang	Other name: La Tho River
2	**Thu Bon River**	**Sea**	**206**	**4.61**	**Quang Ngai, Quang Nam**	**Other name: Cua Dai River**
	Vang River	Thu Bon River	33	240	Quang Ngai, Quang Nam	

Current agencies and organizations that are involved in the Vu Gia Thu Bon River basin management are shown in **Fig 3.2.1**.



Source: JICA Study Team

Figure 3.2.1 Roles of Relevant Ministries and PPCs in Management of Infrastructures Constructions

3.2.1 DONRE

Law on Water Resource[16] stipulates that: MONRE takes responsibility before the Government in implementation of state management on water resources, management on river basin in nationwide, including: making, submitting to the Prime Minister for approval; approving under its authority and organize implementation of strategy, general master plan on basic survey for water resources, master plan on water resources; processing on operation of inter- reservoirs, issuing list of river basins, list or water sources; planning on basic survey, regulation, distribution of water resources, recovery of water sources polluted, depleted. In addition, MONRE is allocated to form databases, information systems

[16] Law No. 17/2012/QH13 dated June 21, 2012 Law on water resources

on water resources; manage and store information and data on water resources; declare and publish documents and information on water resources (Article 70-2h).

As a provincial branch of MONRE, DONRE is responsible for advising and assisting the Provincial People's Committee on state management of natural resources and environment including: land; Water Resources; Mineral resources, geology; environment; Hydro-meteorology; Climate Change; Measurement and mapping; Integrated and integrated management of the sea and islands. Therefore, DONREs are collecting and accumulating the data for the analysis and assessment of the utilization of water resources and natural resources. However, data and information regarding to the management of sediment transport in river basin such as: river cross-section, sediment grain size distribution, water discharge in entire river basin have been not collected continuously and systematically.

3.2.2 DARDs

DARDs assume prime responsibilities on advising and assisting the Provincial People's Committee on state management of agriculture, forestry, aquatic, irrigation, rural development, and flood & disaster prevention. In all targeted provinces, DARDs are being allocated for river/ coastal erosion control. However, because they don't have power regarding planning of sediment related disaster prevention; most erosion prevention measures are conducted after erosion occurred.

3.2.3 Organization Regarding Integrated Management

- **River Basin Organization (RBO)**

The establishment of the river basin organization has been institutionalized in the Law on Water Resources. However, the power of RBO on planning/implementation of the issues related to management of river basin is not clearly indicated. Then, Decree No. 201/2013/ND-CP[17] stipulated that:

- The organization and operation of a river basin organization shall be decided by an interdisciplinary organization.
- The river basin organization is responsible for submitting proposals on conditioning and distributing water resources, supervising the exploitation and protection of water resources, the prevention and mitigation of negative effects of water on the river basin or some of inter-provincial river basins to competent authorities.
- The Prime Minister shall decide the establishment of the river basin organizations of the Red River – Thai Binh River, Mekong River basins at the requests of the Minister of Natural Resources and Environment.
- The Minister of Natural Resources and Environment shall establish river basin organizations of other inter-provincial river basins other than those prescribed in Clause 2 this Article at the requests of the Heads of State management agencies specialized in water resources.

Vu Gia Thu Bon River Basin Organization which has above function has still not been established since Law on Water Resource was enforced in 2012. However, there is a Vu Gia – Thu Bon River Basin Organization established based on agreement between Quang Nam Province and Da Nang City.

- **Vu Gia – Thu Bon River Basin Organization**

On August 21, 2017, Quang Nam Province and Da Nang City organized the Signing Ceremony for the Establishment of the Coordination Board for Integrated Management of the Vu Gia – Thu Bon River Basin and coastal area of Quang Nam – Da Nang (or the Vu Gia – Thu Bon RBO). This is the result of a process of active collaboration between the two municipalities which expected to offer a constructive platform for addressing current issues in flood risk management and water resource management in the shared river basin. The RBO will be alternatively chaired by the Vice Chairs of Quang Nam and Da Nang, for periods of six months.

<u>Joint action content:</u>

1. Organize regular meeting related to river basin and coastal zone management.

[17] Decree No. 201/2013/ND-CP dated November 27, 2013: Detailing the implementation a number of articles of the law on water resources - Article 5. River basin organizations

2. Organize the assessment of current status; identify the risks in the Vu Gia - Thu Bon river basin affecting urban development in river basins and coastal areas. Vu Gia – Thu Bon RBO has inter-provincial responsibilities for development planning on utilization of natural resources in river basins and coastal areas.
3. Increase the inter-branch and inter-regional coordination in the supervision work to archive efficient management and utilization of water resources, attaching importance to the ecological environment protection in river basins and coastal areas.
Coordinate in controlling violation of natural resources utilization and environmental protection in river basins and coastal areas.
4. Develop a common database for river basins and coastal areas; sharing information and data for resource management, environmental protection and climate change response.
5. Strengthening and raising knowledge and awareness to meet the requirements of integrated river and coastal zone management in the two provinces

Members of Vu Gia-Thu Bon RBO
1. Head:
- Mr. Ho Ky Minh, Vice Chairman of Danang People's Committee.
- Mr. Le Tri Thanh, Vice Chairman of Quang Nam People's Committee.

2. Standing Deputy Head:
- Director of Da Nang Department of Natural Resources and Environment.
- Director of Quang Nam Department of Natural Resources and Environment.

3. Members of the Coordination Committee: including leaders of departments of
- Department of Planning and Investment
- Department of Finance
- Department of Agriculture and Rural Development
- Department of Construction
- Department of Transportation
- Department of Industry and Trade
- Department of Health
- Department of Science and Technology
- Office of Provincial People's Committee
- The Meteorological and Hydrographical Station of Quang Nam Province
- Inviting the Central Meteorological and Hydrography Station of Central Vietnam.

As a Coordination Board between Quang Nam and Da Nang, the Vu Gia - Thu Bon RBO is responsible for supporting the integrated management in river basin and coastal area by conducting the regular conversation among related departments. However, Vu Gia - Thu Bon RBO is not authorized to formulate planning and implement specific countermeasures.

3.3 Technical Issues

(1) Basic Data Collection and Utilization

Both data collection and interview surveys reveal that basic data to find the causes and countermeasures of coastal erosion and river bank erosion have not been acquired and accumulated. Moreover, cross-sharing of observed and measured data is not in progress. The access to accumulated data collected by other ministries and agencies is difficult (**Table 3.3.1**).

Table 3.3.1 Current Situation on Basic Data Collection/ Utilization from Interview Results

Interviewee	Interview results
VASI (Vietnam Administration of Seas and Islands)	• They have an advanced shoreline change analysis model. Calibration of calculated results has been conducted based on the past aerial photographs. However, the accuracy of reproduced results is not good due to the low quality images.
MARD (Ministry of Agriculture and Rural Development)	• Cross-sharing of observed and measured data is not in progress. The access to accumulated data collected by other ministries and agencies is difficult
Thuy Loi University Associate Prof. Viet	• In order to investigate the countermeasures against the erosion of the Cua Dai coast, wave data of the target area are necessary, but wave observation is not sufficiently implemented in Vietnam
VAWR (Vietnam Academy for Water Resources)	• There is no continuous acquisition / accumulation of basic data across the entire basin. • Most of the data are acquired by the project but they are neither stored in a database nor disclosed in the public

Source: JICA Study Team

As for hydrographic data, in Vu Gia Thu Bon River Basin, there are only two stations categorized as Level1; measuring the hourly water level, water discharge and turbidity; located at Nong Son and Thanh My. Other stations are categorized as Level3; measuring only the hourly water level. There is one oceanographic station in Son Tra, but only conduct the observation of wave height. Others necessary data are not being measured (**Table 3.3.2**).

Table 3.3.2 Current Situation of Data Collection in Vu Gia Thu Bon River Basin

Area	Items	Current monitoring system	Implement
River area	Water level・velocity	Nong Son, Thanh My, Hoi Khanh, Giao Thuy,Hiep Duc, Ai Nghia, Cau Lau, Hoi An, Cam le (**Fig 3.3.1**)	MONRE
	River discharge	Nong Son, Thanh My (**Fig 3.3.3**)	MONRE
	Sediment discharge	Not implemented	----
	Riverbed profile	Not implemented	----
	River bed materials	Not implemented	----
	Sand mining volume	Not implemented	----
	Sediment trapping on hydropower reservoir	Not implemented	----
	Sediment trapping behind irrigation dam	Not implemented	----
Coastal area	Water level	2 station at Cau Lau and Hoi An	MONRE
	Wave	Son Tra station (only observation)	MONRE
	Shoreline	Not implemented	----
	Beach profile	Not implemented	----
	Sand sampling	Not implemented	----
	Beach nourishment volume	-	----

Source: JICA Study Team

Source: JICA Study Team

Figure 3.3.1 Distribution of Hydrology Observation Station in Vu Gia Thu Bon River Basin

Source: JICA Study Team

Figure 3.3.2 Level 3 Observation Station- Ai Nghia Station

Ai Nghia Station is the manned observation station, categorized as Level3; measuring only the hourly water level (**Fig 3.3.2**).

Source: JICA Study Team

Figure 3.3.3 Thanh My Station

The periodic river cross-section collection was not conducted and it was impossible to accurately quantify the over-time change in sediment transport in Vu Gia Thu Bon River Basin. Therefore, continuous recording of river cross-section change should be implemented to monitor sediment transport efficiently in the future.

(2) Guideline on Anti-Erosion Measures Design and Implementation

Design standards for structures such as river bank, revetment, jetties…are available whereas guidelines to the applying process and applicable measures from the view of integrated coastal management are not available. Existing Structure Design Standards including:

- *Hydraulic structures – Requirements for sea dike design (TCVN 9901: 2014)*: The standard specifies the technical requirements for design, construction, inspection and acceptance of sea dikes; applying for sea dikes, reclamation works, beach protection structures and island protection embankment, etc. This standard may be applied to the design of other dikes with similar working conditions and similar technical specifications such as dikes in estuaries, etc.
- *Hydraulic structures –Requirements for river dike design (TCVN 9902: 2016)*: The standard regulates the requirements for the design of river dikes. The scope of application includes the construction as well as renovation and upgrading of existing river dikes. This standard may be applied to the design of dikes in estuaries and other dikes with similar working conditions.
- *National technical regulation on hydraulic structures - The basic stipulation for design (QCVN 04 - 05: 2012/BNNPTNT)*: This standard specifies the requirements of design, construction, and inspection, of the irrigation works in the stages of planning, creation of investment projects as well as survey and designing. The scope of application includes the construction, repairing, upgrading or expansion of works, irrespective of the investment capital sources (Design of dikes, embankments, waterway, and coastal structure are not covered in the regulation)

Moreover, new methods such as beach nourishment and sand bypass are not sufficiently studied because design standards are not available (**Table 3.3.3**).

Table 3.3.3 Interview Results Regarding Current Technical Standards

Interviewee	Interview results
VAWR	Beach nourishment, and sand bypass are more effective than traditional methods (embankment, jetty…), but design criteria are not formulated, so those measures are still being implemented without sufficient consideration

As mentioned above, the impact of human activities on river basins should be evaluated both in the planning and the project implementation stage. However, there are no specified evaluation items, criteria, and methods as well as the requirement of assessment members for the specific types of projects. In addition, the current impact assessment mainly concentrates on the qualitative/quantitative assessment of air/water/soil pollution; however, the quantitative evaluation of river/coastal erosion is not mentioned in SEA and EIA. The impacts of human activities are evaluated based on following standards:

- Law on environmental protection (No. 55/2014/QH13)
- Decree on environmental protection planning, strategic environmental assessment, environmental impact assessment and environmental protection plans (No. 18/2015/ND-CP)

Decree No. 18/2015/ND-CP dated February 14, 2015 Decree on environmental protection planning, strategic environmental assessment, environmental impact assessment and environmental protection plans

Assessment of SEA reports (Article 10)

Members of SEA report assessment council shall consist of President, 01 Vice President where necessary, 01 Secretary member, 02 Opponent members and other members, which at least 30 percent of the Assessment council members having at least 05 years' experience in the SEA.

Circular No. 27/2015/TT-BTNMT dated May 29, 2015 Circular on strategic environmental assessment, environmental impact assessment and environmental protection plans

Content of Assessment and predictions of environmental impact for project (Appendix 2.3)

Affecting source related to waste: It is required to specify quantity, load and concentration of all specific waste parameters of the Project and compare with standards and technical regulations in force, specify waste generation space and time

Affecting sources non-related to waste (slide, collapse, land subsidence, erosion of river, stream, lake, coast; silting of river-beds, streambed, lakebed, seabed; degradation of environmental physical, etc.)

Conditions and criteria for titles of the assessment council (Article 19)

1. The president or the deputy president must be an environment specialist or a specialist in the field of the project and have at least 07 years' experience if he/she obtains a Bachelor's Degree, at least 05 years' experience if he/she obtains a Master Degree, at least 03 years' experience if he/she obtains a Doctor Degree or he/she is the head of the assessment authority or the standing assessment agency.

2. The critic must be an environment specialist or a specialist in the field of the project and have at least 07 years' experience if he/she obtains a Bachelor's Degree, at least 05 years' experience if he/she obtains a Master Degree, at least 03 years' experience if he/she obtains a Doctor Degree.

3. The secretary must be an official of the standing assessment agency.

4. The council member must be an environment specialist or a specialist in the field of the project and have at least 03 years' experience if he/she obtains a Bachelor's Degree, at least 02 years' experience if he/she obtains a Master Degree, at least 01 years' experience if he/she obtains a Doctor Degree.

4. Conclusions and Recommendations

4.1 Chapter Summary

The survey's results clearly show that: 1) the severe coastal erosion in the central region of Vietnam is mainly due to economic activities that disturb sediment transport at river basin and coastal areas and 2) all the counter measures to prevent sediment related disasters are not really effective due to the lack of solid understandings on sediment transport matters.

As mentioned in project background, CSM has currently been considered as a most effective strategy in many countries facing to serious sediment related disaster such as Japan and it is advised to adopt and implement CSM in Vietnam as a long term goal. Based on studying results of current status of sediment management issues in Vietnam, 3) a proper framework to formulate CSM is proposed and as shown in **Table 4.1**.

In the meantime, due to the increasing magnitude and rapid speed of coastal retreats, some urgent solutions are proposed to mitigate the economic losses and threatening of human lives. These solutions are based on the concept of "sediment engine" which supply more sand to the left bank of Cua Dai beach by means of beach nourishment, sand bypasses or construction of water diversion flow structures to divert mainstream of the river to the left bank (**Table 4.1**).

Table 4.1.1 Recommendations

Period	Purpose	Policy	Contents	Related Authorities
Urgent measures	Reduce the speed of erosion	Supply sand to eroded coastal zone to make up for reduction of sediment supply from river	· Conduct beach nourishment to directly supply the sediment to the left bank (about 400,000～500,000m^3/year) · Construct sand bypasses to increase the sediment supply to left coasts: sand bypasses start from sand depositing points in river channel or right coast to the left coast	MARD, Quang Nam Province, Da Nang City
		Improve the direction of water flow to resolve asymmetric distribution of the sediment supply from the river	· Construct water flow control structures to increase water discharge to the left side of river mouth in order to restore the balance of the sediment discharge from the river	
Long-term measures	Create/ implement the comprehensive sediment management of river basins and coastal areas	Preparation of comprehensive sediment management plan	· Improvement of regulation/organization structure	MARD, MONRE, MOC, MOT, MOIT
			· Formulation of national sediment management policy/strategic program	
			· Preparation of guideline for sediment management planning	
		Implementation of comprehensive sediment management plan	· Formulation of comprehensive sediment control plan for major river basin/coast	PPC, DARD, DONRE
			· Detailed design of erosion control measures for major river basin/coast	
			· Review of approval procedure of sand mining and monitoring of the illegal sand mining	
		Human resources cultivation for comprehensive sediment management	· Establishment of organization for sediment control · Institution · Training system · curriculum	MARD, MONRE, Existing research institutions
			· Capacity building of the central government staff for comprehensive sediment management	
			· Guidance for municipal officials	
			· Capacity building of the local government officials for comprehensive sediment management	PPC, DARD, DONRE
	Create a data source for problem solving and measures evaluation / implementation	· Improvement of Observation system · Continuous data observation · Database construction and utilization	· Formulation of plans for measurement of weather, hydrology and oceanography	MARD, MONRE
			· Enhancement of numerical prediction/ data management capacity	
			· Improvement of meteorological, hydrological and oceanographic monitoring systems	
			· Improvement of database	
			· Implementation of meteorological, hydrological and oceanographic monitoring	PPC, DARD, DONRE
			· Monitoring of sediment volume (both approved and illegal sand mining volume)	
	Enhance scientific knowledge of Comprehensive sediment management	Creation and improvement of relevant technical standards	· Formulation of technical standards related to sediment control (beach nourishment, sand bypass and sand recycling)	MARD
			· Dissemination of scientific knowledge (brochures, workshops)	
			· Implementation of specific projects and feedback on design and management based on technical standards	PPC, DARD, DONRE

4.2 Legal and Institutional Issues

Comprehensive sediment management (CSM) is the consistent management of the human activities from the mountains to the coast, to ensure the sediment transport in river basin as close as possible to that of natural phenomena. CSM is considered as long-term strategies in many countries facing to the serious sediment related disaster. Therefore, Vietnam should consider CSM as a future target in order to reduce the sediment related disaster in river basin, including coastal erosion. Based on the current situation of Vietnam, the following aspects should be implemented step-by-step to archive the CSM:

Firstly, at the national level, the regulations regarding planning and implementation of activities neither directly (dam construction, sand mining) nor indirectly (construction of infrastructure in river basin and coastal area) caused negative consequences on sediment transport in river basin should be amended with the objective:

- To enforce the participation of the appropriate public authorities, research organizations (especially experts on integrated sediment management) and the private sector stakeholders in the development, implementation, updating and evaluation of development planning. It is important to enforce the participation of experts on sediment transports during the making of SEA and EIA.
- To provide a clear penalty system against illegal actions, (such as illegal sand mining) enforcement measurements are essential for making the effective legal system. Examples of penalties against illegal action stipulated in Japan River Law (Art 102-109) are summarized for reference (**Table 4.2.1**).

Table 4.2.1 Penalties against illegal action (Japan River Law)

Act	Penalty
• Illegal water intake (violation of Art 23) • Illegal construction, reconstruction, and removal of a structure within river zones (violation of Art 26(1)) • Illegal excavation etc., (violation of Art 27(1))	Imprisonment for not more than one year or a fine of not more than five hundred yen (About 45,000~50,000USD, depending on currency exchange rate)
• Acts causing damage to a river (violation of the Government Ordinance)	Imprisonment for not more than six months or a fine of not more than 300,000 yen (About 2,500~3,000USD, depending on currency exchanging rate)
• Float down logs or bamboos in violation of the Government Ordinance	Imprisonment for not more than three months or a fine of not more than 200,000 yen (About 1,650~2,000USD, depending on currency exchanging rate)

Along with the improvement of above legal documents, the current river basin management system should be improved with the objective of defining a body that has de facto decision-making power over the sediment management in river basin level. Establishing formal sediment management organizations is not a prerequisite for success. However, it should be noted that the lack of some form of coordinating body can complicate the implementation of integrated sediment management in river basin level.

After that, formulation of national sediment management policy/ strategic program should be conducted to define the targets and direction of long-term sediment management in Vietnam. Following by creation of comprehensive sediment management plans at the national level and river basin level.
Along with the improvement of legal and institute, a high-quality human resource is also an important factor to speed up the implementation of comprehensive sediment transport from the national level to local level. Therefore, enhancement of the public awareness and education on river/coastal erosion should be conducted to in order to achieve an effective long-term management. Purposes of human resources education are to help sediment control managers and practitioners gain complete understanding on the negative consequences of sand mining, dam constructions, and infrastructure

constructions as well as related activities on sediment transport in a river basin. Then, they can devise their intervention methods to address the impacts of sediment transport in a sustainable manner.

4.3 Technical Issues

4.3.1 Basic Data Collection and Utilization

In the future, periodic and continuous data collection and observation should be conducted efficiently to gain the full understanding of sediment transport in river basins. For efficient data collection and utilization, in Japan, collected data and information are categorized by upstream area, middle ~ downstream area, and coastal area. The index for sediment management in the relevant area is as **Table 4.3.1**

Table 4.3.1 Index for sediment management

Area	Relating Crisis	Index for management	Criterion for management
Upstream area (Sediment production area)	Riverbed Decline	Average Riverbed Height	Riverbed at confluence to main stream
Upstream river area	Riverbed Decline	Max Riverbed Height	Foundation Height of Structure
Middle ~ downstream area	Riverbed Decline Riverbed Rising	Average Riverbed Height	Riverbed Height necessary for safety flow as planned
	Local Scouring	Riverbed Height surrounding river structure	Foundation Height of river dike
Coastal area	Erosion	Shoreline Location	Necessary Berm Width
		Contours Location	
		Estuary Terrace Location	

Long-term monitoring of hydrographic/oceanographic data, sediment-related data and so on as well as archiving the data thus collected is essential for understanding mentioned phenomenon and then riverbed/ coastline change processes. Although with the current facilities and manpower ensuring the continuity of measuring networks and maintaining the quality of such data is a major challenge, it is required to maximize the efficiency of the data upon for sediment management. These data, then need to be maintained, updated and should ideally be made accessible to related ministries/organization, and preferably freely available for academic research or educational uses. Detail of proposed of observation/ collection data is shown in **Table 4.2.2** and **Fig 4.3.1.**

Table 4.3.2 Proposed of Data Collection/ Observation and Monitoring

Area	Items	Current monitoring system	Objectives	Method	Place	Time	Frequency
Upstream area (Sediment production area)	River discharge	Nong Son, Thanh My	To grasp the calculation condition		Same as current	Annual	Hourly
	Riverbed change	Not implemented	To grasp the river bed change	River profile survey			
Upstream river area	Riverbed change	Not implemented	To grasp the river bed change	River profile survey	1km interval		once every 5 years
	Riverbed materials	Not implemented		Grain size survey	1km interval		once every 5 years
	Sand mining volume		To grasp loss sand volume	-	1km interval		once every 5 years
Middle~ downstream area	River discharge	Not implemented	To grasp the calculation condition		Current water level observation points	Annual	Hourly
	Water level	Hoi Khanh, Giao Thuy,Hiep Duc, Ai Nghia, Cau Lau, Hoi An, Cam le	To grasp the calculation condition		Current observation points	Annual	Hourly
	Riverbed change	Not implemented	To grasp the river bed change	River profile survey	1km interval		once every 5 years
	Riverbed materials	Not implemented	To grasp the calculation condition	Grain size survey	1km interval		once every 5 years
	Sand mining volume		To grasp loss sand volume	-			when implemente d
Coastal area	Water level	2 stations at Cau Lau and Hoi An	To grasp external force (tide) for coastal area	Tide gauge	Same as current	Annual	Hourly
	Wave	Son Tra station (only observation)	To grasp external force (wave) for coastal area	Wave gauge	Offshore (water depth of 15~20m) Northern of Cham Island	All year	Hourly
	Shoreline	Not implemented	To grasp secular change of shoreline ⇒To obtain basic index for	Shoreline survey (TS, GPS)	Shoreline of Tan An～Da Nang Western beach	・Summer monsoon ・After typhoons	once a year

Area	Items	Current monitoring system	Objectives	Method	Place	Time	Frequency
			management of sediment management	Satellite Image; Photographing	Shoreline of Cua Dai & Tan An beach	Summer monsoon	once every 2or 3 years
				Live Camera	Cua Dai beach	All year	Daily
				Fixed point photograph	Cua Dai beach～Da Nang Eastern beach	・Summer monsoon ・After flooding	Yearly
	Beach profile	Not implemented	・To grasp secular change of beach profile ・To grasp change of longshore sediment transport	Beach profile survey	・10 profiles of Cua Dai & An Bang beach(100m interval) ・5 profiles of Da Nang Eastern beach (200m interval)	・Summer monsoon ・After typhoons	once every 2or 3 years
	Sand sampling	Not implemented	・To grasp secular change of coastal sediment ・To manage sediment change	Grain size survey (Inland drilling & submarine	・Cua Dai beach: 10 samplings (4 samplings for offshore direction and 6 samplings for longshore direction) ・Other beach: 11 samplings (longshore direction)	Summer monsoon	once every 5 years
	Beach nourishment volume	-	To manage artificial sediment change	-	Construction place (Ex: Hotels, resorts)	-	Construction time

Source: JICA Study Team

Source: JICA Study Team

Figure 4.3.1 Proposed Coastal Monitoring Area

4.3.2 Development of technical standards

Creation and improvement of relevant technical standards is also an important task to enhance more effective erosion prevention measures and the following contents should be considered to improve the capacity of sediment management in term of technical aspects:

- Firstly, because of the increasing number of the construction/ implementation of beach nourishment, sand bypass, and sand recycling projects in many places, technical design for those measures should be created as early as possible.
- In order to build more sustainable measures rather than current ad-hoc measures, the guidelines for evaluation, applying process and applicable countermeasures from the view of integrated sediment management should be developed.
- In addition, to increase the knowledge of the local people by brochure distribution, or workshops for local agencies should be conducted to increases the likelihood of local coastal erosion as well as reduces the expanding of erosion to new location due to future development human activities.

4.3.3 Suggestion for Urgent Anti-Erosion Measures

Currently, the coastal erosion in Cua Dai Beach has become more serious and urgent anti- erosion measures are required immediately. But, to suggest a short-time measure, which is effective as soon as possible with minimum cost, the following terms should be considered.

- Design of required performance index for this coastal area (berm height, beach slope, berm width, etc.) and the fundamental plan for erosion control should be created.
- Test construction should be conducted to verify the contributing rate and most effective materials.

(1) Current Situation of Coastal Erosion

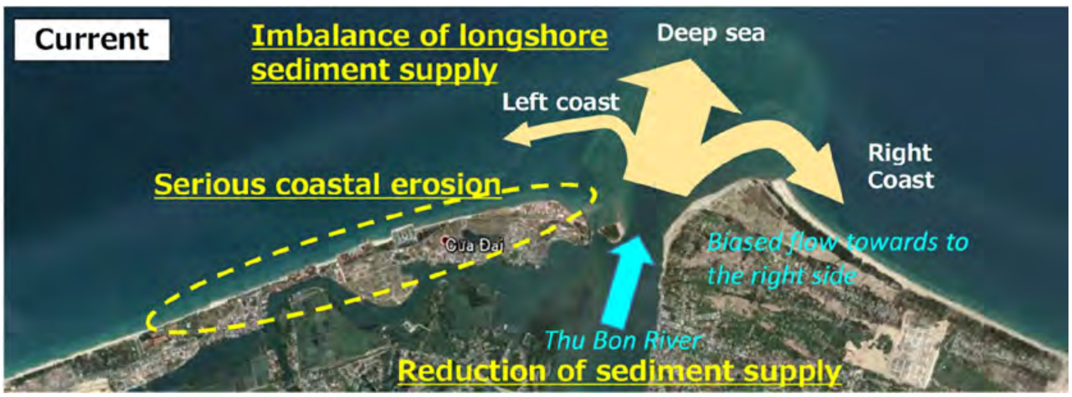
According to the analysis results, coastal erosion in Cua Dai Beach is estimated to have started in 1994 and the main causes of coastal erosion in Cua Dai Beach are shown in **Fig 4.3.2**:

- Reduction of sediment supply from river

  According to analysis results, about 40% decrease in the sediment volume supplied from Cua Dai estuary in the period time of 1997-2017.

- Imbalance of longshore sediment supply

  The balance of sediment supply northward and southward changed between Phase1 (1973-1992) and Phase2 (1992-2017). In Phase1, the northward sediment transport is larger than southward sediment transport. However, this trend is reversed in Phase2.



Source: JICA Study Team

Figure 4.3.2 Current Situation of Coastal Erosion

(2) Basic Concepts for Short-term Measures

Basic concepts for designing short-term measures for Cua Dai Beach based on analysis results of main causes.

- Increasing sediment supply: **Table 4.3.3**

Table 4.3.3 Short-time Measures and Evaluation (1)

Measures	Evaluation
Beach Nourishment	Recommended but volume of materials should be considered
Sand bypass from deposit location at river channel and right coast	Recommended as a way to get the material for beach nourishment
Regulation of sand mining	Recommended

Source: JICA Study Team

- Hard Structure to control and prevent loss of sediment toward longshore and offshore direction: **Table 4.3.4**

Table 4.3.4 Short-time Measures and Evaluation (2)

Measures	Evaluation
Offshore breakwater	Not recommended for tourist beach

Measures	Evaluation
Artificial reef	It requires long time and high cost.
Groin	It requires long time and high cost.

Source: JICA Study Team

- Redistribute sediment from sand terrace: **Table 4.3.5**

Table 4.3.5 Short-time Measures and Evaluation (3)

Measures	Evaluation
Water flow control systems (Training wall, Jetties, spur dike, etc.)	Recommended but the evaluation of the effect should be studied.

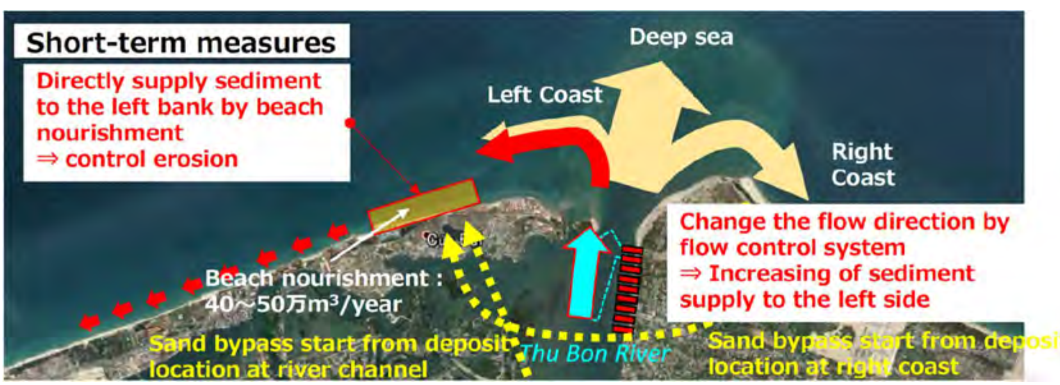
Source: JICA Study Team

(3) Suggestion for Short-time Measures

The following short-time measures are recommended as follows.

- **Mainly conducting beach nourishment** to make up for sediment loss.
- Constructing **water flow control systems** to redistribute sediment from sand terraces.

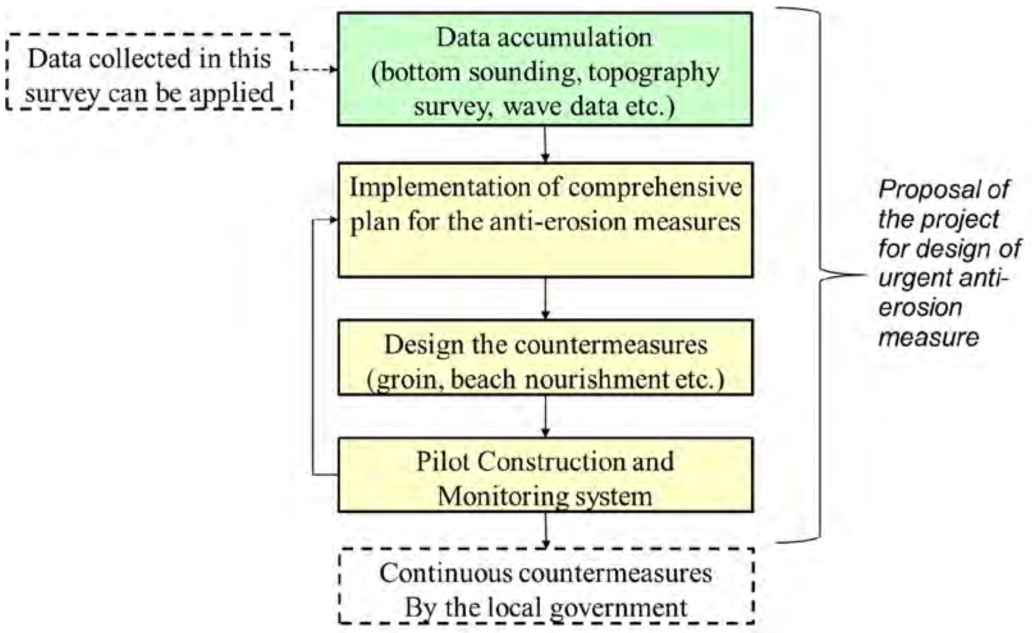
Short-term measures intend to improve the discontinuity and imbalance of sediment transport by the combination of beach nourishment and water flow control systems (**Fig 4.3.3**).



Source: JICA Study Team

Figure 4.3.3 Short-time Measures against Coastal Erosion

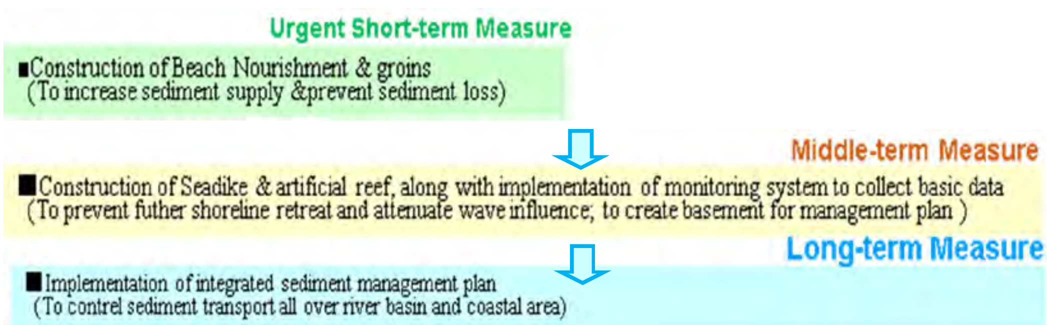
A project for the design of short-time measures may be conducted as the following work flow, in which data collected in this survey could be applied for considering design conditions as shown in **Fig 4.3.4**.



Source: JICA Study Team

Figure 4.3.4 Work Flow for Design of Short-time Measures

Despite short-time measures which are necessary for immediate solution, it should be considered as a starting point among the mid-term and long-term measures for preventing coastal erosion. A Flowchart of Stepwise Measures is shown in **Figure 4.3.5**.



Source: JICA Study Team

Figure 4.3.5 Example of Stepwise Measures

5. Seminar

Final seminar was hold on January 12nd 2018 in Da Nang city to report the results of survey to the relevant officials, researchers and other stakeholders in Vietnam.

5.1 Concept Paper

Concept paper of final seminar (workshop) was shown as below.

Final Workshop: Data Collection Survey on Basin-Based Comprehensive Sediment Management in River Systems of the Central Region

Date: 8:30-12:00, 12th January 2018
Venue: Muong Thanh Luxury Da Nang Hotel
(No. 270 Vo Nguyen Giap Street, My An Ward, Ngu Hanh Son District, Da Nang City, Vietnam)

Organized by Japan International Cooperation Agency (JICA) Vietnam Office
Secretariat: Transport Engineering Design Inc. (TEDI)

Background

In Vietnam, coastal erosion, river bank erosion and degradation of river bed are apparent in many areas, causing serious adverse impacts including loss of land for habitation and production, damage to tourist industry in beach resorts and degradation of structures such as dykes and revetment. There are several causes, which are alternation of sediment balance due to sedimentation in dam reservoirs in upstream areas, excessive excavation of sand and gravel from rivers channels, change of river and coastal flow due to construction of structures and other human-induced alternation of river courses and coastal landforms. These issues will become more serious in the near future. It is important for Vietnam to enhance capacity to properly understand the cause of the problems and to holistically address them.

Objective of the Survey:

1. Clarify the present status and problems relating to the change of sediment transport in river systems and coastal areas in Vietnam with appropriate evidence
2. Collect necessary data and information for developing Comprehensive Sediment Management System in the Vu Gia – Thu Bon river basin and propose an outline of Comprehensive Sediment Management Plan.
3. Propose a participatory framework for development and implementation of Comprehensive Sediment Management Plan in the Vu Gia – Thu Bon river basin; and
4. Develop a proposal for policy development and legal and institutional arrangement which is necessary for appropriate sediment management in Vietnam

Participants:

- Representatives from MARD, Provinces (Quang Nam, Quang Tri, Thua Thien Hue, Quang Ngai, Binh Dinh, and Phu Yen) and Da Nang City,
- Relevant stakeholders and researchers from Water Resource University
- Representatives from JICA Vietnam Office
- Consultant team from TEDI

5.2 Agenda

Agenda of final seminar (workshop) was shown as below.

8:00 - 8:30	Registration
Opening Session	
8:30 - 9:00	*Welcome speech* • Mr. Ryutaro Kobayashi, Senior Representative, JICA Vietnam Office • Mr. Vu Xuan Thanh Deputy Director General - VNDMA - MARD • Mr. Le Tri Thanh Vice Chairman of Quang Nam PC • Mr. Ho Ky Minh Vice Chairman of Da Nang PC *Introduction of all participants*
Session 1: The main outcomes of the Survey	
9:00 - 10:30	• Consultant team Cause and impacts of coastal erosion and other issues related to the change of sediment transport in the river system and the coastal area in center region. *Q&A and Discussion*
10:30 - 10:45	Coffee break
Session 2: Relevant input from other countries researchers	
10:45 - 11:45	• Mr. Kenichiro Tachi Comprehensive Management of River Basin and Coast in Japan • Ph.D Nguyen Trung Viet Coastal erosion in Cua Dai beach: causes and solutions? *Q&A and Discussion*
11:45 - 11:55	Wrap up form consultant team
11:55 - 12:00	Closing remarks from JICA Vietnam Office
12:00 ~	Lunch

5.3 List of participants

Name of participant	Title
From MARD	
Mr. Vu Xuan Thanh	Deputy Director General - VDMA
Ms. Doan Thi Tuyet Nga	Director, Department of Science, Technology and ICD - VDMA
Mr. Tang Quoc Chinh	Director, Department of Natural Disaster Safety Control - VDMA
From Quang Nam Province	
Mr. Le Tri Thanh	Vice Chairman of Quang Nam PC
Mr. Huynh Tan Duc	Director of the DARD
Mr. Nguyen Vien	Director of the DONRE
Mr.Truong Xuan Ty	Director of Irrigation Department
Mr.Truong Tuyen	Director of Meteorological Stations
Ms. Nguyen Hoang Yen	Head of Sea and Island Dept. - DONRE
From Other Provinces	
Quang Tri Province	
Mr. Ho Xuan Hoe	Vice Director of the DARD
Mr.Le Da Son	Director of Irrigation Department
ThuaThien Hue	
Mr.Ho Sy Nguyen	Director of the DARD
Mr.Le Dien Minh	Leader of Disaster Management Department
Da Nang City	
Mr.Ho Ky Minh	Vice Chairman of Da Nang PC
Mr.Nguyen Phu Ban	Director of the DARD
Dr. To Thuy Nga	Faculty of Water Resource Engineering - University of Science and Technology
Dr. Le Hung	
Quang Ngai Province	
Mr.Nguyen Mau Van	Deputy Director of DARD
Mr.Phan Van On	Director of Irrigation Department
BinhDinh Province	
Mr.PhanTrong Ho	Director of the DARD
Mr.Phan Xuan Hai	Director of Irrigation Department
Phu Yen Province	
Mr.NguyenTrong Tung	Director of the DARD
Mr.Pham Chi Toan	Vice Director of Irrigation Department
From Water resources university	

Name of participant	Title
Mr. Nguyen Trung Viet	
JICA Vietnam	
Mr. Kobayashi Ryutaro	Deputy Representative
Ms.Akiko Urakami	Lead Advisor for Environment and Climate Change
Mr. Kenichiro Tachi	JICA Expert
Ms. Nguyen Thi Thu Le	Project Officer
Study team	
Ms. Vu Thi Lan Huong	Deputy Leader/ River Expert
Mr. Shimura Takeshi	River Expert
Mr. Nagasawa Tsuyoshi	Coastal Expert
Ms. Mai Thi ThuThuy	Coastal Expert
Ms. Le My Hanh	Coastal Expert
Mr. Nguyen Manh	Field survey expert

5.4 Q&A Section

1. Question: As for the time of analysis, Song Tranh 2 and Song Tranh 4 are two big dams, so it is thought that sediment transport will change greatly after constructions of these dams. How were those of impacts evaluated in this survey?

Answer of Study team: In Japan, the impact of dam construction has only been observed after dam construction for a long time. Because Song Tranh 2 and Song Tranh 4 were completed around the year of 2011, the immense impacts of these dams will probably come out in the future. In this survey, the effect of dam construction is considered by setting the amount of sediment output behind the dam equal to zero after the construction of the dam.
In Vietnam, because many large dams have been constructed in the midstream, it is possible to estimate that the impacts of dams might be very huge. However, it is difficult to grasp and evaluate the influence accurately without a basic database. In the future, the acquisition and accumulation of data is essential.

2. Question: As a short-term measure, we have proposed beach nourishment and a jetty system at river estuary. However, as you know, there are many dams in the upstream area of Vu Gia-Thu Bon, and the flow rate in the downstream area is decreasing. For this reason, the amount of sediment supplied to the estuary area is not expected to be large. Therefore, even if the flow is modified to the north side, I think that the sediment amount supplied from the river is not so large. Every year, in the typhoon season (September - December), high-energy waves pull a very large amount of sand offshore. Therefore, even if this measure is implemented, it can be estimated that erosion will continue as before because the amount of sediment carried out is still larger than the amount of sediment supply.

Answer of Study team: Such seasonal changes are common in Japan as well. Sediment eroded by the winter wave will gradually return to the beach in the summer season. However, when huge waves come and a large amount of sediment is carried offshore, the sediment will not come back soon. To restore the Cua Dai beach immediately, the contribution ratio of the nourishment material should be calculated in the design stage. Then, the amount of sediment required maintaining the design beach width could be calculated. However, for that purpose, beach nourishment should be implemented step by step as follow:

Design of beach nourishment contribution ratio of the nourishment material should be calculated in the design stage. Then, th

3. Question: Could you please show me an example in Japan in which the impacts of coastal structure on sediment transport are considered in the FS.

Answer of Study team: In Japan, the evaluation is conducted for all coastal structures. Several design options of the structure are considered. Then, the impacts of each option to the shoreline change are predicted by numerical simulations. Finally, the optimal option is selected based on the results of the calculations.

4. Question: In Vietnam, revetment is considered as effective measures to stop coastal erosion, but the presentation pointed out that it is not good as expected. Could you please explain more about this problem? In Sa Huynh coast of Quang Ngai province, a revetment has been constructed from 10 years ago. It was an effective structure until it was destroyed by the high waves of December 2016. If possible could you please let me know the reason?

Answer of Study team: By constructing revetments, the area behind the revetment will be prevented from erosion. However, the root causes of erosion are considered to be the change in sediment amount; the problem cannot be solved by revetment construction.

Moreover, when the coast is hardened by revetment, the sediment behind it cannot be transported. That means the original supply sediment volume from the coast will be reduced. Therefore, there is a high possibility that erosion will occur at the coast located on the lower side of the coastal drift.

We only visited the Sa Huynh coast once in April last year, so we cannot estimate the reasons of the revetment destruction in detail. There is one factor should be considered is the jetty at the river mouth. The extension of the jetty might reduce the amount of sediment reaching the Sa Huynh coast and, consequently, the sand beach disappeared. Then, the beach loss may accelerate the wave energy acting on the revetment. In addition, design wave is an important factor to study the cause of erosion. If the wave that came in December 2016 exceeded the design wave, this may be the cause.

5. Question: Based on the analysis of past aerial photographs, it is said that the Cua Dai coastal erosion started in 1993. Is it possible to think that an increase in the wave energy is one of the reasons of coastal erosion? The results of the AFD survey concluded that the recent increase in the wave energy was one factor of this erosion.

Answer of Study team: The increasing of wave energy in the recent year cannot be known unless the analysis of observation data from the past to the present is conducted. This observation data does not exist and we will not comment to above conclusion. However, even the wave energy is increasing due to climate change, it is a story of these 5 to 10 years, and not remarkable in 1993, the year when erosion started. Since erosion has already started in 1993, it is considered that this main factor is not the increase of wave energy.

6. Question: I would like you to explain in more detail the destruction mechanism of Geo-tube revetment at the Cua Dai coast.

Answer of Study team: It is thought that the destruction of Geo-tube revetment on the Cua Dai coast is due to the toe scouring. I think that the filling material in the sandbag has been gradually washed out due to the action of the incident wave, reflected wave and flow at the front of the structure, eventually leading to the collapse of the geo-tube revetment.

In Vietnam, revetments and piers are often considered as anti-erosion measures. However, as explained study team, in Japan and other developed countries, before the construction of a coastal structure, the future prediction is carried out using numerical models to estimate the long-term effects as well as the resistance of the structure under the external force. Such analyzes have not been adopted in Vietnam up until now and this is a serious problem.

I think the measures (sandbag revetment, jetty…) installed at the coast of Cua Dai are about to be destroyed. Toe scouring has been found at recently constructed revetment, which is 713 m long, starting from Fusion Maia resort.

7. Question: I have some comments on today's report content.

- About sediment volume in dam reservoirs: In Vietnam, this amount is predicted in the planning stage. There are two types of sediment accumulating in the dam reservoir: suspended sediment that subsides in the pond bottom and floating sand contained in the discharged water. According to past cases, the amount of settlement is likely to occupy 20% of the total amount.
- As for sand mining: Three step of planning - proposing - grant permission are carefully being implemented in all provinces. Basically, the mining permission will be granted for an area that has a large amount of sand deposit. Because sediment mining is inevitable due to economic growth, it is difficult to completely stop the mining activities. However, we understand that the mining planning should be considered more strictly from now on.
- There was a proposal to dredge the accumulating sediment and use as a beach nourishment material. However, I think it is difficult to implement. For flood control reservoirs, it might be possible. But for hydropower reservoirs, it is difficult to dredge the sediment because the power generation dam is always operated.
- About Cua Dai coastal erosion measures, many studies have been conducted by various organizations, and the most detailed survey among them was prepared by AFD. Last year, AFD held a meeting to report their findings and propose countermeasures, but it has not been agreed, yet. Therefore, even now, the conclusion of the measure for this problem is not decided. We hope that JICA will propose a good countermeasure to Quang Nam province based on the survey results. Of course, structure measures may take 20-30 years to demonstrate its effectiveness. However, the current problem becomes more and more serious; I think the short-term measures that can be done immediately are also important.

Answer of Study team: I understand that AFD survey results have probably already been reported by the AFD survey team. This JICA survey is the first step of investigation the mechanism of sediment transport at river basin level and it is necessary to conduct a more detailed investigation to make concrete proposals.

Participant from University of Water Resources: It is exactly to say that there are two types of sediment depositing in reservoirs. In the analysis conducted by the JICA survey team, considering the sediment output after the dam equal 0 might be an overvaluation. However, in the situation without any observation data regarding sediment output behind the dam, examining in the worst scenario is a reasonable method.

Japan has many experiences on sand recycling. In this method, the sand accumulating in dam reservoir is used as beach nourishment material. These methods can be applied to Vietnam, as well. However, for that purpose, it is necessary to revise the dam operation rules, laws, etc. In addition, the soil investigation should be conducted before using the accumulated sand as beach nourishment material. According to the AFD survey results, the concentration of mercury is high in the sediment accumulating in Song Tranh Dam.

Finally, we would like to recommend to JICA that please invite Vice Chairman Thanh of Quang Nam PPC to Japan and help him understand the Tenryu River Basin. Since this basin is quite similar to the Vu Gia-Thu Bon catchment basin, that will make possible for us to understand the efforts of comprehensive sediment control in Japan.