CHAPTER 6 REVIEW OF THE FEASIBILITY STUDY REPORT

The Outer Ring Road was planned by the Department of Highways (DOH), Ministry of Transport, as a toll road, in order to solve the congested traffic problem in the capital city, after the completion of the 1st and 2nd Outer ring Roads. The location of the outer ring road is outside of the 2nd Outer Ring Road and design speed is 120 km/hour. A feasibility study of this road was implemented from October 2006 to December 2007.

6.1 Outline of the Feasibility Study

(1) Project Background

Bangkok is the center of the prosperity in Thailand and the urban sprawl goes into the suburbs rapidly. Although the 1st Outer Bangkok Ring Road was completed in 1971 and the 2nd Outer Ring Road was completed in 1999, DOH has planned to construct the Outer Ring Road to solve the congested traffic problem in the capital city.

The route is divided into 3 sections, namely East section, West section and South section. The total length of the route is 254 km.

(2) Objectives of the Feasibility Study

In 2006, DOH decided to conduct the Feasibility Study regarding economic and engineering aspects, EIA, and public consultation before making a huge amount of investment. Objectives of the Study are as follows.

- To study the suitable network and features for the development of the Outer Ring Road of 254 km in length to ensure the complete integration with the main networks; and to suggest the appropriate features from the linkage with the inner ring roads and the motorway system, as well as the feeder roads for the transport of goods and passengers to support the multimodal transport.
- To perform the feasibility study in the economic, engineering, and financial dimensions
- To conduct EIA and public participation
- To study the appropriate form of project implementation and investment, including the suggestion about the sources of funds, preparation of investment plan, and project management and maintenance.

(3) Conclusions

1) Socio-Economic Study

- The socio-economic growth in the study areas is relatively high, especially in the vicinity of Bangkok which will be the built up area extending from Bangkok.
- Several development plans to promote the overall socio-economic growth have been implemented, supporting residential sprawl and expansion of economic activities in industrial

sector.

- People in employment will approximate 14.4 million in 2036 which is the last year of the socio-economic study. The result of the socio-economic study shall be used in the traffic and transport study to analyze the future demand for transport and other related studies.

2) Related Plans and Projects

- Related plans and projects were as follows.
- The 10th National Economic and Social Development Plan (2007-2011) Central and Eastern Provincial Clusters development Strategies
- Spatial Development Plans by Department of Public Works and Town & Country Planning (DPT, 2006)
- Suvarnabhumi Aerotropolis Development Plan Project, Office of the National Economic and Social Development Board (NESDB, 2003)
- Transport Development Plans and Projects by the Office of Transport and Traffic policy and Planning (OTP)
- Traffic and Transport Master Plan（2004-2011）
- Feasibility study reports on Road Transport Development Projects (i.e. "The Toll Highway Development Study in The Kingdom of Thailand" prepared by JICA in 1991)
- Flood Protection Plans (i.e. "Study of Drainage and Flood Protection of Eastern Bangkok and Vicinity Project (RID, 1999) , Canal and Drainage System Improvement Project in the Lower Chao Phraya East bank by Diversion to Bang Pakong River and the Gulf of Thailand (2006))

3) Project Route Selection

Based on the results of grading alternative routes in terms of the engineering and traffic factors, economics investment factor, and environmental impact factor, the most appropriate route was selected as shown in Figure 6.1.1.

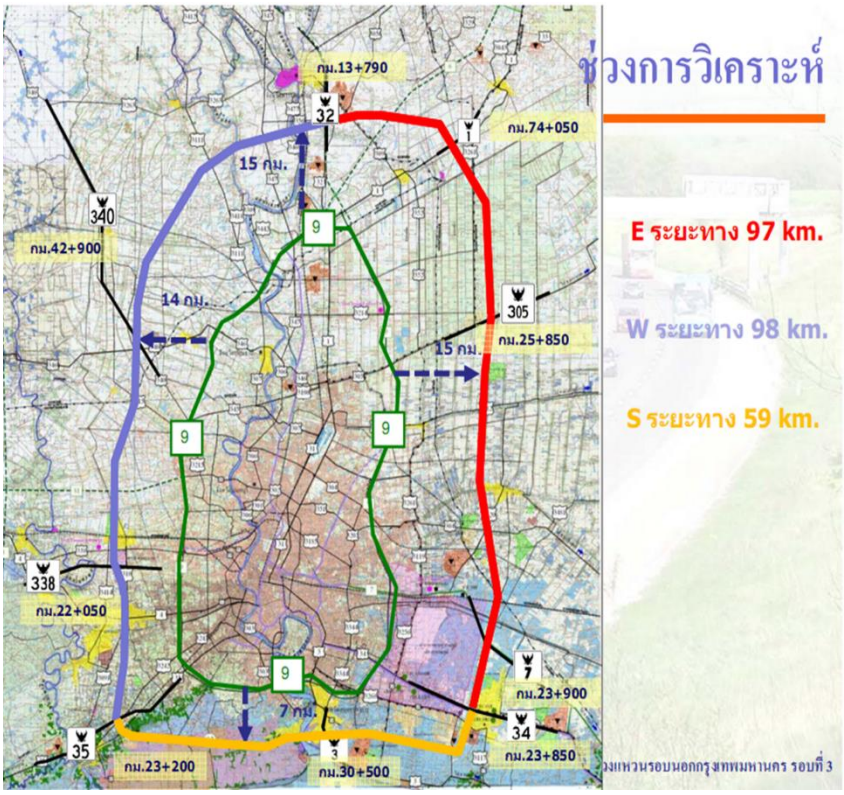


Figure 6.1.1 Selected Routes (DOH FS, Summary page. 4 - 47)

4) Traffic and Transport Study

- In accordance with the result of the future traffic volume study, it was recommended that the construction of the East section, West section, and South section of the Outer Ring Road start in 2016, 2021 and 2026 respectively.
- As for the East section, the number of lanes and the location of service roads are proposed as shown in Table 6.1.1 (Service Roads are discussed in "5) Engineering Study").

Table 6.1.1 Number of Lanes and Location of Service Roads (East Section)

District Name	Inter-change	Station No	Distance (m)	Service Road	Main Road (4 lanes)	Main Road (6 lanes)
			97,112	33,657	44,595	52,517
	IC-1	STA 0 + 0				
Bang Pa-in and			4,399		4,399	
Uthai	IC-2	STA 4 + 399				
			4,020		4,020	
8,419		STA 8 + 419				
			2,619		2,619	
	IC-3	STA 11 + 38				
Wangnoi			9,210		9,210	
	IC-4	STA 20 + 248				
			4,032		4,032	
15,861		STA 24 + 280				
			3,070		3,070	
		STA 27 + 350				
Nong Suea			8,150	8,150	8,150	
		STA 35 + 500				
			7,190	7,190	7,190	
		STA 42 + 690				
			280		280	
18,690		STA 42 + 970				
			1,625		1,625	
	IC-5	STA 44 + 595				
Thanyaburi			1,405			1,405
		STA 46 + 0				
			500	500		500
3,530		STA 46 + 500				
			8,650	8,650		8,650
		STA 55 + 150				
Lum Luk Ka			1,429			1,429
	IC-6	STA 56 + 579				
			1,921			1,921
12,000		STA 58 + 500				
			2,016			2,016
		STA 60 + 516				
Nong Chok			2,367	2,367		2,367
		STA 62 + 883				
			9,840			9,840
	IC-7	STA 72 + 723				
			4,167			4,167
18,390		STA 76 + 890				
			5,360			5,360
	IC-8	STA 82 + 250				
Lat Krabang			1,540			1,540
		STA 83 + 790				
			619			619
	IC-9	STA 84 + 409				
			659			659
8,178		STA 85 + 68				
			1,632			1,632
	IC-10	STA 86 + 700				
Bang Sao Thong			2,100			2,100
		STA 88 + 800				
			6,800	6,800		6,800
		STA 95 + 600				
			1,512			1,512
	IC-11	STA 97 + 112				

5) Engineering Study

- The fill soil for the Outer Ring Road shall be 2.5 - 3.0 m above the existing ground because the drainage study indicated that high water level during flooding was 2 m above existing ground.
- Regarding the East section KM65 -KM97, the proposed soil improvement technique was "Pile Embankment" because of its cost, construction time, and quality control compared to PVD Technique and Cement Column Technique.
- Proposed pavement type was "Concrete Pavement" with the thickness of 25 cm considering its low maintenance cost and traffic safety during the rainy season.
- The proposed typical cross section of the Outer Ring Road is shown in Figure 6.1.2.

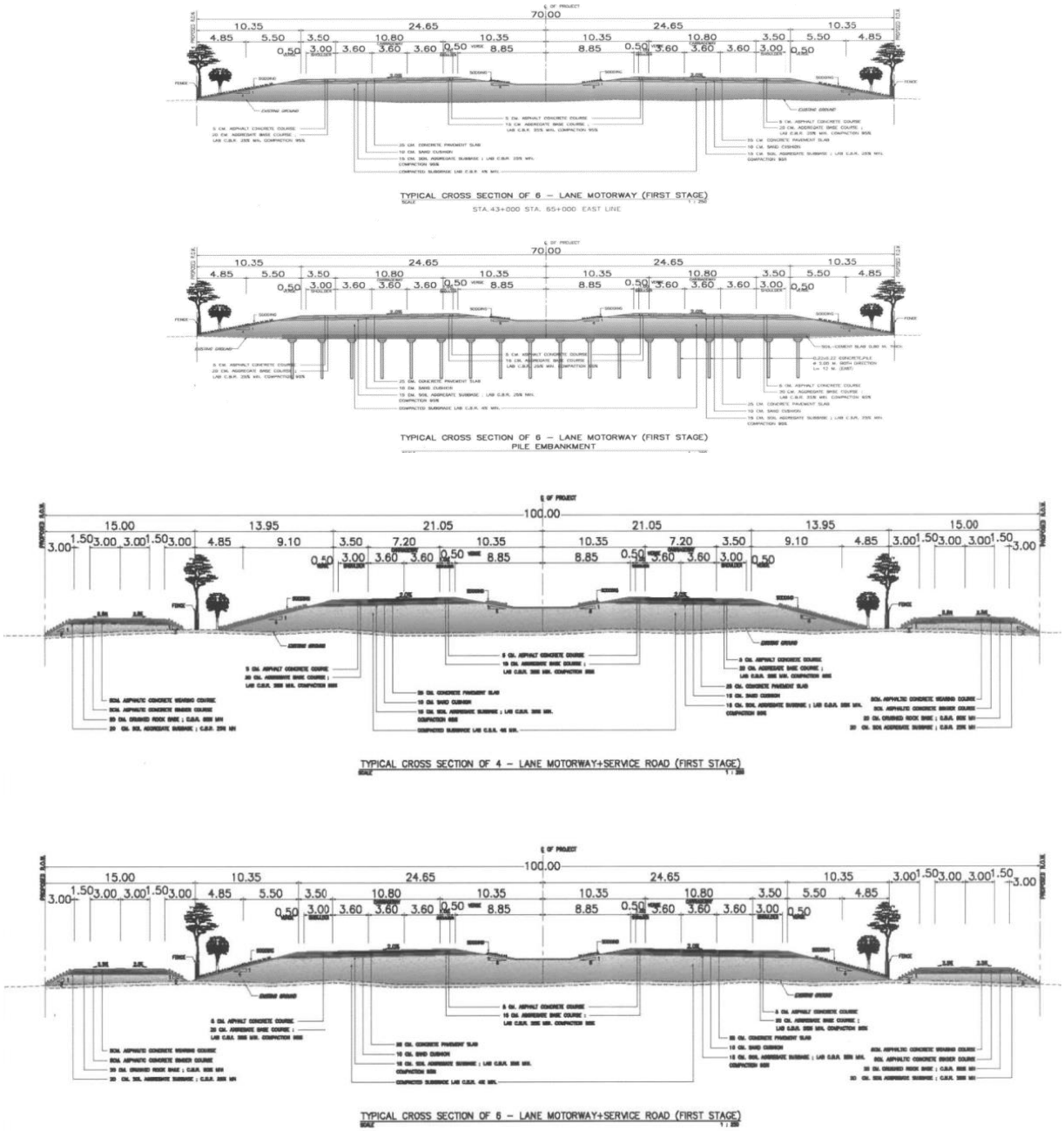


Figure 6.1.2 Typical Cross Section of the Outer Ring Road

6) Environmental Study

- The overall environmental impacts are in low to moderate levels. Most impacts would occur during the construction period, all of which can be mitigated by enforcing contractors to strictly implement the environmental impact mitigation measures.
- Regarding the East section, the topographic characteristics of the project area form a low flat plain. Major land use is agricultural and communities are found scattered around crossing points with main roads. There are some industrial areas around the lower part of the project alignment of the section.

7) Public Relations and Public Participation

Construction of the Outer Ring Road may cause impacts on residents on both sides, divided by the project, such as community separation, difficulty in access. Understanding and response of people and stakeholders will be nurtured to create ultimate benefits to DOH (the Executing Agency of the Project). In pursuance to laws and regulations concerning public relations, it was recommended for DOH to organize public relations and public participation activities with the following objectives.

- To provide project detail information and create understanding with target groups - the stakeholders in the project development plan.
- Offer target groups the opportunity to opine and give suggestions about the project development to create the least possible social and environmental impacts and conform to local needs.

The first Seminar took place on March 7-9, 2007, the second seminar was on January 28 -February 1, 2008, and the third seminar was on March 31 - April 3, 2009 including media relations. Small group meetings were also held for each district in 8 provinces along the alignment of the Outer Ring Road.

8) Project Cost Estimate

Summary of the Project Costs is shown in Table 6.1.2.

Table 6.1.2 Summary of Costs of the Outer Ring Road Project

Activities	Investment Cost (MB)			
	East Section (97 km)	West Section (98 km)	South Section (59 km)	Total Project Route (254 km)
1. Capital Expenditure				
1.1 Expropriation Cost	16,683	22,115	17,533	56,331
1.2 Construction Cost				
• Main Road System (Road, Bridge, and Elevated Road)	14,127	13,844	36,405	64,376
• Interchange	9,487	8,701	1,010	19,198
• Transport System Linking to Communities (Service Road, Overpass, Underpass, Drainage Works)	2,205	2,019	-	4,224
• Inter-City Motorway System	3,571	3,541	1,116	8,228
• Environmental Mitigation and Monitoring Cost	183	147	7	337
Total Construction Cost	**29,573**	**28,252**	**38,538**	**96,363**
1.3 Design and Construction Supervision Cost	589	571	667	1,827
Total Capital Expenditure	***46,845***	***50,938***	***56,738***	***154,521***
2. Operation & Maintenance Expenditure				
2.1 Project Management Cost				
• Project Management Cost for the 1st and 2nd Years (cost per year)	65	66	39	170
• Project Management Cost from the 3rd Year onwards (cost per year)	214	216	130	560
2.2 Project Maintenance Cost				
• Routine Maintenance Cost (cost per year)	107	82	47	236
• Periodic Maintenance Cost—Every 3 Years (cost per year)	32	25	14	71
2.3 Environmental Monitoring Cost (cost per year)				
• 1st–3rd Years	2.42	2.59	1.16	6.17
• 4th–5th Years	0.14	0.14	0.01	0.29
• 8th, 13th, 18th, 23rd, 28th Years	2.34	2.51	1.16	5.99
• Other Years	0.06	0.06	0.01	0.13

Source: The Consultants, 2008

6.2 Review of the Feasibility Study Report

After the review on the Outer Ring Road Feasibility Study Report (DOH, Aug. 2009), the Consultant proposed that the following items can be reconsidered.

(1) FS Section 3: Related Plans and Projects

From the point of view of the "Integrated Project" regarding the Outer Ring Road and Diversion Channel, the following plans, projects and research papers can be additional references.

1) Bangkok - Siracha Highway (Highway 34)

Bangkok - Siracha Highway was completed in 1969, through the rural paddy field area of eastern Bangkok for Siracha and Chonburi town, considering the impact of flood and tidal wave in the area. Before the opening of this Highway, there was only one narrow dike road (Sukhumvid Road) along the coast of this area.

The ground in this area is flat and the ground elevation varies from +0.4 m to 1.0 m (MSL). The elevation of every year's flood water is + 1.2 m. In accordance with the design criteria for new highways, the finished road surface was designed at least 0.5 m above the flood water level.

The design of this road was done by a Norwegian consultant (Norwegian Geotechnical Institute). The consultant implemented a "test embankment" in order to confirm the stability of the fill on the soft clay with thickness of 15 to 25 m. There are one research paper and one thesis related with this project as follows.

*1) Eide, O. and Holmberg, S. :Test Fills to Failure on the Soft Ground of Bangkok Clay, Proc. ASCE, Special Conf. on Performance of Earth and Earth-supported Structures, Vol.1, Part 1, pp.159-180, 1972

In this paper, the result of "test embankment" implemented on Bangkok - Siracha Highway KM28, 5 km east from Interchange 11 of the Outer Ring Road, is shown; the three types of embankments with and without auxiliary methods such as berms and bamboo fascines. Despite the high stability factor, that was more than 1.33 by slope stability analysis (circular slip), it was found that failure of the embankment was observed in each type of embankment.

*2) Atsusi Iizuka : Basic Study on Deformation and Stability Analysis for Soft Ground, Dissertation of Kyoto University, 1988

Based on the Elasto-Plastic constitutive equation (Sekiguchi-Ohota Model), Atsushi Iizuka developed a unified explanation on the behavior of the above mentioned "test embankment" (see reference *1))

2) Suwannabumi Airport Drainage Canal Project

In order to protect Suwannabumi Airport from flood, a drainage canal was built in 2006. The following reference reports the results of soil laboratory test and field monitoring measurement to excavate and build the canal and banks which are used as roads.

*3) Study on Suwannabumi Airport Drainage Canal, Kasetsart University, 2009

The location of instruments for monitoring the ground movements are shown in Figure 6.2.1.

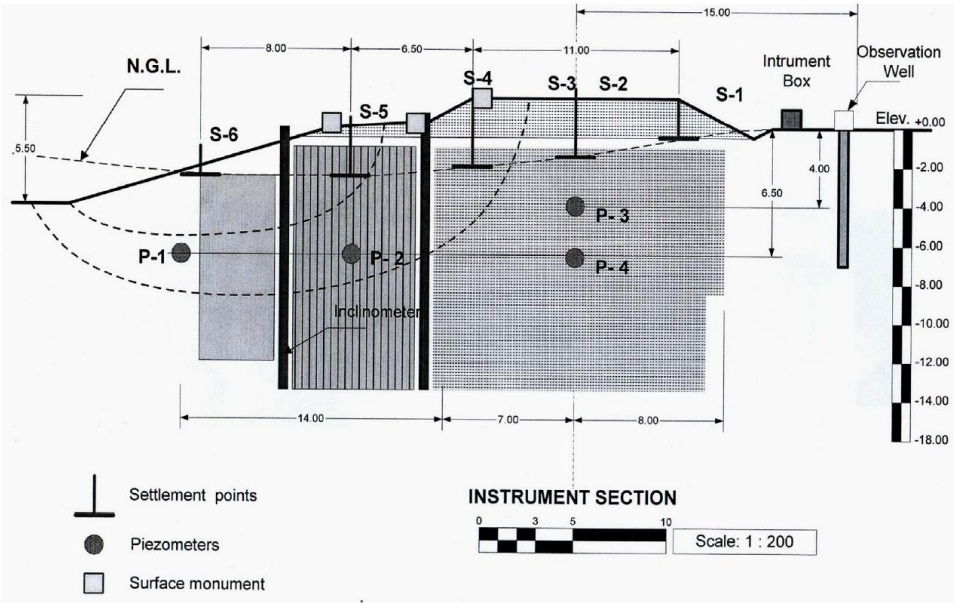


Figure 6.2.1 Location of Instruments for Swannabumi Airport Drainage Canal Ground Movement

The ground displacement data to slope failure monitored by inclinometer is shown in Figure 6.2.2.

Understanding from this paper: These field data can be utilized for ground stability analysis of this project.

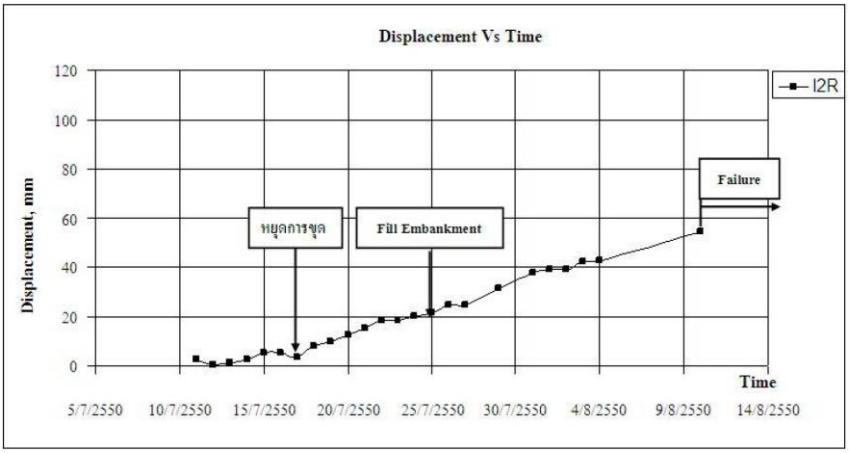


Figure 6.2.2 The Result of Monitoring by Inclinometer at Swannabumi Airport Drainage Canal

3) Bangkok - Chonburi Road (Highway NO.7)

Bangkok-Chonburi Road is an expressway 81.8 km long supported by a Japanese ODA Loan. The construction work on the road was started in 1933, and completed in 1998. A PVD (Prefabricated Vertical Drain) method was applied for soft ground treatment.

*4) A Comparative Study for the worth of using PVD and CEMENT COLUMN in soil improvement in economic engineering, Kasetsart University, 2007

The study shows a comparison of the effect of soft ground treatment and road maintenance cost between Bangkok - Chonburi Road (Expressway No. 7: applied PVD method and completed 1998) and Bangana - Bangpakong Road (Highway No. 34: applied Cement Column method).

As a result, it is recommended that the Cement Column method will be suitable as the soft ground treatment, considering lower maintenance cost compared to the PVD method, although the construction cost of the Cement Column method will be 2.0 to 2.7 times higher than the PVD method.

4) Actual Failure Case of Pile Embankment

In the Feasibility Study of the Outer Ring Road by DOH (2009), it was recommended to apply the Pile Embank method compared to the Cement Column method and PVD method. However, there are some serious cases of failure of embankments as shown in literature 5) and 6) below. The design standards of the Pile Embankment method have not been established yet, therefore this method shall be applied with very careful consideration.

*5) Failure of a Column-Supported Embankment over Soft Ground, William M. Camp, Timothy C. Siegel, Dan Brown and Associates, Proceedings, Fourth International Conference on Deep Foundations, Amsterdam, Netherlands (2006)

This study shows the failure of pile supported road embankment in South Carolina, USA, because of yielding lateral reinforcement in the embankment. Consequently, differential settlement on the road surface was observed.

*6) Failure Model for Geo-synthetic Reinforced Column Supported (GRCS) Embankments, Yapage N. N. S. et al., Proceeding of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, 2013

Using FEM Analysis, the author introduced failure type of piles and embankment of roads which possibly occur when the Pile Embankment method is applied.

5) Utilizing the Excavated Soil for Embankment

In the Feasibility Study of the Outer Ring Road by DOH (2009), utilization of excavated soil was not considered because there is no cut portion in the Eastern Section. On the other hand, in case of a combined project with the diversion channel, a huge amount of soil must be excavated and disposed of. This soil (mainly Bangkok Clay: high water contents soft clay) will be utilized by mixing sand and/or appropriate material. The mixed soil material has been used in Japan as shown in the following literature.

*7）Field Test for Confirmation of Construction Process of Rotary Crushing Mixing Method, Proceeding of Hokkaido Development and Technical Workshop, Satoshi Ookawa et, al. (2012)

This paper shows the possibility of utilizing the excavated soils, soft clay with 50 - 120 % of natural water content and organic clay (peat) with 480 - 620 % of natural water content, mixing with sand (mixing ratio, 1 : 1.6) and slag cement (mixing weight, 32 % of the soil).

Understanding from this paper: The characteristic of the former soil (soft clay with 50 - 120 % of natural water content) is similar to the Bangkok Clay. Considering the experience of the former soil case, it will be possible to utilize the Bangkok Clay by mixing.

(2) FS Section 6: Engineering Study

After the review on the Outer Ring Road Feasibility Study Report (DOH, Aug. 2009), the Consultant proposed that the following items can be reconsidered in terms of the "Combined Project with the Diversion Tunnel".

1) Control of residual settlement

Regarding 4 methods for controlling residual settlement stated in DOH FS section 4, we will propose to revise the evaluation table as shown in Table 6.2.1 from the point of view of the "Combined Project" regarding the Outer Ring Road and the Diversion Channel.

Table 6.2.1 Review of Control Method of Residual Settlement

	Preloading	PVD	Pile Embankment	Soil Cement Column
	This method shall not be applied alone because the soft clay layer is too thick	Applicable	Applicable	Applicable
		79,800 BHT	83,200 BHT	101,000 BHT
Influence on application of Control Method of Construction Period.		6-12 months will be required before most settlement done (considerable effect on construction period).	Effect on construction period will be around 1 month.	Effect on construction period will be around 2 months.
Effect		Residual settlement will be smaller than the Preloading method. Differential settlement will be larger than the Pile Embankment method.	Both residual and differential settlement will be smaller than the other methods.	Although the residual settlement will be small, it is a concern that differential settlement between columns will occur.

Evaluation		△	◎ Advantage in cost and construction period. Quality control will be easiest.	△

DOH FS 2009（original）

Review of DOH FS (Draft)

	Preloading	PVD	Pile Embankment	Soil Cement Column
Screening	Study to utilize excavated soil of diversion channel for preloading.	Applicable	Applicable	Applicable
Cost／m BHT	0 (included in mixing cost as creation of stockpile)	79,800 BHT	83,200 BHT	101,000 BHT
Influence on application of Control Method of Construction Period.	PVD shall be used with Preloading especially in the section of thick soft ground. 6 - 12 months will be required for enough consolidation. If the PVD and Preloading work are completed in the dry season and wait to start the construction work until the start of the next dry season, the effect on the construction period will be minimized by removing the precipitate from the consolidation.		Effect on construction period will be around 1 month.	Effect on construction period will be around 2 months.
Effect	The soft ground shall be consolidated and stabilized to produce larger shear strength by using both Preloading and PVD. Differential settlement will be minimized if the road embankment is constructed after precipitation of consolidation by preloading even the characteristic of soft clay and thickness varies locally. Consequently, the maintenance cost will decrease.		Differential settlement might occur when the slab above the Pile / Column fails due to shear stress or the length of Piles/ Columns are not enough to reach a stiff layer. Differential settlement might arise when characteristic of soft clay and thickness varies locally. Consequently, the maintenance cost will increase.	
Evaluation	◎ This method has assured advantages and good effects with smaller construction and maintenance cost.		△	△

Source: JICA Study Team based on DOH FS 2009

2) Viaduct in Eastern Section

The Southern Section of the Outer Ring Road is 59 km long and all the sections will be viaduct structures. The connecting point of the Southern Section and the Eastern Section is on the ground level of Highway 34.

Bang Na - Bang Pakong Expressway was also built on this road as the second level structure. In this location, a new interchange (IC-11) will be built as one of the Outer Ring Road facilities. The Outer Ring Road should be elevated as the first level structure which passes between those 2 facilities, ground level Highway No.34 and second level Bang Na - Bang Pakong Expressway.

The soft ground condition around IC-11 is the thickest among the eastern section of the Outer Ring Road. Therefore it is necessary to study not only the methods mentioned in "1) Control of residual settlement" but also "viaduct structure". Although the construction cost of the viaduct will be higher than the cost of the embankment structure with the methods shown in Table 6.2.1 (above), the viaduct structure will be reasonable if it meets any of the following conditions.

i. If the method "Preloading + PVD" requires more than the construction period set in DOH FS (4 years) for consolidation, and consequently the project evaluation becomes economically "not feasible" because of increasing loss of earning caused by the delay.
ii. If the method "Pile Embankment" or "Soil Cement Column" is selected for controlling residual settlement, but the piles are not long enough (shorter than the soft ground thickness) , and consequently differential settlement would be a concern, which would increase maintenance cost beyond the existing case.
iii. Even if the construction conditions are not like the above, when the land acquisition of 100 m width with service roads or 70 m without service roads seems to be quite difficult because of progressing urbanization around IC-11 the project may be unfeasible.

The typical cross sections for the viaduct (6 lanes) are shown in Figure 2.4.19 of the Main Report. As shown in the drawings, the right of way (R. O. W) for the viaduct is narrower (70 m with service roads or 40 m without service roads) than those for embankment roads.

The sections to be viaduct structures shall be decided based on the results of geological investigation, consolidation analysis and detailed investigation of current social environmental research. In this reports, the sections for viaducts are presumed to lie between IC-9 - IC-11, 13.32 km, as stated later (refer to

Table 6.2.4).

3) Utilization of excavated soil of diversion channel

The proposed mixing specifications for subgrade and embankment of the Outer Ring Road are shown in

Table 6.2.2.

Table 6.2.2 Tentative Mixing Specifications for Utilization of Excavated Soil for Road Structure

Component	Specifications for DOH FS (2009)	Tentative Mixing Specifications (Proposed by JICA study team)
Sub Base course	CBR≧25% t=15cm	CBR≧25% UCS≧0.75MPa (for stabilized layer)
Subgrade	CBR≧4% t=100cm	CBR＞15% for Upper 30 cm (Capping Layer) CBR＞4% for Lower 70 cm Mixing Ratio Excavated Soil (Clay)：Purchased sand＝2：1 Quick lime 5%（by weight, for Capping Layer）
Embankment	CBR≧4% t=110~180cm	qc＞400 kN/cm^2 Mixing Ratio Excavated Soil (Clay)：Purchased sand＝2：1

Source: JICA Study Team based on DOH FS 2009

The purpose of "utilization of excavated soil" is cost saving by decreasing the amount of soil that must be disposed of and reducing the amount of soil purchased. If soil mixing is required before utilization, the cost for mixing including purchasing materials, such as sand and quick lime or cement, transportation and plant operation cost might be added. In this case, the cost saving by decreasing the amount of soil that must be disposed of, which is the main component of the advantage of the "utilization of excavated soil", and the cost saving by decreasing the amount of soil purchased may be significantly reduced or eliminated.

Table 6.2.3 shows the comparison of road construction cost items between no mixing case (fully embanked by purchased soil: DOH FS) and the mixing case (combined structure of Diversion Channel and the Outer Ring Road: JICA study team proposal).

Table 6.2.3 Comparison of Road Embankment and Subgrade Cost Items (with and without Mixing)

Item	DOH FS (2009) without Mixing	Combined Structure with Mixing	Remarks
Utilization of Excavated Soil	None	Yes	
i Purchasing Cost for Soil	Cost of selected soil is assumed 119 THB/m^3	Cost of sand is assumed 135 TBH/$m^{/3}$. The amount of sand will be 1/3 of the amount of the total material (at the case of clay: sand ratio = 2:1) . Consequently, the cost of purchase material will be 1/3 of selected soil specified in DOH FS.	The quantity of the materials will be fixed based on the result of the mixing test.
ii Transportation, grading and compaction Cost	Location of borrow pit for selected soil is assumed to be in Saraburi Province. The distance for transportation will be 69.5 km (average)	Location of borrow pit for sand is assumed to be in Ang Thong Province. Even if the distance of transportation is the same as for the selected soil, The cost of transportation will be 1/3 because the lower amount than that of selected soil (1/3 in the case of clay : sand ratio = 2:1) .	Low cost mountain sand will be acceptable.
iii Soft Ground treatment Cost	The cost of Pile Embankment will be 2,664 BHT/m^2 (No excavated soil to be utilized for embankment) in 2017 price and including Soil Cement Slab cost.	The cost of PVD will be 1,320 BHT/m^2 The cost of stockpile for material (this stockpile is used as preloading) shall be included in the mixing cost.	It shall be noted that The settlement of precipitated consolidation by PVD and preloading requires additional embankment volume.
iv Mixing Cost	0	Mixing cost includes the following. · Creation of stockpile · Transportation to mixing plant · Operation of mixing plant · (includes assembling and dismantling of the plant, depreciation cost of plant) · Cost of additives (lime or cement)	
v Disposal Cost	0	Disposal cost for excavated soil from diversion channel can be saved.	

Source: JICA Study Team based on DOH FS 2009

The cost from i to iv in the

Table 6.2.3 shall be borne by DOH as the construction cost of subgrade and embankment of the road. The utilization of excavated soil is reasonable when this cost of subgrade and embankment construction with mixing is smaller than the cost of without mixing (purchasing selected soil).

4) Selection of Auxiliary Method for Combined Project

The points for selection of an auxiliary method, which are already discussed above, are shown in

Table 6.2.4.

Table 6.2.4 Selection of Auxiliary Method for Combined Project with Diversion Channel

	DOH F/S August 2009	Result of Reviewing of DOH F/S	Amendment because of Combined Structure
Point of Selection	・It is concerned about differential settlement even at the relatively good conditions where soil improvement methods are not applied (STA.0 – STA.60) ・Design method of Pile Embankment, which will be applied between STA.65 – STA.97, is not established yet.	Based on soil investigation results (source: geological map of Kasetsart Univ., existing and new boring data), the applicable soil improvement method was reviewed and modified. The main points to be amended are follows. ① Viaduct structure shall be applied for the area where the soft clay thickness is more than 18m. ② Countermeasure against differential settlement (PVD + Pre-loading method etc.) shall be applied for the section where the residual settlement is less 30 cm, but the soft clay thickness is more than 10 m .	One of advantages of combined project is utilization of excavated soil which can reduce transportation cost and purchasing cost of qualified soil. Excavated soil will be utilized following two purpose. ① Embankment on PVD as pre-loading ② After pre-loading, the excavated soil (Bangkok Clay) will be mixed with sand (and lime or cement if required) and utilize as subgrade and sub-base. In the section of STA.25 – STA.35, PVD may not installed, however, the excavated soil still can be used as pre-loading.
Applicable Method	established yet, and consequently, itis is concerned about the differential settlement	STA.0 – STA. 35: No soil improvement STA.35 – STA. 56: PVD 2m x 2m + re-loading STA.56 – STA.84: Pile Embankment STA.84 – STA.97: Viaduct	STA.0 – STA. 25: Prevent differential settlement by surcharge of purchased soil materials. STA.25 – STA. 35: Prevent differential settlement by pre-loading of mixed materials STA.35 – STA. 56: Prevent differential settlement by PVD 2m x 2m and pre-loading of mixed materials STA.56 – STA.84: Prevent differential settlement by PVD 1m x 1m and pre-loading of mixed materials STA.84 – STA.97: Viaduct
Selection of Improvement Method for Northern and Central Part	· Thickness of soft clay in southern side of STA 24 (vicinity of IC-4) will be more than 10 m. · It is concerned about differential settlement even if the residual settlement of the area is smaller than 30 cm. · Repair work for differential settlement is difficult especially for Reinforced Concrete Pavement.	Accelerate the consolidation of soft clay layer by pre-loading of purchased soil in order to minimize differential settlement between STA.35 to STA.56. Pile Embankment method (end bearing type) will be applied between STA.56 to STA.84.	Accelerate the consolidation of soft clay layer by pre-loading of excavated soil and purchased sand in order to minimize differential settlement between STA.25 to STA.84. From STA.56 to STA.84, PVD will be installed 1m x 1m, to precipitate the consolidation of thick soft clay as much as possible.
Selection of Improvement Method for Southern Part	Design method for Pile Embankment have not established yet. In south part, from STA.65 of Eastern Section, the proposed length of pile is only 12 meter despite the thickness of soft clay layer is more than 15 m. In this case, it is concerned about differential settlement which might cause defect of concrete pavement.	In the most southern part of East Section (13 km between STA84 and IC-11), final settlement of the ground might be more than 1.5 m by applying pre-loading method because of the thick soft clay layer more than 18m. In this case, the larger settlement requires the larger amount of embankment, and consequently the lager amount of sand. The transportation cost will increase in accordance with the amount of required sand whose borrow pit is located north-eastern of Ayutthaya. In addition, the required time for settlement precipitation may affect the construction period.	In the most southern part of East Section (13 km between STA84 and IC-11), final settlement of the ground might be more than 1.5 m by applying pre-loading method because of the thick soft clay layer more than 18m. In this case, the larger settlement requires the larger amount of embankment, and consequently the lager amount of sand. The transportation cost will increase in accordance with the amount of required sand whose borrow pit is located north-eastern of Ayutthaya. In addition, the required time for settlement precipitation may affect the construction period. Therefore viaduct structure (elevated road) may be suitable for this 13 km section in view of free from the settlement issue and less risk of delaying construction period.

5) Proposal of construction method and issues to be solved

Proposed road structures for the Outer Ring Road eastern section are shown in Table 6.2.5. The southern portion of the eastern section is assumed to be a viaduct structure. For the central portion, the PVD and preloading method will be applied considering the thickness of soft ground layer. In the northern portion, the surcharge method (no mixing material) will be applied if necessary. These proposals are tentative and shall be amended based on the detailed investigation of ground condition at the time of detailed design.

Table 6.2.5 Proposal of Road Structure for the Outer Ring Road（Tentative)

							Road Structure Proposal (Tentative)				
								Embankment			
District Name	Inter-change	Station No	Distance (m)	Service Road	Main Road (4 lanes)	Main Road (6 lanes)	Viaduct	Pre-Loading (1 year) + PVD (1.0x1.0 m) Mixing	Pre-Loading (1 year) + PVD (2.0x2.0 m) Mixing	Pre-Load (0.5 years) Mixing	Surcharge (0.5 years)
			97,112	33,657	44,595	52,517	13,322	27,211	21,079	11,220	24,280
Bang Pa-in and Uthai	IC-1	STA 0 + 0									
			4,399		4,399						4,399
	IC-2	STA 4 + 399									
			4,020		4,020						4,020
8,419		STA 8 + 419									
Wangnoi			2,619		2,619						2,619
	IC-3	STA 11 + 38									
			9,210		9,210						9,210
	IC-4	STA 20 + 248									
			4,032		4,032						4,032
15,861		STA 24 + 280									
Nong Suea			3,070		3,070					3,070	
		STA 27 + 350									
			8,150	8,150	8,150					8,150	
		STA 35 + 500									
			7,190	7,190	7,190				7,190		
		STA 42 + 690									
			280		280				280		
18,690		STA 42 + 970									
Thanyaburi			1,625		1,625				1,625		
	IC-5	STA 44 + 595									
			1,405			1,405			1,405		
		STA 46 + 0									
			500	500		500			500		
3,530		STA 46 + 500									
Lum Luk Ka			8,650	8,650		8,650			8,650		
		STA 55 + 150									
			1,429			1,429			1,429		
	IC-6	STA 56 + 579									
			1,921			1,921		1,921			
12,000		STA 58 + 500									
Nong Chok			2,016			2,016		2,016			
		STA 60 + 516									
			2,367	2,367		2,367		2,367			
		STA 62 + 883									
			9,840			9,840		9,840			
	IC-7	STA 72 + 723									
			4,167			4,167		4,167			
18,390		STA 76 + 890									
Lat Krabang			5,360			5,360		5,360			
	IC-8	STA 82 + 250									
			1,540			1,540		1,540			
		STA 83 + 790									
			619			619	619				
	IC-9	STA 84 + 409									
			659			659	659				
8,178		STA 85 + 68									
Bang Sao Thong			1,632			1,632	1,632				
	IC-10	STA 86 + 700									
			2,100			2,100	2,100				
		STA 88 + 800									
			6,800	6,800		6,800	6,800				
		STA 95 + 600									
			1,512			1,512	1,512				
	IC-11	STA 97 + 112									

Proposed construction method and issues to be solved for each portion of the eastern section road are shown in Table 6.2.6.

Table 6.2.6 Proposed Construction Method and Issues to be Solved for Each Portion (Eastern Section)

Portion	Length (km)	Proposed Construction Method	Issues to be Solved
STA 0+0 STA 24+280	24.280	・Road embankment and subgrade will be created using proper and qualified materials purchased from neighboring borrow pits. ・The earth work shall be done in dry season, and pavement work will be done after rainy season.	・Based on the result of geological investigation, the final settlement amount shall be calculated and amount of surcharge shall be considered.
STA 24+280 STA 35+500	11.220	・Excavated clay and purchased sand are spread alternately (3 times for each) up to 3 m high for pre-loading during the dry season. ・In the next dry season, these preloading materials will be cut by a dozer and mixed at a plant (mixed with quick lime if necessary), then compacted at the location of the planned road.	・Necessity of these methods shall be studied based on the result of geological investigations. The points are; i Necessity of preloading ii Required pitch of PVD (presumably not necessary) iii Duration of preloading (hopefully less than 6 months)
STA 35+500 STA 56+579	21.079	・PVD will be installed in dry season, then excavated clay and purchased sand are spread alternately (3 times for each) up to 3 m high for pre-loading during the dry season. ・In the next dry season, these preloading materials will be cut by a dozer and mixed at a plant (mixed with quick lime if necessary), then compacted at the location of the planned road.	・Necessity of these methods shall be studied based on the result of geological investigations. The points are; i Necessity of preloading ii Required pitch of PVD (presumably 2.0 x 2.0 m) iii Duration of preloading (hopefully less than 1 year)
STA 56+579 STA 83+790	27.211	・PVD will be installed in dry season, then excavated clay and purchased sand are placed alternately (3 times for each) up to 3 m high for pre-loading during the dry season. ・In the next dry season, these preloading materials will be cut by a dozer and mixed at a plant (mixed with quick lime if necessary), then compacted at the location of the planned road.	・Necessity of these methods shall be studied based on the result of geological investigations. The points are; i Necessity of preloading ii Required pitch of PVD (presumably 1.0 x 1.0 m) iii Duration of preloading (hopefully less than 1 year)
STA 83+790 STA 97+112	13.322	・Typical Cross section of the viaduct is shown in Figure 2.1.2.5. ・Cost of Viaduct 10.9 Bil. BHT (2008 price) ・Original Cost of this section by embankment structure（DOH F/S） 2.84 Bil. BHT (2008 price)	・The suitable structure will be selected based on comparison of viaduct and embankment structures. The criteria for selection will be: i Construction cost ii Land acquisition cost iii Schedule (6 lane sections including this portion have high traffic demand , therefore, early completion of the road is expected)

Source: JICA Study Team

6.3 Proposal

The alignment of the Outer Ring Road (East) of the attached document is exactly same as the one in the DOH FS (2009). However the service road, which is between the Outer Ring Road and the Diversion Channel will be relocated to the other side of the Diversion Channel considering the benefits for the local residents.

The alignment of the Diversion Channel is Case-2, which was selected as the most appropriate case compared to the other cases at the time of Interim Report Explanation (In Case-2, the Diversion Channel basically rans side by side with the Outer Ring Road except for the section where the alignment shall be changed to avoid interference with important facilities and to reduce the number of relocation houses).

Although there is no alignment changes for the Outer Ring Road, it must be noted that some structures, such as existing road overpass, underpasses and drainage culverts and interchanges, are modified from DOH FS (2009) because of applying combined structure of road and diversion channel.

6.3.1 Additionally Required Study：Soil Investigation:

Soil investigation for the Outer Ring Road will start earlier than the one for the Diversion Channel. In the latter investigation, it shall be done based on the former one and both results should be shared by DOH and RID so that all the information can be utilized for the detailed design of the combined structure.

Regarding the Outer Ring Road (East), the project cost after detailed design might be considerably changed from the current cost estimation because design changes may be required (as shown in below), depend on the results of additional soil investigation.

(1)Elevated Section（13.322 km：STA 83.790 - STA 97.112）

- The length of elevated section will be modified.
- The length of piles will be modified.

(2)Pre-loading and PVD Section（59.51 m : STA 24.280 - STA 83.790）

- The length and interval of PVD will be modified.
- The amount of embankment will be changed because of reducing settlement amount by pre-loading.
- Mixing Ratio for purchase sand and mixing ratio for cement/lime will be modified

(3)Surcharge Section（24.28 km：STA 0.000 - STA 24.280）

- Transportation plan for embankment materials will be modified after comprehension of the amount of qualified soil arise from diversion channel excavation.

6.3.2 Proposal for Detailed Design Stage:

In the detailed design stage, it will be possible to consider further cost down methods considering the results of additional soil investigation and hydrological study.

For example, the most drastic cost down for the combined structure of road and diversion channel may be realized when the height of road embankment can be reduced. The height of pavement surface was 3.0 to 3.5 m higher than the ground level in DOH FS (2009). This pavement surface height was set so that it will be 2.0 m higher that the 100 year return period flood level. Therefore if the design flood level can be controlled and reduced by applying a combined structure, the pavement surface height of the Outer Ring Road also can be reduced. The estimated cost down effect is as follows.

- Project Cost for Combined Structure (without reducing embankment height): 54,950 Mil. THB
- Project Cost for Combined Structure (with reducing embankment height) : 50,546 Mil. THB

(Decreasing 4,404 Mil. THB)

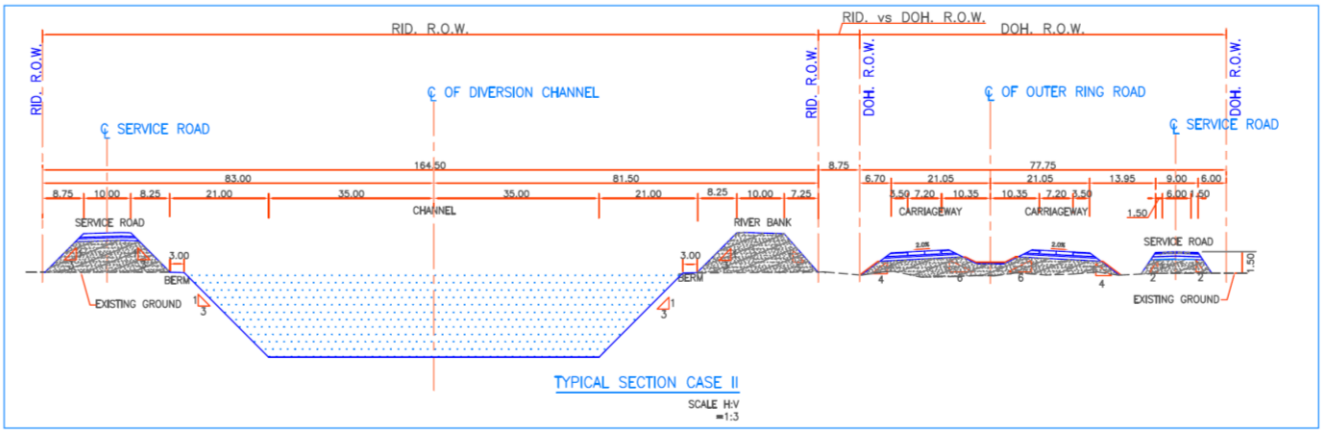


Figure 6.3.1 Standard Cross Section of the Outer Ring Road and Diversion Channel (with reducing embankment height: 1.5 m)

6.3.3 Proposal for Construction Stage:

As for construction stage of combined structure, the case of "Suwannabhumi Airport Drainage Channel" will be a good reference because the structure of excavated channel with berm roads are similar to the Outer Ring Road Diversion Channel.

The conceptual design for the "Airport Drainage Channel", which was divided into 3 lots including two upstream drainage sections and one downstream pumping station section, was done by RID, and implementation design was done by each Contractor, under the Design-Build contracts for three sections. Dr. Warakon from Kasetsart University, who supervised the project as the consultant for the construction stage, pointed out follows based on his experiences on this combined structure of road and channel.

(1) Excavation for the Drainage

The depth of the drainage was 3 m with 1.0 - 1.5 m road embankment on both side. As the slope protection for excavation work, Soil Cement Columns were applied. It is considered that any heavy equipment, such as excavators and dump trucks, shall not work on the installed SCCs so that those SCCs never got damaged.

Those excavators were set in the middle of the width of the channel and temporary roads for dump trucks were also constructed in the middle of the channel, and consequently, the SCCs were not damaged and prevented the slope failures.

(2) Characteristic of Soft Clay during Construction

The main excavated soil for the "Airport Drainage Channel" was very soft clay so called the "Bangkok Clay". The Bangkok Clay has high sensitivity ratio which easily loose its share strength and trafficability after mingled, therefore heavy equipment such as bulldozers could not be used in the drainage channel.

In addition, the creep phenomena, movement of time-dependent, of soft ground was observed immediately after excavation of the drainage, and three weeks later, the deformation of the soft clay causes some slope failures for every three lots despite the slope protection by SCCs.

The monitoring results show the failure mechanism like this; Soft clay and SCCs will be deformed by creep phenomena with the same speed up to around 40 mm, then SCC was broken firstly because of stress concentration on SCCs. After the SCCs were broken, the creep phenomena of soft clay continued and deformed the ground, then finally, the soft clay ground had a slope failure at the deformation of around 150 mm. Thus, the limit equilibrium method may be the risky design method as the slope stability analysis for these soft grounds because the method is based on the assumption of that the largest share strengths of SCCs and soft grounds work together at the same time.

(3) Design and Construction Planning for Excavation of Drainage Channel

In order to prevent slope failure caused by creep phenomena, the original designs were changed as follows.

- Improvement ratio was increased up to 30% of original design which was based on the slope stability analysis.
- The slope stability analysis by limit equilibrium method may give risky results. Therefore FEM elasto-plastic analysis was introduced to comprehend the soft ground behavior and instruments such as inclinometers and piezo-meters were installed to monitor and control ground deformation within 40 mm.

In addition, the excavated ground was planned to be stabilized by 1 - 1.5 m deep water to prevent slope failure by creep phenomena. To keep this depth of water on the excavated ground, dykes were made every 200 m interval and within 2 weeks, water was poured between the dykes just after the completion test for excavation was satisfied (if the pouring water work become more than three weeks later after the excavation, the creep failure may arise).

(4) Residual Soil Treatment

Generally the excavated soil for irrigation channel is the property of RID. However, for "Suwannabhumi Airport Drainage Channel Project", the residual soil by excavation was sold to each contractor, and the amount of the sold price was deducted from the contract amount for each section. The contractor had sold the excavated soil to developers and general firms and it is considered that all the residual soil had been sold out, for, in the location of dumped area, the embanked ground will be stable after one year later and can be utilized.

Thinking of the comment by the Consultant of "Airport Drainage Channel"; Dr. Warakorn, it will be necessary to apply FEM Analysis (Elasto-Viscoplastic Analysis) to simulate ground movement and to study how to deal residual excavated soil at the detailed design and implementation planning stage. In addition, for this kind of a big project, it will be important to make a pilot project prior to start the main project and to monitor actual behavior of soft ground after excavation and embankment works by instruments such settlement plats, inclinometers and piezo-meters. These data gotten from the pilot project will be useful to increase accuracy of FEM analysis by reviewing the parameters regarding creep phenomena of the soft ground, and consequently, the accuracy of the results of FEM analysis for main project will also increase. This effect will secure the stability of the Outer Ring Road and the Diversion Channel during construction stage.

6.4 Recommendation to DOH regarding construction cost reduction

6.4.1 Outline of DOH Plan

When it comes to the construction stage of the combined project, although the merits in construction is considerable such as possibility to make use of residual soil, cost burden for DOH has to be suppressed compared with the figure estimated in the past FS. This is an important topic in future discussion between RID and DOH. A Feasibility Study (FS) for The Outer Ring Road (East section) has been conducted by DOH in 2011 where the Outer Ring Road (East section) was assumed as an individual project demanding a construction cost of 29,573 Million THB (based on price in 2008). Following the estimating method used in the FS, we have updated the estimated cost in which cost for essential soil stabilization is included and the additional cost caused by project combination with the Diversion Channel is all regarded as a part of DOH’s burden. Therefore, several case studies are conducted for DOH to reduce the cost burden as follows.

6.4.2 A proposal of road structure change to reduce construction cost

Some contents of previous Basic Plan of the Outer Ring Road are improved to reduce the construction cost. Since in previous discussion, Case-2 is selected as the most appropriate alignment for the Diversion Channel, thus following methods to reduce construction cost can be applied to road sections where the Outer Ring Road (East section) runs inner side (west side) of the Diversion Channel, namely section 1, 2 and 3:

- To share the road embankment which is inner side of the Diversion Channel as a dike (namely section1 and section 3). This can mitigate the construction cost of bank

・ To lower the road level in the area where is protected by the Diversion Channel

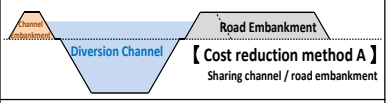
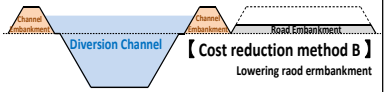
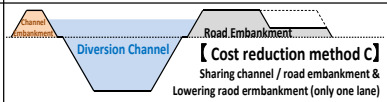
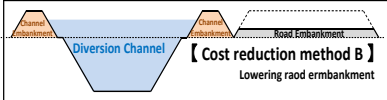
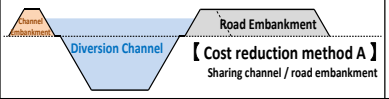
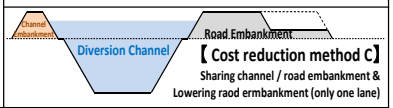
The road level is lowered to be “ground level +1.5m” while it was “ground level + 2.5~3.0m” in the FS of Outer Ring Road. Specifically, 3 types, that are available both in planning and construction, are proposed to DOH as shown below.

Type-A: share the whole road embankment as dike in combined sections (section 1 and 3)

Type-B: lower road level in all 3 sections

Type-C: keep the road level of the lane near to the Diversion Channel as a dike in section 1 and 3, and lower the road level in Section 2

Table 6.4.1 Three possible types to reduce construction cost of the Outer Ring Road

	Type - A	Type - B	Type - C
Section-1 30.0km			
Section-2 29.5km	Nothing		
Section-3 1.8km			
	●Futher EIA is necessary in Method A ●Reduced cost is all distributed to road project	●No need for futher EIA ●All reduced cost will be reflected in road project ●Preferable for DOH	●Futher EIA is necessary in Method C ●Reduced cost is all distributed to road project

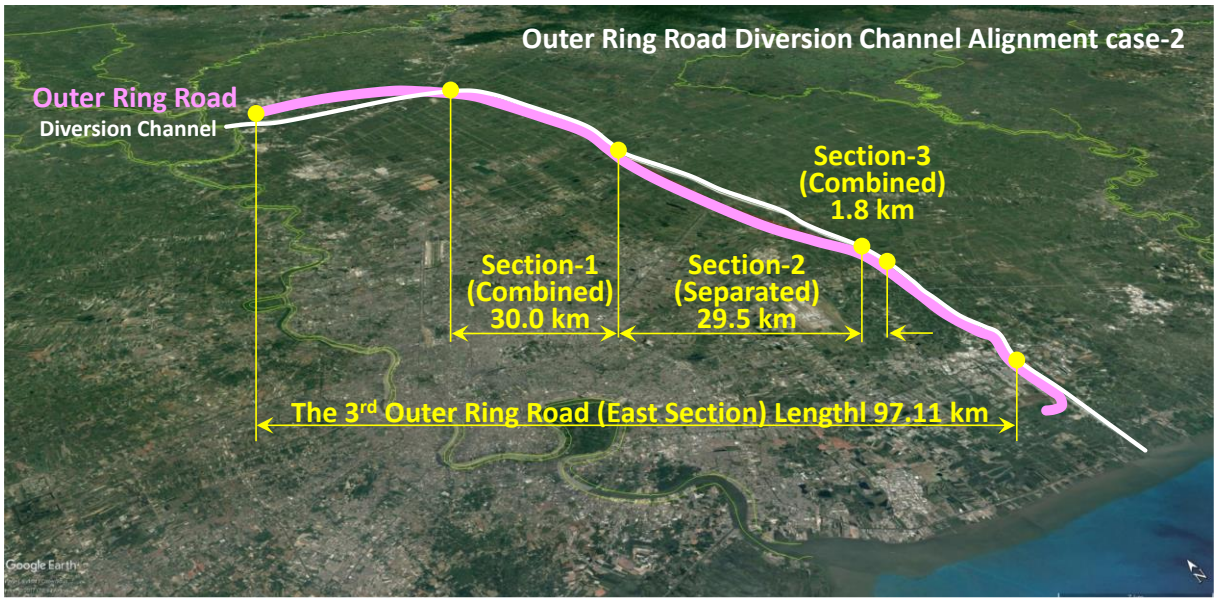


Figure 6.4.1 Alignments of the Diversion Channel and the Outer Ring Road

DOH replied as follows,

・ Multiple-utilization (sharing) of the Road is not preferable since the management becomes complicated.

・ It is possible to discuss road level lowering further.

※Above are confirmed in the meeting with DOH on October 2, 2017. (See appendix)

Therefore, JICA Study Team is now considering Type-B as an option to reduce the construction cost.

6.4.3 Estimated reduction of construction cost

(1) Construction cost as an individual project

An estimated reduction of construction cost is calculated from the view of DOH based on the method of Type-B. It is rational to regard the estimated cost in FS as a base line since the project was assumed to be an individual project by DOH. However, following modifications are necessary because cost estimation in FS was made based on the price in 2008 and road structure has been modified in our proposal.

- estimation is revised using price in 2017
- road structure of south part is changed from embankment to viaduct

The comparison is shown as following table (Case a.～Case c. in Table 6.4.2).
As a result, a cost of 51,033M THB is updated for the individual project (Case c.) as the base line.

Table 6.4.2 Construction cost as an individual project

Items	a. FS Original	b. FS Original	c. FS Original (Elevate road in southern part)
Point of Estimation	Original of DOH	Revise only Unit Price	Change to elevated Structure
Unit Price	as of 2008	as of 2017	as of 2017
Elevating Road in Southern Part	Not Elevate	Not Elevate	Elevate
Direct Construction Cost (Mil.THB)	26,072	34,518	45,162
Indirect Construction Cost (Mil.THB)	3,389	4,487	5,871
Construction Cost (Mil.THB)	29,573	39,005	51,033

Indirect Construction Cost = Direct Construction Cost × Factor-F (ratio of Indirect Cost 0.13)

Source : JICA Study Team

(2) Construction cost as Combined Project

In this report, the construction cost of combined project is estimated to be 54,950M THB which is shown as a basic case (namely Case d) in Table 6.4.3. In this case, all additional cost caused by project combination is counted as DOH's burden which is estimated to be 4,198M THB in Table 6.4.4.
However, if we assume all additional cost caused by project combination is ought to be RID's burden, though it has not yet been discussed by RID and DOH, the cost for DOH will be 4,198M THB less than Case d, to be 50,752M THB as Case e. On the other hand, lowering road level (method Type-B) can bring a cost reduction of 4,403 M THB to make the total cost to be 50,546M THB (Case f), even still counting the additional cost as DOH's burden. Furthermore, if we both count the additional cost as RID's burden and lower the road level, we can obtain a figure of 46,348M THB as Case g, which means 8,602M THB less than the individual project plan (Case c).

Table 6.4.3 Cost Estimation as Combined Project

Items	Basic Design	DOHの負担軽減の検討		
	d. Combined Construction	e. Combined Construction (Review increased cost allocation)	f. Combined Construction (Lower road embankment)	g. Combined Construction (Lower road embankment) (Review increased cost allocation)
Measures to reduce project cost of the Road (Cost reduction measure for DOH)	Nothing. Road cost increament by combining with channel is allocated to DOH	Road cost increment by combining with channel is allocated to RID	Reduce road construction cost lowering road embankment	Conduct measures assumed in case e. and f.
Unit Price	as of 2017	as of 2017	as of 2017	as of 2017
Elevating Road in Southern Part	Elevate	Elevate	Elevate	Elevate
Direct Construction Cost（Mil.THB）	48,628	44,913	44,731	41,016
Indirect Construction Cost（Mil.THB）	6,322	5,839	5,815	5,332
Construction Cost（Mil.THB）	54,950	50,752	50,546	46,348
Reduction Cost from case c. (Mil.THB)	-3,917	281	487	4,685
Reduction Cost from case d. (Mil.THB)	-	4,198	4,403	8,602

Indirect Construction Cost = Direct Construction Cost×Factor-F（ratio of Indirect Cost 0.13)

Source : JICA Study Team

Table 6.4.4 Cost Reduction for DOH derived from project combination

（This is the additional cost caused by project combination, which used to be counted as DOH’s burden while it will be regarded as RID’s burden now）

Items		Amount (Mil.THB)
Crossing points with Diversion Channel (Length of bridge is 820m)		635
Extended length of bridge crossing with Diversion Channel (2 places)		86
Overpass at the crossing with existing road (Width 6m, 28 places)		918
Modifying structure of interchange (4 places)		1,734
Service road in the area of Diversion Channel (use excavated soil)		111
Service road at the side of Diversion Channel (purchased sand)	Material coost (sand), Transportation cost)	88
	Mixing and compaction cost	143
Subtotal (Direct Cost)		3,715
Indirect Cost		483
Total (increased cost caused by combining with Diversion Channel)		4,198

Indirect Construction Cost = Direct Construction Cost×Factor-F（ratio of Indirect Cost 0.13)

Source : JICA Study Team

6.4.4 Conclusion

Cost burden of the Outer Ring Road (East section) for DOH has been revised. As indicated by Case g, project combination can approximately bring a cost reduction of 4,685M THB (approximately 15.9B JPY) for DOH, which is 9% less compared with construction as an individual project in the original FS plan.

Table 6.4.5 Construction cost of the 3rd Outer Ring Road (Case study for cost reduction)

Items			Unit	Case a.			Case b.			Case c.			Case d.				Case f.			
				FS (Original)			FS (2017 unit price)			FS Review (Elevated in Southern Part)			Combined Construction				Combined Construction			
				Quantity	Unit price (THB)	Amount (1000THB)	Quantity	Unit price (THB)	Amount (1000THB)	Quantity	Unit price (THB)	Amount (1000THB)	Quantity	Unit price (THB)	Amount (1000THB)	Remark	Quantity	Unit price (THB)	Amount (1000THB)	Remark
Highway (Embankment)	RC Pavement	t=25cm	m2	1,478,016	885	1,308,044	1,478,016	930	1,374,555	1,277,208	930	1,187,803	1,277,208	930	1,187,803		1,277,208	930	1,187,803	
	Sand Bed	t=10cm	m2	1,478,016	61	90,159	1,478,016	137	202,488	1,277,208	137	174,977	1,277,208	137	174,977		1,277,208	137	174,977	
	AC Road Shoulder	t=5cm	m2	805,600	230	185,288	805,600	195	157,092	729,700	195	142,292	729,700	195	142,292		729,700	195	142,292	
	Base Course	t=20cm (Macadam)	m3	214,289	700	150,002	214,289	314	67,205	220,969	314	69,300	220,969	314	69,300	Excluding Transportation	220,969	314	69,300	Excluding Transportation
	Subbase course	t=15cm (Laterite)	m3	445,256	550	244,891	445,256	119	52,914	375,951	119	44,678	97,861	119	11,630	Excluding Transportation	97,861	119	11,630	Excluding Transportation
	Subgrade / Embankment	t=245cm (High Quality Soil)	m3	12,857,800	340	4,371,652	12,857,800	102	1,307,638	11,064,834	102	1,125,294	2,899,954	102	294,925	Excluding Transportation	2,899,954	102	294,925	Excluding Transportation
	Mixing Material	Sand for Mixing	m3										4,467,362	135	603,094		1,761,520	135	237,805	
		Cement (7%)	ton										42,599	2,700	115,018		42,599	2,700	115,018	
		Lime (5%)	ton										120,553	2,700	325,494		106,321	2,700	287,067	
	Mixing Cost (include Transportation Cost)	Plant (8 places)	m3										13,402,087	292	3,916,090		5,284,559	292	1,544,148	
	Embanking Material Transportation Cost (Sand Pit→IC-4)	t=20cm (Macadam)	m3			Including Transportation	214,289	361	77,420	220,969	361	79,834	220,969	361	79,834		220,969	361	79,834	
		t=15cm (Laterite)	m3				445,256	369	164,267	375,951	369	138,699	97,861	369	36,104		97,861	369	36,104	
		t=245cm (High Quality Soil)	m3				12,857,800	369	4,743,602	11,064,834	369	4,082,127	2,899,954	369	1,069,874		2,899,954	369	1,069,874	
		Sand for Mixing	m3										4,467,362	241	1,076,009		1,761,520	241	424,280	
	Embanking Materil Transportation Cost (IC-4→Construction Site)	t=20cm (Macadam)	m3			Including Transportation	214,289	263	56,384	220,969	204	45,122	220,969	156	34,426		220,969	156	34,426	
		t=15cm (Laterite)	m3				445,256	284	126,367	375,951	264	99,200	97,861	52	5,126		97,861	52	5,126	
		t=245cm (High Quality Soil)	m3				12,857,800	193	2,476,059	11,064,834	183	2,021,754	2,899,954	52	151,911		2,899,954	52	151,911	
		Sand for Mixing	m3										4,467,362	162	725,930		1,761,520	162	286,241	
	Soil Cement Slab	t=60cm	m3	854,640	230	196,567	854,640	278	237,846											
	Pile STA65+0-97+112	22cm x 22cm	m	4,273,200	550	2,350,260	4,273,200	666	2,843,815											
	Soil Cement Slab	t=60cm								723,644	278	201,390								
	Pile STA56+579-83+790	22cm x 22cm								3,618,221	666	2,407,926								
	PVD STA 56+579-83+790	1.0m*1.0m	m										22,641	96,558	2,186,170		22,641	96,558	2,186,170	
	PVD STA 35+500-56+579	2.0m*2.0m	m							21,079	19,950	420,526	20,069	19,950	400,377		20,069	19,950	400,377	
	Sodding Work / Fence etc.					330,637			476,117			410,803			410,803				410,803	
Highway (Elevated)	STA 83+700～97+112	6 lanes	m							13,412	1,001,743	13,435,379	13,412	1,001,743	13,435,379		13,412	1,001,743	13,435,379	
	Service Road	2 lane	m	41,820	16,750	700,485	67,314	5,800	390,421	67,314	5,800	390,421								
	Inside Road Area(Mixed Soil)		m										36,024	3,550	127,885		36,024	3,550	127,885	
	Inside Channel Area(Mixed Soil)		m										31,290	3,550	111,080		31,290	3,550	111,080	
Adjoing Fwacilities etc.	Crossing with Diversion Channel STA21+015	Length of Bridge is 820m	m			0			0			0	820	774,000	634,680	1 place	820	774,000	634,680	1 place
	Bridge	Crossing with existing channel or existing main road				2,308,660			2,978,171			1,882,963			1,882,963	8 places			1,882,963	8 places
	Crossing with existing Road	I Gireder	m	3,200	209,000	668,800	3,200	269,610	862,752	3,200	269,610	862,752	3,200	269,610	862,752	9 places	3,200	269,610	862,752	9 places
	(Additional for Diversion Chanel)	Extended Length is 160m	m										320	269,610	86,275	2 places	320	269,610	86,275	2 places
		Segmental Girder	m	612	400,000	244,800	612	516,000	315,792	612	516,000	315,792	612	516,000	315,792	1 place	612	516,000	315,792	1 place
	Underpass (w=6m)	Community Road	m	2,684	51,600	138,494	2,684	68,112	182,813	2,258	68,112	153,797	486	68,112	33,102	9 places	42	68,112	2,861	1 place
	Overpass (w=6m)	Increament by Combining	m										8,370	109,650	917,771	20 places	11,550	109,650	917,771	28 places
	Interchange	11 places		11か所		9,487,000			10,937,796			10,937,796			10,937,796	11 places			10,937,796	11 places
	(Additional for Diversion Channel)	Increament by Combining													1,734,716	4 places			1,734,716	4 places
	Box Calvert	Small irrigation channel	m	6,818	25,000	170,450	6,818	33,000	170,450	6,504	33,000	214,632	6,504	33,000	214,632	105 places	6,504	33,000	214,632	105 places
	Service Area					117,000			154,440			154,440			154,440				154,440	
	Tallgate, Other Facilities					874,100			1,153,812			1,153,812			1,153,812				1,153,812	
	Traffic Control and Pricing System					1,728,000			2,348,760			2,348,760			2,348,760				2,348,760	
	Traffic Sign etc.					224,000			367,360			367,360			367,360				367,360	
	Environmental Development (Soundproof Wall)					183,285			292,504			292,504			292,504				292,504	
		Subtotal				26,072,600			34,518,800			45,162,133			48,628,886				44,731,568	
		Factor F (13% without VAT)	%	13.0		3,389,438	13		4,487,444	13		5,871,077	13		6,321,755		13		5,815,104	
		Construction Cost				29,573,000			39,006,244			51,033,210			54,950,642				50,546,672	

Source : JICA Study Team

※conference

Table 6.4.6 Estimated Construction Cost for Type-A ～ Type-C

Reduced cost (Alignment case-2)

Case	Method	Length (km)	Items	Quantity	Unit	Unit price (THB)	Total Reduction Cost (MB)	Reduction Cost for DOH (MB)
Type-A	Sharing (Section-1,3)	31.807	Land cost	853,044	m2	1,735	-1,480	-1,480
			Channel embankment (right bank in North area)	392,892	m3	537	-211	-211
			Channel embankment (right bank in Central area)	1,445,887	m3	541	-782	-782
			Channel embankment (right bank in South area)	162,919	m3	98	-16	-16
			Soil stabilization (PVD Central)	23,112	m	10,526	-243	-243
			Soil stabilization (PVD South)	1,807	m	41,189	-74	-74
			Soil disposal (Channel)	1,334,465	m3	319	425	
			(Revetment)	935,126	m2	1,709	1,598	
			Total				-784	-2,807
Type-B	Lowering (Section-1,2,3)	61.307	Road embankment	7,816,643	m3	563	-4,403	-4,403
			Soil disposal (Road)	5,058,350	m3	319	1,612	
			Total				-2,791	-4,403
Type-C	Sharing & Lowering (1 lane) (Section-1,3))	31.807	Land cost	853,044	m2	1,735	-1,480	-1,480
			Channel embankment (right bank in North area)	392,892	m3	537	-211	-211
			Channel embankment (right bank in Central area)	1,445,887	m3	541	-782	-782
			Channel embankment (right bank in South area)	162,919	m3	98	-16	-16
			Road embankment	2,027,696	m3	563	-1,142	-1,080
			Soil stabilization (PVD Central)	23,112	m	10,526	-243	-243
			Soil stabilization (PVD South)	1,807	m	41,189	-74	-74
			Soil disposal (Channel)	1,334,465	m3	319	425	
			Soil disposal (Road)	839,381	m3	319	267	
			(Revetment)	935,126		1,709	1,598	
			Sub total				-1,658	-3,887
	Lowering (Section-2)	29.500	Road embankment	3,761,250	m3	563	-2,119	-2,004
			Soil disposal (Road)	2,507,500	m3	319	799	
			Sub total				-1,320	-2,004
			Total				-2,978	-5,891

Chapter 6: Appendix

Meeting Memo

Meeting	**Date: March 20, 2017** **Time: 13:30 - 15:00**	**Location: DOH**
Subject:	**3rd outer ring road diversion channel**	
Attendance (DOH):	Mr. Tawee Gasisam-Ang, Deputy director-general for management , DOH Mr. Arkkapat Sawangsurachai, bureau of research and development, DOH Mr. Poranic Jitareekul, bureau of material analysis and inspection, DOH Mr. Chutar Sunitsakul, bureau of material analysis and inspection, DOH Mr. Somsak Boonpratanporn, Senior engineer, DOH Mr. Kitti Subprasom, Bureau of Planning, DOH	
Attendance (JICA Team)	Mr. Masaki Todo (Team Leader) Mr. Hideki Yoneyama (Road Planning) Mr. Chaisak Sripadungtham	
Main Topic	Feasibility of Integrated Structure of Diversion Channel and the 3rd Ring Road (Presented by Mr. Yoneyama)	
Discussion	JICA: There are 2 types of soil improvement mix with sand and mix with cement. These two method can reduce the construction cost. DOH: soil cement and PVD for embankment are used to improve the soil and reduce a settlement. How long will a soil gain more strength and consolidation? JICA: It spend 1-2 years. We are now studying about consolidation of embankment. A channel are 8 meter deep, 150 m wide and approximately 100 kilometers long. There are 4 cases. However, we interested in case 1 and case 2. DOH: We think there are a failure of embankment during the channel and road construction. DOH: This is a big project. We should have a meeting. The main problem is an expropriation. Who supposed to do this? DOH already submit EIA for only road. If channel is integrated, EIA must change. The process is to stop the EIA first. RID should discuss with board of ministry to break EIA. And then we can revise EIA together. DOH: Practically, a settlement in 20 years is 1-2 meters. Water content is 150%. Su is equal to 0.5-1.5 kPa. A soil is very soft clay. In the past, a soil cement along the suwannabhumi irrigation channel collapsed. We think that a construction process is not a point. DOH: Is a channel only for flood control? DOH: The point is expropriation. If we want to expropriate 300 meters a people will refuse. This should be a national agenda. RID have to be a representative for cooperate between ministries. The channel should not be only flood control. It should be both flood control and irrigation. The people may accept this condition. JICA: An objective of channel in the master plain is only for flood control.	

DOH Meeting Memo

2 Oct 2017

At Mr.Pramon Office

The Department of Highways

Participants:

1. Mr. Pramon Sathapornnanon （Chief Engineer of Location and Design, DOH)
2. Mr. Somboon Tienthammachat （Expert Engineer, Bureau of Location and Design, DOH)
3. Mr. Pichakorn Srijanthong (Civil Engineer, Senior Professional Level, DOH)
4. Dr. Hideki Yoneyama (Road Planning, JICA Study team)
5. Mr. Jadoon Pansuwan (Road Structure Design, JICA Study Team)

Agenda1 : Explanation of Cost Reduction Method for *the Third Outer Ring Road Combined with the Diversion Channel*

Mr.Yonenama: present about cost reduction m in term 3 alternative methods.

1) Method A : Sharing Channel/Road Embankment
2) Method B : Lowering Road Embankment
3) Method C : Method A+ Method B

The Study Team will propose the appropriate method according to the suggestion of the Department of Highways in the Draft Final Reports for JICA in October.

Mr.Pramon : (1) Disagreed with the methods to use the road embankment as the Diversion Channel .Therefore method B would be more appropriate.

(2) In case of project integration, JICA should to consider about the other sustainable benefits such as developing adjacent areas between both of RID. And DOH.R.O.W for public activities, emphasizing the Rest Area of 3rd Ring Road to be landmark adjacent the diversion channel etc.

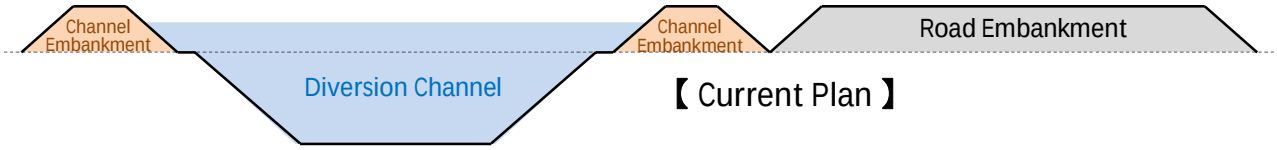
(3) The Department of Highways desires to proceed the 3rd Outer Ring Road according DOH.'s planning ahead and The Royal Irrigation Department should adjust the Diversion Channel Project figuration to accommodate the Road Project later.

Mr.Somboon : (1) Relocating the service road to another side of Diversion Channel Bank cause inconvenient travelling for people and higher construction costs.

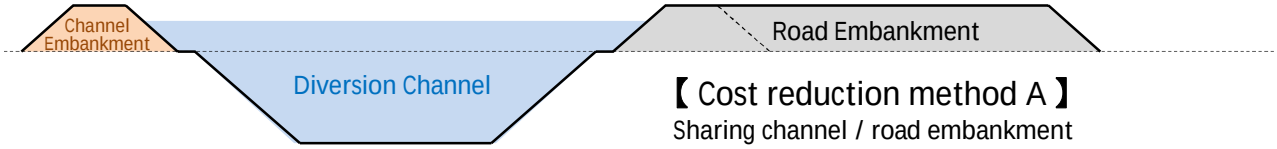
(2) In case the project is integrated, the protest from expropriated villagers may be much more than separated project.

Agenda2 : Draft Drawing *for the Third Outer Ring Road Combined with the Diversion Channel*

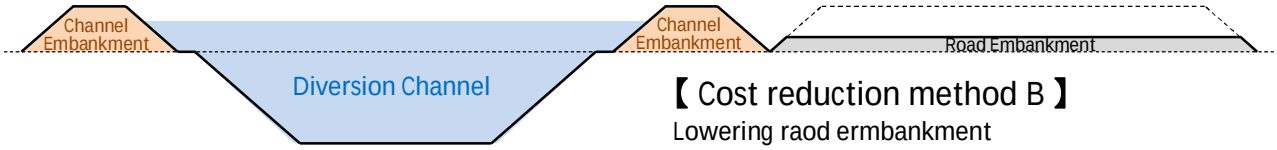
DOH. Vs JICA Study Team : DOH. (Mr.Pichakorn) and JICA Study Team (Mr.Jadoon) will discuss about adjusting the drawings during October 2017.



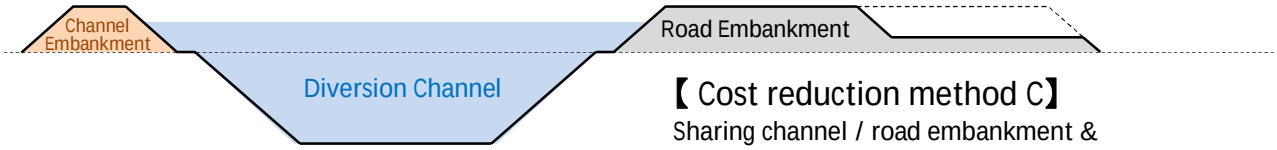
【 Current Plan 】



【 Cost reduction method A 】
Sharing channel / road embankment



【 Cost reduction method B 】
Lowering raod ermbankment



【 Cost reduction method C】
Sharing channel / road embankment &
Lowering raod ermbankment (only one lane)

	DOH: Why don't you elevate a road for both side for 1-2 meters? Is it cheaper than soil improvement and easier to manage in long-term? JICA: In Japan, the elevated road is in the center of channel. This is a good suggestion. DOH: Over pass for channel with road and tollway booth should include in this study. JICA: The soil near suwannabhumi is very soft. The suggestion from DOH is very interesting. We will discuss with JICA team and propose an appropriate method. DOH: You have to determine a dimension of waste soil pit. Then, geotechnical is studied. Is the channel only flood control or irrigation? Does water drain from Chaopraya to the sea? JICA: A water gate will be installed to control water level for irrigation. The water level in the channel is higher than another irrigation. End

CHAPTER 7 PROCUREMENT AND CONSTRUCTION PLAN

7.1 Principle work quantities

Principal work quantities of Outer Ring Road Diversion Channel is shown in the following table.

Table 7.1.1 Principal work quantities

Work Items			Unit	Northern Part	Central Part	Southern Part
(1) Removal Existing Facilities			Not counted in this study			
(2) Reclamation / Laying Construction Road			m^3/500m	0	0	100,000
(3) Changing Route of Existing Channel			Not counted in this study			
(4) Soil Stabilization	PVD	Sandmat	m^3/500m	0	36,700	31,600
		PVD	m^3/500m	0	249,200	949,800
	SCC		Column/500m	0	9,900	22,200
(5) Excavation	Total	Laying construction road	m^3/500m	28,650		
		Excavation	m^3/500m	264,000		
		Soil disposal	m^3/500m	226,000	140,100	180,000
	Excavation (depth 0-3m) (Dry season)	*Laying construction road*	*m^3/500m*	*19,850*		
		Excavation	*m^3/500m*	*145,500*		
		Soil disposal	*m^3/500m*	*107,500*	*21,600*	*61,500*
	Excavation (depth 3-6m) (Rainy season)	*Laying construction road*	*m^3/500m*	*8,800*		
		Excavation	*m^3/500m*	*118,500*		
		Soil disposal	*m^3/500m*	*118,500*	*118,500*	*118,500*
(6) Temporary Placing			m^3/500m	185,800	185,800	185,800
(7) Preparing Stock Pile / Pre-Loading	Channel		m^3/500m	57,000	62,600	90,200
	Road		m^3/500m	61,700	123,200	35,900
(8) Plant Mixing			m^3	14,824,000		
(9) Embanking	Channel	Embankment	m^3/500m	57,000	62,600	90,200
		Embankment utilizing excavated soil	m^3/500m	57,000	62,600	90,200
		Clay (Excavated soil)	m^3/500m	38,000	41,800	60,100
		Sand	m^3/500m	19,000	20,800	30,100
	Road	Embankment	m^3/500m	61,700	123,200	35,900
		Embankment utilizing excavated soil	m^3/500m	0	123,200	35,900
		Clay (Excavated soil)	m^3/500m	0	82,100	23,900
		Sand	m^3/500m	0	41,100	12,000

Source：JICA study team

7.2 Shift and worktime

As discussed in construction planning for the Outer Ring Road Diversion Channel, principally construction shall be operated 7 hours per day (daytime) with 2 shifts.

7.3 Workable days

The number of workable days calculated from daily precipitation (2000 to 2009) observed in Bangkok by Thai Meteorological Department's is as shown in the table below. According to the calculation method in Japan, workable days will be 185 days per year, 123 days in dry seasons, 62 days in rainy season. However, due to the large scale of combined construction of Outer Ring Road and Diversion Channel, in consideration of the following table, the number of workable days in the dry season should be 150 days, and the number of workable days in the rainy season should be 75 days.

- In order to complete within the assumed construction period, it is necessary to increase the number of construction days per year more than usual
- It is also possible to increase the working time per day which is usually seven hours for construction planning

Table 7.3.1 Workable days

Items		May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
1) Days		30	31	31	31	30	31	30	31	31	28	31	30	365
2) Sunday and National Holiday		7	4	8	6	4	8	4	7	6	6	4	9	73
3) Machine maitenance		1	1	1	1	1	1	1	1	1	1	1	1	12
4) Unworkable rainy days		14	12	11	12	15	15	3	1	1	2	3	6	95
5) Total unworkable days	2)+3)+4)	22	17	20	19	20	24	8	9	8	9	8	16	180
6) Workable days	1)-5)	8	14	11	12	10	7	22	22	23	19	23	14	185
		62						123						

Unit : days

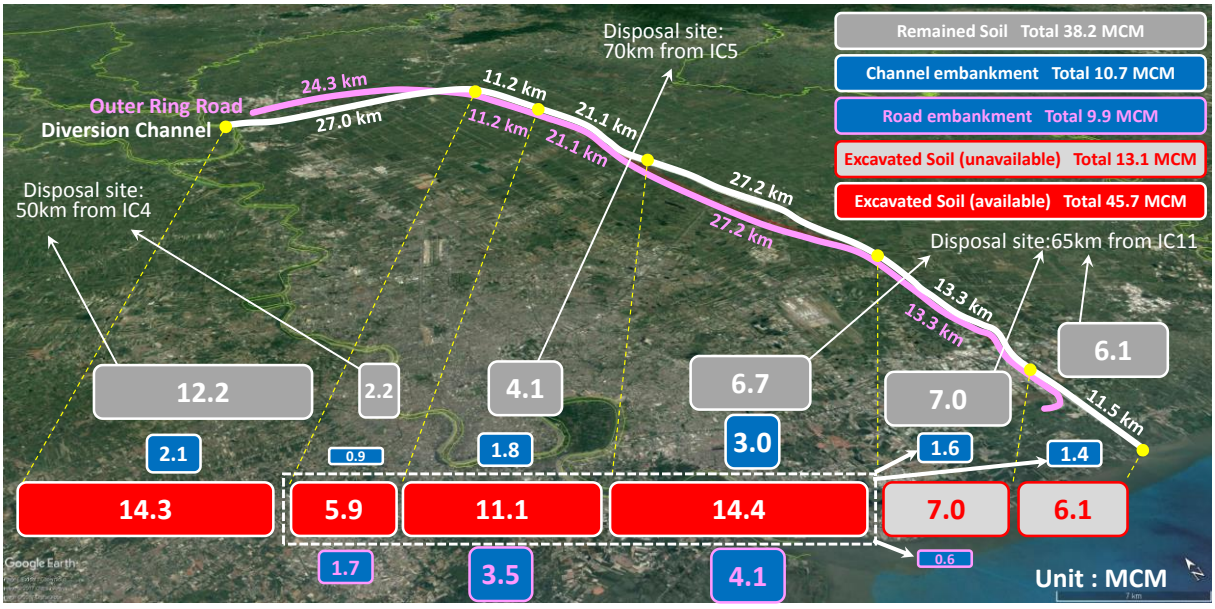
Workable days in rainy season 75	Workable days in dry season 150

Refer to Daily rainfall observed by TMD at Bangkok from 2000 to 2009.
Unworkable days depends on weather condition : If daily rainfall is 5mm/day or more, this day is unworkable. Number of unworkable days are as below depend on daily rainfall. Daily rainfall is 5mm/d or more, and less than 20mm/d / 1day Daily rainfall is 20mm/d or more, and less than 35mm/d : 2days / Daily rainfall is 35mm/d or more, and less than 65mm/d : 3days / Daily rainfall is 65mm/d or more, and less than 100mm/d : 4days / Daily rainfall is 100mm/d or more, and less than 170mm/d : 5days / Daily rainfall is 170mm/d or more : 6days

Source : JICA study team

7.4 Soil volume balance

The clay excavated from the Diversion Channel shall be used as a material for the embankment of the road and the embankment of the channel. The amount of excavated soil, the amount of soil used as a material of the embankment of the road and the embankment of the channel, and the amount of the remained soil are shown in the figure below. Excavated clay from the channel cannot be used as embankment material directly, but shall be used when it is mixed with sand. The sand to be mixed is brought to the construction site by being purchased and transported.



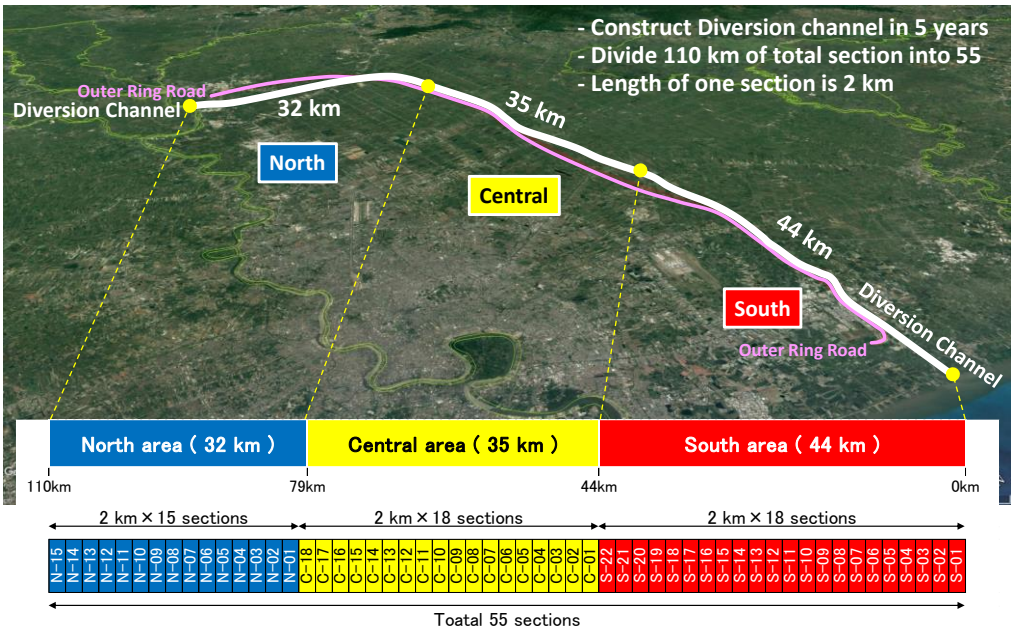
Source : JICA study team

Figure 7.4.1 Soil volume balance of Outer Ring Road Diversion Channel combined construction

The figure above shows the excavated soil volume of Diversion Channel, the amount of embankment usage, and the amount of soil remaining in each section. For example, in the second section from the north side (length 11.2 km), excavate 5.9 MCM soil to construct the Diversion Channel, use 0.9 MCM as the material of channel embankment, 1.7 MCM as material of road embankment, and 2.2 MCM is treated as surplus soil. In the two sections on the south side, water content of the excavated soil is high, so this soil cannot be used as a material for embankment. Therefore, the whole amount of remained soil will be disposed.

7.5 Soil volume balance in the sec

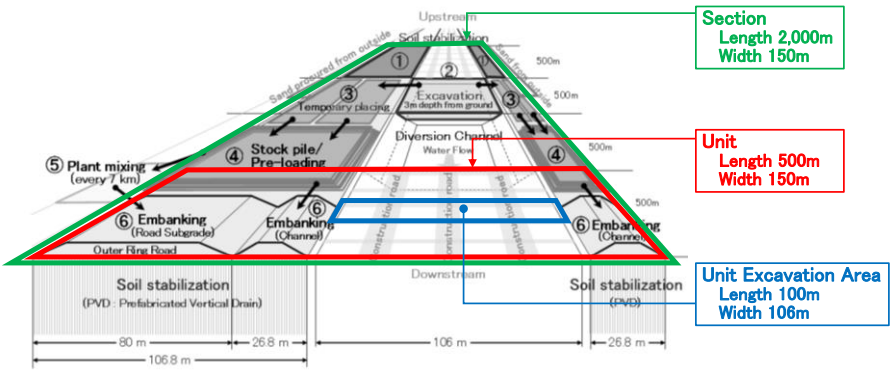
Construction period of the combined project of the Outer Ring Road and Diversion Channel is assumed to be 5 years considering the previous plan of the Road. In order to finish the construction in time, every 2km is defined as one section and construction (excavation and embankment) shall be on operation simultaneously in 55 sections. Number of sections will be too many if section distance is less than 2km while it will be impossible to complete the construction in 5 years if it is larger.



Source ：JICA study team

Figure 7.5.1 Divided sections of the Road and Diversion Channel combined construction

In this report, minimum excavation area which is 100m long in longitudinal direction and 106m wide in cross direction is defined as "Unit Excavation Area". A "Unit" is defined to be composed by 5 Unit Excavation Area, specifically 500m long in longitudinal direction and 150m wide in cross direction. Analogically, a "Section" consists of 4 Unit with 2000m long in longitudinal direction and 150m wide in cross direction. From existing facility removal to embankment, all construction steps can be conducted in one section, therefore, simultaneous construction in 55 sections is possible.



Source ：JICA study team

Figure 7.5.2 Explanation of "Section", "Unit" and "Unit Excavation Area"

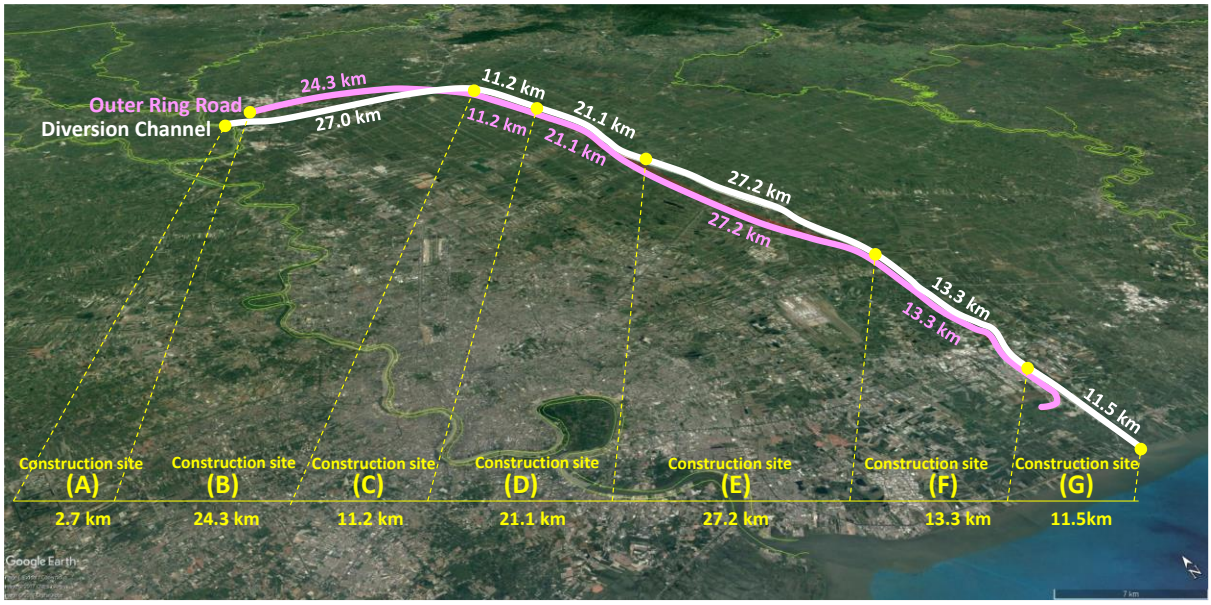
7.6 Construction site

Construction sites are defined as (A) to (G), shown as follows. The division of Road sites is according to DOH's F/S and the part of Diversion Channel is based on soil classification (research results by Kasetsart University).

Table 7.6.1 Construction Sites

Construction Area		Outer Ring Road		Soil Classification	Diversion Channel	
	Length (km)		Length (km)			Length (km)
(A)	2.738			Green	Northern Part	32.109
(B)	24.280	①	24.280	Blue		
(C)	11.220	②	11.220	Yellow	Central Part	35.213
(D)	21.079	③	21.079			
(E)	27.211	④	27.211	Red	Southern Part	44.011
(F)	13.322	⑤	13.322			
(G)	11.483			Brown		
Total	111.333	Total	97.112		Total	111.333

Source : JICA study team



Source : JICA study team

Figure 7.6.1 Construction Sites

7.7 Construction steps

Construction steps of the combined project are shown in following figure. For construction site A ~ E, only road construction of step (2) is needed while wet land reclamation can be omitted since they are not wet lands. As the result of simulation analysis, ground Stabilization, step (4) in the figure, is unnecessary for site A and B because the safety factor of the excavated slope turns out to be over 1.3 and both residual and final subsidence are lower than tolerance limit. Also, step (8) can be omitted for these two sites since soil for embankment will be newly purchased.

	Construction Site		
	(A)-(B)	(C)-(E)	(F)-(G)
(1) Removal Existing Facilities	●	●	●
(2) Reclamation / Laying Construction Road	▲	▲	●
(3) Changing Route of Existing Channel	●	●	●
(4) Soil Stabilization	---	●	●
(5) Excavation	●	●	●
(6) Temporary Placing	●	●	●
(7) Preparing stock pile / Pre-Loading	●	●	●
(8) Plant Mixing	---	●	---
(9) Embanking	●	●	●

Legend
● : Implement in this site
▲ : Implement part of this work
--- : Not necessary in this site

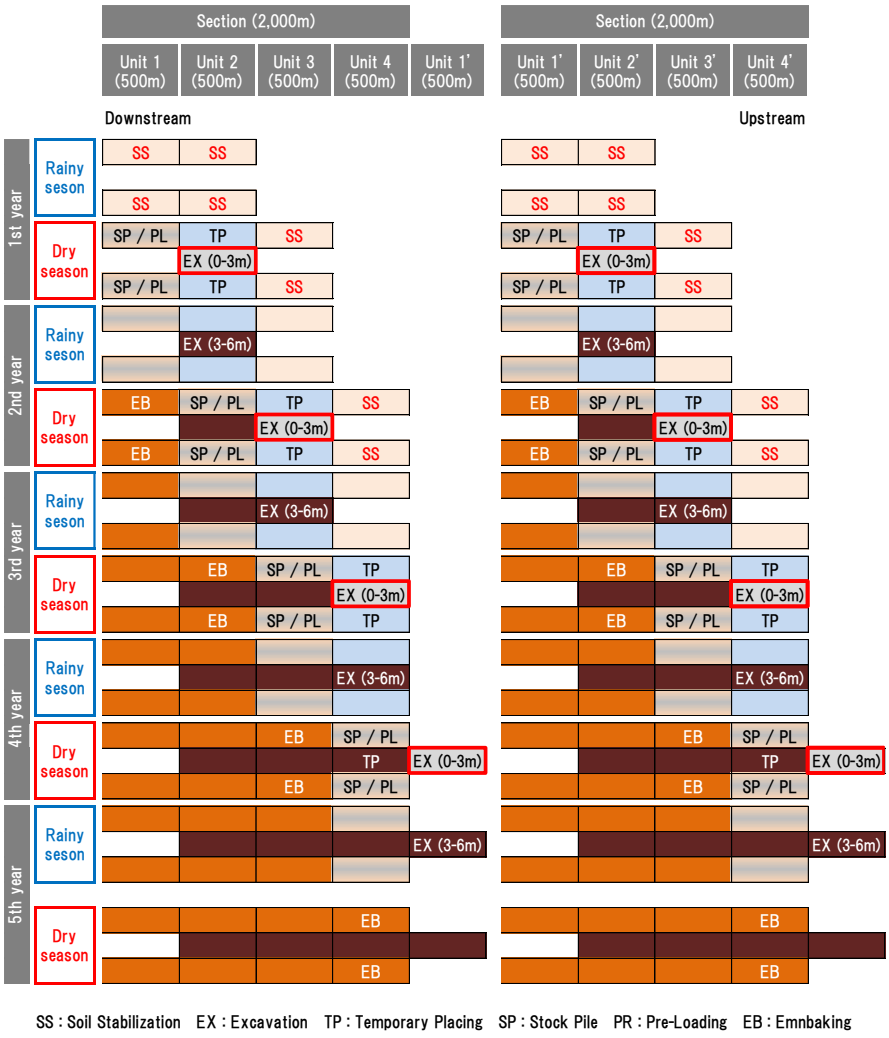
Source : JICA study team

Figure 7.7.1 Construction steps

7.8 Construction process in the Section

7.8.1 Construction process during five years

Taking construction site D as an example, here is a brief instruction of the construction steps for the 5 years. Construction period for the whole project is assumed to be 5 years which is given in previous F/S by DOH. In this study, construction period of Outer Ring Road and Diversion Channel is set to five years. In order to complete the construction in 5 years, one section is set to 2 km, and excavation and embankment work are carried out simultaneously in 55 sections. The following figure indicates the construction process about two sections nest to each other. In the rainy season of the first year, soil stabilization should be carried out at the downstream two sections. In the dry season of the first year, excavation (three meters depth from the ground level) of the channel at the second section from downstream should be carried out. At the same time, temporary placing of excavated clay and purchased sand, and preparing stock pile should be carried out. In the rainy season of the second year, excavation of the channel (from three meters to six meters in depth) should be carried out at the same area excavated in the dry season of the first year. Excavated clay from the depth of 3-6 m should be disposed because water content of these clay is very high and it is not available as material of embankment. In the dry season of the second year, at the third section from downstream, excavation of the channel should be carried out, and at the same time, the embankment at the most downstream section should be carried out. In the same way, if this construction work is carried out until the dry season of the fifth year, excavation and embankment in the extension of 2 km in length are completed.

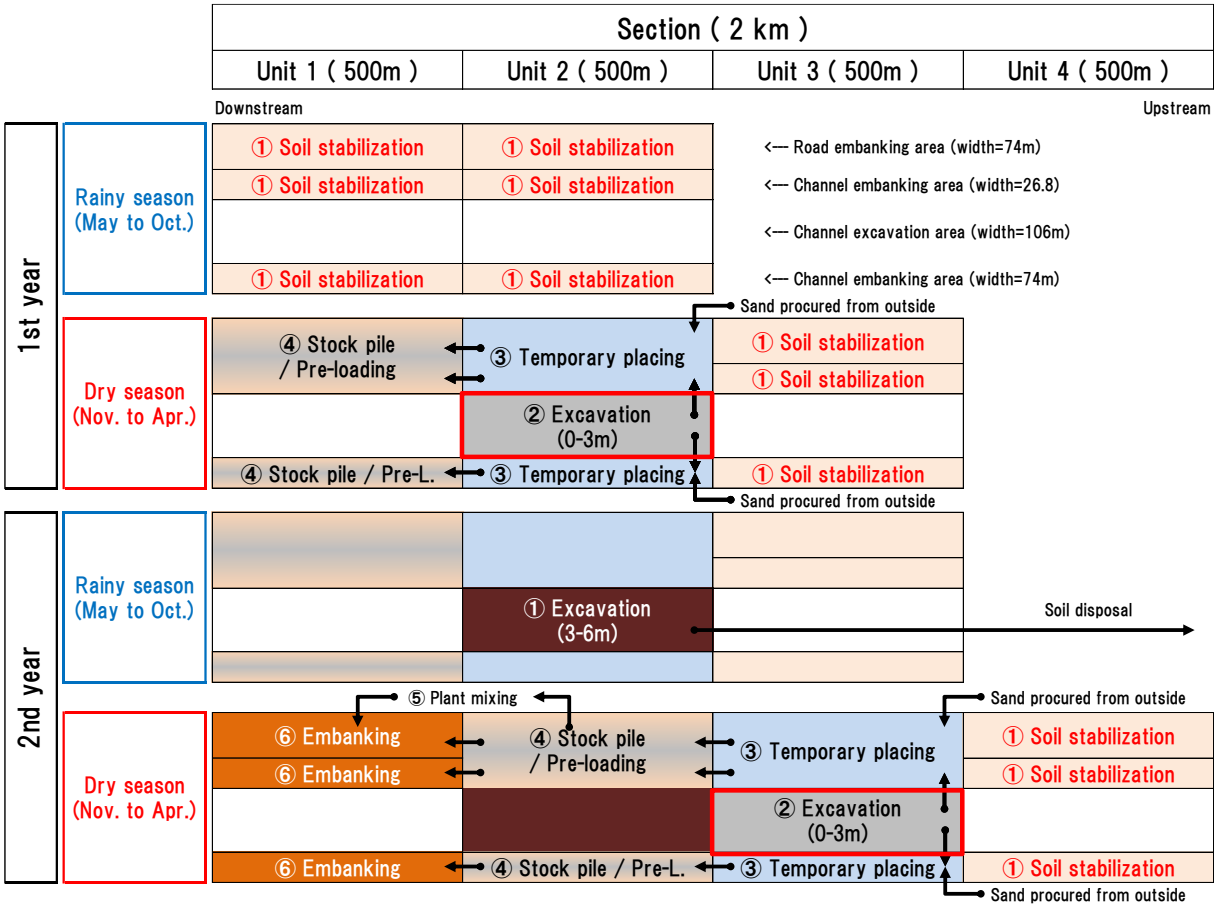


Source : JICA study team

Figure 7.8.1 Five year construction process of Outer Ring Road and Diversion Channel combined construction

7.8.2 Construction process during first two years

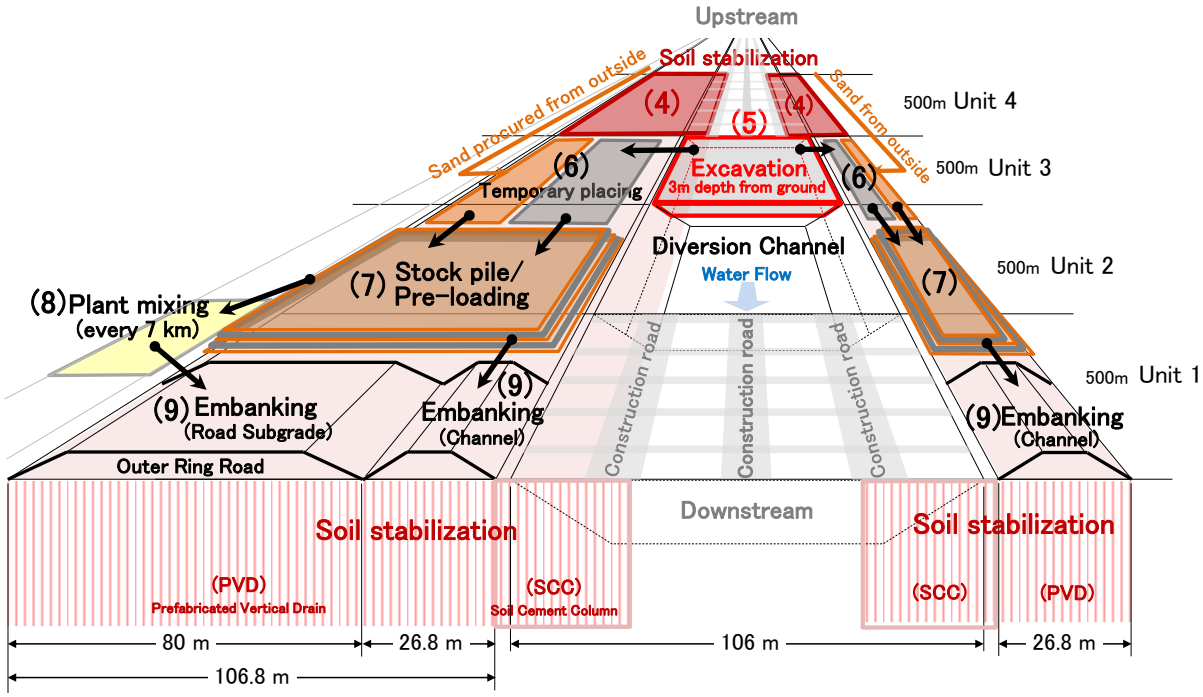
Taking construction site D as an example, here is a brief instruction of the construction steps for the first 2 years. The construction steps in one Unit is shown in the figure below. The construction process in the first two years of the total 5 year construction period, demonstrated in one section, is shown in the figure below. Excavation and embankment construction shall be carried out from downstream towards upstream within the respective section. In the rainy season of the first year, soil stabilization shall be carried out in two downstream units. In the dry season of the first year, further upstream soil stabilization, excavation from the ground to 3 m depth, temporary placing of excavated soil, and preparing stockpile shall be carried out. The prepared stockpile is kept as it is for a year and it functions as pre-loading in the site (embankment area). In the rainy season of the second year, excavation shall be performed at a depth of 3 to 6 m. Soil generated by this excavation is disposed as a remained soil. In the dry season of the second year, construction shall be carried out in the same way as in the dry season of the first year, and embankment of the most downstream unit shall be carried out. By this time, for the embankment of the Diversion Channel, clay and sand shall be mixed up by cutting off the prepared stockpile. Regarding the road embanking, after cutting off the stockpile, the mixed soil shall be further mixed in a mixing plant used for road embankment. Although the above method is generally assumed, but depending on circumstances, Levels-1 to 4 (as mentioned above) shall be appropriately utilized case by case.



Source : JICA study team

Figure 7.8.2 Construction process in the Section

Details of the construction process in one Section from (4) Soil Stabilization to (9) Embanking in the dry season of the second year are as shown in the figure below.



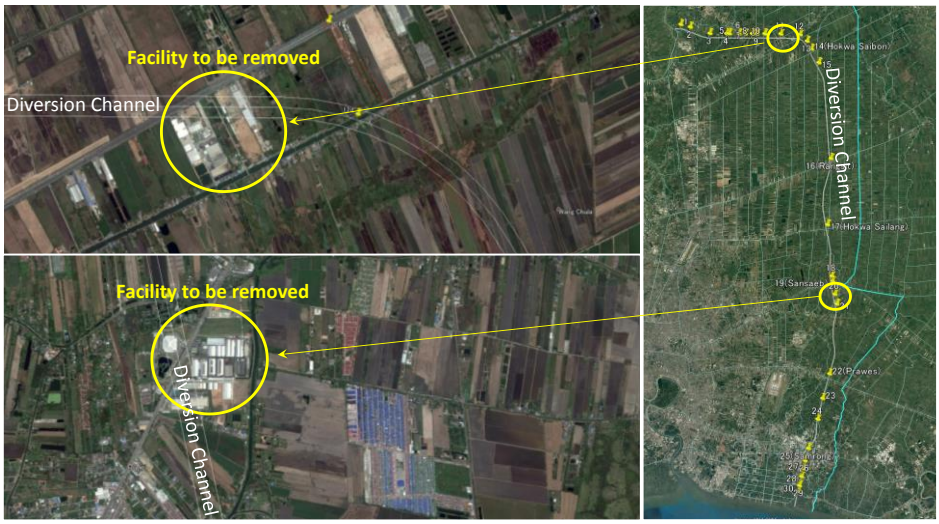
Source : JICA study team

Figure 7.8.3 Construction process in the dry season of second year

7.9 Work contents in each construction step

7.9.1 Removal Existing Facilities

Existing facilities in construction sites will be removed. It is assumed that removal of existing facilities can be finished during the rainy season of the 1st year. However, detailed survey about existing facilities' condition and how long it takes to remove them is needed in the future.



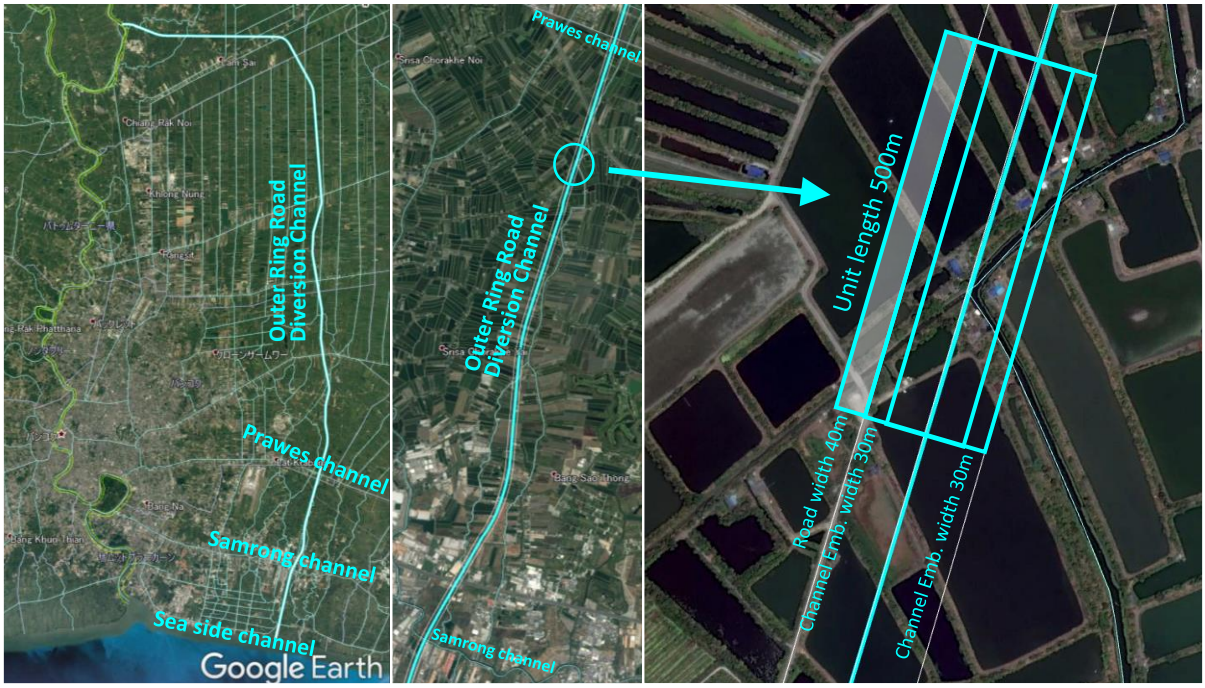
Source : JICA study team

Figure 7.9.1 Removal Existing Facilities

7.9.2 Reclamation / Laying Construction Road

(1) General description

The downstream of Prawes Channel (23km from estuary) is presently used as culture pond. Before the excavation of the Diversion Channel, these ponds shall be dried by reclamation or pumping. Construction steps are shown as follows. Both sides of channel bank in the unit will be built by reclamation soil. Reclamation on left bank will be 30m wide to build a dike of the Diversion Channel while 70m on the right bank for dike and road. Reclamation will also be applied to both upstream and downstream of the unit, then existing irrigation canals will be linked to dry the excavation site.



Source : JICA study team

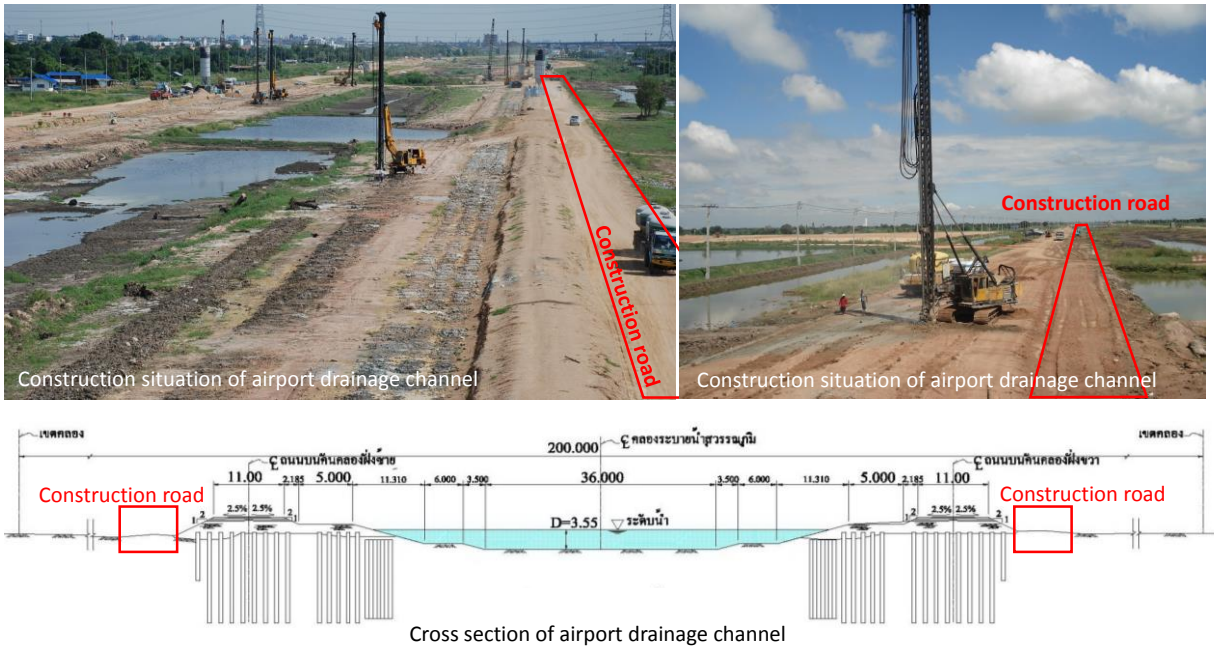
Figure 7.9.2 Wetland Reclamation at the southern part of Outer Ring Road Diversion Channel

There are culture ponds in Southern Section of the DC. Construction road will be laid by reclaiming these ponds. Following photo is taken during the construction of Suvarnabhumi Airport Drainage Channel which shows the reclamation situation.

Source : RID document

Figure 7.9.3 Situation of Laying Construction Road during the Suvarnabhumi Airport Drainage Channel construction period

Construction road was laid at the outside of the channel during construction period of Suvarnabhumi Airport Drainage Channel as shown in following figure.



Source : RID document

Figure 7.9.4 Construction Road laying situation during construction period of Suvarnabhumi Airport Drainage Channel

(2) Work quantities

Total reclamation width is supposed to be 100m, including 26.8m for dike, 3m for the berm, and 40m for construction road respectively. By assuming reclamation depth to be 2m, work quantity for one Unit is estimated to be 100,000m^3 (width 100m×depth 2m×length 500m). Then, apart from reclamation along river banks, reclamation in longitudinal direction (20m wide, 106m long and 2m deep) is also essential in order to dry the channel, causing 4,240m^3 in addition. Therefore, the total work quantity for one Unit is estimated as 105,000m^3.

(3) Construction method/Construction machines / Work days

350 10t-level dump trucks will be used to transport soil for reclamation from sand pit, about 20km away, to construction sites. Transported soil will be placed evenly by 10 15t-level bulldozers. Transporting capacity of one dump truck is supposed to be 2.4m^3/hr when from 20km away, thus total capacity for 350 dump trucks will be 5,869m^3/d (7 hours per day). As for bulldozers, they can place 83.5m^3/hr when placing distance is 20m, thus total capacity for 7 bulldozers will be 5,844m^3/d (7 hours per day). Therefore, work days will be 72 days (work quantity 42,000m^3 divided by 5,844m^3/d).

7.9.3 Changing Route of Existing Channel

In order to keep existing canals functional, transition work will be done where the Diversion Channel runs across these canals. Meanwhile, siphon will be built to maintain these canals working after the construction of the Diversion Channel. The transition is supposed to be finished during the dry season of the 1st year. As a reference, following photos are taken before (2004) and during (2008) the construction of Suvarnabhumi Airport Drainage Channel.

Source : JICA study team

Figure 7.9.5 Situation of Changing Route of Existing Channel during Suvarnabhumi Airport Drainage Channel construction period

7.9.4 Soil Stabilization

(1) General description

Soil stabilization shown below will be applied to middle and southern part. Specifically, Soil Cement Column (SCC) will be applied to the slope part of the bank on both sides of the Diversion Channel. As for embankment part of dike and road, Prefabricated Vertical Drain (PVD) method will be utilized to restrain the subsidence.

(2) Work quantities

Work quantities in one Unit (500m length) is shown in the following table.

Table 7.9.1 Work quantities of Soil Stabilization per Unit (500m)

Items		Unit 1,2 (Implement in two Units during rainy season in 1st year)		Unit 3,4 (Implement in each Unit during dry season)	
		Central part	Southern part	Central part	Southern part
SCC (m^3/500m)	Channel	136,000	270,540	68,000	135,270
PVD Sand mat (m^3/500m)	Channel	26,800	26,800	13,400	13,400
	Road	46,600	36,400	23,300	18,200
	Total	73,400	63,200	36,700	31,600
PVD (m/500m)	Channel	207,000	810,000	103,500	405,000
	Road	291,400	1,089,600	145,700	544,800
	Total	498,400	1,899,600	249,200	949,800

Source : JICA study team

(3) Construction method / Construction machines / Work days

1) SCC (Soil cement Column)

Standard machines layout for the installation of Soil Cement Column (SCC) is shown in the following figure. Before installing SCC with base machine, it is necessary to install slurry pump, cement silo and other devices. These preparation will be conducted before installing SCC during preparation period. Therefore, this process will not delay the SCC installing work.

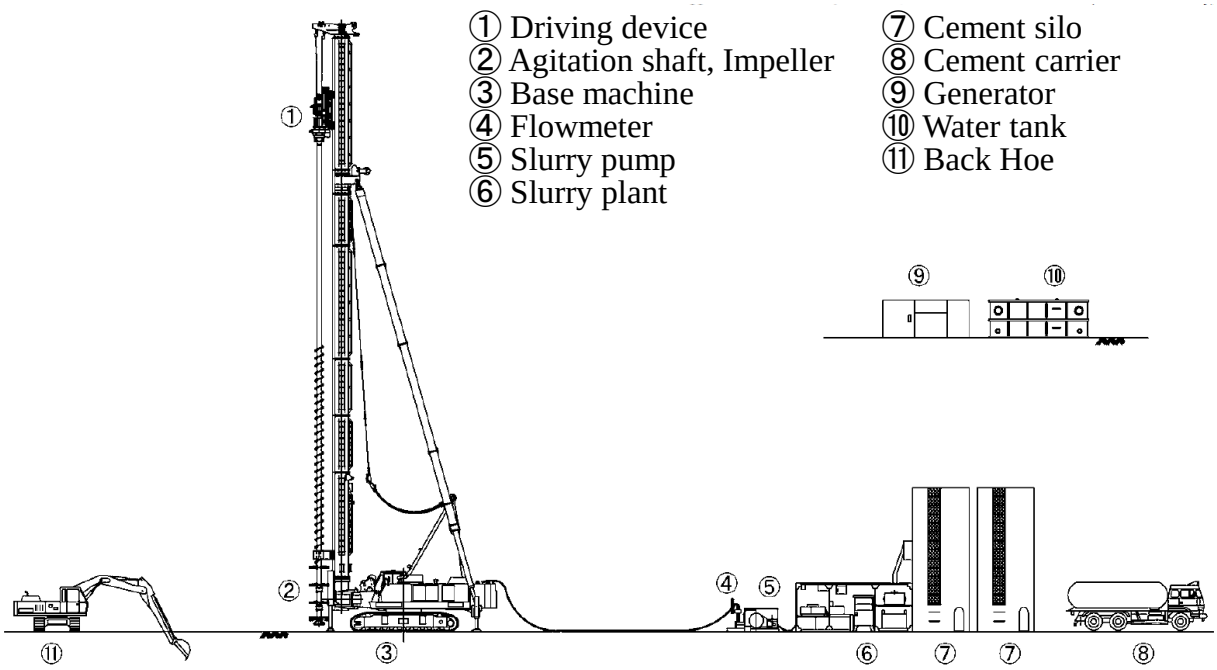


Figure 7.9.6 Standard machines layout for the installation of Soil Cement Column (SCC)

2) PVD (Prefabricated Vertical Drain)

Sand mat will be laid in the Prefabricated Vertical Drain (PVD) installation area, therefore, purchased sand will be transferred by 10t-class dump truck. And scattered sand from dump truck will be laid by 15t-class bulldozer. PVD will be installed by 0.8m^3-class base machine attached casing.

< Construction in Unit 1 & 2 during rainy season > : construction will be operated in Unit 1 & 2 during the rainy season in the first year. Therefore, work quantity is 2 times of that in Unit 3 & 4. As given previously, unit working capacity of 10t-level dump truck is 8.9m^3/hr and 83.5m^3/hr for 15t-level bulldozer (placing distance 20m). For 27 dump trucks and 5 bulldozers, total working capacity will be 2,894m^3/d and 2,922m^3/d respectively. On the other hand, work quantity of sand mat and daily working capacity are estimated to be 73,400m^3 and 2,894m^3/d, therefore, 25 days will be needed for sand mat paving. As for construction of PVD, the work quantity and working capacity are 498,400m and 2,000m/d, thus 50 days will be counted. In total, sand mat and PVD supposedly requires 75 days for construction which is smaller than construction-possible days of rainy season (75 days).

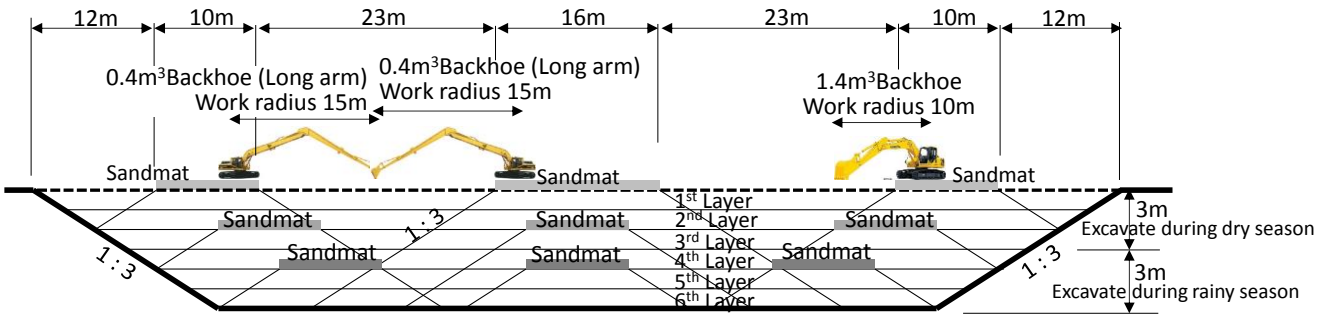
< Construction in Unit 3 & 4 during dry season > : construction will be operated in Unit 3 & 4 during the dry season. As given previously, unit working capacity of 10t-level dump truck is 8.9m^3/hr and 83.5m^3/hr for 15t-level bulldozer (placing distance 20m). For 15 dump trucks and 3 bulldozers, total working capacity will be 1,608m^3/d and 1,753m^3/d respectively. On the other hand, work quantity of sand mat and daily working capacity are estimated to be 36,700m^3 and 1,608m^3/d, therefore, 23 days will be needed for sand mat paving. As for construction of PVD, the work quantity and working capacity are 249,200m and 2,000m/d, thus 125 days will be counted. In total, sand mat and PVD supposedly requires 147 days for construction which is smaller than construction-possible days of dry season (150 days).

7.9.5 Excavation

(1) General description

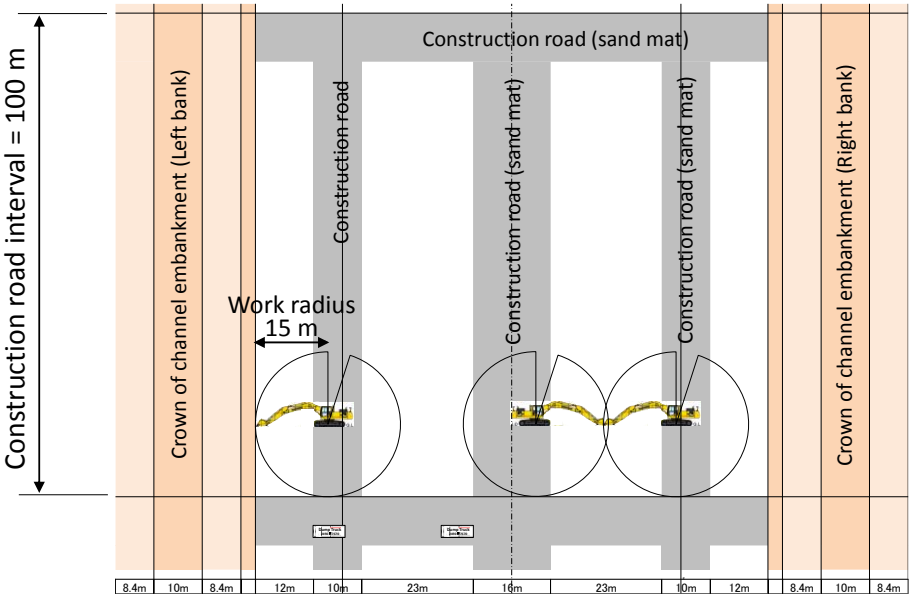
The method of excavating the Diversion Channel is basically as follows. This method was examined with reference to the construction method of Suvarnabhumi Airport Drainage Channel in Thailand. The excavation method is considered to be different in the north part, central part, and south part, depending on the soil condition of the excavation area. Therefore, the optimal method according to the soil condition of each part is adopted based on the method shown below.

- Excavation of the Diversion Channel is carried out by considering the stability of the excavation surface and installation of a heavy machine inside the channel. When the excavation is carried with heavy machines placed outside the excavation area, there is a danger of causing sliding failure in the already excavated area. Therefore, avoid placing the heavy machines outside the waterway.
- In order to place the heavy machines for excavation, side road is constructed in the area to be excavated. The road is constructed with 50 cm-thick sand layer.
- Excavation of 6 m-deep is necessary in construction of the Diversion Channel. The excavation shall be divided into 6 layers with a depth of 1 m each. After excavation of one layer, there shall be a separation by a period of several days before the next excavation. This is to increase and maintain the stability of the excavation surface.
- The gradient of the excavated slope shall be 1:3.
- Excavation from ground level to 3 m in depth shall be done during the dry season (November to April), and the next excavation from 3 m to 6 m in depth shall follow during the rainy season (May to October).
- 1.4m^3-class backhoe, whose work range is 10m, will be used for excavation in area that is less than 10m away from the edge of construction road. As for area of 10 ~ 15m away, 0.4m^3-class backhoe with a 15m-long arm will be used.



Source : JICA study team

Figure 7.9.7 Cross section image of the Diversion Channel Excavation



Source : JICA study team

Figure 7.9.8 Plane figure of Diversion Channel Excavation

(2) Work quantities

Work quantities in one Unit (500m length) is shown in the following table.

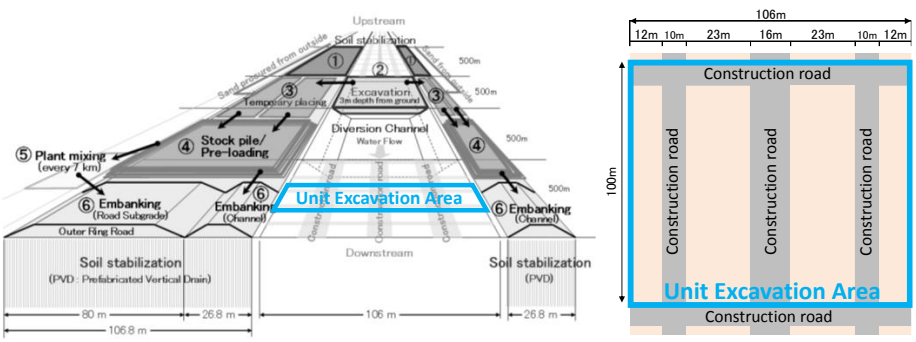
Table 7.9.2 Work quantities of Excavation per Unit (500m)

Items		Work quantities (m^3/500m)		
		Northern part	Central part	Southern part
Construction road (Sandmat)	Dry season : ground level ～ 3m depth	19,850		
	Rainy season : 3～6m depth	8,800		
	Total	28,650		
Excavated soil	Dry season : ground level ～ 3m depth	145,500		
	Rainy season : 3～6m depth	118,500		
	Total	264,000		
Remained soil	Dry season : ground level ～ 3m depth	107,500	21,600	61,500
	Rainy season : 3～6m depth	118,500	118,500	118,500
	Total	226,000	140,100	180,000

Source : JICA study team

(3) Construction method

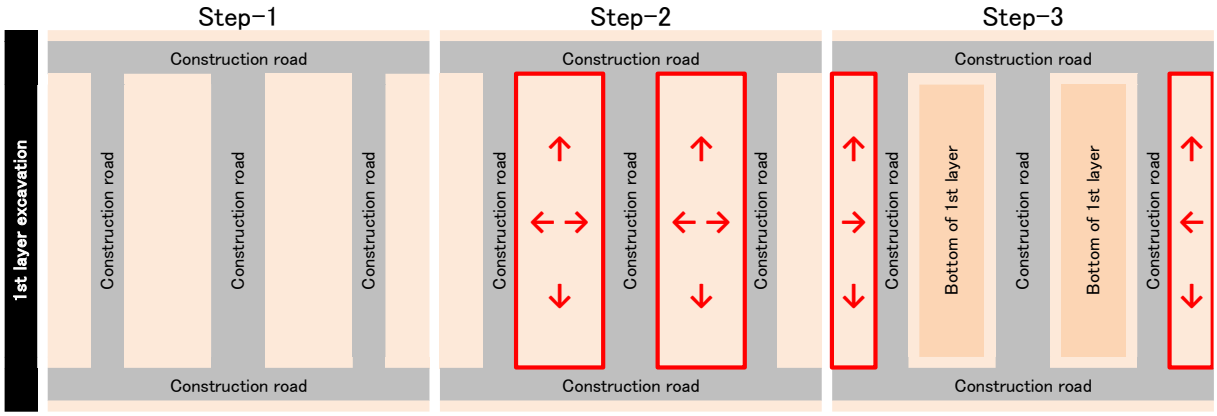
Excavation steps in one Unit Excavation Area is shown in the following figures.



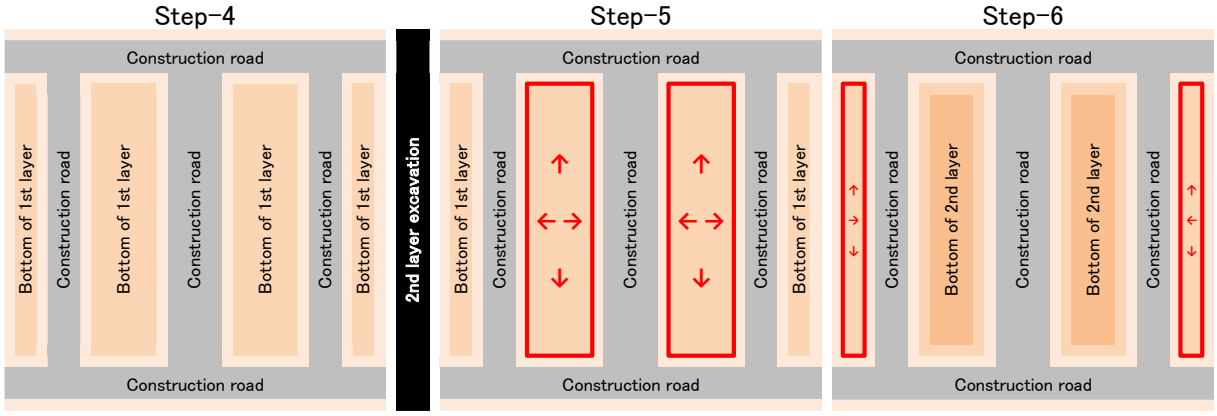
Source : JICA study team

Figure 7.9.9 Explanation of Unit Excavation Area

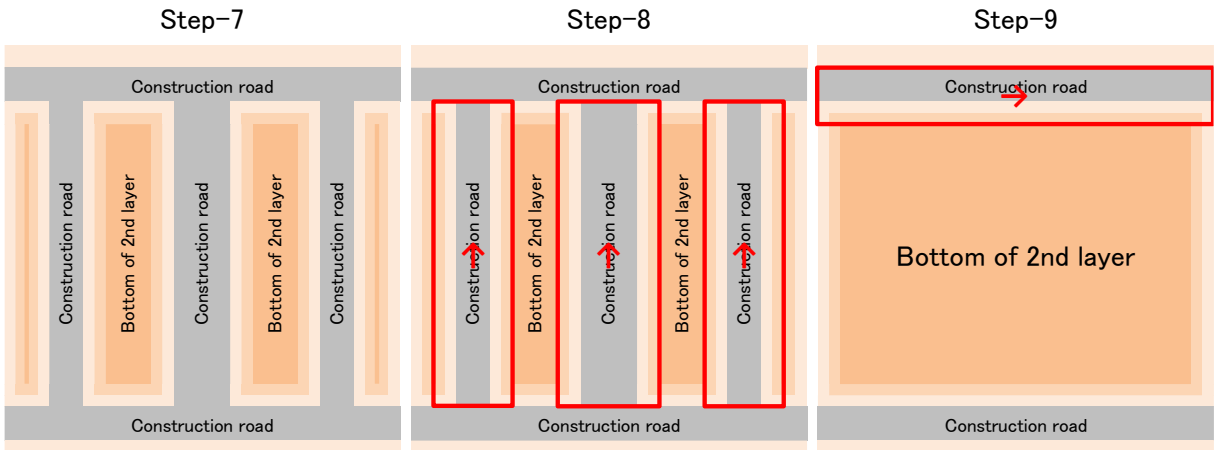
Right figure in the above figures indicates the detail of the blue line area in the left figure. The following figures indicates the excavation steps in one Unit Excavation Area.



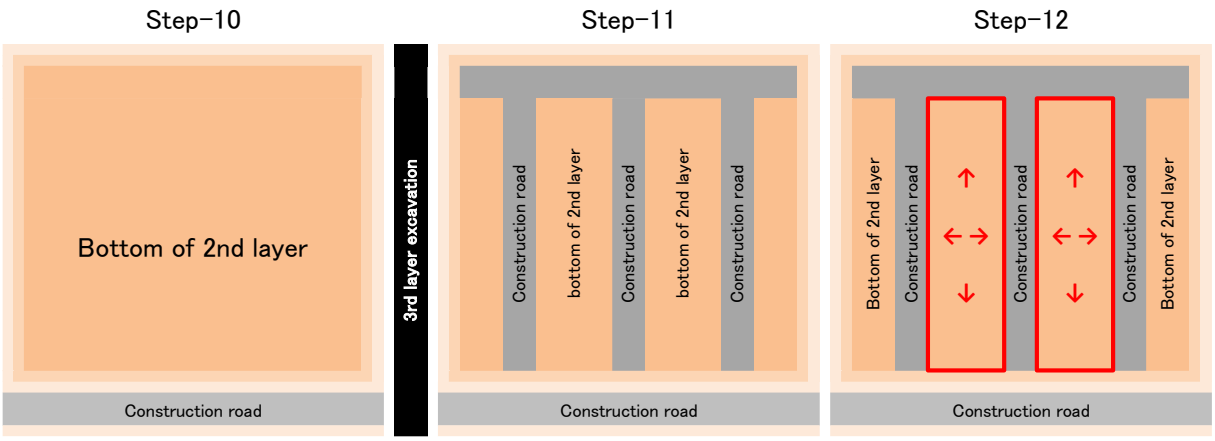
Step-1: pave sand mat as construction road. Step-2: excavate red-framed area in arrowed direction with backhoes on construction road. Step-3: excavate in the same way with backhoes on the construction road inside the channel. Backhoes shall not be placed outside the channel in order to prevent slope failure.



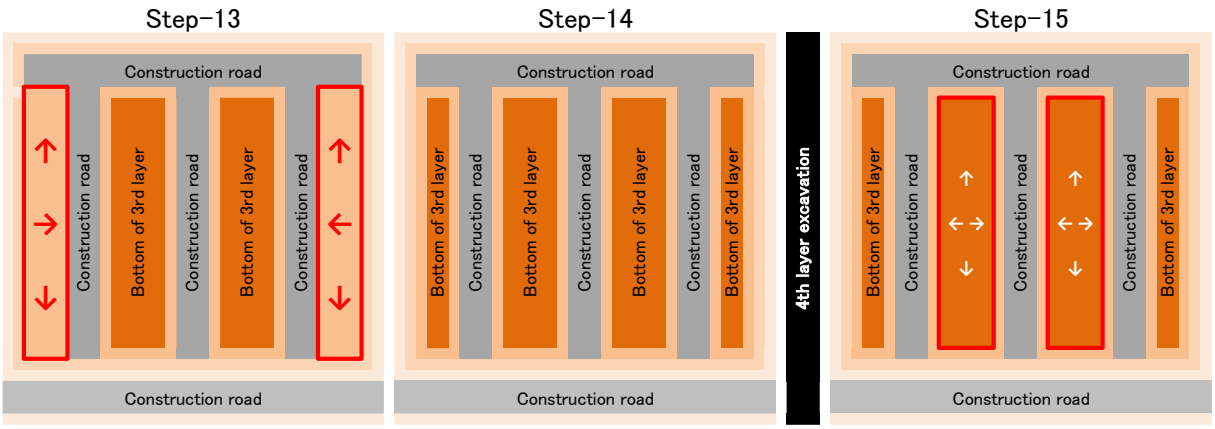
Step-4: complete the 1st layer (1m deep from ground surface) except construction road area. Step-5: excavate the 2nd layer (1~2m deep) by repeating Step-2. Step-6: repeat Step-3 for the 2nd layer. Number in the figure means layer number. (For example, 2 means excavating until the bottom of the 2nd layer.)



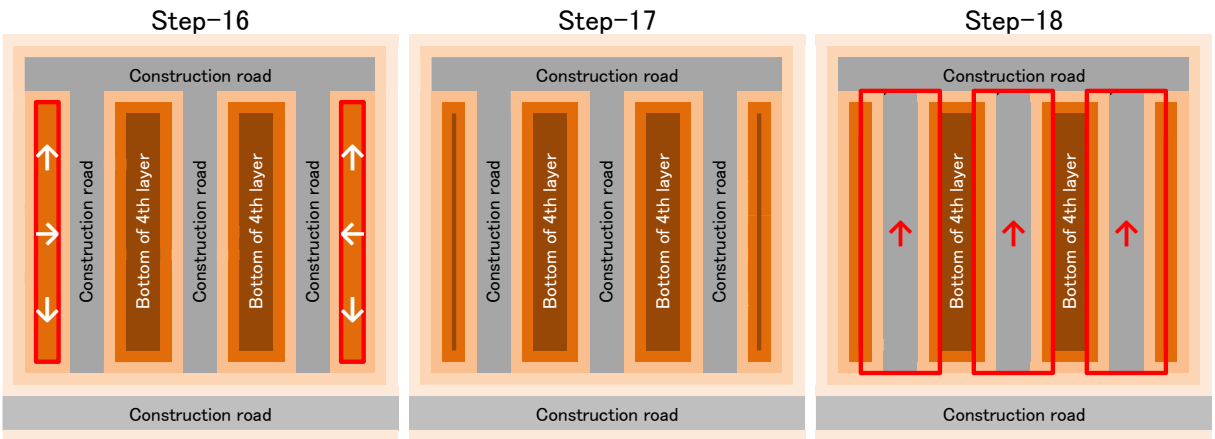
Step-7: complete the 2nd layer except construction road area. Step-8: excavate red-framed construction road in arrowed direction with backhoes. Remove the construction road after excavating every 2m and pave new construction road on the excavated bottom. (Maximum excavating depth from the construction road is assumed to be 2m). Step-9: excavate red-framed construction road in arrowed direction with backhoes.



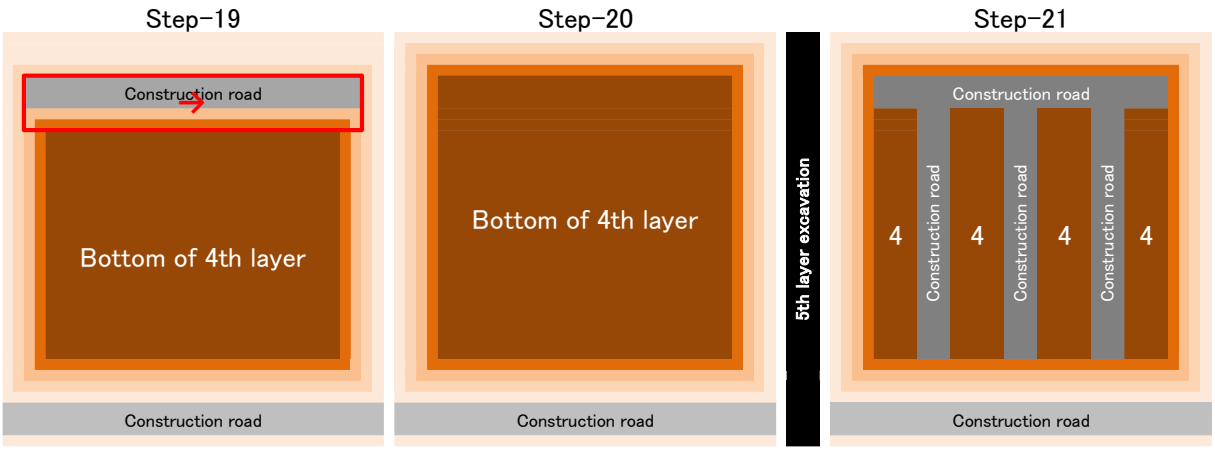
Step-10: complete the entire 2nd layer. Step-11: pave new construction road (sand mat) on the bottom of the 2nd layer. Step-12: begin excavation for the 3rd layer (2~3m deep). Excavate red-framed construction road in arrowed direction with backhoes.



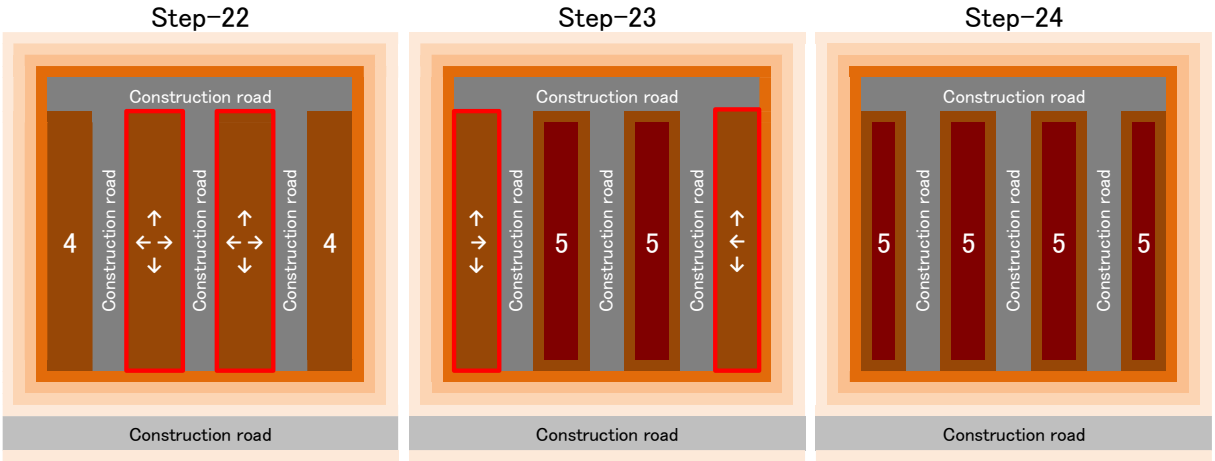
Step-13: excavate in the same way with backhoes on the construction road inside the channel. Step-14: complete the 3rd layer except construction road area. Step-15: begin excavation for the 4th layer (3~4m deep). Excavate red-framed construction road in arrowed direction with backhoes.



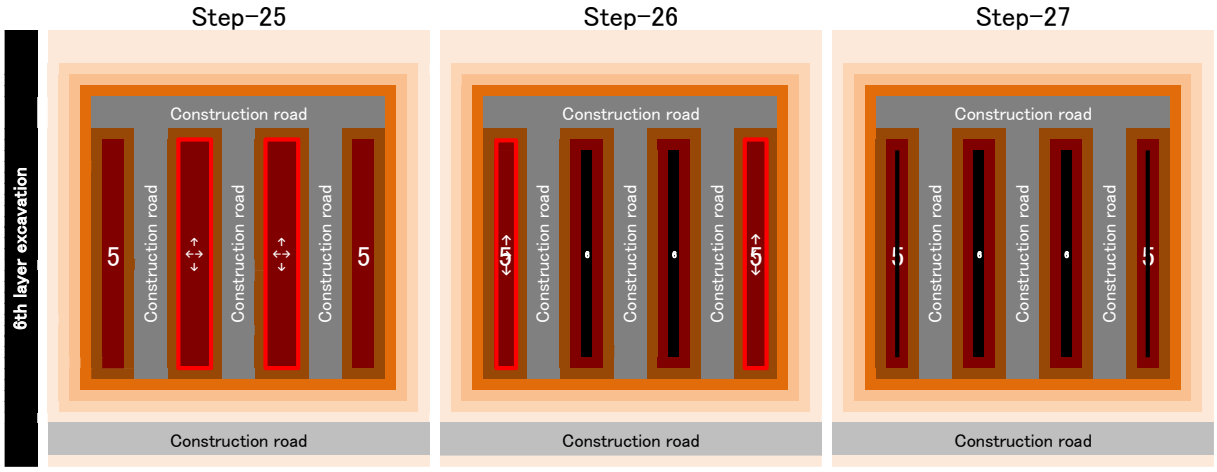
Step-16: excavate in the same way with backhoes on the construction road inside the channel. Step-17: complete the 4th layer except construction road area. Step-18: Excavate red-framed construction road in arrowed direction with backhoes.



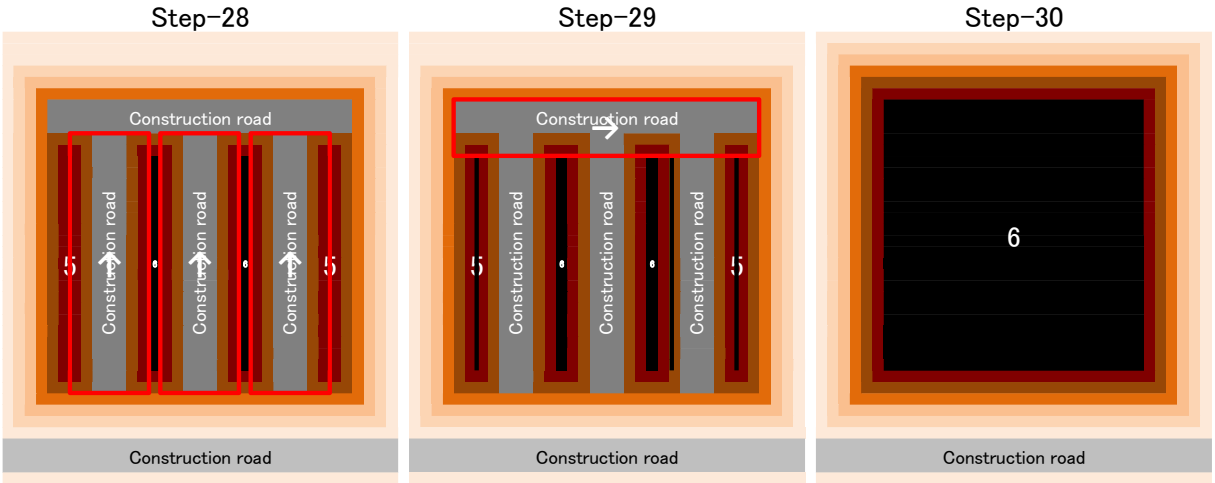
Step-19: excavate in the same way with backhoes on the construction road inside the channel. Step-20: complete the entire 4th layer. Step-21: pave new construction road (sand mat) on the bottom of the 4th layer.



Step-22: begin excavation for the 5th layer (4~5m deep). Excavate red-framed construction road in arrowed direction. Step-23: excavate in the same way with backhoes on the construction road inside the channel. Step-24: complete the 5th layer except construction road area.



Step-25: begin excavation for the 6th layer (5~6m deep). Excavate red-framed construction road in arrowed direction. Step-26: excavate in the same way with backhoes on the construction road inside the channel. Step-27: complete the 6th layer except construction road area.



Step-28: Excavate red-framed construction road in arrowed direction with backhoes. Step-29: excavate in the same way with backhoes on the construction road inside the channel. Step-30: complete the entire 6th layer.

Source : JICA study team

Figure 7.9.10 Diversion Channel excavation steps

(4) Construction machine / Work days

1) Transportation of construction road material (from sand pit to construction yard)

50cm Sand mat is paved on ground surface and excavated bottoms of 2m and 4m deep. The material will be transported from a 20km-away sand pit using 12 10t-level dump trucks and then paved by 15t-level bulldozers. Unit working capacity is given as 2.4m^3/hr for dump truck and 83.5m^3/hr for bulldozer. Thus total capacity are estimated to be 201m^3/d for 12 dump trucks, and 584m^3/d for 1 bulldozer. On the other hand, work quantity is 28,650m^3 while the daily working capacity is 201m^3/d. Therefore 42 days will be needed which is less than construction-possible days (150days) of a dry season.

2) Excavation from ground level to 3m depth during dry season

< Laying construction road (sand mat) > Sand will be loaded onto dump trucks by using 1.6m^3-class tractor shovels in a temporary sand pit which is 500m downstream to the Unit. Then sand will be transported to construction site by dump truck, paved and double compacted by bulldozers. Unit working capacity is supposed to be 19.3m^3/hr for tractor shovel, 13.0m^3/hr for dump truck and 41.7m^3/hr for bulldozer. Thus total capacity are estimated to be 676m^3/d for 5 tractor shovels, 636m^3/d for 7 dump trucks, and 584m^3/d for 2 bulldozers. On the other hand, work quantity is 3,970m^3 while the daily working capacity is 584m^3/d. Therefore, 7 days will be needed.

< Excavation > Excavation will be conducted with 1.4m^3-class backhoes and 0.4m^3-class long-arm backhoes. Excavated soil will be transported to temporary disposal place by dump truck since it is going to be utilized as embanking material. Unit working capacity is supposed to be 38.9m^3/hr for 1.4m^3-level backhoe, 11.1m^3/hr for long-arm backhoe, and 14.3m^3/hr for dump truck. Thus total capacity are estimated to be 1,089m^3/d for 4 backhoes, 311m^3/d for 4 long-arm backhoes, and 1,099m^3/d for dump 11 trucks. On the other hand, work quantity is 145,500m^3 while daily working capacity is the total of two kinds of backhoes, 1,400m^3/d. Therefore, 104 days will be needed. Added with essential days for paving

construction road and waiting excavated slope stabilized, this is still less than construction-possible days of a dry season (150days).

< Remained soil disposal > Surplus soil disposal is required since only a part of excavated soil is planned to be utilized as embanking material. Surplus soil will be temporarily placed in adjacent Unit excavation area upstream to where the soil is excavated. Temporarily placed soil will be loaded onto 10t-level dump trucks by 1.6m^3-class tractor shovel, and then transported to a final disposal 70km away. Unit working capacity is supposed to be 19.3m^3/hr for tractor shovel, 0.78 m^3/hr for dump truck. Work hour is 12 hours per day. Thus total working capacity is 232 m^3/d for 1 tractor shovel and 121m^3/d for 13 dump trucks. On the other hand, work quantity is estimated as 21,000m^3, therefore, 174 days is needed which is small than dry-season days on the calendar (181days).

3) Excavation from 3m depth to 6m depth during rainy season

< Construction road (sand mat) > Construction method, machine amount, and working capacity are supposed as same as in dry season. Work quantity is 1,760m^3 and daily working capacity is 584m^3/d, thus 3 days will be satisfied.

< Excavation > Construction method is the same as in dry season. In order to finish in 75 days, additional machines is required. Unit working capacity is supposed to be 38.9m^3/hr for 1.4m^3-class backhoe, 11.1m^3/hr for 0.4m^3-class long-arm backhoe, and 14.3m^3/hr for 10t-Class dump truck. Work is 7 hours per day. Thus total capacity are estimated to be 1,633m^3/d for 6 backhoes, 467m^3/d for 6 long-arm backhoes, and 2,198m^3/d for dump 22 trucks. On the other hand, work quantity is 118,500m^3 while daily working capacity is the total of two kinds of backhoes, 2,100m^3/d. Therefore, 56 days will be needed. Added with essential days for paving construction road and waiting excavated slope stabilized, this is still less than construction-possible days of a rainy season (75days).

< Remained soil disposal > Excavated soil from 3m~6m depth during the rainy season is supposed to be Surplus soil instead of embanking material due to its high moisture content. The soil will be temporarily placed in adjacent Unit excavation area upstream to where the soil is excavated. Then it will be loaded onto 10t-class dump trucks by 1.6m^3-class tractor shovel, and transported to a final disposal 70km away. Unit working capacity is supposed to be 19.3m^3/hr for tractor shovel, 0.78m^3/hr for dump truck. Work hour is 18 hours per day. Thus total working capacity is 676m^3/d for 5 tractor shovels and 656m^3/d for 47 dump trucks. On the other hand, work quantity is estimated as 118,500m^3, therefore, 181 days is needed which is small than rainy-season days on the calendar (184days).

7.9.6 Temporary Placing

(1) General description

Soil, which is not deeper than 3m from the ground level, excavated in dry season can be utilized as embankment material, thus it shall be temporarily placed in designated area.

(2) Work quantities

From ground surface to 3m depth, work quantity in a Unit (500m) during dry season is 145,500m^3.

(3) Construction method / Construction machines / Work days

Excavated soil in temporary placing site will be placed evenly by 15t-class bulldozers. Unit working capacity is 83.5m^3/hr (1,169m^3/d for 2, 7 hours per day). Therefore, 124 days is needed.

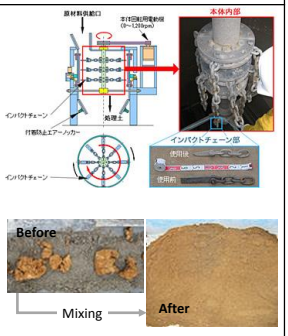
7.9.7 Preparing Stock Pile / Pre-Loading

(1) General description (Mixing methods of clay and sand)

Regarding the method for mixing clay and sand, the following four methods shown in the table below are proposed. Level-1 and Level-2 are for the uses of soil mixtures as a material for the construction of the Diversion Channel embankment. While Level-3 and Level-4 are those for the Ring Road embankment.

Table 7.9.3 Mixing methods of clay and sand

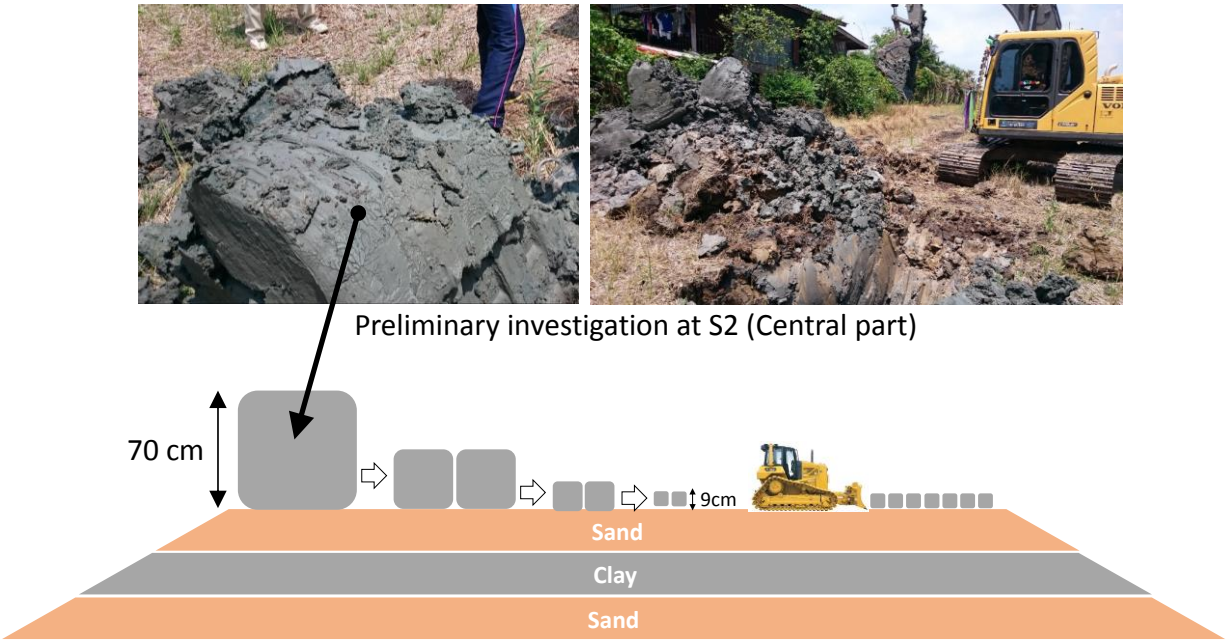
Simple mixing ⟷ Plant mixing

	Level-1	Level-2	Level-3	Level-4
	Stock-Pile	Mixing by Stabilizer	Plant Mixing	Twister Mixing (Rotary crushing and mixing)
Mixing Method	Push down stock-pile by bulldozer and drop pushed down soil about three times by wheel loader ＜Stock-Pile Preparing Method＞ 1) Excavate clay by clamshell or Backhoe 2) Dry up excavated clay under sun shine during temporary placing and split mass clay into small pieces 3) Prepare stock-pile stacking clay and sand alternately	Mix at embanking work site by Stabilizer 	Set up stationary type plant. Clay and sand that are put into this plant will be stirred and mixed. 	
Application	This method is adopted aiming to shorten construction period and reduce construction cost.	This method is adopted as an additional process to Level-1 method if mixing using Level-1 method is insufficient.	This method is adopted to mix more carefully than Level-2 method. If clay and sand mixing is difficult, Level-4 method is adopted.	This method is adopted to mix three or more kinds of materials for example clay, sand and lime. Plant mixing except for this method can mix only two kinds of materials.

Source : JICA study team

For all the mixing methods shown in the above table, it is necessary to consider an appropriate method according to the situation at the construction site. The results of the study are shown below. Regarding the Level-1, the stockpile where clay and sand are stacked alternately is created in the planned embankment area on the left and right banks of the Diversion Channel. The area of the bottom of the stock pile shall be approximately 5,000 m^2 (about 100 meters in width and about 500 meters in length in the upstream and

downstream direction) on the right bank, and approximately 3,000 m^2 on the left bank (about 30 meters in width and about 500 meters in length in upstream and downstream direction). Stockpile shall be built in the dry season for about 150 days. The size of the mass of clay immediately after excavation is assumed to be approximately 70 cm. The clay shall be placed on a layer of sand and sliced to a required size by backhoe or manpower work and then dry it on the sun at the same time.



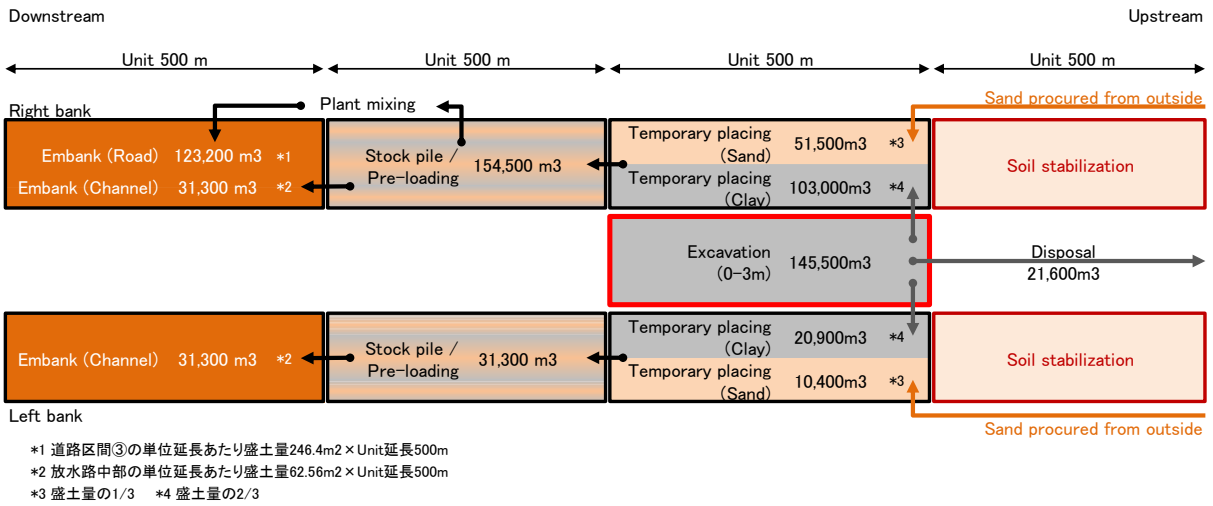
Source：JICA study team

Figure 7.9.11 Stock Pile stacking clay and sand alternately

(2) Work quantities

1) Required volume of stock pile in the Section of Central part

In this study, the target section is the section that is corresponds to ③ in the classification of the Outer Ring Road and corresponds to "Central" in the classification of the Diversion Channel. Regarding this section, the result of setting the amount of soil is as shown below. The amount of soil required for embankment of road and channel in one unit is as follows. Road embankment in the right bank of the channel is 123,200 m^3. Right embankment of the channel is 32,200 m^3 .Left embankment of the channel is 32,200 m^3. For these embankments it is necessary to prepare stockpiles of 155,400 m^3 on the right bank and 32,200 m^3 on the left bank. Stock piles are prepared by stacking clay (excavated soil) and sand at a ratio of 2 : 1 in layers. Therefore, temporary placing of 103,600 m^3 clay and 51,800 m^3 sand is required on the right bank. Sand is bought and transported to temporary placing yard. For clay, excavated soil is transported to temporary placing yard. The amount of clay generated when excavating channel to 3 m depth is 145,500 m^3. The amount of soil that exceeds the amount required for the embankment is disposed.



Source : JICA study team

Figure 7.9.12 Construction process of the Outer Ring Road and Diversion Channel in the dry season of second year

2) Required area for the preparation of stock pile

In this study, the target section is the section that is corresponds to ③ in the classification of the Outer Ring Road and corresponds to "Central" in the classification of the Diversion Channel. In this section, stock pile of 155,400m^3 at the right bank and stock pile of 32,200m^3 at the left bank should be prepared. It is desirable that stockpiles are prepared in approximately one unit. As shown in the table below, clay and sand are alternately stacked with 106.8m width of the bottom of stock pile, 511m length of the bottom in the upstream and downstream direction, embankment gradient 1: 1.5, 3m height, and stock pile of 155,465m^3 can be prepared. The stock pile length 511 m is 11 m longer than the unit length 500 m. However, the unit adjacent to the downstream side of the unit that prepares the stock pile is the unit where embankment is done. The embankment construction is carried out while breaking the stock pile. Therefore, even if the stock pile is prepared temporarily in the unit for embankment only 11 m in length, inconvenience in construction does not occur. At the left bank, clay and sand are alternately stacked with 26.8m width of the bottom of stock pile, 486m length of the bottom in the upstream and downstream direction, embankment gradient 1: 1.5, 3m height, and stock pile of 32,233m^3 can be prepared.

Table 7.9.4 Area and volume of stock pile

Layer	Soil	Thickness	Height	Right bank						Left bank						Total	
				Bottom Length	Bottom Width	Upper Length	Upper Width	Area	Volume	Bottom Length	Bottom Width	Upper Length	Upper Width	Area	Volume	Area	Volume
		m	m	m	m	m	m	m2	m3	m	m	m	m	m2	m3	m2	m3
8th layer	Clay	0.50	2.50	503.50	99.30	502.00	97.80	49,998	24,773	478.50	19.30	477.00	17.80	9,235	4,431	59,233	29,204
7th layer	Sand	0.25	2.25	504.25	100.05	503.50	99.30	50,450	12,556	479.25	20.05	478.50	19.30	9,609	2,355	60,059	14,911
6th layer	Clay	0.50	1.75	505.75	101.55	504.25	100.05	51,359	25,452	480.75	21.55	479.25	20.05	10,360	4,992	61,719	30,444
5th layer	Sand	0.25	1.50	506.50	102.30	505.75	101.55	51,815	12,897	481.50	22.30	480.75	21.55	10,737	2,637	62,552	15,534
4th layer	Clay	0.50	1.00	508.00	103.80	506.50	102.30	52,730	26,136	483.00	23.80	481.50	22.30	11,495	5,558	64,226	31,694
3rd layer	Sand	0.25	0.75	508.75	104.55	508.00	103.80	53,190	13,240	483.75	24.55	483.00	23.80	11,876	2,921	65,066	16,161
2nd layer	Clay	0.50	0.25	510.25	106.05	508.75	104.55	54,112	26,825	485.25	26.05	483.75	24.55	12,641	6,129	66,753	32,954
1st layer	Sand	0.25	0.00	511.00	106.80	510.25	106.05	54,575	13,586	486.00	26.80	485.25	26.05	13,025	3,208	67,600	16,794
total	Clay							208,199	103,187					43,731	21,110	251,930	124,297
	Sand							210,030	52,278					45,247	11,122	255,277	63,401
	total	3.00						418,229	155,465					88,979	32,233	507,207	187,698

Source : JICA study team

(3) Construction method / Construction machines / Work days

1) In case of working time per day is 7 hours

In one unit, it is necessary to prepare stock piles of 155,465m^3 on the right bank and 32,233m^3 on the left bank. The stock piles are prepared by the following process. 1) Load the temporarily placed clay and sand into the dump truck by a tractor excavator (wheel loader). 2) Transport the clay and sand to the stock pile construction site by the dump truck and distribute it to this site. 3) Spread clay and sand with bulldozer. Sand is spread only with bulldozer. The laying of the clay is done by working with a small backhoe and manpower work as it requires work to divide the mass clay small. The clay needs to be leveled and dried under the sunshine at the same time. For this reason, it takes about 30 days to spread the clay one layer. In order to carry out the above work within 150 workable days in the dry season as working time per day is 7 hours, 47 tractor excavators (1.6 m^3 class), 70 dump trucks (10 t class), 70 bulldozers (15 t Class) is required. In addition, as a supplementary work of clay spreading, 12 small backhoes (0.008 m^3 class) and 12 normal workers are necessary. The total working days of these heavy machines are 1,389 days for tractor excavators, 2,069 days for dump trucks, 443 days for day bulldozers, 1,440 days for small backhoes, and 1,440 days for normal workers.

Table 7.9.5 Calculation table of stock pile preparing days (in case of working time per day is 7hr)

Soil	Layer	Work item	Machine	Specification	Work capacity	N.of M.	work cap.	Minmum capcity			Volume			Work days	Total work days
											Right bank	Left bank	Total		
					a	b	c	d	e	f	g	h	i	j	k (b*j)
					m3/hr	machines	m3/hr	m3/hr	hr/day	m3/day	m3	m3	m3	days	Machine *days
Sand	1st layer	Loading	TS	1.6m3	19.30	47	907.20	907.20	7	6,350	13,586	3,208	16,794	2.64	124.29
		Transportaion	DT	10t	12.98	70	908.69								185.12
		Laying	BD	15t	61.42	15	921.29								39.67
Clay	2nd layer	Loading	TS	1.6m3	19.30	47	907.20	907.20	7	6,350	26,825	6,129	32,954	5.19	243.90
		Transportaion	DT	10t	12.98	70	908.69								363.25
		Laying	BD	15t	61.42	15	921.29								77.84
		Drying	BH etc	0.008m3										30.00	
Sand	3rd layer	Loading	TS	1.6m3	19.30	47	907.20	907.20	7	6,350	13,240	2,921	16,161	2.54	119.61
		Transportaion	DT	10t	12.98	70	908.69								178.15
		Laying	BD	15t	61.42	15	921.29								38.17
Clay	4th layer	Loading	TS	1.6m3	19.30	47	907.20	907.20	7	6,350	26,136	5,558	31,694	4.99	234.57
		Transportaion	DT	10t	12.98	70	908.69								349.36
		Laying	BD	15t	61.42	15	921.29								74.86
		Drying	BH etc	0.008m3										30.00	
Sand	5th layer	Loading	TS	1.6m3	19.30	47	907.20	907.20	7	6,350	12,897	2,637	15,534	2.45	114.97
		Transportaion	DT	10t	12.98	70	908.69								171.23
		Laying	BD	15t	61.42	15	921.29								36.69
Clay	6th layer	Loading	TS	1.6m3	19.30	47	907.20	907.20	7	6,350	25,452	4,992	30,444	4.79	225.32
		Transportaion	DT	10t	12.98	70	908.69								335.58
		Laying	BD	15t	61.42	15	921.29								71.91
		Drying	BH etc	0.008m3										30.00	
Sand	7th layer	Loading	TS	1.6m3	19.30	47	907.20	907.20	7	6,350	12,556	2,355	14,911	2.35	110.36
		Transportaion	DT	10t	12.98	70	908.69								164.37
		Laying	BD	15t	61.42	15	921.29								35.22
Clay	8th layer	Loading	TS	1.6m3	19.30	47	907.20	907.20	7	6,350	24,773	4,431	29,204	4.60	216.14
		Transportaion	DT	10t	12.98	70	908.69								321.92
		Laying	BD	15t	61.42	15	921.29								68.98
		Drying	BH etc	0.008m3										30.00	
Total		Loading	TS	1.6m3							155,465	32,233	187,698	149.6	1389.17
		Transportaion	DT	10t											2068.98
		Laying	BD	15t											443.35

T.P. : Temporary Placing S.P. : Stock Pile N.of M. : number of machines Transportation : from T.P. to S.P.
TS : TractorShovel DT : Dump Truck BD : Bulldozer BH : Backhoe

Source : JICA study team

2) In case of working time is 24 hours

In order to carry out the above work within 150 workable days in the dry season as working time per day is 24 hours, 14 tractor excavators (1.6 m^3 class), 21 dump trucks (10 t class), 5 bulldozers (15 t class) is required. The total number of working days for heavy machines are 405 days for tractor excavators, 608 days for dump trucks, 145 days for bulldozers. The supplementary work of clay spreading by 12 small backhoes (0.008 m^3 class) and 12 ordinary workers is as follows. Since it is necessary to spend days to dry clay under the sunshine, the necessary number of days is same as the case of working time per day is 7 hours.

Table 7.9.6 Calculation table of stock pile preparing days (in case of working time per day is 24hr)

Soil	Layer	Work item	Machine	Specification	Work capacity	N.of M.	work cap.	Minmum capcity			Volume			Work days	Total work days
											Right bank	Left bank	Total		
					a	b	c	d	e	f	g	h	i	j	k (b*j)
					m3/hr	machines	m3/hr	m3/hr	hr/day	m3/day	m3	m3	m3	days	Machine *days
Sand	1st layer	Loading	TS	1.6m3	19.30	14	270.23	270.23	24	6,486	13,586	3,208	16,794	2.59	36.25
		Transportaion	DT	10t	12.98	21	272.61								54.38
		Laying	BD	15t	61.42	5	307.10								12.95
Clay	2nd layer	Loading	TS	1.6m3	19.30	14	270.23	270.23	24	6,486	26,825	6,129	32,954	5.08	71.14
		Transportaion	DT	10t	12.98	21	272.61								106.71
		Laying	BD	15t	61.42	5	307.10								25.41
		Drying	BH etc	0.008m3										30.00	
Sand	3rd layer	Loading	TS	1.6m3	19.30	14	270.23	270.23	24	6,486	13,240	2,921	16,161	2.49	34.89
		Transportaion	DT	10t	12.98	21	272.61								52.33
		Laying	BD	15t	61.42	5	307.10								12.46
Clay	4th layer	Loading	TS	1.6m3	19.30	14	270.23	270.23	24	6,486	26,136	5,558	31,694	4.89	68.42
		Transportaion	DT	10t	12.98	21	272.61								102.63
		Laying	BD	15t	61.42	5	307.10								24.43
		Drying	BH etc	0.008m3										30.00	
Sand	5th layer	Loading	TS	1.6m3	19.30	14	270.23	270.23	24	6,486	12,897	2,637	15,534	2.40	33.53
		Transportaion	DT	10t	12.98	21	272.61								50.30
		Laying	BD	15t	61.42	5	307.10								11.98
Clay	6th layer	Loading	TS	1.6m3	19.30	14	270.23	270.23	24	6,486	25,452	4,992	30,444	4.69	65.72
		Transportaion	DT	10t	12.98	21	272.61								98.58
		Laying	BD	15t	61.42	5	307.10								23.47
		Drying	BH etc	0.008m3										30.00	
Sand	7th layer	Loading	TS	1.6m3	19.30	14	270.23	270.23	24	6,486	12,556	2,355	14,911	2.30	32.19
		Transportaion	DT	10t	12.98	21	272.61								48.28
		Laying	BD	15t	61.42	5	307.10								11.50
Clay	8th layer	Loading	TS	1.6m3	19.30	14	270.23	270.23	24	6,486	24,773	4,431	29,204	4.50	63.04
		Transportaion	DT	10t	12.98	21	272.61								94.56
		Laying	BD	15t	61.42	5	307.10								22.52
		Drying	BH etc	0.008m3										30.00	
Total		Loading	TS	1.6m3							155,465	32,233	187,698	148.9	405.17
		Transportaion	DT	10t											607.76
		Laying	BD	15t											144.71

T.P. : Temporary Placing S.P. : Stock Pile N.of M. : number of machines Transportation : from T.P. to S.P.
TS : TractorShovel DT : Dump Truck BD : Bulldozer BH : Backhoe

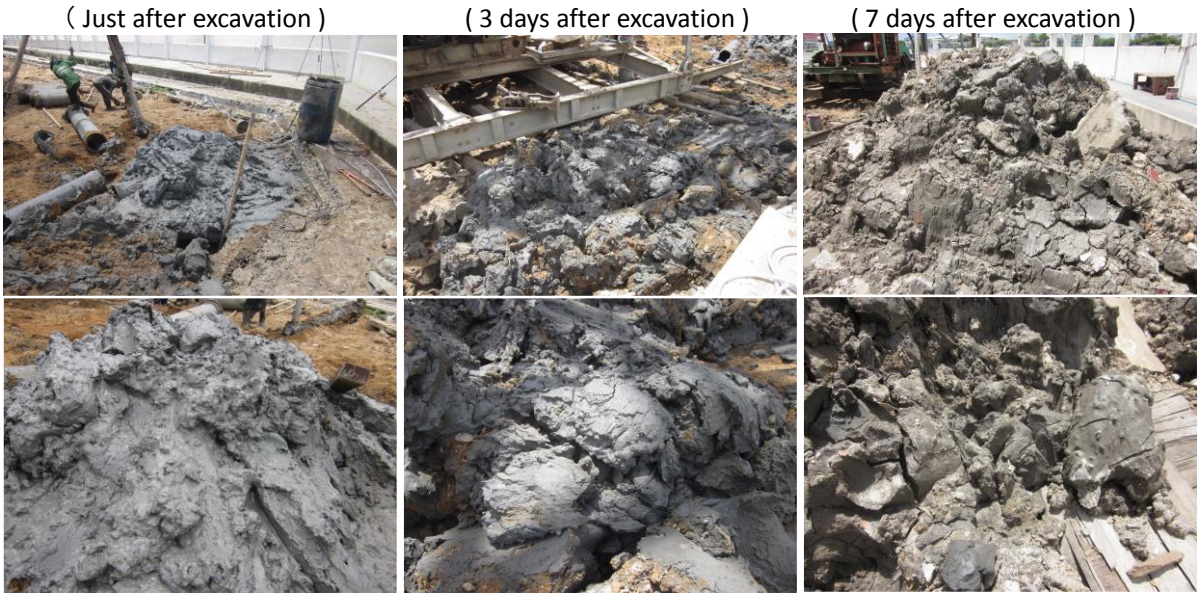
Source : JICA study team

(4) Reference : Regarding sunshine drying of excavated clay

To be utilized as embanking material, excavated soil (so-called Bangkok Clay) needs to be dried in air until moisture content, density and workability meet requirement. A similar soil (clay soil excavated during pile construction at a site of RID's ownership.) is tested to check how moisture content changes during air drying.

1) Material for the confirmation of water content reduction

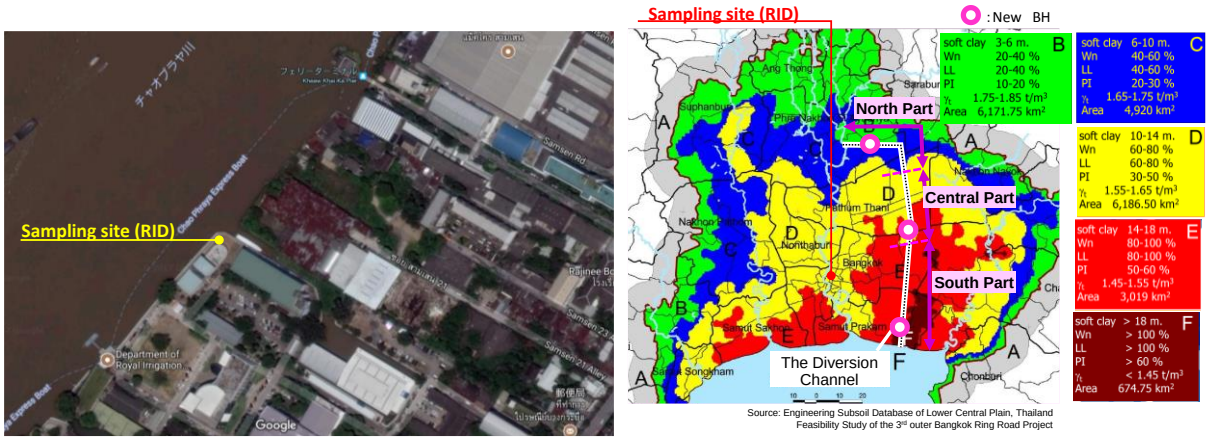
Clay soil has been sampled during a piling work in a site of RID's ownership, as shown in following figure. Construction site is located in the area of soft soil (Rank D) according to a soil classification map by Kasetsart university. Therefore, this clay soil supposed to be similar to what is going to be excavated during the construction of the DC.



2017.9.26 13:00 RID building site (photo by JICA study team)

Source : JICA study team

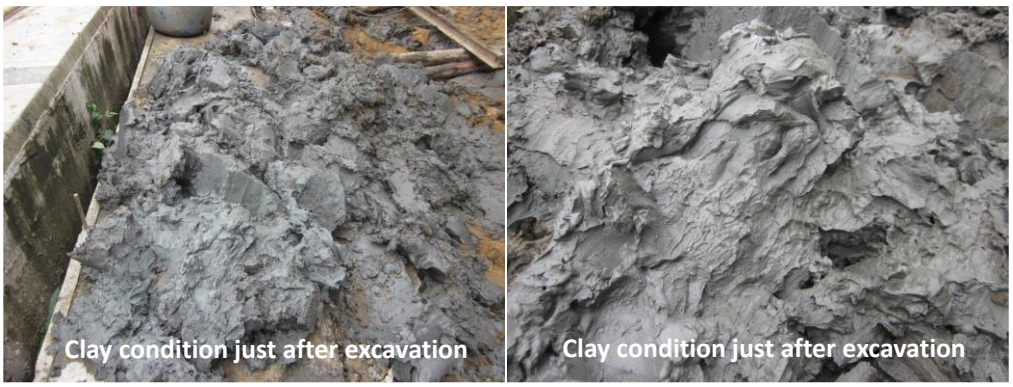
Figure 7.9.13 Piling work installation situation in RID



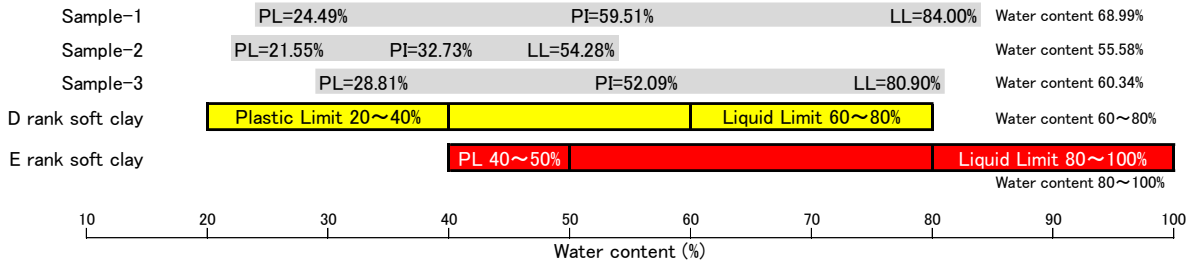
Source : JICA study team

Figure 7.9.14 Piling work sites in RID building area

Sampled soil (from RID's pile construction site) has been tested for natural moisture content, liquid limit, plastic limit, and Plasticity index. According to the result (shown as follows), property of tested sample shows a similarity to soil excavated from planned alignment of DC.



↑ Clay generated in piling work site in RID



Source：JICA study team

Figure 7.9.15 Physical property of clay generated at the piling work site in RID

2) Measurement items

Massive clay of about 35 cm size was digged up from the piling site in RID, and this massive clay was dried up during 28 days under the sun shine. Weight of this massive clay was measured 1,3,7,14,28 days after sampling and water content was calculated. As drying method, following two methods were adopted.

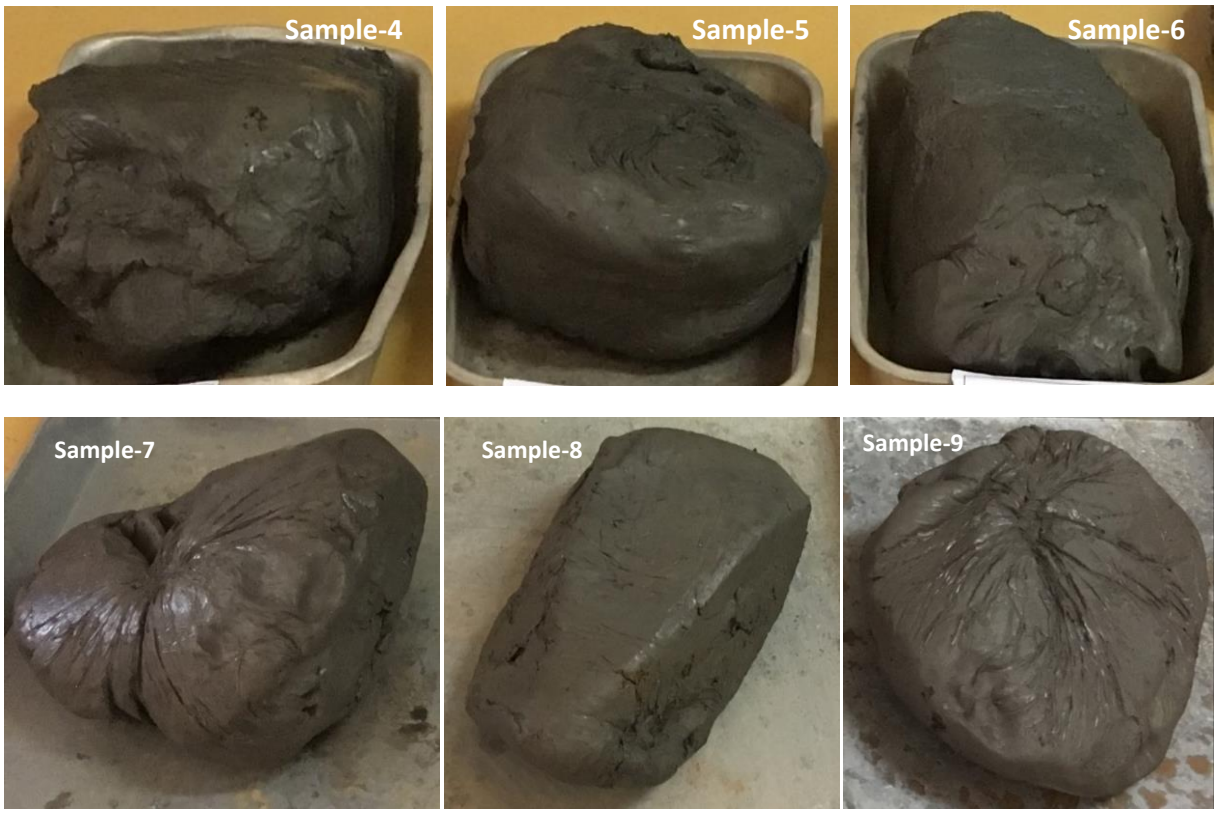
< In case of not split > Keep massive condition of the 35 cm size clay during 28 days (sample-4,5,6)

< In case of split > Massive clay of about 35 cm is splitted into 2 pieces after sampling 7 days. And splitted into 4 pieces after 14 days and into 8 pieces after 21 days. In the actual preparing of stock pile, excavated clay will be splitted and dried under the sun shine, therefore, above method was adopted. (Sample-7,8,9)

Table 7.9.7 Table of water content measuring plan

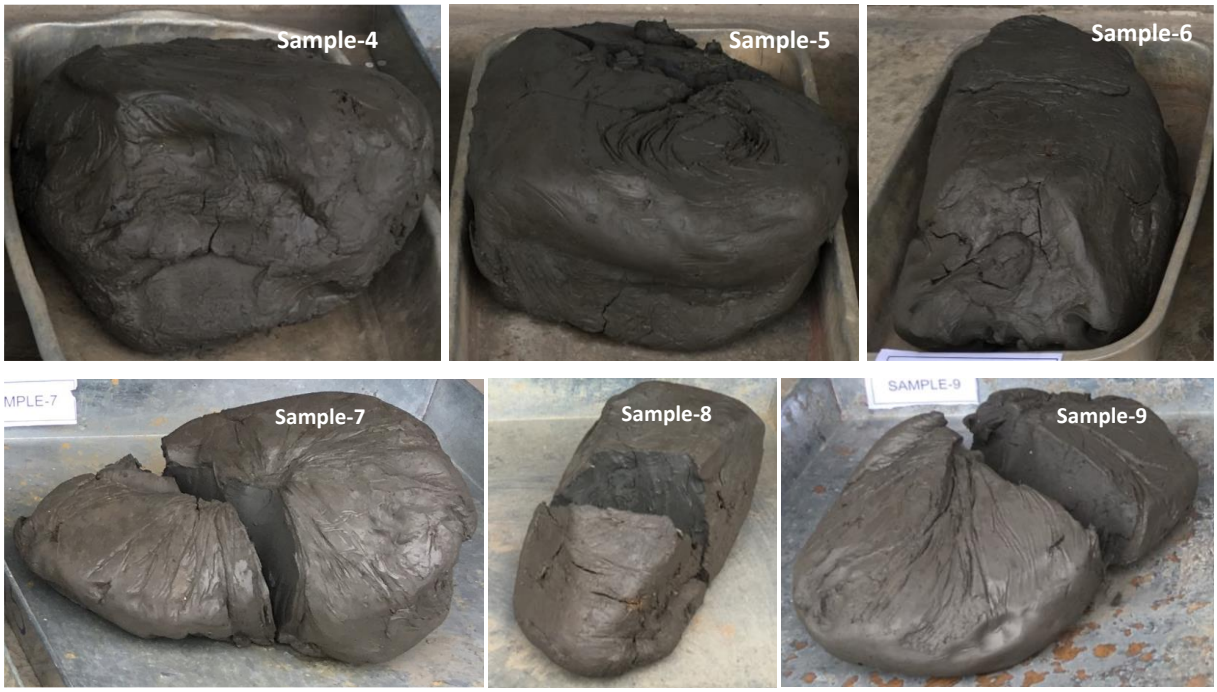
	Items to be measured							
	Clay Mass size = 35 cm							
	Sample-4	Sample-5	Sample-6	Size	Sample-7	Sample-8	Sample-9	Size
After 1 days	Water content (%)	Water content (%)	Water content (%)		Water content (%)	Water content (%)	Water content (%)	35 cm 1 piece
After 3 days	Water content (%)	Water content (%)	Water content (%)	35 cm	Water content (%)	Water content (%)	Water content (%)	
After 7 days	Water content (%)	Water content (%)	Water content (%)		Water content (%) Split into two	Water content (%) Split into two	Water content (%) Split into two	
After 14 days	Water content (%)	Water content (%)	Water content (%)		Water content (%) Split into two	Water content (%) Split into two	Water content (%) Split into two	2 piece
After 21 days	Water content (%)	Water content (%)	Water content (%)		Water content (%) Split into two	Water content (%) Split into two	Water content (%) Split into two	4 piece
After 28 days	Water content (%)	Water content (%)	Water content (%)		Water content (%)	Water content (%)	Water content (%)	8 piece

Source：JICA study team



Source：JICA study team

Figure 7.9.16 Clay after drying under the sun shine (2 days after sampling)



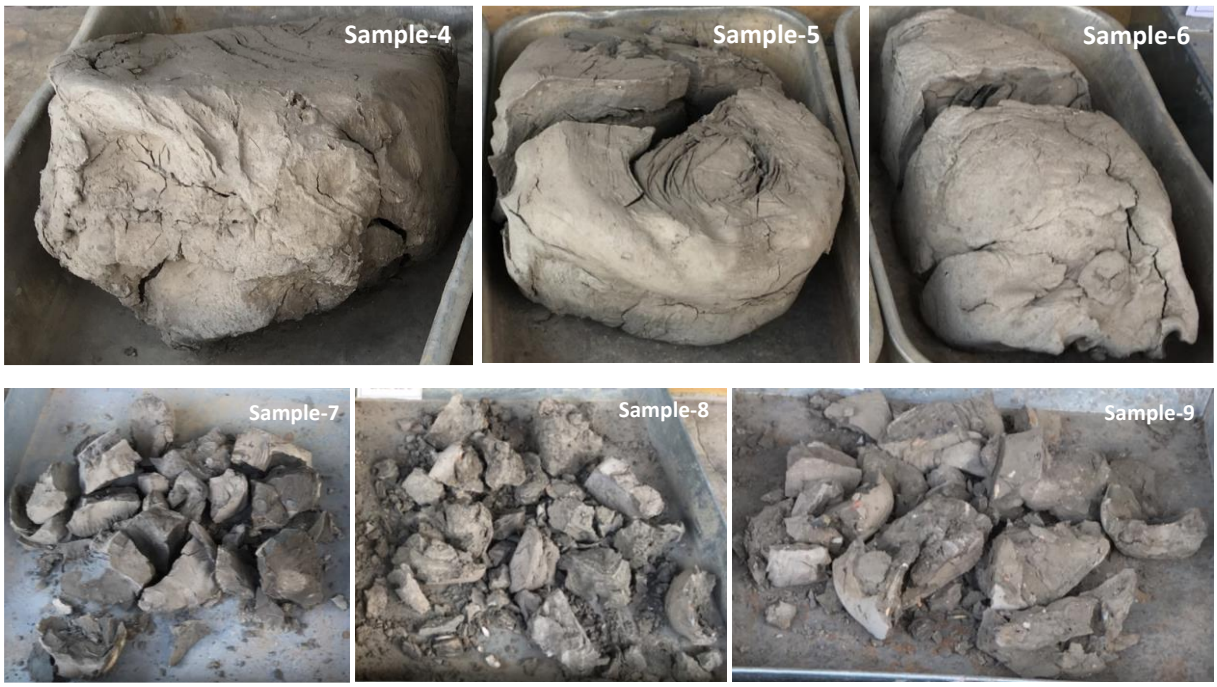
Source：JICA study team

Figure 7.9.17 Clay after sunshine drying (3 days after sampling. Sample-7,8,9 are after splitting into 2 pieces)

※Sample-5,6 were splitted spontaneously under the sunshine

Source：JICA study team

Figure 7.9.18 Clay after sunshine drying（21days after sampling、Sample-7,8,9 are after splitting into 4 pieces）



※Sample-5,6 were splitted spontaneously under the sunshine *Source : JICA study team*

Figure 7.9.19 Clay after sunshine drying（28days after sampling、Sample-7,8,9 are after splitting into 8 pieces）

3) Result of water content reduction measurement

Sampled soil has been test to check how its moisture content changes during air-drying. The result is shown as follows. Sample 4, 5, and 6 are dried with block size of 35cm while block of sample 7, 8, 9 are the same volume but splitted into pieces. The optimal moisture content for embanking material has been revealed to be 24% in previous experiment, thus this test focuses on how long it takes for the moisture content of these samples decreases to 24% under air-drying condition.

Table 7.9.8 Water content reduction situation under the sunshine (Measurement result)

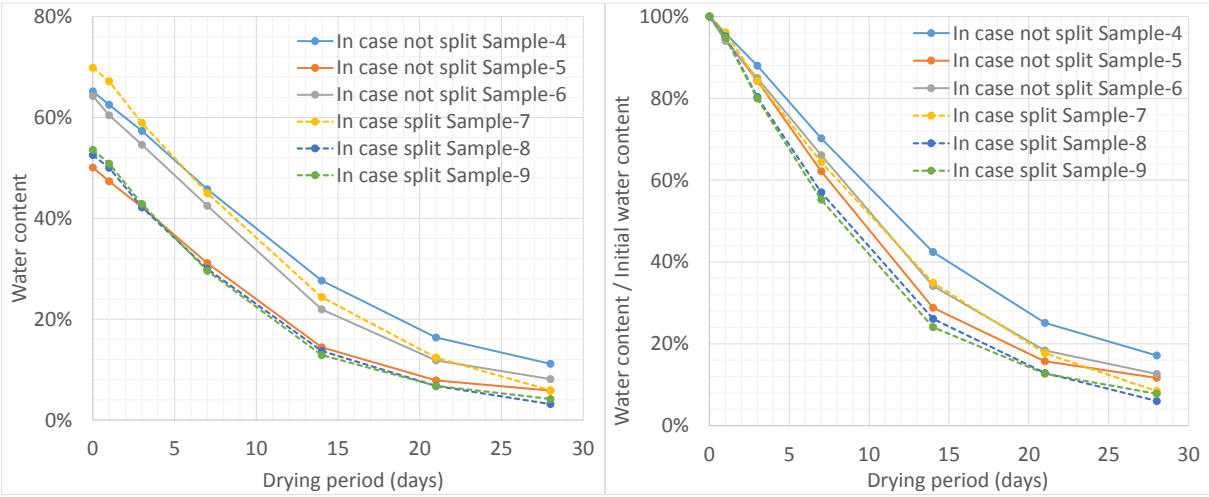
In case that sample clay mass is not split

	days	Weight (kg)					Water content
		soil, water, tray	tray	soil, water	water	soil	
Sample-4	0	12.72	0.30	12.42	4.90	7.52	65%
	1	12.52	0.30	12.22	4.70	7.52	63%
	3	12.13	0.30	11.83	4.31	7.52	57%
	7	11.26	0.30	10.96	3.44	7.52	46%
	14	9.90	0.30	9.60	2.08	7.52	28%
	21	9.05	0.30	8.75	1.23	7.52	16%
	28	8.66	0.30	8.36	0.84	7.52	11%
Sample-5	0	12.94	0.35	12.59	4.20	8.39	50%
	1	12.71	0.35	12.36	3.97	8.39	47%
	3	12.28	0.35	11.93	3.54	8.39	42%
	7	11.35	0.35	11.00	2.61	8.39	31%
	14	9.95	0.35	9.60	1.21	8.39	14%
	21	9.40	0.35	9.05	0.66	8.39	8%
	28	9.23	0.35	8.88	0.49	8.39	6%
Sample-6	0	11.06	0.35	10.71	4.19	6.52	64%
	1	10.81	0.35	10.46	3.94	6.52	60%
	3	10.43	0.35	10.08	3.56	6.52	55%
	7	9.64	0.35	9.29	2.77	6.52	42%
	14	8.30	0.35	7.95	1.43	6.52	22%
	21	7.64	0.35	7.29	0.77	6.52	12%
	28	7.40	0.35	7.05	0.53	6.52	8%

In case that sample clay mass is split

	days	Weight (kg)					Water content
		soil, water, tray	tray	soil, water	water	soil	
Sample-7	0	17.05	2.63	14.42	5.93	8.49	70%
	1	16.82	2.63	14.19	5.70	8.49	67%
	3	16.12	2.63	13.49	5.00	8.49	59%
	7	14.94	2.63	12.31	3.82	8.49	45%
	14	13.19	2.63	10.56	2.07	8.49	24%
	21	12.17	2.63	9.54	1.05	8.49	12%
	28	11.62	2.63	8.99	0.50	8.49	6%
Sample-8	0	17.08	2.62	14.46	4.98	9.48	53%
	1	16.84	2.62	14.22	4.74	9.48	50%
	3	16.10	2.62	13.48	4.00	9.48	42%
	7	14.94	2.62	12.32	2.84	9.48	30%
	14	13.40	2.62	10.78	1.30	9.48	14%
	21	12.74	2.62	10.12	0.64	9.48	7%
	28	12.40	2.62	9.78	0.30	9.48	3%
Sample-9	0	15.48	2.61	12.87	4.49	8.38	54%
	1	15.25	2.61	12.64	4.26	8.38	51%
	3	14.58	2.61	11.97	3.59	8.38	43%
	7	13.47	2.61	10.86	2.48	8.38	30%
	14	12.07	2.61	9.46	1.08	8.38	13%
	21	11.56	2.61	8.95	0.57	8.38	7%
	28	11.34	2.61	8.73	0.35	8.38	4%

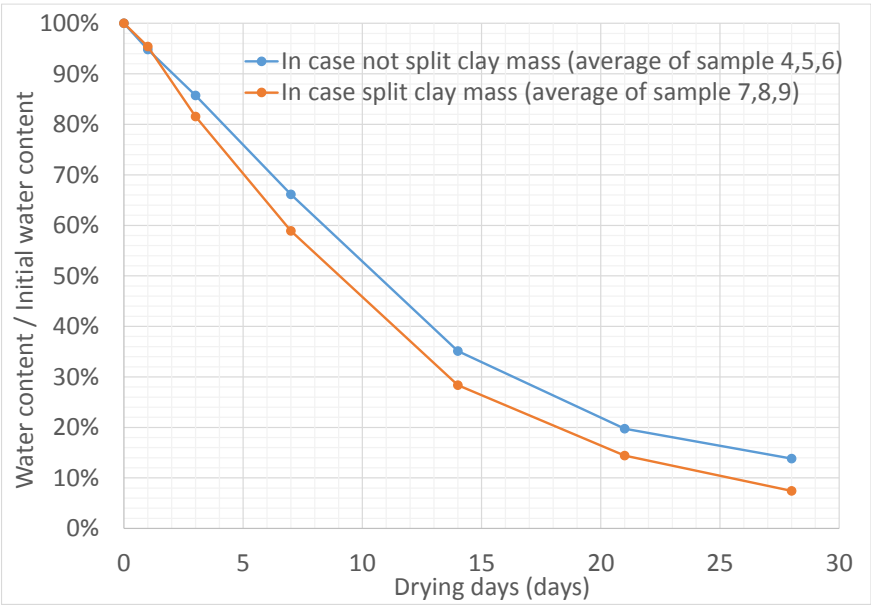
Source: JICA Study Team



Source: JICA Study Team

Figure 7.9.20 Water content reduction situation under the sunshine (Measurement result)

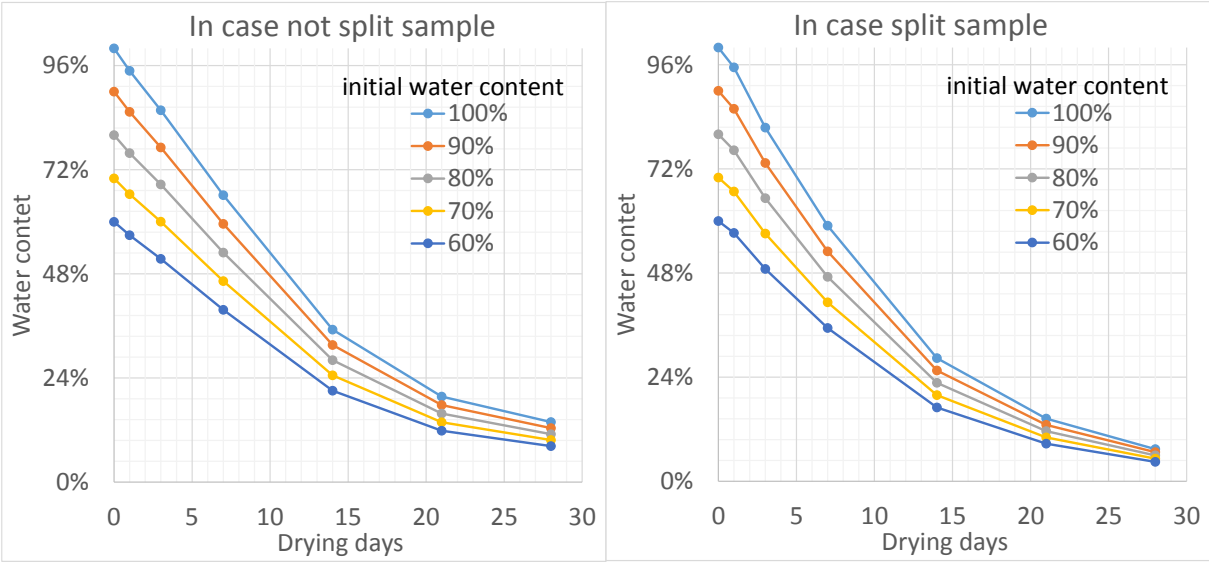
The relationship between moisture content and days of air-drying is shown on the left-top. While relationship between the proportion of measured moisture content over initial moisture content and days of air-drying is shown on the right-top. According to the right-top figure, after several days of air-drying, splitted samples (7,8,9) have a lower proportion of moisture content over initial moisture content rather than complete samples, indicating splitting makes moisture content decrease faster.



Source: JICA Study Team

Figure 7.9.21 Water content reduction situation under the sunshine (Measurement result)

Above figure shows the decrease tendency of moisture content. Blue plots are the average value of proportion of measured moisture content over initial moisture content of sample 4,5,6 (complete block), while orange ones are Sample-7,8,9 (splitted). According to this figure, moisture content of splitted blocks decrease faster than complete ones.



Source: JICA Study Team

Figure 7.9.22 Water content reduction situation under the sunshine (Measurement result)

Then, we assumed various initial moisture content namely 100%, 90%, 80%, 70%, 60%, and estimated for each case based on the test result of proportion of measured moisture content over initial moisture content. Estimation result is shown in following figure (left: splitted block, right: complete block). Following table shows estimated days until the moisture content decreasing to 24%. Excavated soil from the DC is supposed to be rank D and E, whose moisture contents are 70% and 90% respectively. According to the table, for rank D soil, 14 and 13 days are needed while it is 18 and 15 days for rank E ,for complete and splitted blocks respectively.

Table 7.9.9 Required days for reducing water content to optimum water content 24%

Case	Initial water content				
	100%	90%	80%	70%	60%
In case not split clay mass	19	18	16	14	13
In case split clay mass	16	15	14	13	11

unit:days

Source: JICA Study Team

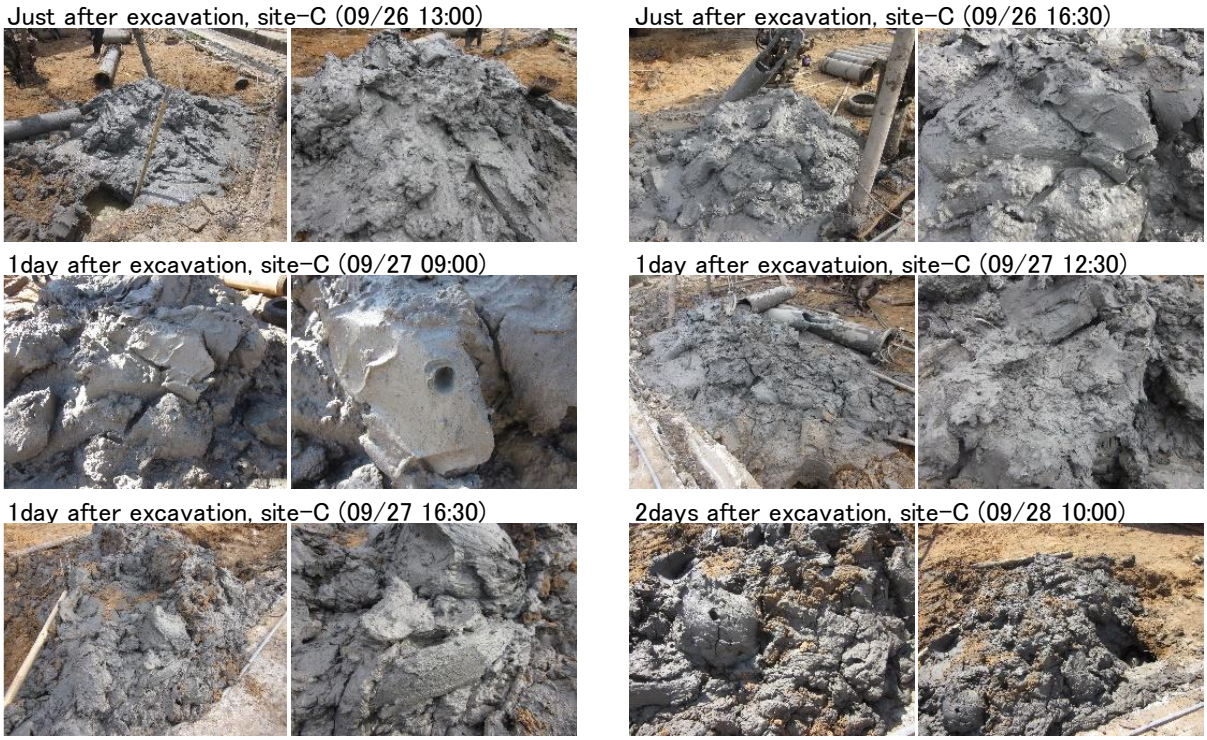
4) Change in state of clay left after excavation

Clay soil excavated in the RID's site was found its moisture content decreased and trafficability increased after left aside for several days. Following photos are taken 4 sites of the construction site (Site-A,B,C,D). tested soil is sampled from site D while soil from site A,B and C were left aside and observed for trafficability.

Source: JICA Study Team

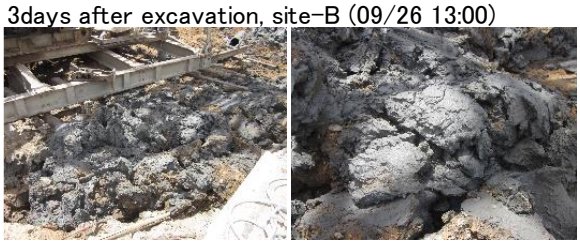
Figure 7.9.23 Sampling site condition (piling work site in RID)

Following photographs show the situations of clay left for some days after excavation.

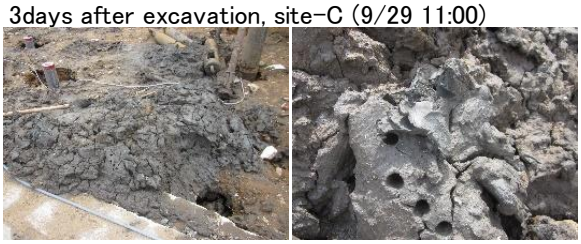


Clay left one day after excavation is soft and easy to insert finger. (Refer to photo second from left and second from top)

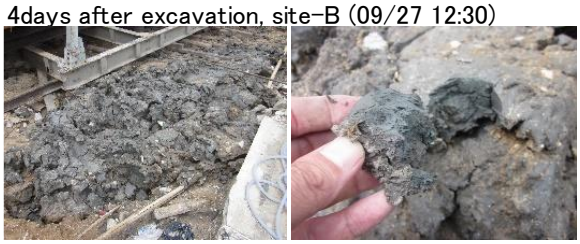
3days after excavation, site-B (09/26 13:00)



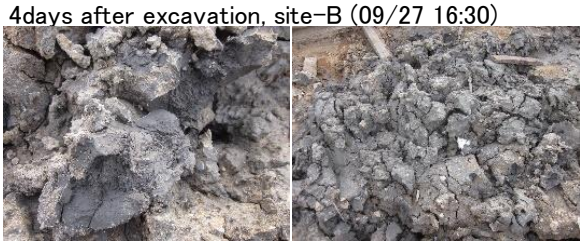
3days after excavation, site-C (9/29 11:00)



4days after excavation, site-B (09/27 12:30)



4days after excavation, site-B (09/27 16:30)

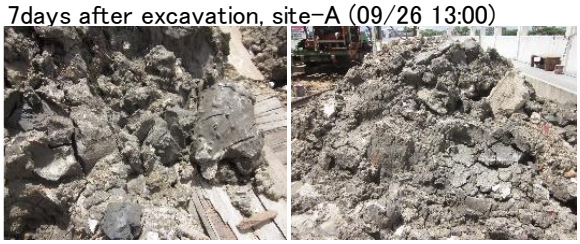


5days after excavation, site-B (09/28 10:00)

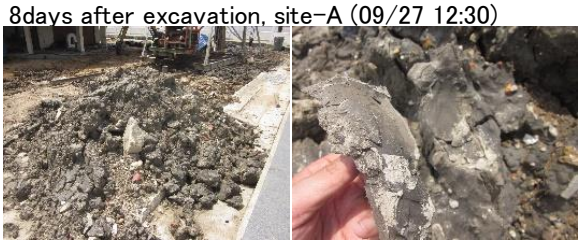
6days after excavation, site-B (09/29 11:00)

Clay left 4 days after excavation has solidity not to sink even when human body weight on. Inside of the clay left 5 days after excavation has softness that allows grooves when scratched with fingers. (Refer to photo second from left and 3rd from top)

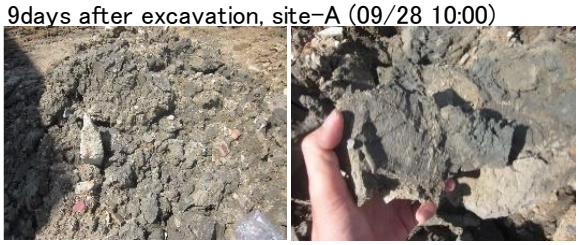
7days after excavation, site-A (09/26 13:00)



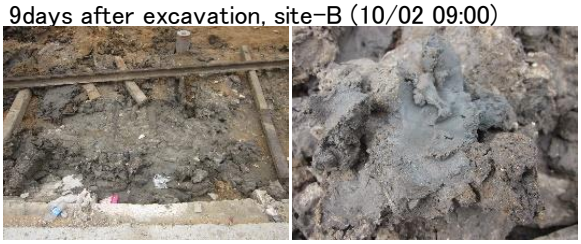
8days after excavation, site-A (09/27 12:30)



9days after excavation, site-A (09/28 10:00)



9days after excavation, site-B (10/02 09:00)



10days after excavation, site-A (09/29 11:00)

13days after excavation, site-A (10/02 09:00)

Inside of the clay left 8 days after excavation has softness that allows grooves when scratched with fingers but has solidity not to sink even when human body weight on. (Refer to photo 3rd from left and 3rd from top)

Source: JICA Study Team

Figure 7.9.24 Clay condition after leaving near the piling site in RID

7.9.8 Plant Mixing

(1) General description

Mixed soil (excavated clay soil mixed with purchased sand) can be utilized as embankment material. For subgrade, California Bearing Ratio (CBR) of the mixed soil shall be larger than 4%. Therefore, soil from stockpile needs further mixing in plant. As for road embankment, Cone index larger than 400kN/m^2 (kPa) is required. This value is the same with the material of dike embankment and soil from stockpile can be directly embanked for dike, however, considering the importance of the Road where traffic load constantly applies, plant mixing is also necessary for the base.

(2) Work quantities

14,824,000m^3 of soil is supposed to be mixed for material of subgrade and subbase of the road. It is planned to be mixed at 8 mixing plants during 4 years. Thus, 463,000m^3 soil should be mixed in one plant during one dry season. 8 mixing plants are built for material mixing for approximately 60km embankment so each of which produce materials for about 7.5km (14.9 units) construction. Therefore, each plant should mix 31,000m^3（463,000m^3／14.9 units） for one unit during one dry season.

Table 7.9.10 Work quantities of Plant Mixing per Unit (500m length)

Construction Site		(C)	(D)	(E)	(F)
Length (m)		11,220	21,079	27,211	
		59,510			
Number of Units		119			
Mixing volume (m3/8plants)		2,510,000	5,193,000	6,166,000	955,000
		14,824,000			
Number of Mixing Plants		8			
Number of Units covered by one plant		14.9			
Capacity per one plant (m3/plant)		1,853,000			
Capacity during one dry season	per one plant (m3/plant/yeatr)	463,000			
	per Unit (m3/Unit)	31,000			

Source: JICA Study Team

(3) Construction method / Construction machines / Work days

Soil will be pushed out from stockpile by 15t-level bulldozer, loaded onto 10t-level dump trucks by 1.6m^3-level tractor shovel, and transported to mixing plants. Unit working capacity is supposed to be 83.5m^3/hr for bulldozer (pushing distance 20m), 19.3m^3/hr for tractor shovel, and 8.3m^3/hr dump truck (transport distance 3km). Work hour is 7 hours per day. Thus total working capacity is 584m^3/d for 1 bulldozer, 270m^3/d for 2 tractor shovels and 232m^3/d for 4 dump trucks. On the other hand, work quantity is estimated as 25,500m^3, therefore, 110 days is needed which is smaller than construction-possible days of one dry season (150days). Mixing capacity and work hour of the plant are supposed to be 200m^3/hr and 16 hours per day, thus mixing can be finished within 145 days.

7.9.9 Embanking

(1) General description

The dike will be embanked and compacted by using soil from stockpile with inter-stratification of sand and clay. As for the Road, mixed soil from stockpile will be further mixed in mixing plant and then embanked and compacted.

(2) Work quantities

Work quantities in one Unit (500m length) is shown in the following table.

Table 7.9.11 Work quantities of Channel and Road Embanking per Unit (500m)

Items		Work quantity (m^3/500m)		
		North	Central	South
Channel Embankment	Embankment	57,000	62,600	90,200
	Embankment utilizing excavated soil	57,000	62,600	90,200
	Clay (Excavated soil)	38,000	41,800	60,100
	Sand	19,000	20,800	30,100
Road Embankment / Road Subgrade	Embankment	61,700	123,200	35,900
	Embankment utilizing excavated soil	0	123200	35900
	Clay (Excavated soil)	0	82,100	23,900
	Sand	0	41,100	12,000

Source: JICA Study Team

(3) Construction method / Construction machines / Work days

1) Diversion Channel embankment

Soil will be pushed out from stockpile by 15t-class bulldozer, loaded onto 10t-class dump trucks by 1.6m^3-class tractor shovel, and transported to embanking sites. Then, soil will be placed evenly by 15t-class bulldozers and compacted by 10t-class vibrating roller. Unit working capacity is supposed to be 83.5m^3/hr for bulldozer (pushing distance 20m), 19.3m^3/hr for tractor shovel, 14.3m^3/hr dump truck (transport distance 100m), and 273.6m^3/hr for vibrating roller (compact 5 times). Work hour is 7 hours per day. Thus total working capacity is 584m^3/d for 1 bulldozer, 540m^3/d for 4 tractor shovels, 500m^3/d for 5 dump trucks, and 1,915m^3/d for 1 vibrating roller. On the other hand, work quantity is estimated as 64,400m^3, therefore, 129 days is needed which is smaller than construction-possible days of one dry season (150days).

2) Road embankment / Road subgrade

Mixed soil will be loaded onto 10t-class dump trucks by 1.6m^3-class tractor shovel, and will be transported to construction sites. Then, soil will be placed evenly by 15t-class bulldozers and compacted by 10t-class vibrating roller. Unit working capacity is supposed to be 8.3m^3/hr for dump truck (transport distance 3km). Work hour is 7 hours per day. Thus total working capacity is 870m^3/d for 15 dump trucks. 8 mixing plants are located along middle and southern sections of 73km in total, thus each plant covers a distance of about 10km. If the plant is located at the middle point of the 10km, average distance from the plant to

construction sites is 30km. Unit working capacity is supposed to be 83.5m^3/hr for bulldozer (pushing distance 20m), and 273.6m^3/hr for vibrating roller (compact 5 times). Thus daily working capacities are 1,169m^3/d for 2 bulldozers and 1,915m^3/d for 1 vibrating roller. On the other hand, work quantity is estimated as 123,200m^3, therefore, 142 days is needed which is smaller than construction-possible days of one dry season (150days).

7.10 Process plan

7.10.1 Work days during each construction step in the Unit

Required work days per Unit (500m length) in each construction step are shown in the following tables.

Table 7.10.1 Work days during each construction steps in the Unit (Northern part)

North

Work Items				Remark	Machines	Capacity (m3/hr)	Number of machines	Working volume per day (m3/d) (7hr/day)		Minimum	Required work volume per unit (m3)	Work Days (day)		
(1) Removal Existing Facilities												75		These works will be completed within rainy season of 1st year
(3) Changing Route of Existing Channel														
(5)	(a) Transportation (Sand mat)		Transportation (Sand mat)	From pit to construction yard Hauling distance 2.5km	10t DT	8.9	7	438		438	28,650	65		< 75 days in Rainy season Sand is temporarily placed in adjacent downstream Unit before excavation. This work is carried out during previous season.
			Laying	Dozerimg distance 20m	15t BD	83.5	1	584						
	(b) Excavation (depth 0-3m) (Dry season)	Laying construction road	Loading	From adjacent downstream Unit to construction yard, Hauling distance 500m	1.6m3 TS	19.3	5	676		584	19,850	34	138	< 150 days in Dry season
			Transportation		10t DT	13.0	7	636						
			Laying	Since compact twice, work capacity is halved	15t BD	41.7	2	584						
		Excavation	Excavation & Loading		1.4m3 BH	38.9	4	1,089	1,400	1,400	145,500	104		
					0.4m3 BH(LA)	11.1	4	311						
			Transportation	Hauling distance 100m	10t DT	14.3	15	1,499						
		Soil disposal	Loading	Work for 12hr/day	1.6m3 TS	19.3	1	232		121	21,000	174		< 181 calendar days in Dry season
			Transportation	Hauling distance 70km Work for 12hr/day	10t DT	0.8	13	121						
	(c) Excavation (depth 3-6m) (Rainy season)	Laying construction road	Loading	From adjacent downstream Unit to construction yard, Hauling distance 500m	1.6m3 TS	19.3	5	676		584	8,800	15	71	< 75 days in Rainy season
			Transportation		10t DT	13.0	7	636						
			Laying	Since compact twice, work capacity is halved	15t BD	41.7	2	584						
		Excavation	Excavation & Loading		1.4m3 BH	38.9	6	1,633	2,100	2,100	118,500	56		
					0.4m3 BH(LA)	11.1	6	467						
			Transportation	Hauling distance 100m	10t DT	14.3	22	2,198						
		Soil disposal	Loading	Work for 18hr/day	1.6m3 TS	19.3	5	676		656	118,500	181		< 184 calendar days in Rainy season
			Transportation	Hauling distance 70km Work for 18hr/day	10t DT	0.8	47	656						
(6) Temporary Placing			Laying	Dozering distance 20m	15t BD	83.5	3	1,753		1,753	185,800	106		< 150 days in Dry season
(7)	(a) Preparing Stock Pile / Pre-Loading (Channel)		Loading		1.6m3 TS	19.3	47	Refer to another table						< 150 days in Dry season
			Transportation	Hauling distance 500m	10t DT	12.98	70							
			Laying	Dozering distance 33m	15t BD	61.42	15							
			Drying		0.008m3 BH	-	12							
(9)	(a) Embanking (Chnnel)		Cutoff Stock Pile	Dozering distance 20m	15t BD	83.5	1	584		400	57,000	143		< 150 days in Dry season
			Loading		1.6m3 TS	19.3	3	405						
			Transportation	Hauling distance 100m	10t DT	14.3	4	400						
			Laying	Dozering distance 20m	15t BD	83.5	1	584						
			Compaction		10tVR	273.6	1	1,915						
	(b) Embanking (Road)		Transportation	Hauling distance 3km	10t DT	8.3	8	464		464	61,700	133		< 150 days in Dry season
			Laying	Dozering distance 20m	15t BD	83.5	1	584						
			Compaction		10t VR	273.6	1	1,915						

DT:Dump Truck / BD:Bulldozer / TS:Tractor Shovel / BH:Back Hoe / LA:Long Arm / VR:Vibrating Roller

Source: JICA Study Team

Table 7.10.2 Workdays during each steps in the Unit (Central part)

Central

Work Items				Remark	Machines	Capacity (m3/hr)	Number of machines	Working volume per day (m3/d) (7hr/day)	Minimum	Required work volume per unit (m3)	Work Days (day)		
(1) Removal Existing Facilities (3) Changing Route of Existing Channel											75		These works will be completed within rainy season of 1st year
(4)	(a) PVD (Rany season)	Sandmat	Transportation	From pit to construction yard Hauling distance 2.5km Work for 12hr/day	10t DT	8.9	27	2,894	2,894	73,400	25	75	< 75 days in Rainy season
			Laying	Dozerimg distance 20m	15t BD	83.5	5	2,922					
		PVD	Installation		0.8m3 BH(CE)	-	5	2,000 m/d		498,400 m	50		
	(b) SCC (Rainy season)		Installation		0.8m3 BH(CE)	-	44	6 Column/d		19,800 Column	75		< 75 days in Rainy season
(4)	(a) PVD (Dry season)	Sandmat	Transportation	From pit to construction yard Hauling distance 2.5km Work for 12hr/day	10t DT	8.9	15	1,608	1,608	36,700	23	147	< 150 days in Dry season
			Laying	Dozerimg distance 20m	15t BD	83.5	3	1,753					
		PVD	Installation		0.8m3 BH(CE)	-	1	2,000 m/d		249,200 m	125		
	(b) SCC (Dry season)		Installation		0.8m3 BH(CE)	-	22	3 Column/d		9,900 Column	150		< 150 days in Dry season
(5)	(a) Transportation (Sand mat)		Transportation (Sand mat)	From pit to construction yard Hauling distance 2.5km	10t DT	8.9	7	438	438	28,650	65		< 75 days in Rainy season Sand is temporarily placed in adjacent downstream Unit before excavation. This work is carried out during previous season.
			Laying	Dozerimg distance 20m	15t BD	83.5	1	584					
(5)	(b) Excavation (depth 0-3m) (Dry season)	Laying construction road	Loading	From adjacent downstream Unit to construction yard, Hauling distance 500m	1.6m3 TS	19.3	5	676	584	19,850	34	138	< 150 days in Dry season
			Transportation		10t DT	13.0	7	636					
			Laying	Since compact twice, work capacity is halved	15t BD	41.7	2	584					
		Excavation	Excavation & Loading		1.4m3 BH	38.9	4	1,089 1,400	1,400	145,500	104		
					0.4m3 BH(LA)	11.1	4	311					
			Transportation	Hauling distance 100m	10t DT	14.3	15	1,499					
		Soil disposal	Loading	Work for 12hr/day	1.6m3 TS	19.3	1	232	121	21,000	174		< 181 calendar days in Dry season
			Transportation	Hauling distance 70km Work for 12hr/day	10t DT	0.8	13	121					
(5)	(c) Excavation (depth 3-6m) (Rainy season)	Laying construction road	Loading	From adjacent downstream Unit to construction yard, Hauling distance 500m	1.6m3 TS	19.3	5	676	584	8,800	15	71	< 75 days in Rainy season
			Transportation		10t DT	13.0	7	636					
			Laying	Since compact twice, work capacity is halved	15t BD	41.7	2	584					
		Excavation	Excavation & Loading		1.4m3 BH	38.9	6	1,633 2,100	2,100	118,500	56		
					0.4m3 BH(LA)	11.1	6	467					
			Transportation	Hauling distance 100m	10t DT	14.3	22	2,198					
		Soil disposal	Loading	Work for 18hr/day	1.6m3 TS	19.3	5	676	656	118,500	181		< 184 calendar days in Rainy season
			Transportation	Hauling distance 70km Work for 18hr/day	10t DT	0.8	47	656					
(6) Temporary Placing			Laying	Dozering distance 20m	15t BD	83.5	3	1,753	1,753	185,800	106		< 150 days in Dry season
(7)	(a) Preparing Stock Pile / Pre-Loading (Channel)		Loading		1.6m3 TS	19.3	47	Refer to another table					< 150 days in Dry season
			Transportation	Hauling distance 500m	10t DT	12.98	70						
			Laying	Dozering distance 33m	15t BD	61.42	15						
			Drying		0.008m3 BH	-	12						
(8) Plant Mixing			Cutoff Stock Pile	Dozering distance 20m	15t BD	83.5	1	584	232	25,500	110		< 150 days in Dry season
			Loading		1.6m3 TS	19.3	2	270					
			Transportation	Hauling distance 3km	10t DT	8.3	4	232					
(9)	(a) Embanking (Chnnel)		Cutoff Stock Pile	Dozering distance 20m	15t BD	83.5	1	584	500	62,600	125		< 150 days in Dry season
			Loading		1.6m3 TS	19.3	4	540					
			Transportation	Hauling distance 100m	10t DT	14.3	5	500					
			Laying	Dozering distance 20m	15t BD	83.5	1	584					
			Compaction		10tVR	273.6	1	1,915					
	(b) Embanking (Road)		Transportation	Hauling distance 3km	10t DT	8.3	15	870	870	123,200	142		< 150 days in Dry season
			Laying	Dozering distance 20m	15t BD	83.5	2	1,169					
			Compaction		10t VR	273.6	1	1,915					

DT:Dump Truck / BD:Bulldozer / TS:Tractor Shovel / BH:Back Hoe / LA:Long Arm / VR:Vibrating Roller CE:Casing Equipment

Source: JICA Study Team

Table 7.10.3 Work days during each construction steps in the Unit (Southern part)

South

Work Items				Remark	Machines	Capacity (m3/hr)	Number of machines	Working volume per day (m3/d) (7hr/day)		Minimum	Required work volume per unit (m3)	Work Days (day)		
(1) Removal Existing Facilities												75		< 75 days These works will be completed within rainy season of 1st year
(2) Reclamation / Laying Construction Road			Transportation	From pit to construction yard Hauling distance 2.5km Work for 12hr/day	10t DT	8.9	52	5,574		5,574	420,000			
			Laying	Dozerimg distance 20m	15t BD	83.5	10	5,844						
(3) Changing Route of Existing Channel														
(4)	(a) PVD (Rany season)	Sandmat	Transportation	From pit to construction yard Hauling distance 2.5km Work for 12hr/day	10t DT	8.9	27	2,894		2,894	73,400	25	75	< 75 days in Rainy season
			Laying	Dozerimg distance 20m	15t BD	83.5	5	2,922						
		PVD	Installation		0.8m3 BH(CE)	-	5	2,000 m/d			498,400 m	50		
	(b) SCC (Rainy season)		Installation		0.8m3 BH(CE)	-	99	6 Column/d			44,400 Column	75		< 75 daysin Rainy season
(4)	(a) PVD (Dry season)	Sandmat	Transportation	From pit to construction yard Hauling distance 2.5km Work for 12hr/day	10t DT	8.9	10	1,072		1,072	31,600	29	148	< 150 days in Dry season
			Laying	Dozerimg distance 20m	15t BD	83.5	2	1,169						
		PVD	Installation		0.8m3 BH(CE)	-	4	2,000 m/d			949,800 m	119		
	(b) SCC (Dry season)		Installation		0.8m3 BH(CE)	-	50	3 Column/d			22,200 Column	148		< 150 daysin Dry season
(5)	(a) Transportation (Sand mat)		Transportation (Sand mat)	From pit to construction yard Hauling distance 2.5km	10t DT	8.9	7	438		438	28,650	65		< 75 days in Rainy season Sand is temporarily placed in adjacent downstream Unit before excavation. This work is carried out during previous season.
			Laying	Dozerimg distance 20m	15t BD	83.5	1	584						
(5)	(b) Excavation (depth 0-3m) (Dry season)	Laying construction road	Loading	From adjacent downstream Unit to construction yard, Hauling distance 500m	1.6m3 TS	19.3	5	676		584	19,850	34	138	< 150 days in Dry season
			Transportation		10t DT	13.0	7	636						
			Laying	Since compact twice, work capacity is halved	15t BD	41.7	2	584						
		Excavation	Excavation & Loading		1.4m3 BH	38.9	4	1,089	1,400	1,400	145,500	104		
					0.4m3 BH(LA)	11.1	4	311						
			Transportation	Hauling distance 100m	10t DT	14.3	15	1,499						
		Soil disposal	Loading	Work for 12hr/day	1.6m3 TS	19.3	1	232		121	21,000	174		< 181 calendar days in Dry season
			Transportation	Hauling distance 70km Work for 12hr/day	10t DT	0.8	13	121						
(5)	(c) Excavation (depth 3-6m) (Rainy season)	Laying construction road	Loading	From adjacent downstream Unit to construction yard, Hauling distance 500m	1.6m3 TS	19.3	5	676		584	8,800	15	71	< 75 days in Rainy season
			Transportation		10t DT	13.0	7	636						
			Laying	Since compact twice, work capacity is halved	15t BD	41.7	2	584						
		Excavation	Excavation & Loading		1.4m3 BH	38.9	6	1,633	2,100	2,100	118,500	56		
					0.4m3 BH(LA)	11.1	6	467						
			Transportation	Hauling distance 100m	10t DT	14.3	22	2,198						
		Soil disposal	Loading	Work for 18hr/day	1.6m3 TS	19.3	5	676		656	118,500	181		< 184 calendar days in Rainy season
			Transportation	Hauling distance 70km Work for 18hr/day	10t DT	0.8	47	656						
(6) Temporary Placing			Laying	Dozering distance 20m	15t BD	83.5	3	1,753		1,753	185,800	106		< 150 days in Dry season
(7)	(a) Preparing Stock Pile / Pre-Loading (Channel)		Loading		1.6m3 TS	19.3	47	Refer to another table						< 150 days in Dry season
			Transportation	Hauling distance 500m	10t DT	12.98	70							
			Laying	Dozering distance 33m	15t BD	61.42	15							
			Drying		0.008m3 BH	-	12							
(9)	(a) Embanking (Chnnel)		Cutoff Stock Pile	Dozering distance 20m	15t BD	83.5	1	584		500	62,600	125		< 150 days in Dry season
			Loading		1.6m3 TS	19.3	4	540						
			Transportation	Hauling distance 100m	10t DT	14.3	5	500						
			Laying	Dozering distance 20m	15t BD	83.5	1	584						
			Compaction		10tVR	273.6	1	1,915						
	(b) Embanking (Road)		Transportation	Hauling distance 3km	10t DT	8.3		0		0				< 150 days in Dry season
			Laying	Dozering distance 20m	15t BD	83.5		0						
			Compaction		10t VR	273.6		0						

DT:Dump Truck / BD:Bulldozer / TS:Tractor Shovel / BH:Back Hoe / LA:Long Arm / VR:Vibrating Roller

Source: JICA Study Team

7.10.2 Construction schedule in the Unit

Each section is 2km long which is composed of four 500m-long units. Construction schedule for each section is shown in following figure. For one section, construction, from removal of existing facilities to embankment, will be completed in 5 years. In order to finish the whole combined project in 5 years, construction shown in following table must be on operation simultaneously in all 55 sections.

Table 7.10.4 Construction schedule in the Unit (Northern part)

Work items			Work days		1st year		2nd year		3rd year		4th year		5th year	
					Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
					75days	150days	75days	150days	75days	150days	75days	150days	75days	150days
(1) Removal Existing Facilities			75		Unit 1～4									
(2) Reclamation / Laying Construction Road			0											
(3) Changing Route of Existing Channel			75											
(4) Soil Stabilization			0											
(5)	(a) Transportation（Sand mat)		65			Unit 2		Unit-3		Unit 4		Unit 1'		
	(b) Excavation (depth 0-3m) (Dry season)	Laying Con.Road	34	138		Unit 2		Unit-3		Unit 4		Unit 1'		
		Excavation	104			Unit 2		Unit-3		Unit 4		Unit 1'		
		Soil disposal	174			Unit 2		Unit 3		Unit 4		Unit 1'		
	(c) Excavation (depth 3-6m) (Rainy season)	Laying Con.Road	15	71			Unit 2		Unit-3		Unit 4		Unit 1'	
		Excavation	56				Unit 2		Unit-3		Unit 4		Unit 1'	
		Soil disposal	181											
(6) Temporary Placing			106			Unit 2		Unit 3		Unit 4		Unit 4 *1		
(7)	(a) Preparing Stock Pile / Pre-Loading (Channel)		150			Unit 1		Unit 2		Unit 3		Unit 4		
	(b) Preparing Stock Pile / Pre-Loading (Road)					Unit 1		Unit 2		Unit 3		Unit 4		
(8) Plant Mixing														
(9)	(a) Embanking (Chnnel)		143					Unit 1		Unit 2		Unit 3		Unit 4
	(b) Embanking (Road)		133					Unit 1		Unit-2		Unit 3		Unit 4

Table 7.10.5 Construction schedule in the Unit (Central part)

Work items			Work days		1st year		2nd year		3rd year		4th year		5th year	
					Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
					75days	150days	75days	150days	75days	150days	75days	150days	75days	150days
(1) Removal Existing Facilities			75		Unit 1～4									
(2) Reclamation / Laying Construction Road			0											
(3) Changing Route of Existing Channel			75											
(4)	(a) PVD (Rany season)	Sandmat	25	75	Unit 1,2	Unit 3		Unit 4						
		PVD Installation	50		Unit 1,2	Unit 3		Unit 4						
	(b) SCC (Rainy season)	SCC Installation	75		Unit 1,2	Unit 3		Unit 4						
	(a) PVD (Dry season)	Sandmat	23	147	Unit 1,2	Unit 3		Unit 4						
		PVD Installation	125		Unit 1,2	Unit 3		Unit 4						
	(b) SCC (Dry season)	SCC Installation	150		Unit 1,2	Unit 3		Unit 4						
(5)	(a) Transportation（Sand mat)		65			Unit 2		Unit-3		Unit 4		Unit 1'		
	(b) Excavation (depth 0-3m) (Dry season)	Laying Con.Road	34	138		Unit 2		Unit-3		Unit 4		Unit 1'		
		Excavation	104			Unit 2		Unit-3		Unit 4		Unit 1'		
		Soil disposal	174			Unit 2		Unit 3		Unit 4		Unit 1'		
	(c) Excavation (depth 3-6m) (Rainy season)	Laying Con.Road	15	71			Unit 2		Unit-3		Unit 4		Unit 1'	
		Excavation	56				Unit 2		Unit-3		Unit 4		Unit 1'	
		Soil disposal	181											
(6) Temporary Placing			106			Unit 2		Unit 3		Unit 4		Unit 4 *1		
(7)	(a) Preparing Stock Pile / Pre-Loading (Channel)		150			Unit 1		Unit 2		Unit 3		Unit 4		
	(b) Preparing Stock Pile / Pre-Loading (Road)					Unit 1		Unit 2		Unit 3		Unit 4		
(8) Plant Mixing														
(9)	(a) Embanking (Chnnel)		125					Unit 1		Unit 2		Unit 3		Unit 4
	(b) Embanking (Road)		142					Unit 1		Unit-2		Unit 3		Unit 4

"Unit 1" locates most downstream position in "Section". "Unit 2" locates in second position from downstream in "Section". "Unit 3" locates in third position from downstream in "Section". "Unit 4" locates most upstream position in "Section". "Unit 1' " is adjacent to the upstream side of "Unit 4". *1 : Temporary placing at the bottom of channel in the downstream adjacent Unit. Excavation will be already completed in this Unit.

Source: JICA Study Team

Table 7.10.6 Construction schedule in the Unit (Southern part)

Work items			Work days		1st year		2nd year		3rd year		4th year		5th year	
					Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
					75days	150days	75days	150days	75days	150days	75days	150days	75days	150days
(1) Removal Existing Facilities			75		Unit 1～4									
(2) Reclamation / Laying Construction Road			75											
(3) Changing Route of Existing Channel			75											
(4)	(a) PVD (Rany season)	Sandmat	25	75	Unit 1,2	Unit 3		Unit 4						
		PVD Installation	50		Unit 1,2	Unit 3		Unit 4						
	(b) SCC (Rainy season)	SCC Installation	75		Unit 1,2	Unit 3		Unit 4						
	(a) PVD (Dry season)	Sandmat	29	148	Unit 1,2	Unit 3		Unit 4						
		PVD Installation	119		Unit 1,2	Unit 3		Unit 4						
	(b) SCC (Dry season)	SCC Installation	148		Unit 1,2	Unit 3		Unit 4						
(5)	(a) Transportation（Sand mat)		65			Unit 2		Unit-3		Unit 4		Unit 1'		
	(b) Excavation (depth 0-3m) (Dry season)	Laying Con.Road	34	138		Unit 2		Unit-3		Unit 4		Unit 1'		
		Excavation	104			Unit 2		Unit-3		Unit 4		Unit 1'		
		Soil disposal	174			Unit 2		Unit 3		Unit 4		Unit 1'		
	(c) Excavation (depth 3-6m) (Rainy season)	Laying Con.Road	15	71			Unit 2		Unit-3		Unit 4		Unit 1'	
		Excavation	56				Unit 2		Unit-3		Unit 4		Unit 1'	
		Soil disposal	181											
(6) Temporary Placing			106			Unit 2		Unit 3		Unit 4		Unit 4 *1		
(7)	(a) Preparing Stock Pile / Pre-Loading (Channel)		150			Unit 1		Unit 2		Unit 3		Unit 4		
	(b) Preparing Stock Pile / Pre-Loading (Road)					Unit 1		Unit 2		Unit 3		Unit 4		
(8) Plant Mixing														
(9)	(a) Embanking (Chnnel)		125					Unit 1		Unit 2		Unit 3		Unit 4
	(b) Embanking (Road)		0					Unit 1		Unit-2		Unit 3		Unit 4

"Unit 1" locates most downstream position in "Section". "Unit 2" locates in second position from downstream in "Section". "Unit 3" locates in third position from downstream in "Section". "Unit 4" locates most upstream position in "Section". "Unit 1' " is adjacent to the upstream side of "Unit 4". *1 : Temporary placing at the bottom of channel in the downstream adjacent Unit. Excavation will be already completed in this Unit.

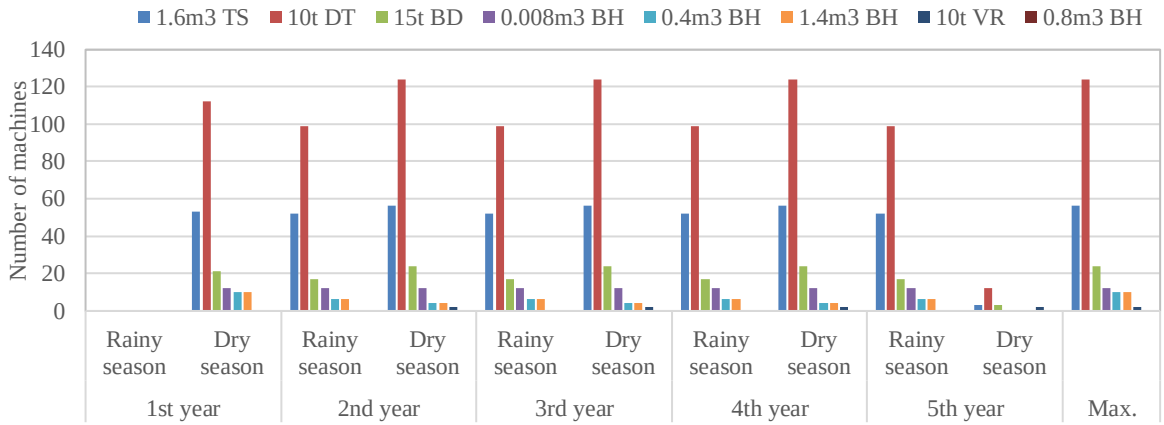
Source: JICA Study Team

7.11 Procurement plan

Required machine number in one Section during every half year (dry season or rainy season) was estimated according to the part (Northern part, Central part or Southern part). And required maximum number of each machine during 5 year construction period was estimated. Number of each machine that should be procured can be estimated multiplying above mentioned maximum machine number in each part by the number of sections in each part. Estimation result is shown in following figures. Maximum number of machines that should be procured is roughly 18,000 at the peak time.

North

Construction machines	1st year		2nd year		3rd year		4th year		5th year		Max.
	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	
1.6m3 TS	0	53	52	56	52	56	52	56	52	3	56
10t DT	0	112	99	124	99	124	99	124	99	12	124
15t BD	0	21	17	24	17	24	17	24	17	3	24
0.008m3 BH	0	12	12	12	12	12	12	12	12	0	12
0.4m3 BH	0	10	6	4	6	4	6	4	6	0	10
1.4m3 BH	0	10	6	4	6	4	6	4	6	0	10
10t VR	0	0	0	2	0	2	0	2	0	2	2
0.8m3 BH	0	0	0	0	0	0	0	0	0	0	0

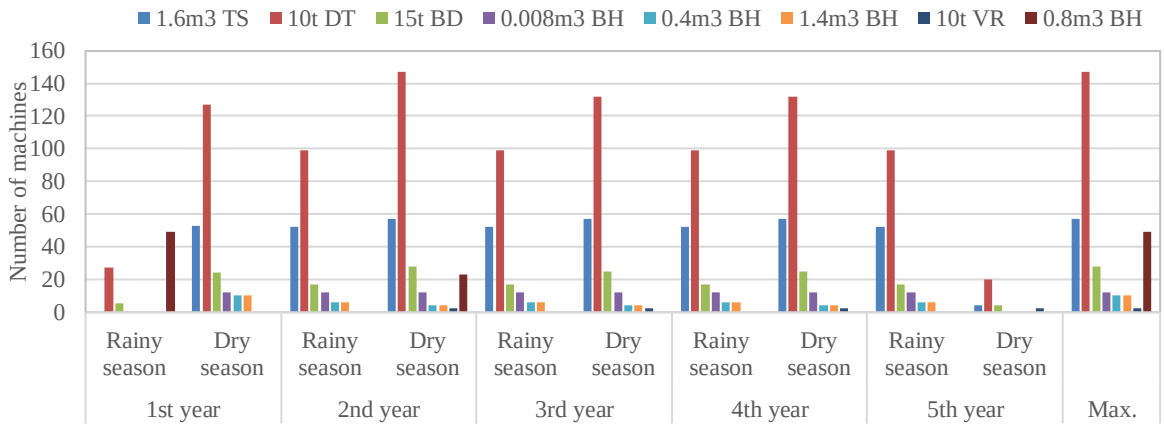


Source: JICA Study Team

Figure 7.11.1 Required machines number for the Outer Ring Road and Diversion Channel combined construction (Northern part)

Central

Construction machines	1st year		2nd year		3rd year		4th year		5th year		Max.
	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	
1.6m3 TS	0	53	52	57	52	57	52	57	52	4	57
10t DT	27	127	99	147	99	132	99	132	99	20	147
15t BD	5	24	17	28	17	25	17	25	17	4	28
0.008m3 BH	0	12	12	12	12	12	12	12	12	0	12
0.4m3 BH	0	10	6	4	6	4	6	4	6	0	10
1.4m3 BH	0	10	6	4	6	4	6	4	6	0	10
10t VR	0	0	0	2	0	2	0	2	0	2	2
0.8m3 BH	49	0	0	23	0	0	0	0	0	0	49

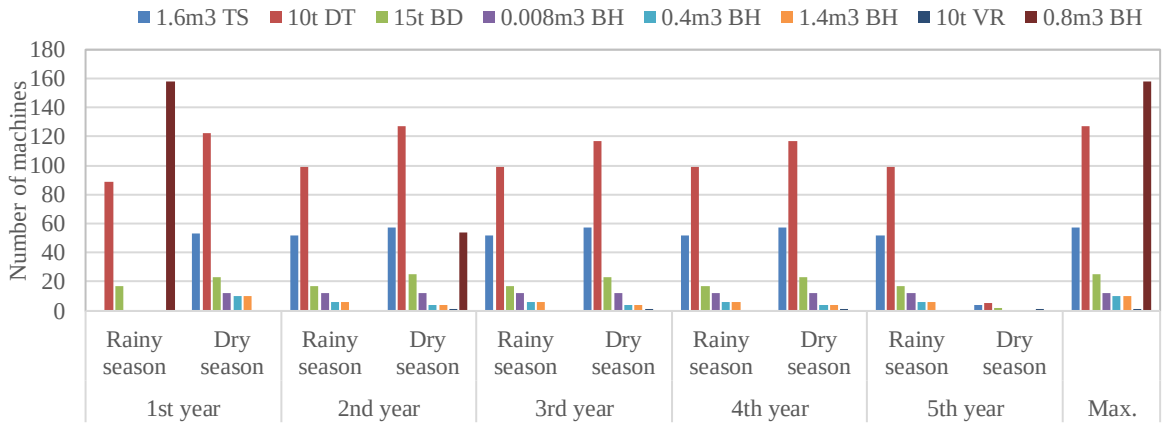


Source: JICA Study Team

Figure 7.11.2 Required machines number for the Outer Ring Road and Diversion Channel combined construction (Central part)

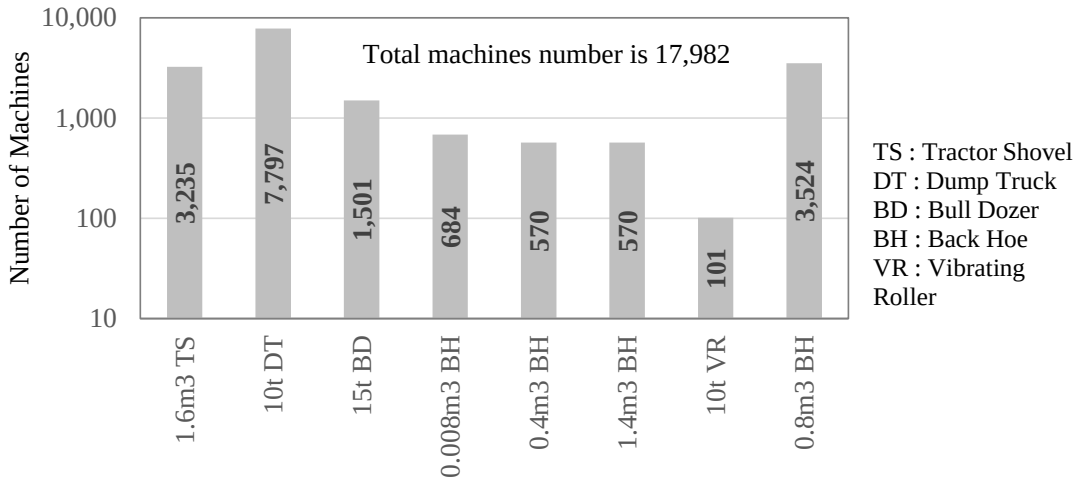
South

Construction machines	1st year		2nd year		3rd year		4th year		5th year		Max.
	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season	
1.6m3 TS	0	53	52	57	52	57	52	57	52	4	57
10t DT	89	122	99	127	99	117	99	117	99	5	127
15t BD	17	23	17	25	17	23	17	23	17	2	25
0.008m3 BH	0	12	12	12	12	12	12	12	12	0	12
0.4m3 BH	0	10	6	4	6	4	6	4	6	0	10
1.4m3 BH	0	10	6	4	6	4	6	4	6	0	10
10t VR	0	0	0	1	0	1	0	1	0	1	1
0.8m3 BH	158	0	0	54	0	0	0	0	0	0	158



Source: JICA Study Team

Figure 7.11.3 Required machines number for the Outer Ring Road and Diversion Channel combined construction (Southern part)



Source: JICA Study Team

Figure 7.11.4 Required machines number for the Outer Ring Road and Diversion Channel combined construction (Peak period)

7.12 Proposal of additional survey

(1) Experimental construction for channel excavation

The difficulty of channel excavation on soft ground is known in Thailand from the experience of Suvarnabhumi Airport Drainage Channel. Therefore, countermeasures have been suggested such as stabilizing the ground using SCC before excavation to prevent slope failure, setting excavation slope to be 1:3 and machines inside the channel, and waiting for slope stabilized after excavating every 1m. They need to be verified in experimental construction.

(2) Experimental construction to verify the possibility for embanking material

Approximately 58millions m^3 of soil is supposed to be excavated during the construction of the 110km-long Diversion Channel. One of the important cores of our proposal is to utilize these soft soil, so-called Bangkok Clay, as embanking material by mixing it with purchased sand. 4 levels of mixing method are supposed, namely stockpile (level 1), stabilizer mixing (level 2), and plant mixing (level 3 & 4). However, suitability of each method needs to be verified in experimental construction since the soil property varies in regions as well as mixing ratio.

(3) Possibility of simultaneous construction in 55 sections

In order to complete the construction of the 110km-long Diversion Channel in 5 years, one prerequisite is having simultaneous construction in 55 sections (each section is 2km long) with approximately 18,000 machines and trucks operating when peak. We have generally checked the registered amount of machines around Bangkok as well as the possibility to procure them in future, however, a further survey about contractors and their machines is essential to ensure finishing construction in time.

CHAPTER 8 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

8.1 Summary of environmental and social consideration in the Outer Ring Road construction

The preceding EIA report of the Outer Ring Road serves as a useful reference and documents the prior condition for consideration of possible environmental and social impacts in the Diversion Channel construction.

In the EIA report of the Outer Ring Road, an environmental impact investigation was conducted for the area within a distance of 500m from the central line of the Outer Ring Road. Especially, the atmospheric environment and noise impact level is assumed to be low or moderate as mentioned below.

(1) Current environmental condition

1) Air quality

- There are 63 places along the project road line that are sensitive to the atmospheric impact caused by the project.
- They consist of 17 communities, 17 religion areas, 15 educational facilities, 7 hospital and medical facilities, and 7 other regions.
- Sampling of air quality was conducted at 2 places, during February 15th to 20th 2008 and May 29th to June 4th 2008.
- For the 5-day sampling period, the result showed that for most parameters, the maximum concentrations of air pollutants in the places investigated all satisfied the standards.
- However, concentration of hydrocarbon, nitrogen dioxide and PM-10 could slightly the exceed standards in some areas.

2) Noise

- Along the road line in this project, there are 31 areas sensitive to the impact of noise, including 23 villages, 2 religion areas, 2 educational facilities, 2 hospital and medical facilities, and 2 other regions.
- The noise level was measured at 2 places during February 15th to 20th 2008.
- The result showed that they were within the “normal noise level” based on the 15th Notification by the National Environment Board in 1997.

(2) Analysis of environmental impacts

1) Air quality

- During the construction period, there could be dispersion of dust caused by construction activities and transportation of the construction materials and equipment on both sides of the project road. Calculation of dust concentration (24 hour average TSP) from land surface excavation and landfill shows that maximum

dust concentration could be 32.44 microgram/m³. It became clear that dust concentration in both the current situation and future estimation could satisfy the standard (330 microgram/m³). Therefore, the level of impact is assumed to be low.

- As for the operation period, according to the result of air quality simulation from 2016 to 2036 for areas along the road within a band 50m either side from the right-of-way limit, only a few pollutants will exceed the standard of air quality, such as PM10 and NO2. Therefore, the impact level is assumed to be moderate.

2) Noise

- During the construction period, residents living in the vicinity may suffer from noise caused by machine operation including transportation of materials. But it will only happen temporarily during the construction. Therefore, it is assumed to be a moderate impact. Besides, the noise is assumed to be limited inside the construction site because the noise level will attenuate by the distance.
- It was predicted that the average hourly noise level during the operation period from 2016 to 2036 would be 71~73dB (A) at the distance of 100m away from the road, which is slightly higher than the standard value (70dB (A)). At the distance of 50m away from the road, the maximum noise level was predicted to be 72~75dB (A), which is also slightly higher than the standard value. Therefore, it is assumed to be a moderate impact.
- According to the simulation result, there are 24 areas that will be affected by noise higher than standard during 2016 to 2036. Therefore, a moderate impact can be predicted that it is necessary to take actions such as installation of noise insulation walls.

Table 8.1.1 Areas sensitive to the influence of noise level (24 communities in bold-faced letters)

No.	Community/ Facility	Province	District	Sub-district
1	Smile Land & House Village	Phra Nakhon Si Ayutthaya	Bang Pa-In	Kung Lam
2	Somwang Sub Muen Saen Village			Sam Ruean
3	Ban Chang		U-Thai	Ban Chang
4	Liab Khlong Hok Community		Wang Noi	Lamtasao
5	Liab Khlong 27 Community			Hantaphao
6	Liab Khlong 26 Community			Khao Ngam
7	Khao Ngam SAO Office			
8	Wat Pakhlong 11	Pathum Thani	Nong Suea	Bung Kasam
9	Ban Suan Si Pathum			Bung Ba
10	Ban Bung Sanan		Thanyaburi	Bung Sanan
11	Ban Ua Athon Pathumthani			
12	Thamle Thong Community		Lamlookka	Bung Thonglang

No.	Community/ Facility	Province	District	Sub-district
13	Ban Khlong Sib	Bangkok	Nong Jok	Khlong Sib
14	Ban Lam Chedi			
15	Temsiri Park			Khu Fang Nua
16	Lam Hin Police Station			
17	Nong Jok Community (NHA)			
18	Bayan 2 Village	Bangkok	Nong Jok	Khu Fang Nua
19	Darussalam Mosque			Khok Faed
20	Darussalam Foundation			
21	Erua Mosque School			
22	Nanthawan Bayan Village			
23	Al-Amiah Cemetery			
24	Ban Lam Erua			
25	Sue Trong Suwinthawong Village			Lam Phakchi
26	Watthana Village			
27	Watthana 2 Village			
28	Soi Kheha Chumchon Chalong Krung			
29	Wat Lamphra-ong Community			
30	Lamphakchi School			
31	Lamphakchi Children Dev. Center			
32	Orchid Ville	Samut Prakan	Bang Sao Thong	Bang Sao Thong
33	Bang Sao Thong Residential Area			

Source : JICA Study Team

(3) Mitigation of environmental impacts

1) Noise mitigation plan by installing noise barrier

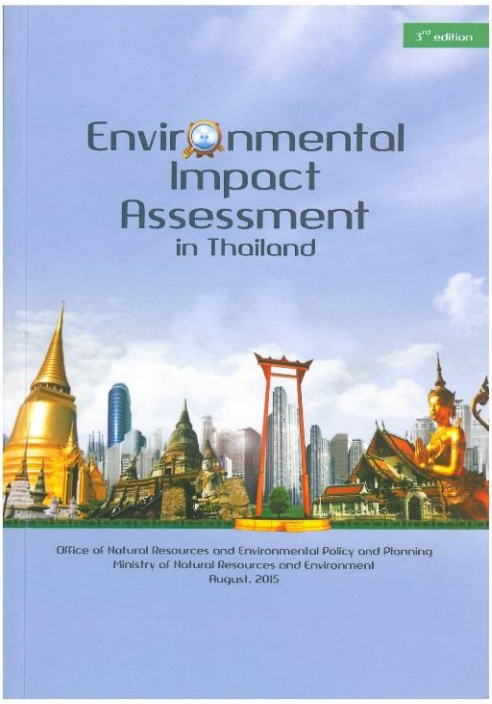
- Target areas are the 24 areas to be affected by noise listed above.
- The method is to install Noise Barriers along the project road (fiber reinforced concrete, reflective type, vertical height 3m, and inclination angle 45 degree).
- DOH shall take responsibility to supervise the installation and maintenance of the noise barrier as the implementing agency.
- The cost for the barrier installation is estimated as THB 146,010,000.

8.2 Necessity of environmental and social considerations for the Diversion Channel construction

Following is the consideration of possible impacts of construction of the Outer Ring Road Diversion Channel on the natural and social environments.

(1) Necessity of EIA for the project

In principle, the necessity of an EIA for the project is determined according to the current law in Thailand, the "National Environment Quality Act (NEQA, 1992)" and specific operational rule "Environmental Impact Assessment in Thailand, 2015, ONEP".



According to "Types and sizes of projects or activities requiring preparation of Environmental Impact Assessment reports", this project will possibly fall under the following three project type categories. At least, at the periphery of the outlet of the Diversion Channel, possible impact on "Mangrove forests designated as National Forest Reserve" will have to be considered. Hence, judging in a comprehensive manner, this project is subject to the EIA process in Thailand.

- 20. Highway or road which is defined by the Highway Act. passing through the following areas (especially, "20.4 Mangrove forests designated as National Forest Reserve" will have to be considered)
- 34. Trans Watershed Diversion
- 35. Sluicegate in the Major River

Table 8.2.1 Types and sizes of projects or activities requiring preparation of Environmental Impact Assessment reports (35 Types)

1. Mining defined by the Mineral Act
2. Petroleum Industry
3. The Petroleum and Fuel Oil Pipeline System Project
4. Industrial Estate as defined by the Industrial Estate Authority of Thailand Act or Projects with identical features or Land Allocation Project for industrial development
5. Petrochemical Industry using chemical Processes in production
6. Petroleum Refining Industry
7. Natural Gas Separation Industry or Natural Gas Reforming Industry
8. Chlor-alkaline Industry that requires Sodium Chloride as raw material to produce Sodium Carbonate, Sodium Hydroxide, Hydrochloric Acid, Chlorine, Sodium Hypo-Chloride and Bleaching powder
9. Cement Industry
10. Pulp Industry
11. Pesticide Industry or Industry producing active ingredients by chemical processes
12. Chemical Fertilizer Industry using chemicals
13. Sugar Industry
14. Iron and Steel Industry
15. Mineral Smelting Industry. Mineral Dressing Industry or Metal Melting Industry except Iron or Steel
16. Liquor and Alcohol Industries Including beer and wine
17. Central Waste Treatment Plant defined by the Factory Act
18. Thermal Power Plant
19. Expressway as defined by the Express way and rapid Transit Authority of Thailand Act or other projects alike
20. Highway or road which is defined by the Highway Act passing through the following areas:

    20.1 Wildlife sanctuaries and Wildlife non-hunting area as defined by the Wildlife Conservation and Protection Act

    20.2 National Park which is defined by the National Park Act

    20.3 Watershed area classified as class 2 by the cabinet resolution

    20.4 Mangrove forests designated as National Forest Reserve

    20.5 Coastal area within 50 meters of the highest sea level by nature

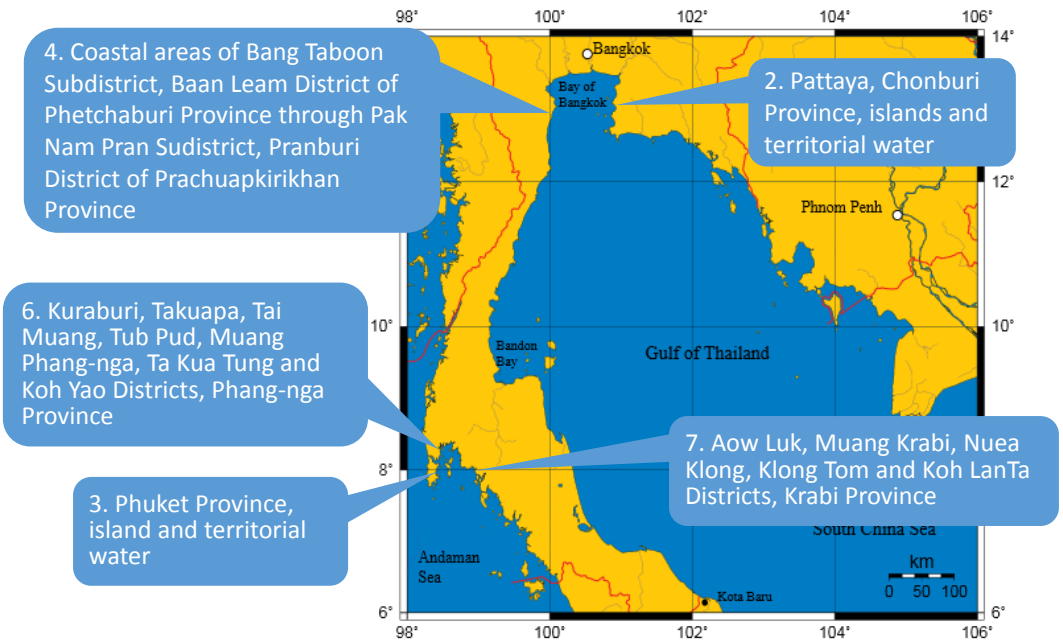
    20.6 Areas located next to RAMSAR sites or World Heritage Site inscribed in World Heritage List according to World Heritage Convention within 2 kilometer distance

    20.7 Areas located next to Ancient Remains.
21. Rail-Type Mass Transit System
22. Port
23. Recreational Port
24. Land Reclamation
25. Construction or Expansion of Structures close to or in the sea
26. Aviation Transportation System
27. Building which is defined by the Building Control Act that has location near rivers, seacoast, lakes or beaches or in the vicinity or inside National Parks or Historical Parks
28. Land Allocation for residential or commercial purposes which are defined by the Land Allocation Act
29. Hospitals or Nursing Homes that are defined by the Medical Services Act
30. Hotel or Resort which is defined by the Hotel Act
31. Residential Building which is defined by the Building Control Act
32. Irrigation
33. All projects located in the areas classified as Class 1 watershed area by the cabinet resolution
34. Trans Watershed Diversion

    34.1 Trans major watershed diversion as temporarily operated except for disaster or impact to public security

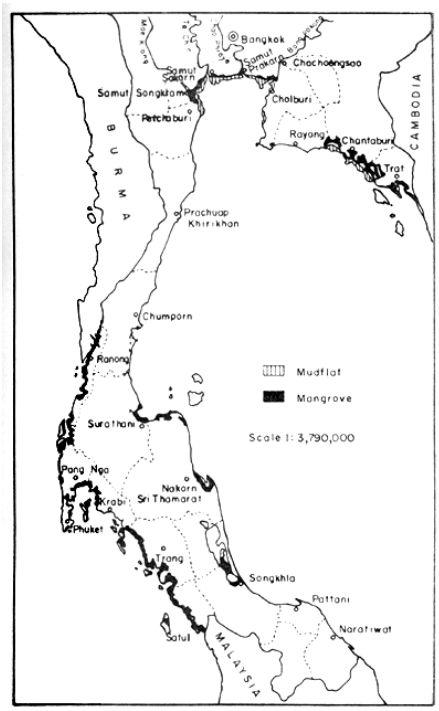
    34.2International trans watershed diversion as temporarily operated except for disaster or impact to public security
35. Sluicegate in a Major River
36. Coke production

Source：Environmental Impact Assessment in Thailand, 2015, ONEP



Source : JICA Study Tram

Figure 8.2.1 Environmentally Protected Areas according to "the Notification of Environmentally Protected Area" Ministry of Natural Resources and Environment, Thailand (MoNRE)



Source : The Present State of Mangrove Ecosystems in Southeast Asia and the Impact of Pollution, 1980, FAO

Figure 8.2.2 Distribution of mangrove wetlands in the Gulf of Thailand

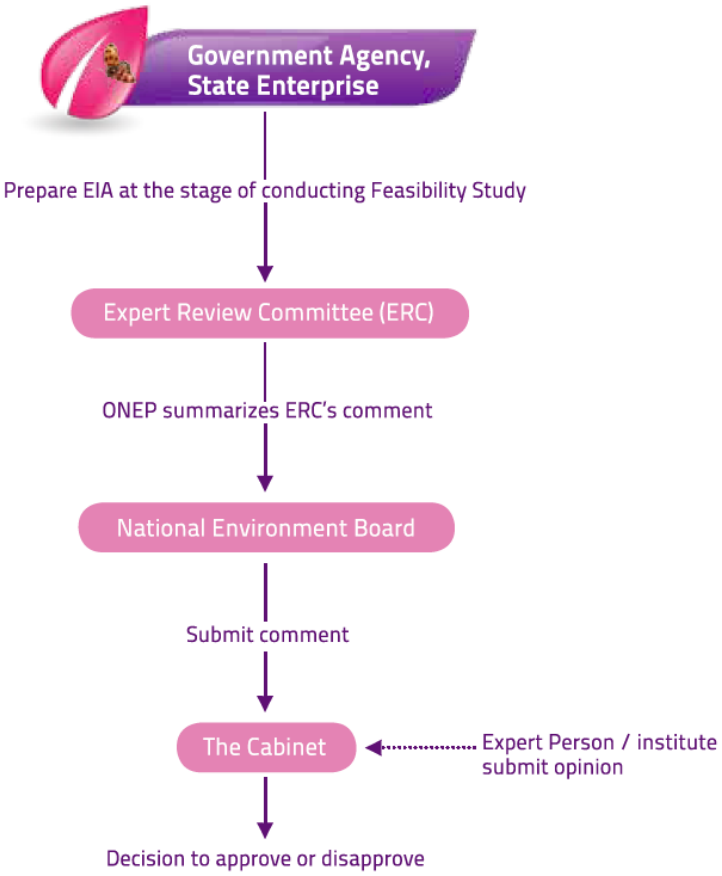
(2) Review and approval process of EIA report

According to the "Environmental Impact Assessment in Thailand, 2015, ONEP", this project meets the criteria of a joint project implemented by a government agency, state enterprise and/or private company.

Hence, an EIA report, which will be prepared by EIA consultants licensed by Office of Natural Resources and Environmental Policy and Planning (ONEP), at the stage of conducting feasibility study (F/S), will have to be subject to review by the National Environment Board (NEB) and approval by the Cabinet.

The EIA review process for a project or activity of a government agency, state enterprise, or to be jointly undertaken with private enterprises which requires the approval of the Cabinet is detailed below.

In accordance with the NEQA (1992), the project proponent shall have the duty to prepare the EIA report at the stage of conducting the feasibility study and submit the EIA report to NEB for its review and comments after which the EIA report will then be submitted to the Cabinet for its consideration. However, in practice, the EIA report will be submitted to ONEP, and ONEP will examine the EIA report, make preliminary comments and then refer ONEP's preliminary comments to the ERC for consideration before submitting comments of the ERC to NEB. If the EIA report is approved by the Cabinet, the official legally empowered to grant permission shall accordingly order that the permission be granted to the agency responsible for the project.



Source : Environmental Impact Assessment in Thailand, 2013, ONEP

Figure 8.2.3 Approval process for projects or activities requiring the approval of the cabinet

According to the "Environmental Impact Assessment in Thailand, 2015, ONEP", the description of rules on land acquisition and involuntary relocation, which prescribes the land acquisition process only, is relatively unelaborate compared to common international standards such as IFC Performance Standards.

However, public participation/meetings will have to take place at least two times (1) at the stage of scoping the EIA study and (2) at the stage of drafting the EIA report.

Currently, the F/S and public meetings regarding EIA of the Outer Ring Road project have been completed, and are still waiting for the approval.

Therefore, shortening of the duration of the F/S and EIA of the Diversion Channel project will have to be sought by employing several EIA consultant firms and holding public meetings in several provinces around the same time.

8.3 Proposal

8.1.1 Appropriate Response toward Environmental Impact Assessment (EIA)

In accordance with the "National Environment Quality Act (NEQA, 1992)", RID shall have the duty to prepare the EIA report at the stage of conducting feasibility study (FS) and submit the EIA report to the National Environment Board (NEB) for its review and comments, after which the EIA report

will then be submitted to the Cabinet for its consideration.

In practice, the EIA report will be submitted to the Office of Natural Resources and Environmental Policy and Planning (ONEP), and ONEP will examine the EIA report, make preliminary comments and then refer its preliminary comments to the Expert Review Committee (ERC) for consideration before submitting comments of the ERC to NEB.

When the EIA report is approved by the Cabinet, the official legally empowered to grant permission shall accordingly order that the permission be granted to RID.

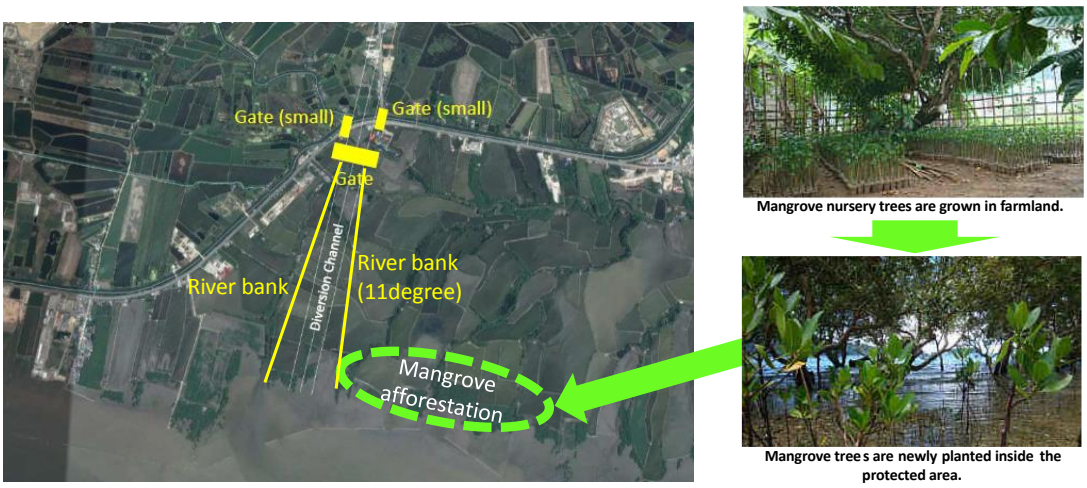
In parallel, public meetings will have to take place at least two times (1) at the stage of scoping the EIA study and (2) at the stage of drafting the EIA report.

Therefore, shortening of the duration of FS and EIA of the Diversion Channel project will have to be sought by employing several EIA consultant firms and holding public meeting at several provinces around the same time.

8.1.2 Natural Environment (Nature Refuge, Biota and Ecosystem)

Mangrove within Inner Gulf of Thailand is designated as Thai national forest reserve (2000 August, cabinet decision) and wetland within Inner Gulf of Thailand is nominated for the Ramsar Convention registration.

For the purpose of conservation and maintenance of mangrove and wetland along the coastal area, Afforestation and restoration of mangrove at the periphery of outlet of the Outer Ring Road Diversion Channel is necessary.



Source : JICA Study Tram

Figure 8.3.1 Image of compensatory approach of mangrove conservation

Compensatory approach an equivalent area of mangrove afforestation and restoration should be considered for unavoidable cutting down of existing mangrove trees around the outlet of the Diversion Channel.

When the EIA concerned with the Diversion Channel is implemented, consultation will be necessary with not only ONEP, but also and with the Department of Marine and Coastal Resources, MoNRE,

who is in charge of mangrove conservation.

So far, any precious species of animals and plants are not found in the surrounding areas. However, in case any precious species are newly found in the future, some conservation measures become necessary and need attention.

8.1.3 Social Environment

In terms of social Environment (involuntary resettlement, cultural heritage, etc.), comparison analysis of the most appropriate alignment of the Outer Ring Road Diversion Channel is conducted and decided in order to minimize the involuntary relocation number in this survey.

In the feasibility study, the following possible social environmental impacts and mitigation measures due to the Diversion Channel construction need to be considered.

- Minimization of land acquisition area and involuntary relocation number
  - Optimization of the Diversion Channel alignment
- Promotion of re-establishment of the relocated residents
  - Application of appropriate compensation for property (land, house, building, tree, etc.)
  - Reconstruction of residential area of new address
- Conservation of historical and cultural heritage
  - Optimization of the Diversion Channel alignment

Table 8.3.1 Important properties to need attention when constructing the Outer Ring Road Diversion Channel

No.	Community/ Facility	Province	District	Subdistrict
1	Smile Land & House Village	Phra Nakhon Si Ayutthaya	Bang Pa-In	Kung Lam
2	Somwang Sub Muen Saen Village			Sam Ruean
3	Ban Chang		U-Thai	Ban Chang
4	Liab Khlong Hok Community		Wang Noi	Lamtasao
5	Liab Khlong 27 Community			Hantaphao
6	Liab Khlong 26 Community			Khao Ngam
7	Khao Ngam SAO Office			
8	Wat Pakhlong 11	Pathum Thani	Nong Suea	Bung Kasam
9	Ban Suan Si Pathum			Bung Ba
10	Ban Bung Sanan		Thanyaburi	Bung Sanan
11	Ban Ua Athon Pathumthani			
12	Thamle Thong Community		Lamlookka	Bung Thonglang
13	Ban Khlong Sib	Bangkok	Nong Jok	Khlong Sib
14	Ban Lam Chedi			

No.	Community/ Facility	Province	District	Subdistrict
15	Temsiri Park			Khu Fang Nua
16	Lam Hin Police Station			
17	Nong Jok Community (NHA)			
18	Bayan 2 Village	Bangkok	Nong Jok	Khu Fang Nua
19	Darussalam Mosque			Khok Faed
20	Darussalam Foundation			
21	Erua Mosque School			
22	Nanthawan Bayan Village			
23	Al-Amiah Cemetery			
24	Ban Lam Erua			
25	Sue Trong Suwinthawong Village			Lam Phakchi
26	Watthana Village			
27	Watthana 2 Village			
28	Soi Kheha Chumchon Chalong Krung			
29	Wat Lamphra-ong Community			
30	Lamphakchi School			
31	Lamphakchi Children Dev. Center			
32	Orchid Ville	Samut Prakan	Bang Sao Thong	Bang Sao Thong
33	Bang Sao Thong Residential Area			

Source：JICA Study Team

CHAPTER 9 PROJECT EVALUATION

9.1 Condition of the hydraulic analysis for economic evaluation of flood control

9.1.1 Cases for discussion

Cases for discussion are as follows.

With / Without	Case	Countermeasures
Without	Case 0	Leveling the National Route 9
With	Case 1-0	・ Leveling the National Route 9 ・ Improvement of operation rules of existing dam ・ Outer Ring Diversion Channel (500m3/s)
	Case 1-1	・ Leveling the National Route 9 ・ Improvement of operation rules of existing dam ・ Ayutthaya Bypass (1,2000 m3/s) ・ Outer Ring Diversion Channel (500m3/s)

Source ：JICA study team

9.1.2 Boundary condition

(1) Rainfall

Rainfall condition is the result of runoff analysis of rainfall at upstream end of river channel with return periods of 2, 3, 5, 10, 30, 50, and 100.

It should be noted that rainfall in the flood plain area is not considered in order to clarify the effect of each countermeasure.

(2) Runoff from the residual basin

The calculation results with each probability scale rainfall was taken as the runoff from the residual basin. This method is similar to the method for calculating the runoff at the upstream end.

(3) Outflow from the Bhumibol Dam and the Sirikit Dam

Current dam operation is organized as described below according to reports from the RID.

<Operation suggested in the existing M/P>

- May 1st –- August 1st : Inflow = Outflow, maintain the storage level
- August 1st – November 1st (Flood season): Maximal outflow (Bhumibol Dam: 210m^3/s, Sirikit Dam: 190 m^3/s)

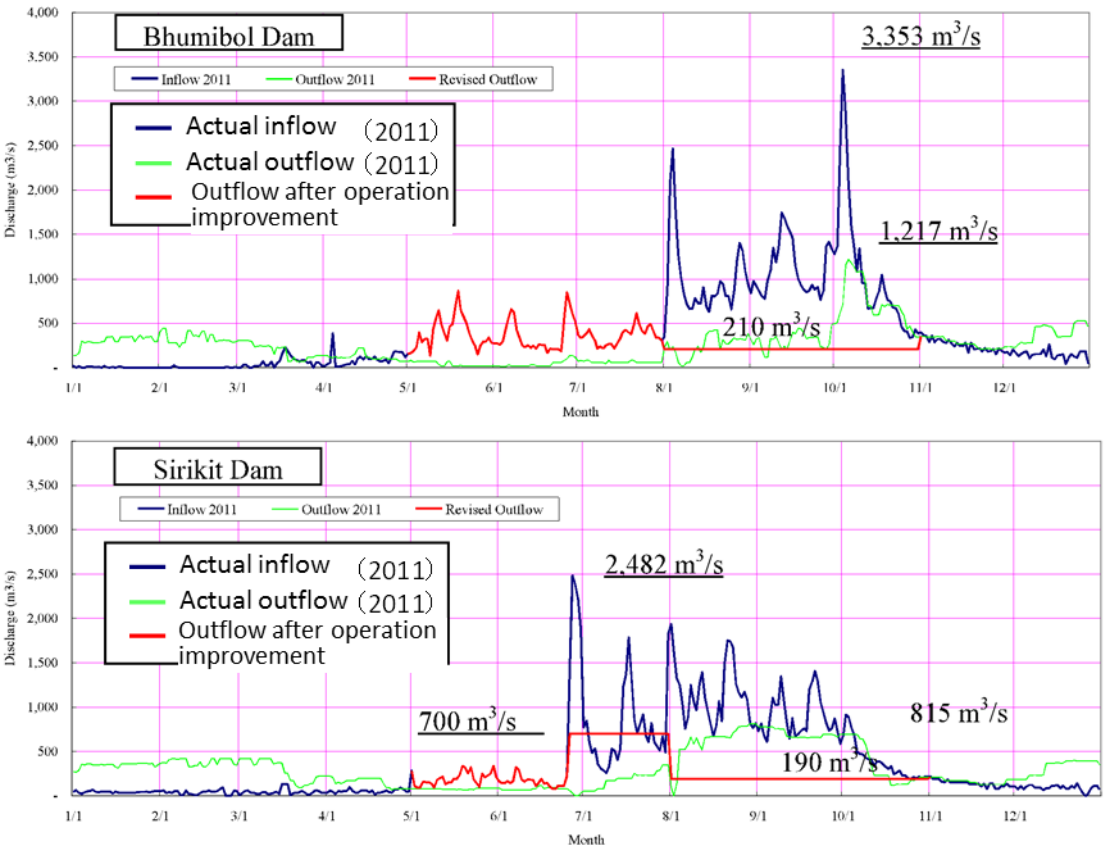
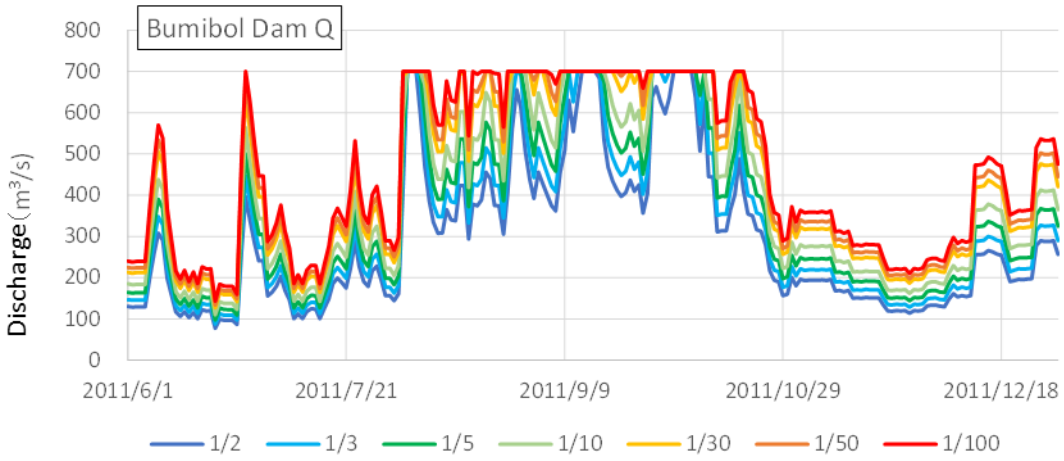
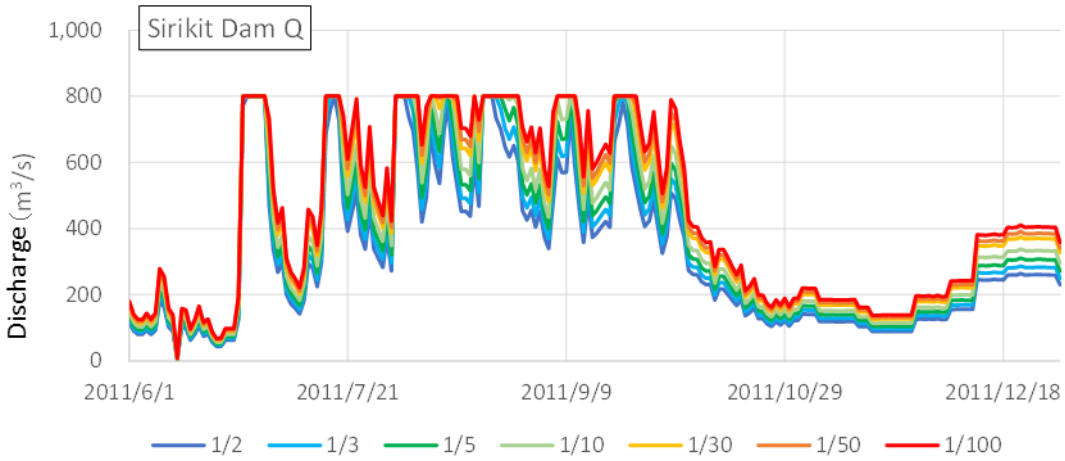


Figure 9.1.1 Hydrograph of Bhumibol Dam and Sirikit Dam

<Dam operation based on the current situation>

- Maximal outflow is 700m^3/s at Bhumibol Dam, and 800m^3/s at Sirikit Dam
- There is no seasonal change in operation rules and no fixed rules.
- Based on the current situation as described above, in the calculation duration, from June 1st to December 31st, dam operation is set according the rules as follows:
  - Basically, Inflow = Outflow
  - When inflow is 700m^3/s at Bhumibol Dam and more than 800m^3/s at Sirikit Dam, store more water.





Source：JICA study team

Figure 9.1.2 Setting of the outflow from Bumibol Dam and Sirikit Dam

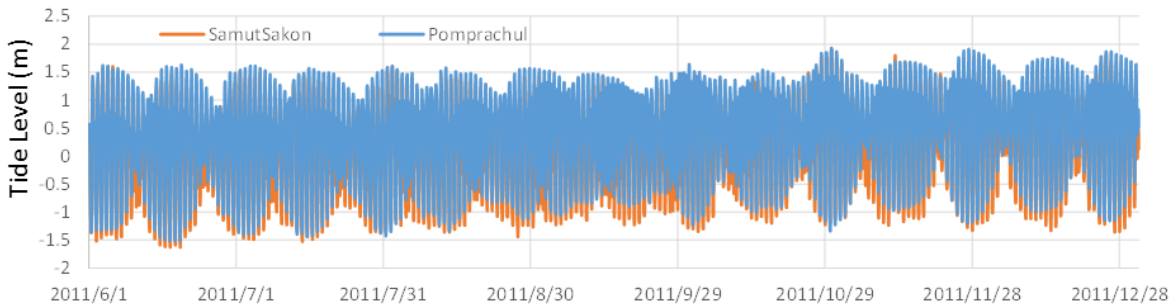
(4) Condition of water level at the downstream end

As well as the report on the existing M/P, the water level at the downstream end of the Chao Phraya River and the Tachin River is calculated given the tide in the Gulf of Thailand as a boundary condition.

Table 9.1.1 Water level at the downstream end

Boundary Point	Position	Observatory of Tide
Downstream end	River-mouth of the Chao Phraya River	Pomprachul
	River-mouth of the Tachin River	Samut Sakon

Source : JICA study team

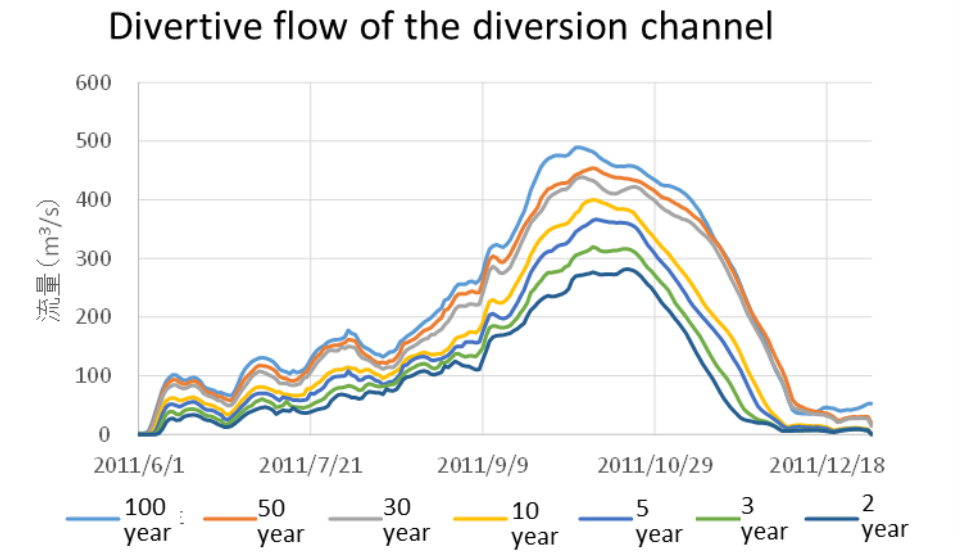


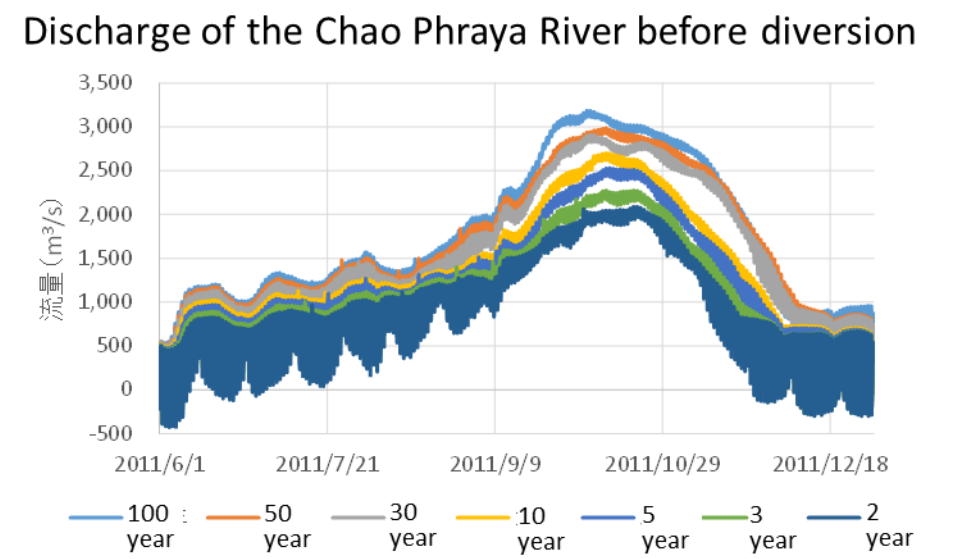
Source : JICA study team

Figure 9.1.3 Hydrograph of the water level at the downstream end

(5) Diversion discharge to the Outer Ring Road Diversion Channel

If the discharge at the entrance in Chao Phraya River will reach to 500m^3/s, the discharge diversion to the Diversion Channel will be started. This discharge (500m^3/s) corresponds to the plentiful discharge (95-day discharge) that is estimated based on the observed discharge from 2007 to 2015 in Chao Phraya River. From the above, the ratio of remained discharge in Chao Phraya River to the diversion discharge during flooding time is set as 8.3 : 1.7.





Source ：JICA study team

Figure 9.1.4 Hydrology of divertive flow to the Outer Ring Road Diversion Channel

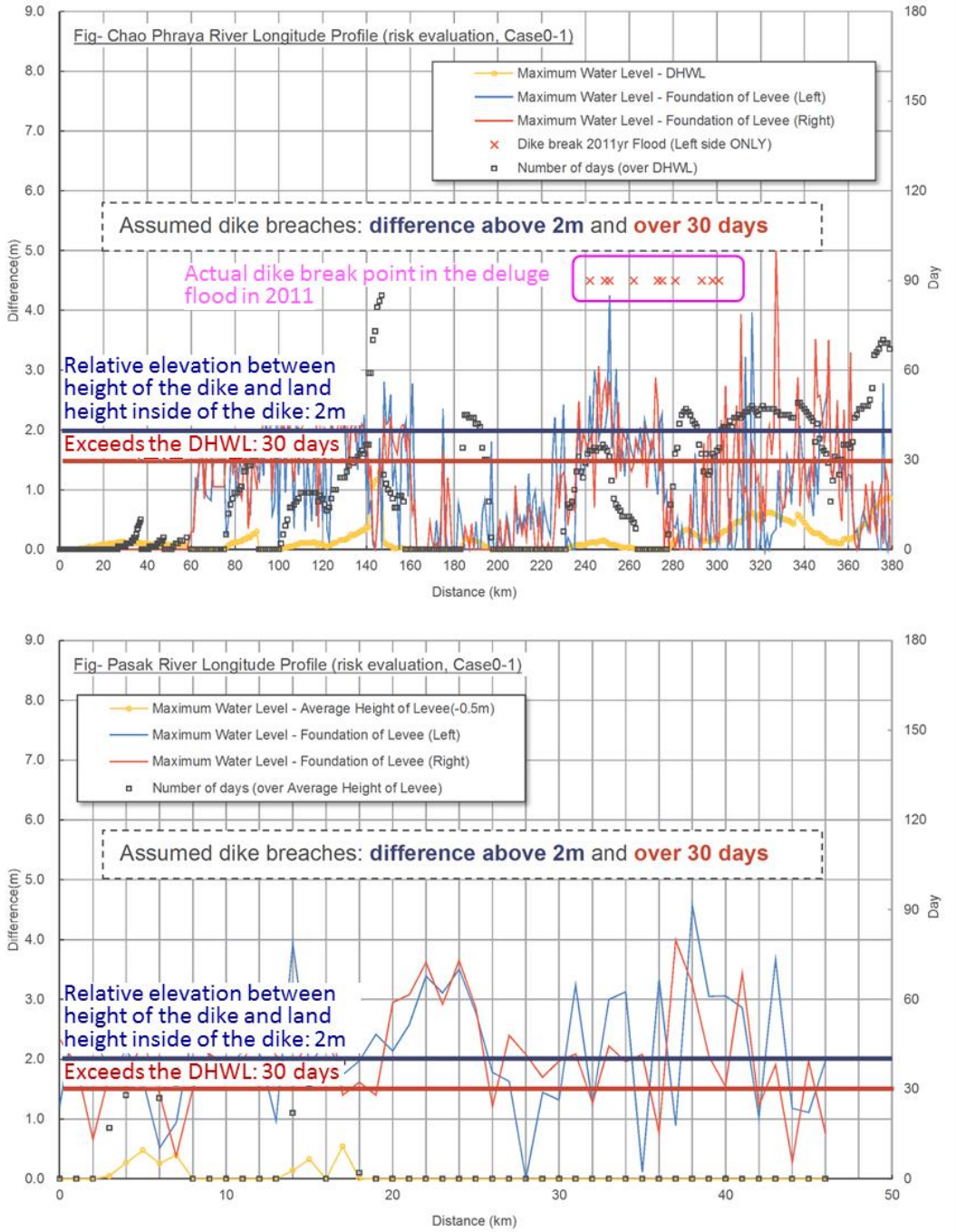
9.1.3 Condition of the river channel

(1) Dike break location

In the deluge flood in 2011, dike break occurred along the Chao Phraya River. In the economic evaluation of flood control, in order to evaluate based on conceivable risks of flood even after the project is complete, an analysis was conducted considering the risk of dike break. The conditions to select assumed dike break locations include the conditions listed below that were used in the report on the existing M/P and in reference to the features of dike break locations in the deluge flood in 2011. The conditions are as follows:

- Subject river channel : Chao Phraya River and Pasak River
- Relative elevation difference between the dike height and the land height in the dike is more than 2m

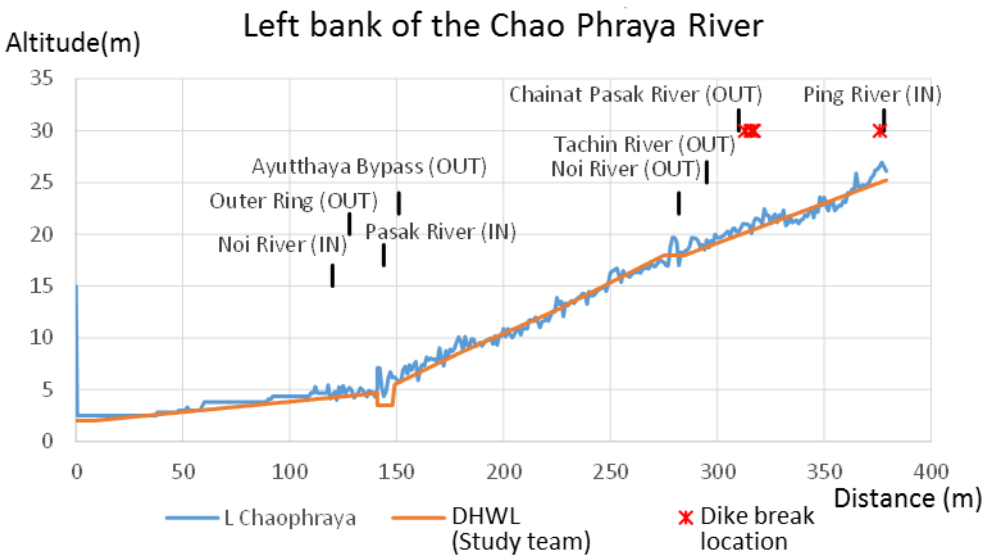
- Chao Phraya River: The river water level exceeds the DHWL for more than 30 days
- Pasak River: The river water level exceeds the height which is 0.5m lower than the average height of the right and left dikes for more than 30 days

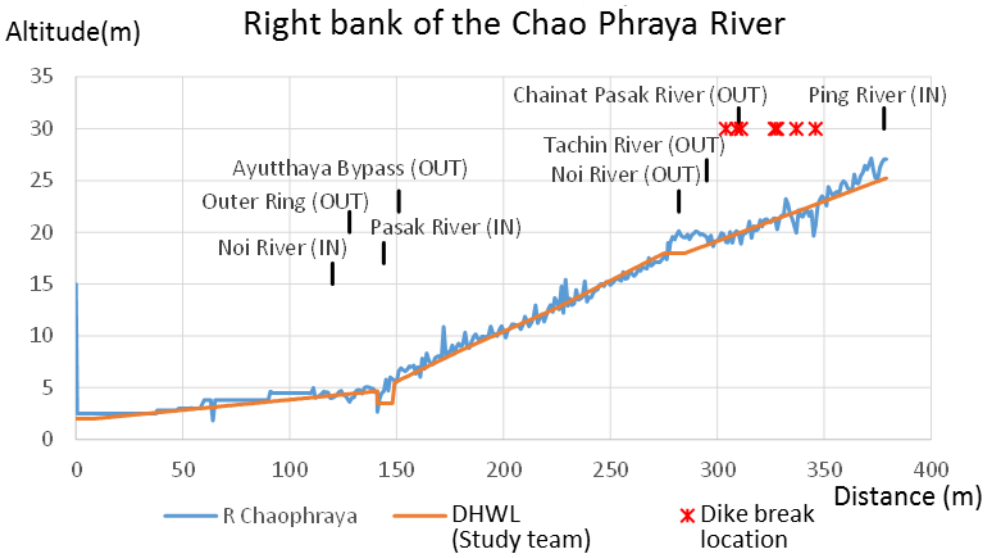


※*Source: Supporting Report Sector P*

Figure 9.1.5 Comparison of dike break locations between calculated results by reproduction simulation and actual locations in the deluge flood in 2011

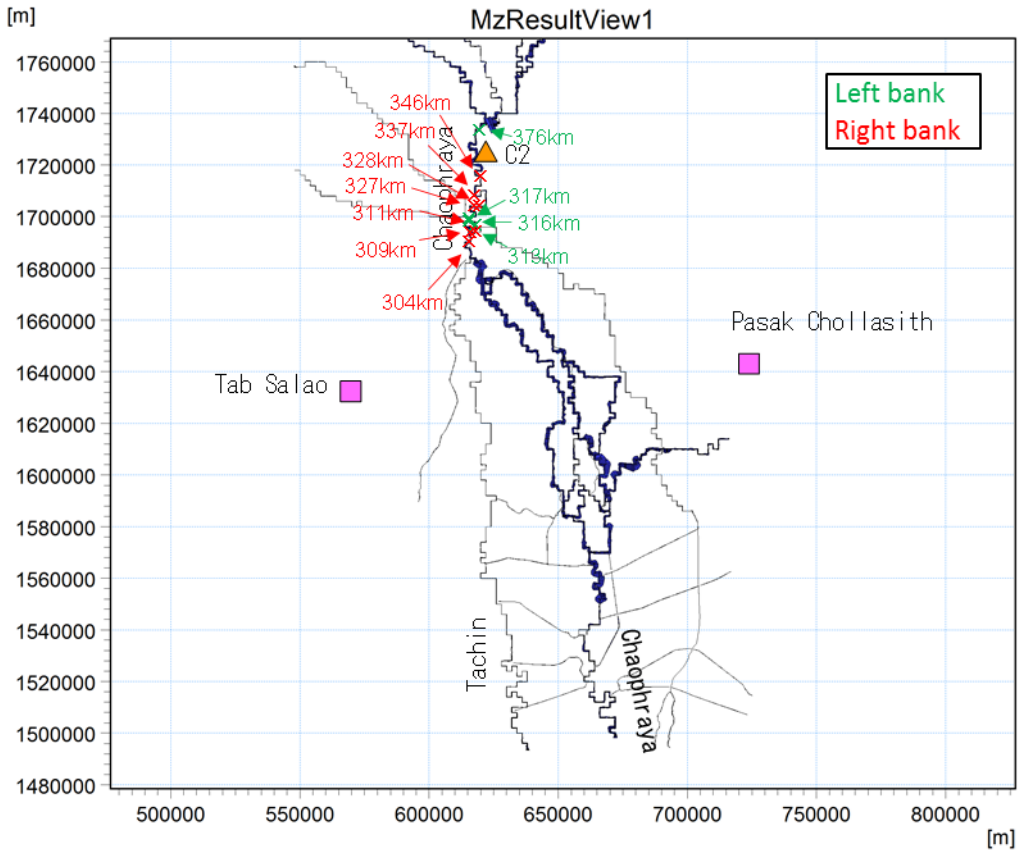
The following shows the breach starting point in this discussion.





Source : JICA study team

Figure 9.1.6 Longitudinal positions of the dike breaks



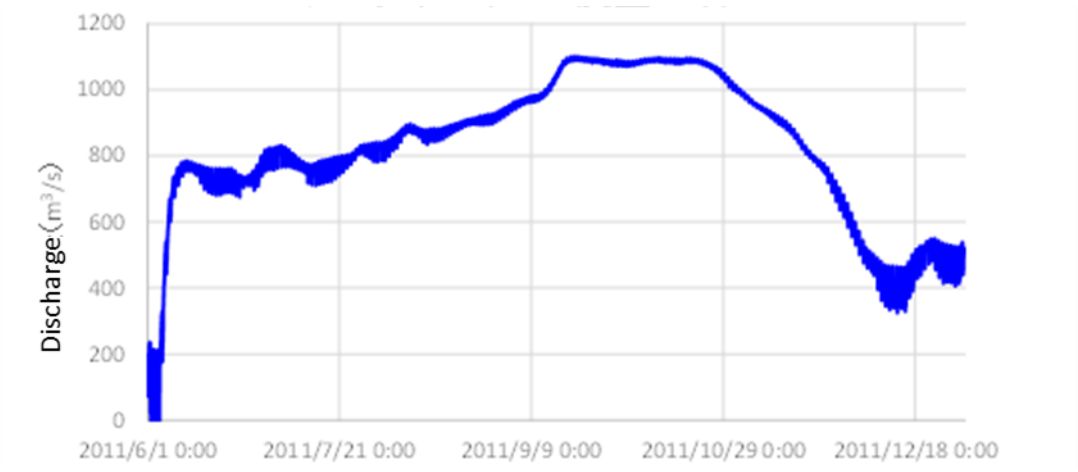
Source ：JICA study team

Figure 9.1.7 Two-dimensional positions of dike breaks

(2) Conditions of river channels near the Ayutthaya Bypass

The current RID Plan plans to construct a weir across the main stream of the Chao Phraya River at the diversion point of the Ayutthaya Bypass and discharge all the water into the Ayutthaya Bypass when a flood occurs. However, operation procedures of the weir are unplanned currently.

Thus, in this model, the discharge from the main stream of the Chao Phraya River is assumed to flow down into the Ayutthaya Bypass during all the period of calculation. The hydrograph of the flows in the Case 1-1 (100-year probability scale) is as follows.



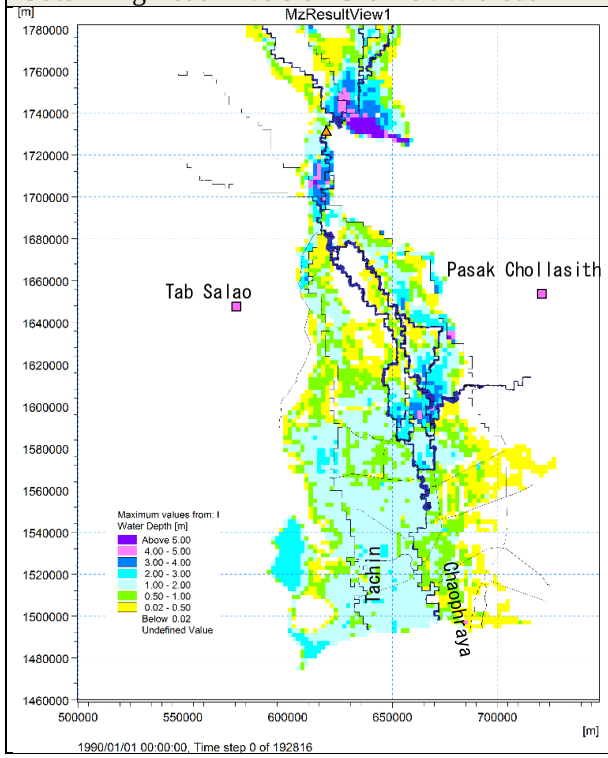
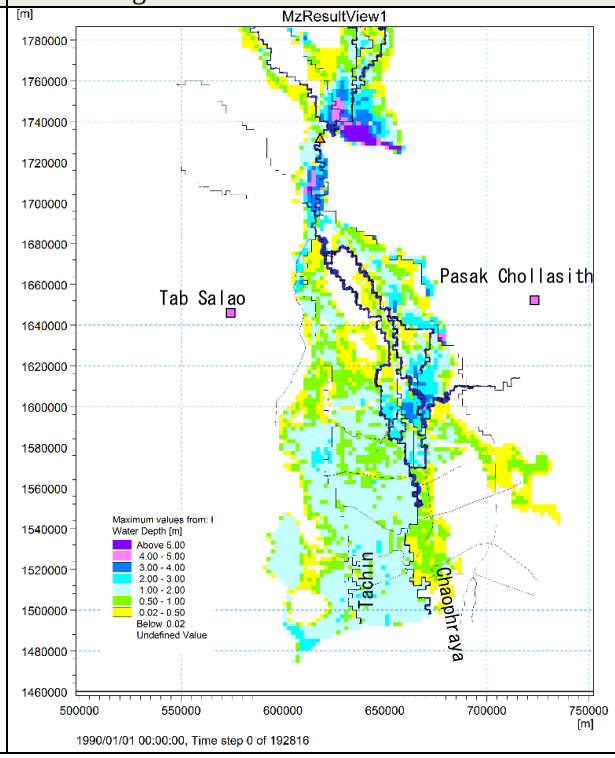
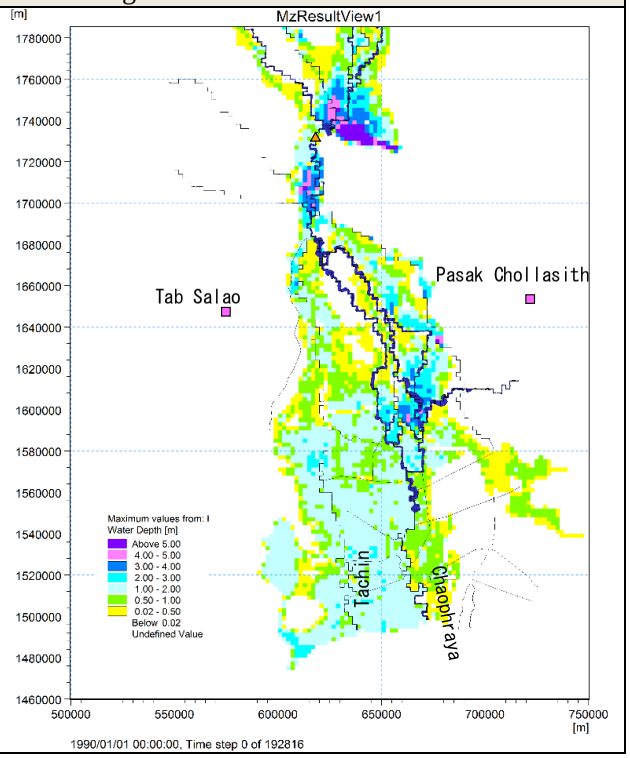
Source：JICA study team

Figure 9.1.8 Hydrograph of the flows of Ayutthaya Bypass

9.1.4 The result of hydraulic analysis

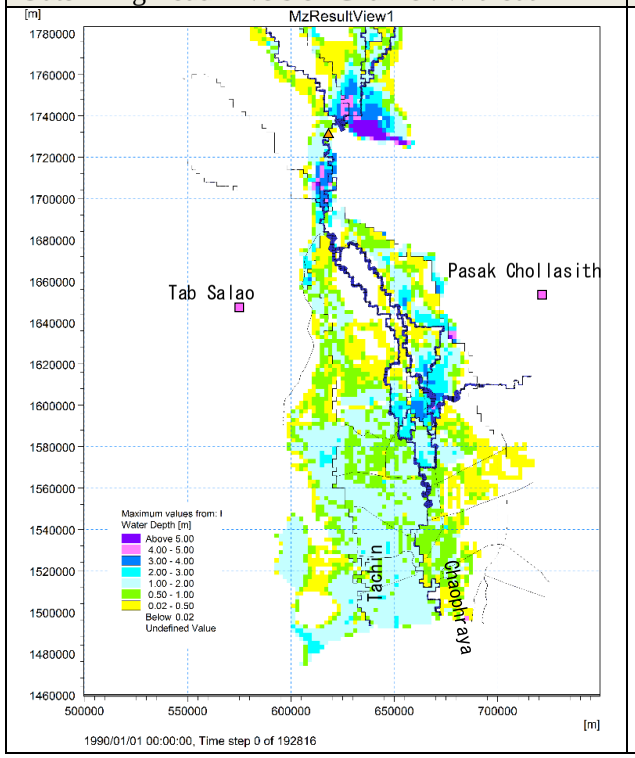
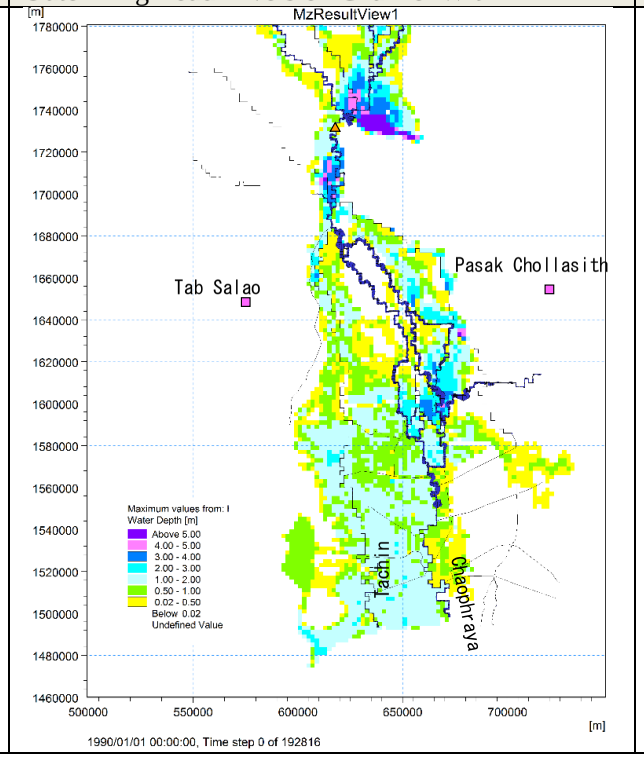
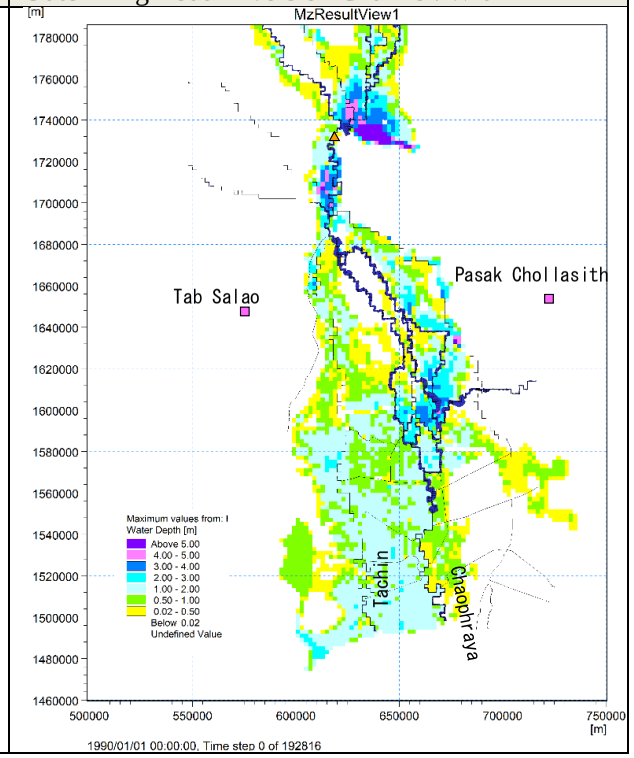
As a result of the hydraulic analysis to apply to the economic evaluations of flood control, inundation area and discharge at the point of Chao Phraya River 116 km for each case are shown as follows:

Table 9.1.2 The maximum inundation depth for each case (100-year probability)

100-year		
Case 0	Case 1-1	Case 1-0
Ayutthaya Bypass : Without Outer Ring Road Diversion Channel: Without	Ayutthaya Bypass : : With Outer Ring Road Diversion Channel : With	Ayutthaya Bypass: Without Outer Ring Road Diversion Channel : With
		

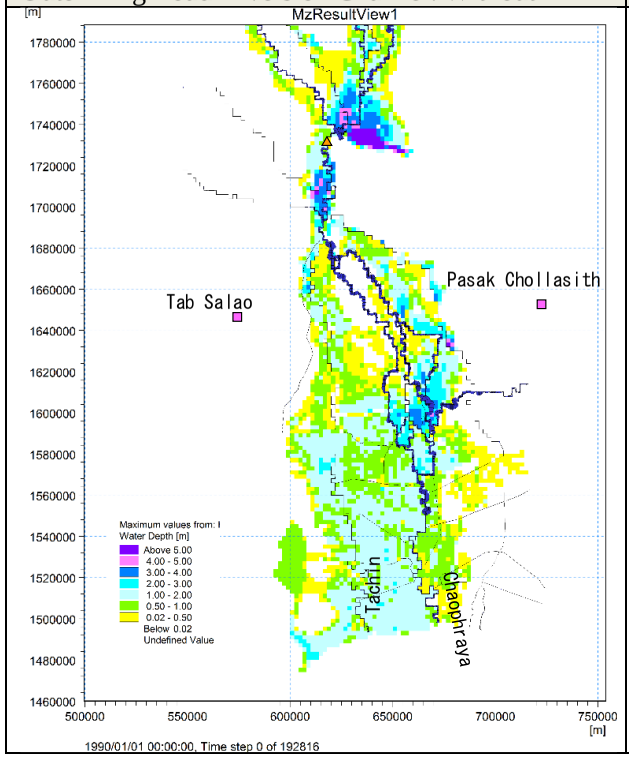
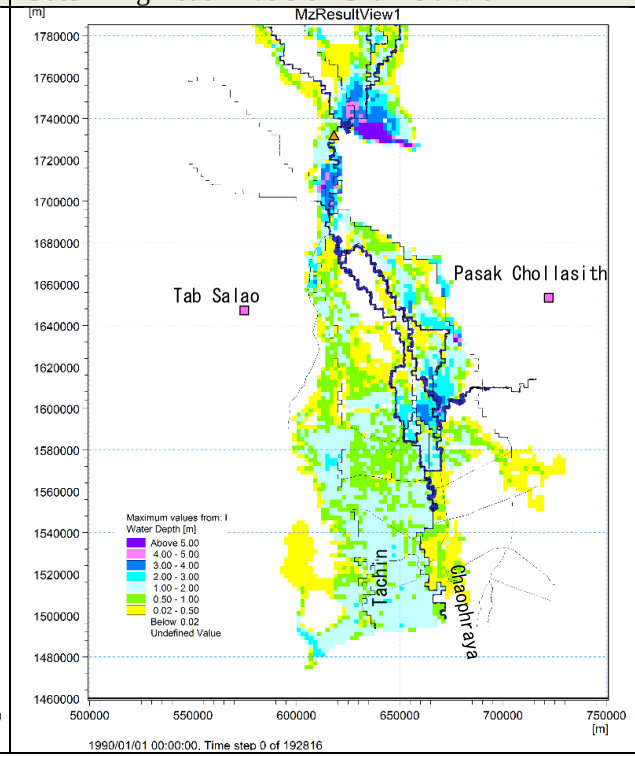
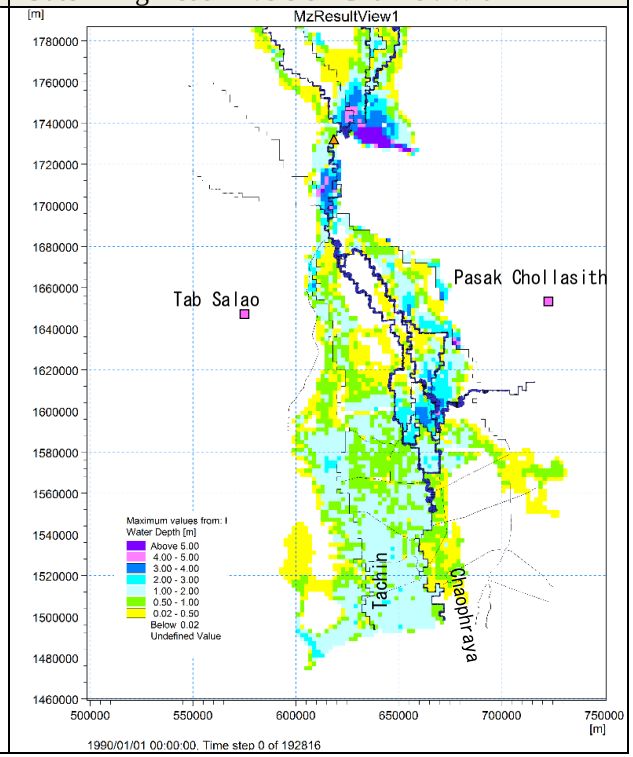
Source : JICA study team

Table 9.1.3 The maximum immersion depth for each case (50-year probability)

50-year		
Case 0	Case 1-1	Case 1-0
Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: Without	Ayutthaya Bypass: With Outer Ring Road Diversion Channel With	Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: With
		

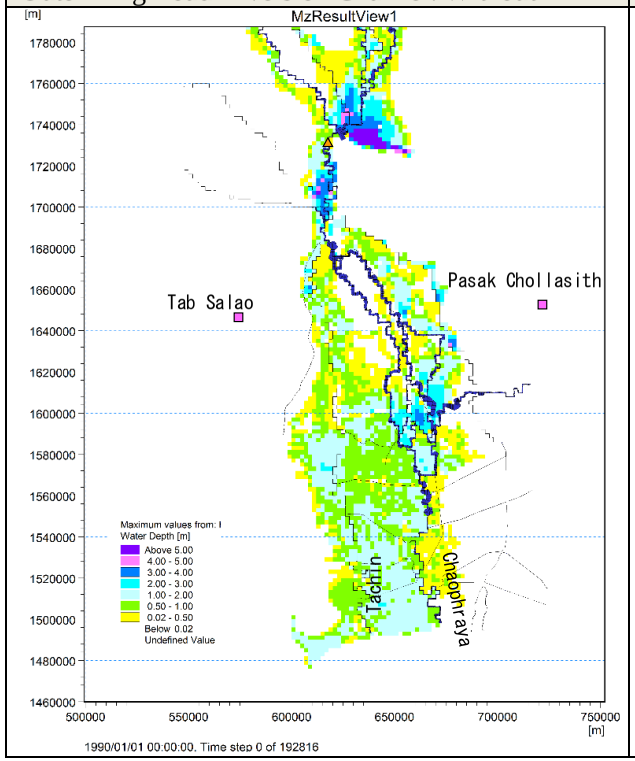
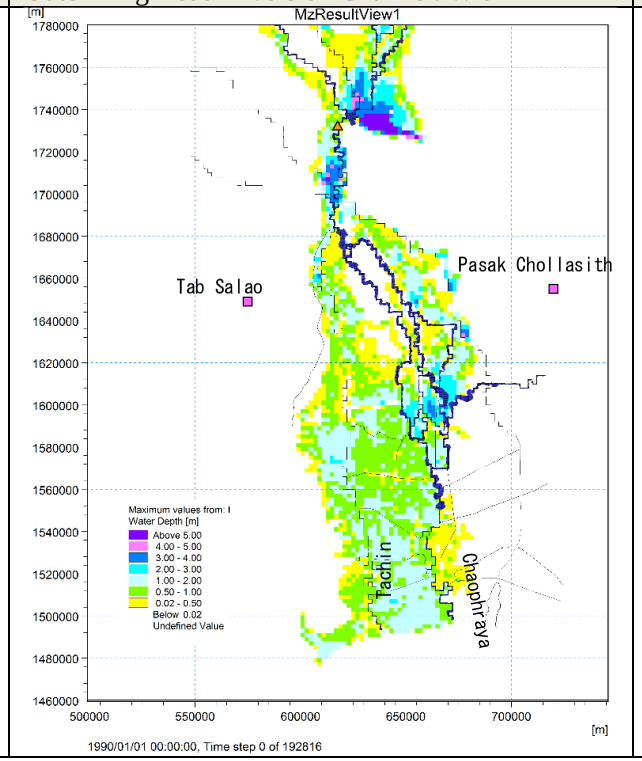
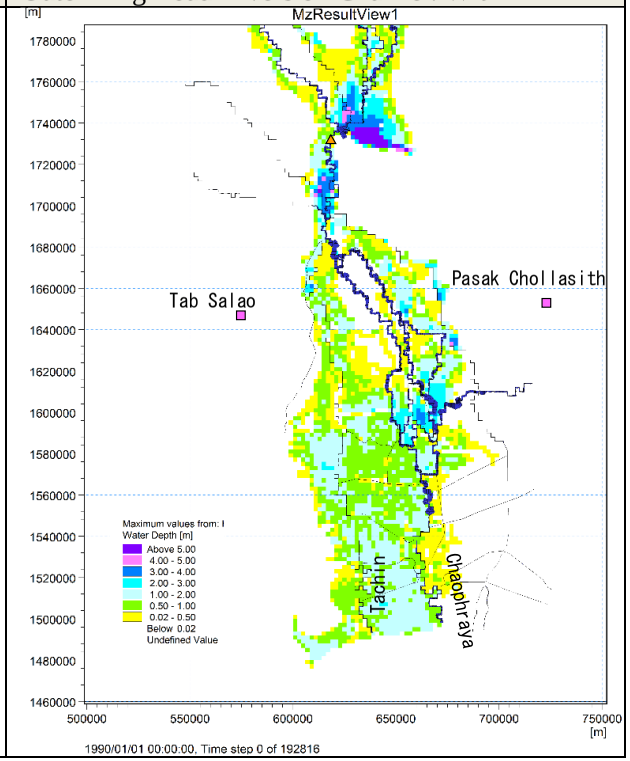
Source : JICA study team

Table 9.1.4 The maximum immersion depth for each case (30-year probability)

30-year		
Case 0	Case 1-1	Case 1-0
Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: Without	Ayutthaya Bypass: With Outer Ring Road Diversion Channel: With	Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: With
		

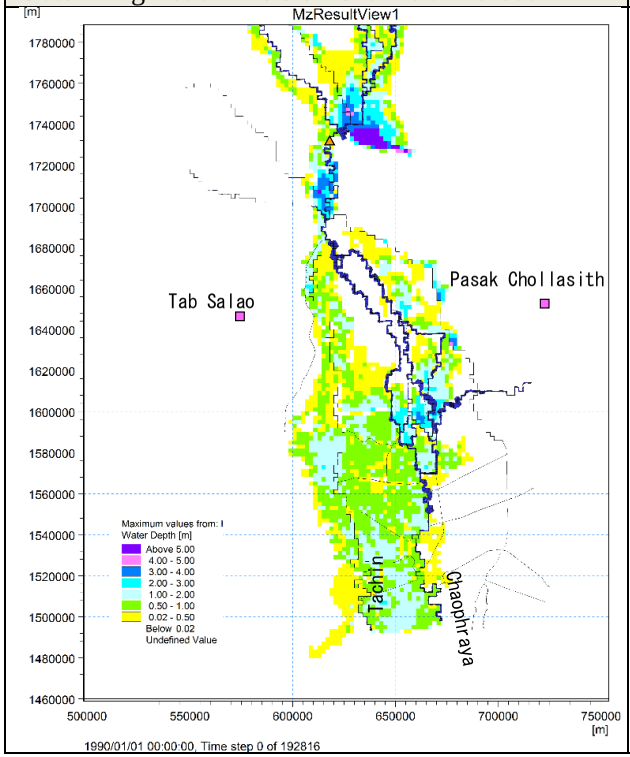
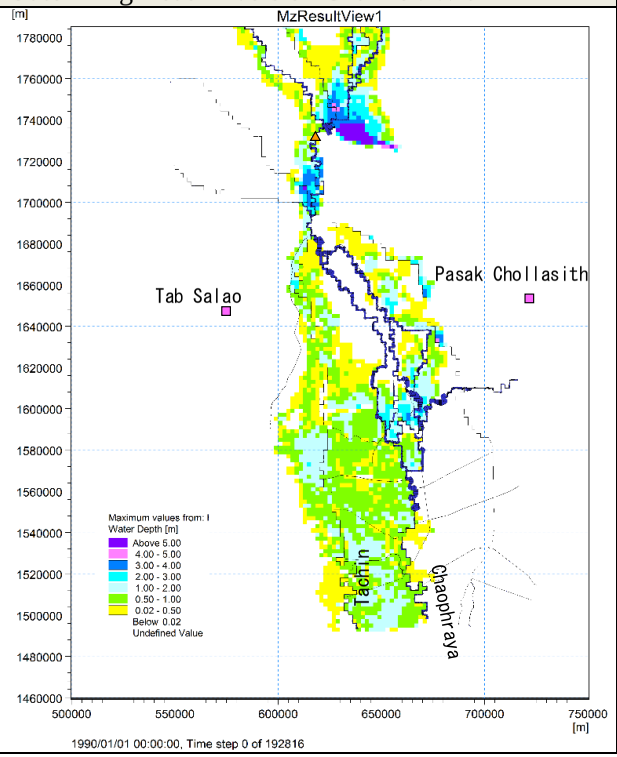
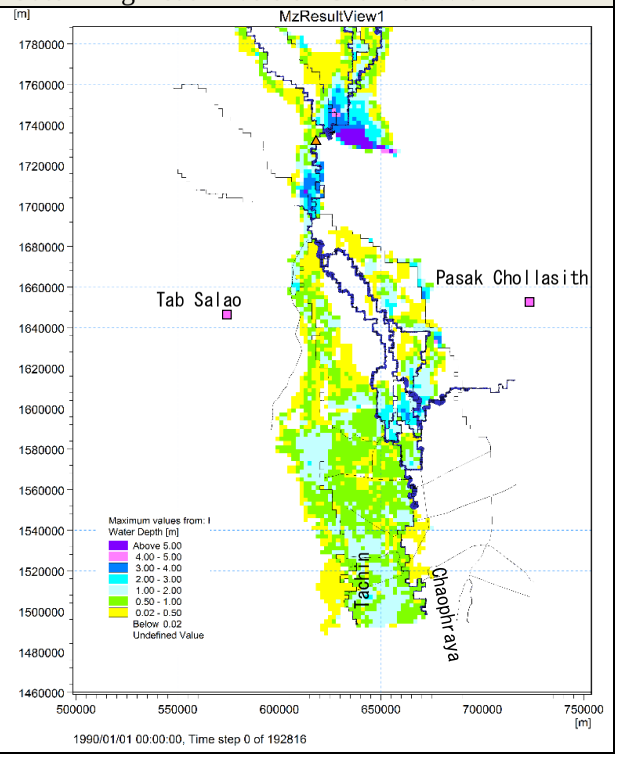
Source : JICA study team

Table 9.1.5 The maximum immersion depth for each case (10-year probability)

10-year		
Case 0	Case 1-1	Case 1-0
Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: Without	Ayutthaya Bypass: With Outer Ring Road Diversion Channel: With	Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: With
		

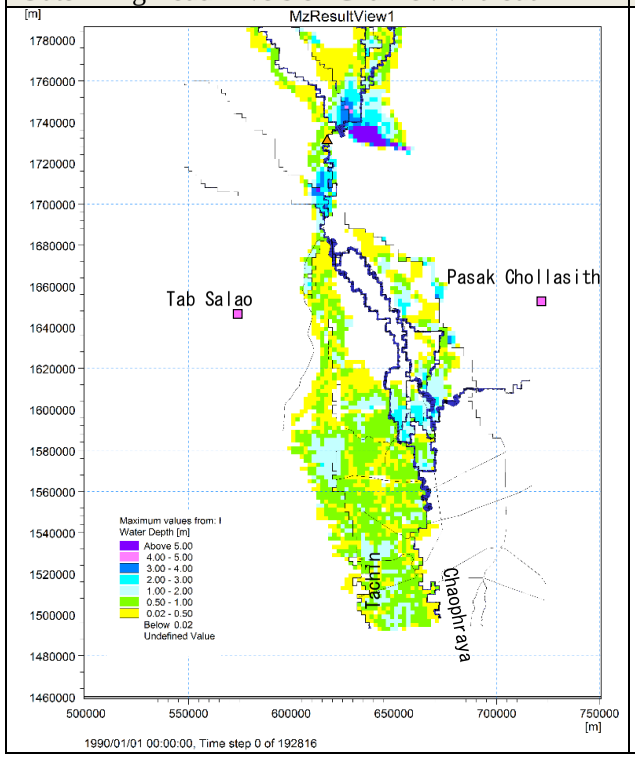
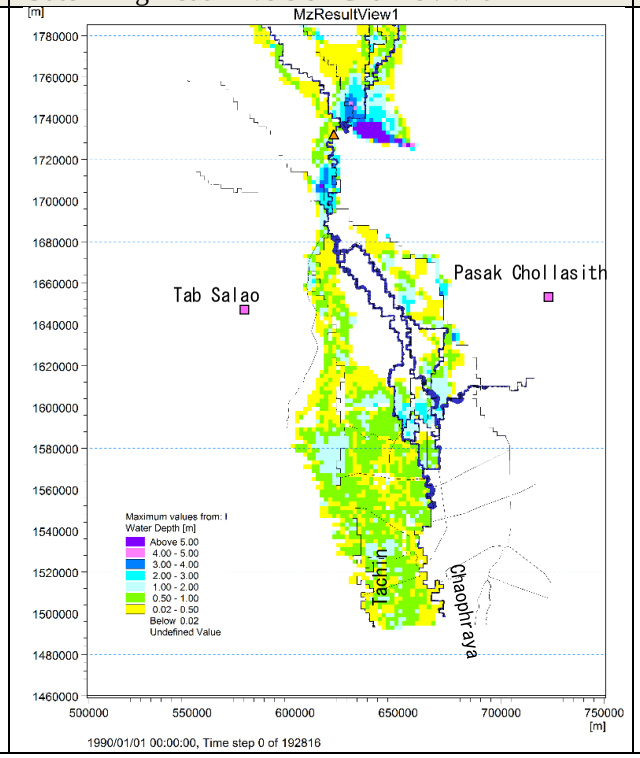
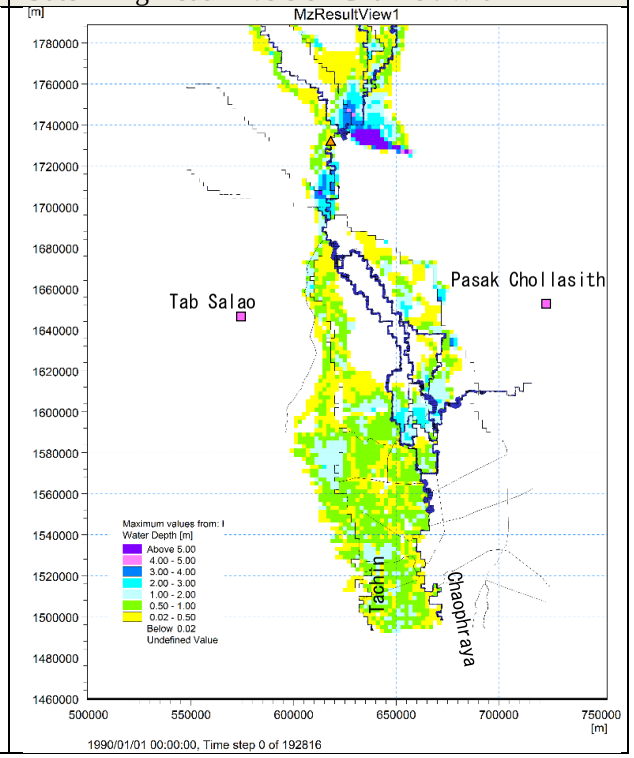
Source : JICA study team

Table 9.1.6 The maximum immersion depth for each case (5-year probability)

5-year		
Case 0	Case 1-1	Case 1-0
Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: Without	Ayutthaya Bypass: With Outer Ring Road Diversion Channel: With	Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: With
		

Source : JICA study team

Table 9.1.7 The maximum immersion depth for each case (3-year probability)

3-year		
Case 0	Case 1-1	Case 1-0
Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: Without	Ayutthaya Bypass: With Outer Ring Road Diversion Channel: With	Ayutthaya Bypass: Without Outer Ring Road Diversion Channel: With
		

Source : JICA study team

Table 9.1.8 Inundation area (Whole Area)

(Square measure: km2)

Case	100-year	50-year	30-year	10-year	5-year	3-year	2-year
Case 0	21,237	20,176	19,658	16,934	15,140	13,213	12,072
Case 1-1	20,479	19,670	19,265	16,355	-	-	-
Case 1-0	20,819	20,071	19,447	16,816	-	-	-
Difference (Case 1-1)	-757	-506	-393	-579	-	-	-
Difference (Case 1-0)	-417	-105	-211	-117	-	-	-

Source: JICA Study Team

Table 9.1.9 Inundation area (In Protected Area)

(Square measure: km2)

Case	100-year	50-year	30-year	10-year	5-year	3-year	2-year
Case 0	5,080	4,597	4,382	3,549	41	38	30
Case 1-1	4,048	3,880	3,829	3,055	-	-	-
Case 1-0	4,232	4,066	3,910	3,474	-	-	-
Difference (Case 1-1)	-1,032	-717	-554	-494	-	-	-
Difference (Case 1-0)	-848	-531	-473	-75	-	-	-

Source: JICA Study Team

Table 9.1.10 Discharge of the river channel (Point 116km of the Chao Phraya River)

(Discharge: m^3)

Case	100-year	50-year	30-year	10-year	5-year	3-year	2-year
Case 0	3,838	3,802	3,772	3,458	3,187	2,979	2,746
Case 1-1	3,849	3,815	3,795	3,400	-	-	-
Case 1-0	3,619	3,581	3,560	3,260	-	-	-
Difference (Case 1-1)	+11	+12	+23	-58	-	-	-
Difference (Case 1-0)	-219	-221	-212	-198	-	-	-

Source: JICA Study Team

9.2 Project Cost

9.2.1 Diversion Channel

The rough cost estimate was updated by using the unit prices in 2017 that are shown in the following tables.

The decrease in the total cost, -9,882,576 THB, is due to the utilization of the excavated soil at middle part of Diversion Channel for construction of the embankment of the Outer Ring Road.

Table 9.2.1 Summary of the rough cost estimate of Diversion Channel

Unit: million THB

	(1) JICA Study	(2) JICA MP	(3) Ratio ((1)/(2))
Construction cost of DC	50,619	23,140	2.2
Structures of the facility	21,331	24,769	0.9
Land cost	52,450	18,821	2.8
Project cost	124,400	66,730	1.9

Source: JICA Study Team

Table 9.2.2 Rough cost estimate of Diversion Channel

Items			Quantity	Unit	Unit price (THB)	Amount (THB)		Remark
Earthwork	Excavation		58,783,824	m^3	20	1,175,676,480	44,795,262,061	a)
	Embankment	Mixing / Compaction (V)	16,004,910	m^3	292.2	4,676,634,702		
		Purchased sand for mixing (V/3)	5,334,970	m^3	135	720,221,085		
		Purchase sand transportation (Sand pit → Interchange 4)	5,334,970	m^3	240	1,280,393,040		
		Purchased sand transportation (Interchange 4 → Excavation yard)	5,334,970	m^3		995,262,785		
	Remained soil disposal	Remained soil disposal	38,231,309	m^3	282	10,781,229,138		
		Excavated soil	*58,783,824*	*m^3*				
		Utilize excavated soil	*-10,669,939*	*m^3*				
		Road embanking material	*-9,882,576*	*m^3*				
Planting work		Sodding	3,786,795	m^2	65	246,141,675		
Crest Pavement (2 lanes 10m width)		Under layer roadbed T=200mm	437,432	m^3	118.8	51,966,922		
		Upper layer roadbed T=150mm	308,729	m^3	313.6	96,817,414		
		Surface layer t=150mm	292,101	m^3	930.0	271,653,930		
Soil Stabilization		SCC (Soil Cement Column)	16,695,704	m^3	1,200	20,034,844,800		
		PVD (Prefabricated Vertical Drain)	42,938,001	m	90	3,864,420,090		
Boxculvert		Interchange 11 (4 places)	4	sites	150,000,000	600,000,000		
Factor F（Indirect construction cost rate)							5,823,384,068	b)=a)×0.13
Construction cost (Diversion Channel)							50,618,646,129	c)=a)+b)
Facility structure	Road bridge		27,000	m^2	82,000	2,214,000,000	18,876,624,000	d)
	Railway bridge		677,000	m	800	541,600,000		
	Gate	Upstream end, Downstream end	2	place		5,466,000,000		
	Syphon	14 places	1	set		7,429,000,000		
	Lock gate		1	set		2,500,000,000		
	General work	4% of the above				726,024,000		
Factor F（Indirect construction cost rate)							2,453,961,120	e)=d)×0.13
Construction cost (Facility structure)							21,330,585,120	f)=d)+e)
Construction cost							71,949,231,249	g)=c)+f)
Engineering Cost / Construction Control							5,755,938,500	h)=g)×0.08
Project Management Cost / Processing							2,158,476,937	i)=g)×0.03
Value added Tax							0	
Land Cost / Compensation							52,450,447,449	j)
Project cost							132,314,094,135	k)=g)+h)+i)+j)

The project cost including Engineering Cost / Construction adjustment Cost 5,756 Mil B and Project Management Cost / Processing 2,158 Mil B will be 132,314 Mil B.

Source JICA Study Team

9.2.2 The 3rd Outer Ring Road

The results of the rough cost estimate for the Outer Ring Road, which have been updated with the current unit prices, are shown in the next table.

Comparison of 4 cases are as follows (Factor F is not applied yet).

Case 1: DOH FS (prices of 2008) Construction Cost : 26.07 Bil THB

Case 2: DOH FS (updated prices of 2017) Construction Cost : 34.52 Bil. THB

Case 3: Amended DOH F/S (southern 13km elevated) : 45.16 Bil. THB

Case 4: Combined Project (southern 13km elevated) : 48.63 Bil. THB

Case 4 includes the additional construction costs for being a combined project as follows.

a) Service road inside of ROW for Diversion Channel (31.29km)

Asphalt Pavement	: 0.111 Bil. THB
Material & Transportation cost for subgrade and embankment	: 0.180 Bil. THB
Mixing & Compaction cost for subgrade and embankment	: 0.294 Bil. THB

b) New bridge for crossing Diversion Channel near IC-4 (820m : 0.635 Bil. THB

c) Existing Local Road Overpass（for crossing DC : 2 nos.） : 0.086 Bil. THB

d) New Community Road Overpass (for crossing DC : 20 nos.) : 0.917 Bil.THB

e) Additional cost for amended Interchanges (4 nos,) : 1.735 Bil. THB

a)～e）TOTAL 3.958Bil. THB

If RID bear the cost mentioned above, the amount of construction cost borne by DOH will be;

Case 5: ＝ Case 4 －（ TOTAL of a)～e) ）＝ 48.63-3.96=44.67 Bil. THBBHT

Compared Case 5 with Case 3;

Case 5 － Case 3 = 44.67 － 45.16 = － 0.49 Bil. THB

Therefore the cost saving by applying combined projects is: 0.49 Bil. THB

There are another merits for RID by decreasing the amount of excavated soil to be transported to a disposal area. The saved amount for using soft clay for embankment will depend on the distance from the site to the disposal area as follows.

Distance from the site to disposal area:	10 km	: about 0.51 Bil. THB
	50 km	: about 1.77 Bil. THB
	100 km	: about 3.53 Bil. THB

Consequently, taking account of the advantage for RID, considerable cost reduction can be expected by combining the projects of the outer ring road and the Diversion Channel.

Table 9.2.3 Comparison of Rough Cost Estimate for The outer ring road

		Case 1: DOH FS (prices of 2008)				Case2: DOH FS (updated prices of 2017)				Case 3: Amended DOH F/S (southern 13km elevated)				
		Quantity	Unit	Unit Price (TBH)	Amount	Quantity	Unit	Unit Price (TBH)	Amount	Quantity	Unit	Unit Price (TBH)	Amount	
Main Road (Fill Section)														
RC Pavement	t=25cm	1,478,016	m2	885	1,308,044,160	1,478,016	m2	930	1,374,554,880	1,277,208	m2	930	1,187,803,440	
Sand Bed	t=10cm	1,478,016	m2	61	90,158,976	1,478,016	m2	137	202,488,192	1,277,208	m2	137	174,977,496	
AC Shoulder	t=5cm	805,600	m2	230	185,288,000	805,600	m2	195	157,092,000	729,700	m2	195	142,291,500	
Upper Base-course	t=20cm(Crushed Stone)	214,289	m3	700	150,002,300	214,289	m3	313.62	67,205,316	220,969	m3	313.62	69,300,298	without haul cost
Lower Base-course	t=15cm(Laterite)	445,256	m3	550	244,890,800	445,256	m3	118.8	52,914,223	375,951	m3	118.8	44,678,037	without haul cost
Subgrade and Embankment	t=245cm (Selected Soil)	12,857,800	m3	340	4,371,652,000	12,857,800	m3	101.7	1,307,638,260	11,064,834	m3	101.7	1,125,293,646	without haul cost
Mixing Material	Sand for Mixing													
	Cement (7%)													
	Quick Lime (5%)													
Mixing Cost	Mixing Plant (8 sets)													
Transport Cost:Bollow Pit→IC-4	t=20cm(Crushed Stone)				Include haul cost	214,289	m3	361.3	77,420,473	220,969	m3	361.3	79,833,890	
	t=15cm(Laterite)					445,256	m3	368.9	164,267,406	375,951	m3	368.9	138,698,913	
	t=245cm (Selected Soil)					12,857,800	m3	368.9	4,743,602,438	11,064,834	m3	368.9	4,082,127,181	
	Sand for Mixing													
Transport Cost:IC-4→Site	t=20cm(Crushed Stone)				Include haul cost	214,289	m3	263.1	56,384,386	220,969	m3	204.2	45,121,545	
	t=15cm(Laterite)					445,256	m3	283.8	126,366,837	375,951	m3	263.9	99,200,427	
	t=245cm (Selected Soil)					12,857,800	m3	192.6	2,476,058,655	11,064,834	m3	182.7	2,021,753,670	
	Sand for Mixing													
Soil Cement Slab	t=60cm	854,640	m3	230	196,567,200	854,640	m3	278.3	237,846,312					
Pile STA65+0-97+112	22cm x 22cm	4,273,200	m	550	2,350,260,000	4,273,200	m	665.5	2,843,814,600					
Soil Cement Slab	t=60cm									723,644	m3	278.3	201,390,173	
Pile STA56+579-83+790	22cm x 22cm									3,618,221	m	665.5	2,407,925,977	
PVD STA 56+579-83+790	1.0m*1.0m													
PVD STA 35+500-56+579	2.0m*2.0m									21,079	m	19,950	420,526,050	
Planting, Fence, etc.					330,637,000				476,117,280				410,802,649	
Main Road (Viaduct)														
STA 83+700~97+112	6 lanes									13,412	m	1,001,743	13,435,378,574	
Service Road		41,820	m	16,750	700,485,000	67,314	m	5,800	390,421,200	67,314	m	5,800	390,421,200	
Inside of Ring Road R.O.W.	2 lane													
Inside of Diversion C. R.O.W.	2 lane													
Other Facilities														
Bridge on Diversion Channel	STA21+015				0				0				0	1 no.
Bridge on other channel and road					2,308,660,000				2,978,171,400				1,882,962,690	8 nos.
Existing Road Bridges	1 Girder	3,200	m	209,000	668,800,000	3,200	m	269,610	862,752,000	3,200	m	269,610	862,752,000	9 nos.
(Additional for Diversion Chanel)	160m extension													2 nos.
	Segmental Girder	612	m	400,000	244,800,000	612	m	516,000	315,792,000	612	m	516,000	315,792,000	1 no.
Existing Road Underpass (w=6m)	Community Road	2,684	m	51,600	138,494,400	2,684	m	68,112	182,812,608	2,258	m	68,112	153,796,896	9 nos.
Existing Road Overpass (w=6m)	Additional for Combine													20 nos.
Interchange	11 nos.	11か所			9,487,000,000				10,937,796,480				10,937,796,480	11 nos.
(Additional for Diversion Channel)	Additional for Combine													4 nos.
Box Culvert	for small irrigation channels	6,818	m	25,000	170,450,000	6,818	m	33,000	170,450,000	6,504	m	33,000	214,632,000	105 nos.
Service Area					117,000,000				154,440,000				154,440,000	
Motorway Facility Buildings					874,100,000				1,153,812,000				1,153,812,000	
Toll Collection and Safty System					1,728,000,000				2,348,760,000				2,348,760,000	
Sign, Marking , Guide Post					224,000,000				367,360,000				367,360,000	
Emvironment Mitigation Cost	Noise Barrier etc.				183,284,500				292,504,129				292,504,129	
Sub-total					26,072,600,000				34,518,800,000				45,162,132,861	
Factor F (13% without VAT)		13.0	%		3,389,438,000	13	%		4,487,444,000	13	%		5,871,077,272	
Construction Cost Total					29,573,000,000				39,006,244,000				51,033,210,133	
Land Aquisition and Compensation		7,807,550	m2	2,137	16,683,000,000	7,807,550	m2	**4,129**	**32,237,373,950**	7,407,890	m2	**4,129**	**30,587,177,810**	
TOTAL PROJECT COST					46,256,000,000				71,243,617,950				81,620,387,943	

	Case 4: Combined Project (southern 13km elevated)				STA 0+0 ～ STA 24+280				STA 24+280 ～ STA 35+500				STA 35+500 ～ STA 56+579				STA 56+579 ～ STA 83+790				83+790 ～ 97+112			
	Quantity	Unit	Unit Price (TBH)	Amount	Quantity	Unit	Unit Price (TBH)	Amount	Quantity	Unit	Unit Price (TBH)	Amount	Quantity	Unit	Unit Price (TBH)	Amount	Quantity	Unit	Unit Price (TBH)	Amount	Quantity	Unit	Unit Price (TBH)	Amount
Main Road (Fill Section)																								
RC Pavement	1,277,208	m2	930.0	1,187,803,440	273,456	m2	930	254,314,080	142,560	m2	930	132,580,800	372,146	m2	930	346,096,152	489,046	m2	930	454,812,408	0	m2	0	0
Sand Bed	1,277,208	m2	137.0	174,977,496	273,456	m2	137	37,463,472	142,560	m2	137	19,530,720	372,146	m2	137	50,984,057	489,046	m2	137	66,999,247	0	m2	0	0
AC Shoulder	729,700	m2	195.0	142,291,500	197,800	m2	195	38,571,000	105,300	m2	195	20,533,500	200,490	m2	195	39,095,550	226,110	m2	195	44,091,450	0	m2	0	0
Upper Base-course	220,969	m3	313.6	69,300,298	52,721	m3	313.6	16,534,423	28,010	m3	314	8,784,433	53,330	m3	314	16,725,461	60,252	m3	314	18,896,126	26,656	m3	314	8,359,855
Lower Base-course	97,861	m3	118.8	11,629,807	97,861	m3	118.8	11,629,807	51,966	m3	0	0	111,787	m3	0	0	136,366	m3	0	0	28,832	m3	0	0
Subgrade and Embankment	2,899,954	m3	101.7	294,925,281	2,899,954	m3	101.7	294,925,281	1,934,073	m3	0	0	4,031,512	m3	0	0	5,877,604	m3	0	0	212,160	m3	0	0
Mixing Material	4,467,362	m3	135.0	603,093,898	0	m3	135.0	0	744,165	m3	135.0	100,462,239	1,545,807	m3	135.0	208,683,922	2,028,516	m3	135.0	273,849,657	148,875	m3	135.0	20,098,080
	42,599	ton	2700.0	115,017,700	0	ton	2700.0	0	6,730	ton	2700.0	18,169,755	14,476	ton	2700.0	39,086,442	17,659	ton	2700.0	47,680,395	3,734	ton	2700.0	10,081,109
	120,553	ton	2700.0	325,494,396	0	ton	2700.0	0	19,341	ton	2700.0	52,219,961	40,315	ton	2700.0	108,850,812	58,776	ton	2700.0	158,695,302	2,122	ton	2700.0	5,728,320
Mixing Cost	13,402,087	m3	292.2	3,916,089,709	0	m3	292.2	0	2,232,494	m3	292.2	652,334,802	4,637,420	m3	292.2	1,355,054,266	6,085,548	m3	292.2	1,778,197,107	446,624	m3	292.2	130,503,533
Transport Cost:Bollow Pit→IC-4	220,969	m3	361.3	79,833,890	52,721	m3	361.3	19,047,642	28,010	m3	361.3	10,119,661	53,330	m3	361.3	19,267,719	60,252	m3	361.3	21,768,322	26,656	m3	0.0	9,630,546
	97,861	m3	368.9	36,103,681	97,861	m3	368.9	36,103,681	0	m3	0.0	0	0	m3	0.0	0	0	m3	0.0	0	0	m3	0.0	0
	2,899,954	m3	368.9	1,069,874,082	2,899,954	m3	368.9	1,069,874,082	0	m3	0.0	0	0	m3	0.0	0	0	m3	0.0	0	0	m3	0.0	0
	4,467,362	m3	240.9	1,076,008,861	0	m3	240.9	0	744,165	m3	240.9	179,239,517	1,545,807	m3	240.9	372,323,033	2,028,516	m3	240.9	488,588,359	148,875	m3	240.9	35,857,952
Transport Cost:IC-4→Site	220,969	m3	155.8	34,426,344	52,721	m3	155.8	8,213,813	28,010	m3	155.8	4,363,847	53,330	m3	155.8	8,308,716	60,252	m3	155.8	9,387,038	26,656	m3	155.8	4,152,929
	97,861	m3	52.4	5,126,364	97,861	m3	52.4	5,126,364	0	m3	52.4	0	0	m3	52.4	0	0	m3	52.4	0	0	m3	52.4	0
	2,899,954	m3	52.4	151,911,487	2,899,954	m3	52.4	151,911,487	0	m3	52.4	0	0	m3	52.4	0	0	m3	52.4	0	0	m3	52.4	0
	4,467,362	m3	162.5	725,930,272	0	m3	162.5	0	744,165	m3	162.5	120,924,089	1,545,807	m3	162.5	251,188,043	2,028,516	m3	162.5	329,626,542	148,875	m3	162.5	24,191,597
Soil Cement Slab																								
Pile STA65+0-97+112																								
Soil Cement Slab																								
Pile STA56+579-83+790																								
PVD STA 56+579-83+790	22,641	m	96,558	2,186,169,678	0	m	96,558	0	0	m	96,558	0	0	m	96,558	0	22,641	m	96,558	2,186,169,678	0	m	96,558	0
PVD STA 35+500-56+579	20,069	m	19,950	400,376,550	0	m	19,950	0	0	m	19,950	0	20,069	m	19,950	400,376,550	0	m	19,950	0	0	m	19,950	0
Planting, Fence, etc.				410,802,649				119,039,126				55,009,019				103,345,376				133,409,129				0
Main Road (Viaduct)																								
STA 83+700~97+112	13,412	m	1,001,743	13,435,378,574	0	m		0	0	m		0	0	m		0	0	m		0	13,412	m	1,001,743	13,435,378,574
Service Road																								
Inside of Ring Road R.O.W.	36,024	m	3,550	127,885,200	0	m	3,550	0	8,150	m	3,550	28,932,500	16,340	m	3,550	58,007,000	4,734	m	3,550	16,805,700	6,800	m	3,550	24,140,000
Inside of Diversion C. R.O.W.	31,290	m	3,550	111,079,500	0	m	3,550	0	8,150	m	3,550	28,932,500	16,340	m	3,550	58,007,000	0	m	3,550	0	6,800	m	3,550	24,140,000
Other Facilities																								
Bridge on Diversion Channel	820	m	774,000	634,680,000	820	m	774,000	634,680,000																
Bridge on other channel and road				1,882,962,690				677,753,100				23,150,340				48,820,050				1,133,239,200				0
Existing Road Bridges	3,200	m	269,610	862,752,000	2,000	m	269,610	539,220,000	400	m	269,610	107,844,000	400	m	269,610	107,844,000	400	m	269,610	107,844,000	0	m		0
(Additional for Diversion Chanel)	320	m	269,610	86,275,200	0	m		0	160	m	269,610	43,137,600	160	m	269,610	43,137,600	0	m		0	0	m		0
	612	m	516,000	315,792,000	612	m	516,000	315,792,000	0	m		0	0	m		0	0	m		0	0	m		0
Existing Road Underpass (w=6m)	486	m	68,112	33,102,432	42	m	68,112	2,860,704	0	m		0	0	m		0	444	m	68,112	30,241,728	0	m		0
Existing Road Overpass (w=6m)	8,370	m	109,650	917,770,500	0	m		0	3,750	m	109,650	411,187,500	4,620	m	109,650	506,583,000	0	m		0	0	m		0
Interchange				10,937,796,480				3,997,382,340				0				2,032,709,760				2,011,455,720				2,896,248,660
(Additional for Diversion Channel)				1,734,716,251												288,248,384								1,446,467,867
Box Culvert	6,504	m	33,000	214,632,000	924	m	33,000	30,492,000	1,554	m	33,000	51,282,000	2,844	m	33,000	93,852,000	1,182	m	33,000	39,006,000	0	m	33,000	0
Service Area				154,440,000				0				0								154,440,000				0
Motorway Facility Buildings				1,153,812,000				288,476,763				133,307,631				250,444,880				323,300,708				158,282,019
Toll Collection and Safty System				2,348,760,000				587,238,372				271,367,979				509,818,684				658,127,815				322,207,150
Sign, Marking , Guide Post				367,360,000				91,847,566				42,443,562				79,738,667				102,935,095				50,395,110
Emvironment Mitigation Cost				292,504,129				73,132,056				33,794,962				63,490,553				81,960,312				40,126,246
Sub-total				48,628,886,337				9,301,629,159				2,549,652,917				7,460,087,676				10,671,527,038				18,645,989,547
Factor F (13% without VAT)	13	%		6,321,755,224	13	%		1,209,211,791	13	%		331,454,879	13	%		969,811,398	13	%		1,387,298,515	13	%		2,423,978,641
Construction Cost Total				54,950,641,561				10,510,840,950				2,881,107,796				8,429,899,074				12,058,825,553				21,069,968,188
Land Aquisition and Compensation	6,903,035	m2	**4,129**	**28,502,631,515**	1,699,600	m2	**4,129**	**7,017,648,400**	907,650	m2	**4,129**	**3,747,686,850**	1,720,630	m2	**4,129**	**7,104,481,270**	1,940,275	m2	**4,129**	**8,011,395,475**	634,880	m2	**4,129**	**2,621,419,520**
TOTAL PROJECT COST				83,453,273,076				17,528,489,350				6,628,794,646				15,534,380,344				20,070,221,028				23,691,387,708

9.3 Project Evaluation

(1) Method of benefit evaluation for diversion channel project

The benefit of the Diversion Channel is defined as the benefit from the prevention of flood owing to the existence of the Diversion Channel with the calculation based on the Draft of the Economic Survey Manual for Water Control Projects of 2005 published by the Ministry of Land, Infrastructure, Transport and Tourism of Japan.

The Draft of the Economic Survey Manual for Water Control Projects targets the benefit from the reduction of direct damage and indirect damage by flood as currently evaluable benefits with statistical information. The benefit from direct damage reduction is evaluated by the damage reduction of depreciable assets and inventory assets in economic sectors such as manufacturing, agriculture, office, public and households by flood prevention. On the other hand, the benefit from indirect damage reduction is evaluated based on the reduction of operational damage such as suspension of business activities, and reduction of recovery cost in economic sectors.

If the evaluation of the benefits from the reduction of human damage and psychological damage, risk premium, and other benefits from the flood prevention can be done, the values of items that can be determined should be added to the benefits from direct and indirect damage reduction.

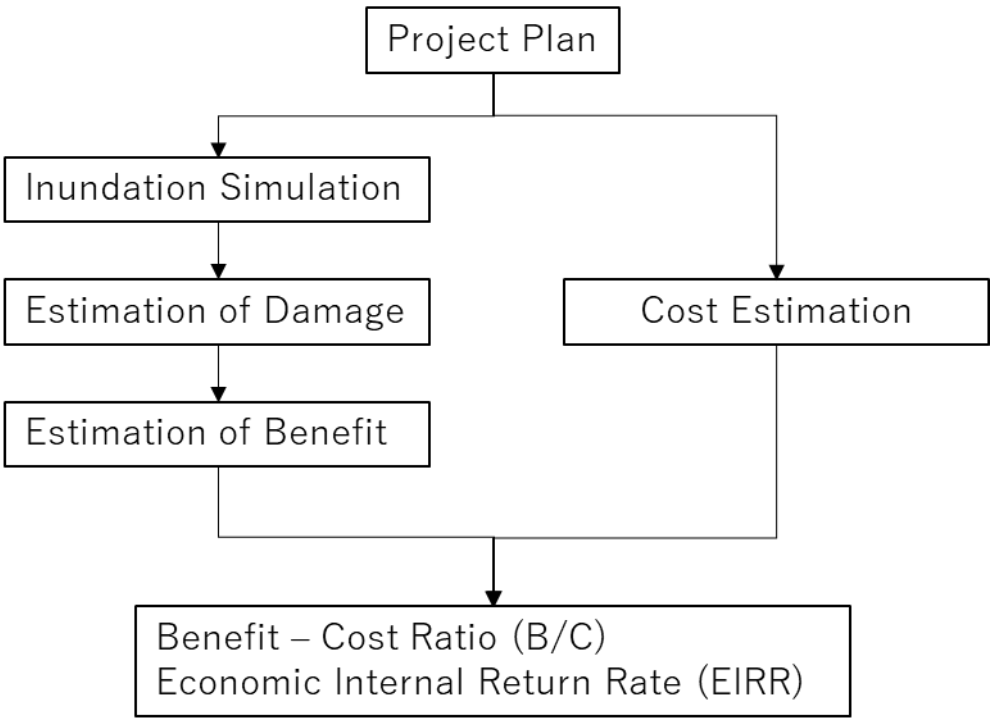
This study is subjected to the principles presented in the Draft of the Economic Survey Manual for Water Control Projects; this study targets reduction of asset damage by flood (direct damage reduction) and reduction of operational damage and recovery cost (indirect damage reduction). That means that the benefit evaluated in this study, to be exact, is one part of the whole benefit of the Diversion Channel and the value is “moderate”.

The classification of benefits and benefit evaluation flow chart of the Draft of the Economic Survey Manual for Water Control Projects are shown below;

Table 9.3.1 Classification of the benefits for flood measures

Category				
Benefit from Damage Reduction	Direct Damage	Reduction of Damage to Asset	General Damage	Housing
				Housing Goods
				Office Asset
				Office Stock
				Agriculture and Fishery Asset
				Agriculture and Fishery Stock
			Damage to Agricultural Products	
			Damage to Public Works	
		Reduction of Damage to Human		
	Indirect Damage	Reduction of Operational Damage	Damage from Business Suspension	Household
				Office
				Public Service
		Reduction of Recovery Cost	Emergency Measures	Household
				Office
				Central/Regional Government
			Spillover Damage by Damage to Transportation	Road, Railway, Airport, Seaport, etc.
			Spillover Damage by Damage to Utility Infrastructure	Electricity, Tap water, Gas, Telecommunication, etc.
			Spillover Damage by Business Suspension	
		Reduction of Mental Damage	Caused by Damage to Asset	
			Caused by Operational Damage	
			Caused by Human Damage	
			Caused by Recovery Cost	
			Caused by Spillover Damage	
		Risk Premium		
Advanced Benefit				

Source: "Draft Manual for economic survey on flood control" prepared by the Ministry of Land, Infrastructure, Transport and Tourism, Japan



Source: "Draft Manual for economic survey on flood control" prepared by the Ministry of Land, Infrastructure, Transport and Tourism, Japan

Figure 9.3.1 Flow of the benefit evaluation for flood control measures

The Draft of the Economic Survey Manual for Water Control Projects targets Households (Housing, Housing goods), Offices (Assets, Stock), Agriculture and Fishery (Assets, Stock, and Agricultural Products) and Public Works for damage estimation.

However, the estimation by NESDB and the Ministry of Industry referred to by the World Bank "Thai Flood 2011 Rapid Assessment for Resilient Recovery and Reconstruction Planning – overview" shows that the manufacturing sector and household sector accounts for 88.8% of total direct damage and 66.8% of total indirect damage. In total, the manufacturing sector and household sector account for 76.5% of the damage in all sectors.

Table 9.3.2 Damage by the floods of December 1st, 2011

Items	Contents
Affected Areas	43,600 villages, 4,917 sub-districts, 684 districts of 65 provinces.
Affected Population	In total 13,425,869 people of 4,039,459 families are affected.
Damaged Houses	2,329 houses: wholly damaged. 96,833 houses: partly damaged.
Agriculture damage	1.8 million hectare cultivated area,
Damages of Infrastructures	13,961 roads, 982 weirs, 142 embankments, 724 bridges,
Damage of livestock	13.41 million livestock
Damages of fish/shrimp/shell ponds	over 37,107 ha
Death toll	657 deaths(in 44 provinces)

出典：DDPM

Table 9.3.3 Sectorial flood damage in 2011

Unit: Mil THB

Sub Sector	Disaster Effects			Ownership	
	Damage	Losses	Total	Public	Private
Infrastructure					
Water Resources Management	8,715	–	**8,715**	8,715	–
Transport	23,538	6,938	**30,476**	30,326	150
Telecommunication	1,290	2,558	**3,848**	1,597	2,251
Electricity	3,186	5,716	**8,901**	5,385	3,517
Water Supply and Sanitation	3,497	1,984	**5,481**	5,481	
Production					
Agriculture, Livestock and Fishery	5,666	34,715	**40,381**	–	40,381
Manufacturing	513,881	493,258	**1,007,139**	–	1,007,139
Tourism	5,134	89,673	**94,808**	403	94,405
Finance and Banking	–	115,276	**115,276**	74,076	41,200
Social					
Health	1,684	2,133	**3,817**	1,627	2,190
Education	13,051	1,798	**14,849**	10,614	4,235
Housing	45,908	37,889	**83,797**	–	83,797
Cultural Heritage	4,429	3,076	**7,505**	3,041	4,463
Cross Cutting					
Environment	375	176	**551**	212	339
TOTAL	**630,354**	**795,191**	**1,425,544**	**141,477**	**1,284,066**

Source: DALA estimates, NESDB, and Ministry of Industry.
Note: Losses for each sector include higher expenditures due to floods.

Source : World Bank "Thai Flood 2011 Rapid Assessment for Resilient Recovery and Reconstruction Planning – overview"

Therefore, in this study, while direct damages in the manufacturing and household sectors are estimated from statistical data, direct damages in the other sectors are estimated from the ratio between the damage of the two sectors and the damage of the other sectors in 2011.

(2) **Estimation of the Direct Damage in the Manufacturing Sector**

1) Estimation of the amount of assets in the Manufacturing Sector

The factory assets (buildings, Machines, etc.) and stock assets (input material, components, etc.) are estimated for a 2km by 2km mesh also used in the inundation analysis. The estimation process is shown below;

【Factory Asset Estimation Process】

- "The 2012 Business and Industrial Census" published by the National Statistical

Office of Thailand (NSO) includes the amount of the factory assets and stock assets (book value), and number of employees of 28 industrial sectors at the end of 2011 by province. From these data, “the amount of factory assets per employee by province by industrial sector” and “the amount of stock assets per employee by province by industrial sector” are estimated.

- The Factory Data published on the website of the Department of Industrial Works, Ministry of Industry includes every factory’s name, address, industrial sector, employee and other information about the factory in Thailand. The targeted 24 provinces have 53,748 factories as of May 2017.
- The amount of factory assets and stock assets of each factory is estimated from the amount of factory assets per employee by province by industrial sector and the amount of stock assets per employee by province by industrial sector estimated from the 2012 Business and Industrial Census, and 53,748 factories’ employee data in the Factory Data.
- The address of each factory in the Factory Data specifies its locating mesh, and the amount of each factory’s assets is aggregated by mesh.
- The data in the 2012 Industrial and Business Census is as of the end of 2011, so the amount should be adjusted by the price increase rate, 6.26% per annum, between December 2011 to December 2016, which is referred to in the website of the Ministry of Commerce (http://www.indexpr.moc.go.th).

Table 9.3.4 Factory assets and stock assets per employee in each province by type of business

Total Asset/workers	National	BKK	Ang Thong	Auttaradit	Chachoe ngsao	Chainat	Kampaen gphet	Lopburi	Nakorn nayok	Nakorn Pathom	Nakhon Sawan	Nonthabu ri	Pathum Thani	Phichit	Phitsanul ok	Phra Nakhon Si Ayutthaya	Ratchabu ri	Samut Prakan	Samut Sakhon	Samut Songkha m	Saraburi	Sing Buri	Sukhothai	Suphan Buri	Uthai Thani	Average
Manufacture of food products	1,306	758	882	912	3,061	1,976	10,123	22,528	2,495	920	980	917	2,019	466	439	981	644	596	610	419	869	691	650	554	1,168	2,319
Manufacture of beverages	2,369	2,461	542	354	1,635	394	10,819	262	539	2,477	1,738	136	4,721	241	753	5,096	665	8,373	385	411	450	2,114	318	295	432	1,900
Manufacture of tobacco products	467	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Manufacture of textiles	380	516	557	121	1,348	993	157	330	369	738	143	267	1,010	87	132	633	520	750	749	468	459	1,882	112	623	35	542
Manufacture of wearing apparels	245	218	286	131	1,994	123	331	146	295	374	190	215	319	59	323	304	538	313	207	213	317	176	154	374	130	322
Manufacture of leather and related products	236	192	138	0	725	85	52	145	0	121	121	906	101	144	0	251	174	525	194	0	0	0	138	280	42	241
Manufacture of wood and products of wood and cork (except furniture); manufacture of articles of straw and plaiting materials	282	510	177	132	645	59	0	112	209	405	112	440	672	62	157	331	263	525	371	409	4,332	1,488	112	167	130	514
Manufacture of paper and paper products	1,118	947	1,129	252	700	0	0	0	0	1,035	0	557	905	0	0	578	1,653	795	1,004	0	590	0	170	0	0	793
Printing and reproduction of recorded media	1,369	1,809	833	136	1,203	479	420	649	417	898	822	643	690	233	707	672	198	828	843	349	905	979	196	445	333	654
Manufacture of coke and refined petroleum products	6,995	14,520	0	0	1,185	0	0	0	0	0	0	0	444	0	0	2,099	1,126	1,213	482	0	0	0	0	0	0	3,010
Manufacture of chemicals and chemical products	2,644	1,042	259	0	689	3,213	1,257	2,073	1,072	1,158	520	307	549	270	200	1,702	992	875	786	0	1,609	899	544	2,082	0	1,052
Manufacture of pharmaceuticals, medicinal chemical and botanical products	783	716	62	0	854	0	0	0	0	628	0	1,382	1,208	0	534	937	0	594	181	0	0	0	36	529	0	638
Manufacture of rubber and plastic products	788	711	335	0	700	138	122	355	456	549	1,966	641	844	129	670	668	717	613	685	685	4,020	481	265	222	7,856	1,036
Manufacture of other non-metallic mineral products	1,466	3,387	223	296	1,157	950	422	1,740	428	630	1,965	414	930	238	493	969	410	929	563	673	2,429	855	386	386	195	878
Manufacture of basic metals	2,367	4,373	450	0	1,329	0	0	200	272	471	278	423	930	514	438	4,241	260	1,758	834	396	1,928	0	664	182	0	1,050
Manufacture of fabricated metal products (excepts machinery and equipment)	601	585	444	348	588	282	0	228	291	444	535	418	735	189	469	778	512	617	505	378	1,123	293	281	279	223	458
Manufacture of computers, electronic and optical products	876	957	0	0	1,051	0	0	43	0	1,292	108	614	1,916	0	0	578	4,227	756	236	0	0	0	0	0	0	1,071
Manufacture of electrical equipment	771	526	0	153	761	0	0	0	0	679	0	814	1,105	0	0	590	988	739	475	0	540	0	0	0	0	670
Manufacture of machinery and equipment, n.e.c	1,478	642	0	310	602	0	0	340	0	2,169	592	1,210	1,734	0	633	1,119	341	2,494	6,639	0	594	0	90	536	0	1,253
Manufacture of motor vehicles, trailers and semi-trailers	1,334	788	281	15	1,117	246	0	504	294	435	152	257	2,911	26	130	2,042	261	1,351	818	323	5,113	545	251	294	190	798
Manufacture of other transport equipment	353	512	0	0	131	64	0	0	0	105	174	120	279	0	0	334	170	278	308	414	0	156	0	228	0	234
Manufacture of furniture	329	311	90	204	169	66	114	184	188	260	493	396	264	101	288	195	170	654	572	183	771	371	284	214	53	275
Other manufacturing	457	450	130	102	254	178	356	182	222	298	225	464	1,779	117	297	847	213	584	395	233	174	298	107	173	133	342
Repair and installation of machinery and equipment	782	629	347	305	354	326	772	372	255	465	447	552	1,592	210	357	435	722	1,911	352	553	333	638	407	169	320	534
Sewerage	513	0	0	0	0	0	0	0	0	0	319	608	0	0	0	0	396	547	0	0	0	0	0	0	0	467
Waste collection, treatment and disposal activities; materials recovery	529	213	176	15	429	474	0	621	0	643	196	228	1,167	271	295	4,811	1,101	155	183	188	0	208	0	109	112	580
Remediation activities and other waste management services	727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Publishing activities	604	604	0	0	848	0	0	0	0	233	410	73	0	345	0	0	0	168	4,369	0	0	0	0	0	0	881

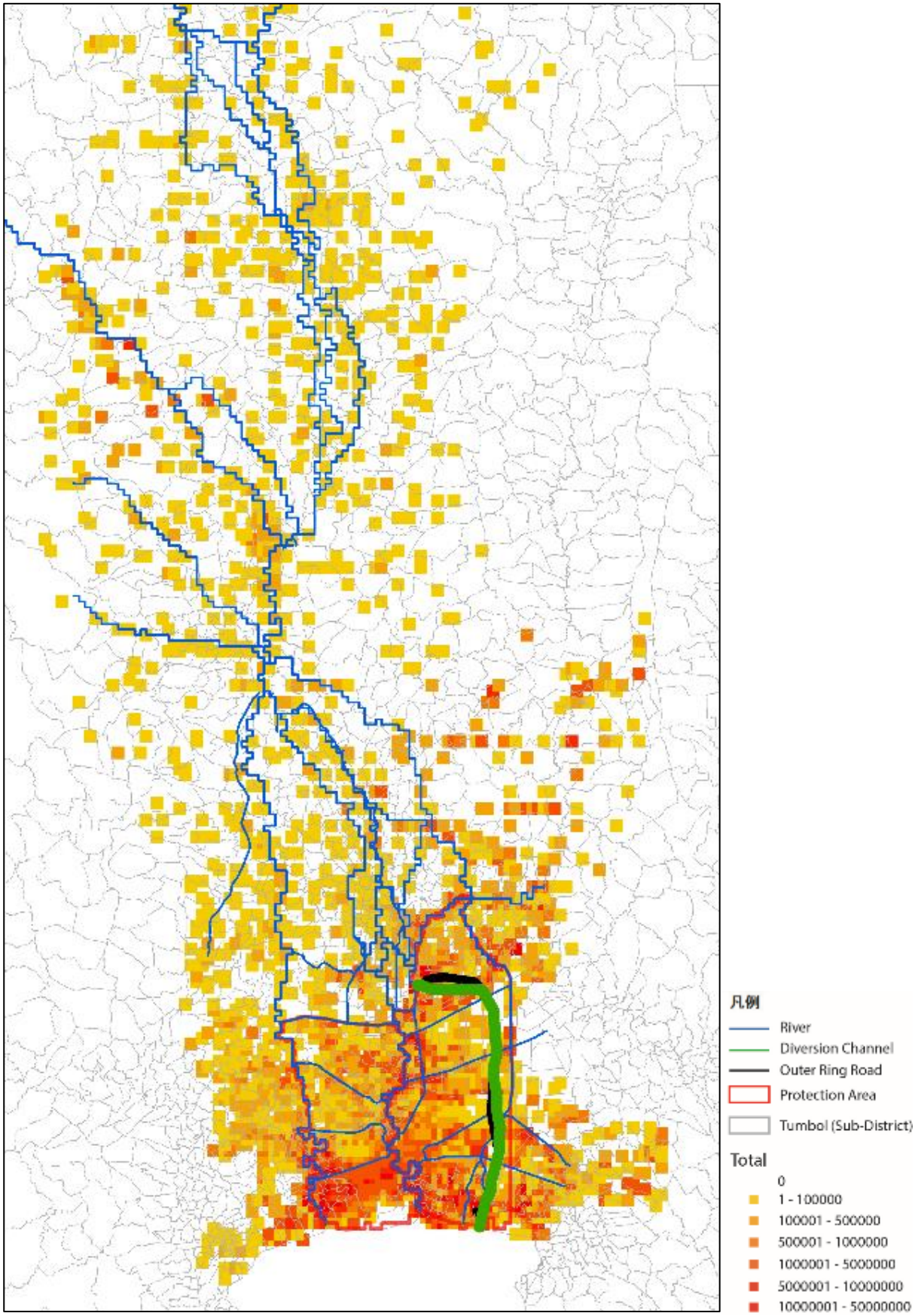
Total Stock/workers	National	BKK	Ang Thong	Auttaradit	Chachoe ngsao	Chainat	Kampaen gphet	Lopburi	Nakorn nayok	Nakorn Pathom	Nakhon Sawan	Nonthabu ri	Pathum Thani	Phichit	Phitsanul ok	Phra Nakhon Si Ayutthaya	Ratchabu ri	Samut Prakan	Samut Sakhon	Samut Songkha m	Saraburi	Sing Buri	Sukhothai	Suphan Buri	Uthai Thani	Average
Manufacture of food products	277	345	209	461	1,060	879	1,576	292	380	255	466	517	448	724	46	1,774	329	515	291	175	320	577	650	359	383	543
Manufacture of beverages	542	504	7	9	404	31	499	7	8	2,168	6	345	801	66	32	731	118	2,381	82	12	15	100	318	105	4	365
Manufacture of tobacco products	415	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Manufacture of textiles	141	261	313	4	600	15	5	9	19	202	25	365	381	2	1	324	323	348	214	135	267	56	112	9	1	166
Manufacture of wearing apparels	89	107	67	2	363	72	5	18	16	160	156	140	113	65	81	58	16	286	116	6	121	63	154	56	5	94
Manufacture of leather and related products	123	100	37	0	227	86	6	120	0	66	2	206	12	0	0	92	8	417	76	0	0	0	138	160	1	97
Manufacture of wood and products of wood and cork (except furniture); manufacture of articles of straw and plaiting materials	96	311	5	13	121	6	0	13	37	129	5	436	418	11	5	384	27	334	266	234	1,151	637	112	112	12	208
Manufacture of paper and paper products	237	188	215	82	221	0	0	0	0	335	0	290	174	0	0	309	334	357	230	0	107	0	170	0	0	232
Printing and reproduction of recorded media	147	171	5	84	829	6	9	14	13	58	0	149	117	6	44	539	20	154	142	15	35	4	196	17	14	115
Manufacture of coke and refined petroleum products	2,073	468	0	0	34	0	0	0	0	0	0	0	220	0	0	777	415	1,831	448	0	0	0	0	0	0	599
Manufacture of chemicals and chemical products	737	533	5	0	334	728	593	352	815	585	10	335	1,162	277	6	957	168	739	680	0	1,835	120	544	113	0	519
Manufacture of pharmaceuticals, medicinal chemical and botanical products	284	290	66	0	1,255	0	0	0	0	241	0	287	123	0	9	314	0	549	345	0	0	0	36	60	0	298
Manufacture of rubber and plastic products	400	304	10	0	235	84	103	34	254	353	247	259	264	67	139	187	109	357	367	247	715	154	265	40	53	211
Manufacture of other non-metallic mineral products	239	251	14	50	239	58	66	106	42	283	227	131	230	44	41	201	101	260	329	406	431	85	386	67	7	169
Manufacture of basic metals	1,119	1,984	5	0	612	0	0	39	15	196	26	294	577	88	723	1,727	69	1,798	416	772	448	0	664	102	0	556
Manufacture of fabricated metal products (excepts machinery and equipment)	276	339	9	52	305	24	0	36	37	199	114	214	476	39	9	265	347	269	310	110	405	88	281	73	8	174
Manufacture of computers, electronic and optical products	486	330	0	0	1,989	0	0	21	0	310	45	193	330	0	0	268	140	929	168	0	0	0	0	0	0	429
Manufacture of electrical equipment	354	203	0	3	418	0	0	0	0	262	0	559	234	0	0	200	137	600	367	0	2,581	0	0	0	0	506
Manufacture of machinery and equipment, n.e.c	664	807	0	55	186	0	0	223	0	364	110	188	955	0	337	678	296	467	204	0	296	0	90	95	0	334
Manufacture of motor vehicles, trailers and semi-trailers	472	464	9	38	549	8	0	183	148	105	53	57	214	3	123	686	49	533	218	142	681	5	251	60	20	200
Manufacture of other transport equipment	228	155	0	0	202	26	0	0	0	37	15	72	330	0	0	619	114	252	209	49	0	18	0	10	0	151
Manufacture of furniture	125	129	3	17	58	11	19	15	13	134	20	96	172	9	11	193	188	214	215	34	395	15	284	44	2	95
Other manufacturing	263	383	25	3	114	56	4	12	6	142	10	285	1,113	5	4	398	53	324	236	4	50	20	107	33	6	141
Repair and installation of machinery and equipment	296	420	20	9	108	165	4	10	54	87	64	50	401	10	11	80	67	1,119	207	20	176	9	407	23	7	147
Sewerage	35	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	1	106	0	0	0	0	0	0	0	38
Waste collection, treatment and disposal activities; materials recovery	231	102	2	0	212	52	0	28	0	131	10	13	210	80	5	4,305	376	58	100	36	0	16	0	24	10	288
Remediation activities and other waste management services	170	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Publishing activities	108	113	0	0	13	0	0	0	0	3	9	60	0	8	0	0	0	137	123	0	0	0	0	0	0	58

Source: JICA Study Team

Table 9.3.5 Factory assets in each province (Unit: Million THB)

	Factory Assets	Stock Assets	Total Assets
Ang Thong	1,678	217	1,896
Auttaradit	2,813	1,236	4,048
BKK	271,177	125,304	396,481
Chachoengsao	104,453	64,922	169,375
Chainat	2,284	660	2,944
Kampaengphet	20,134	2,979	23,113
Lopburi	62,675	1,306	63,981
Nakhon Sawan	7,451	2,092	9,544
Nakorn Pathom	105,453	40,924	146,377
Nakornnayok	0	0	0
Nonthaburi	36,529	18,281	54,811
Pathum Thani	318,580	90,017	408,598
Phichit	1,223	890	2,112
Phitsanulok	2,026	306	2,332
Phra Nakhon Si Ayutthaya	144,715	74,360	219,075
Ratchaburi	131,764	45,756	177,519
Samut Prakan	329,866	192,233	522,099
Samut Sakhon	141,951	56,199	198,151
Samut Songkham	695	293	987
Saraburi	80,536	20,188	100,723
Sing Buri	2,238	864	3,102
Sukhothai	1,037	1,037	2,074
Suphan Buri	6,468	2,241	8,709
Uthai Thani	961	248	1,210
Total	1,776,708	742,554	2,519,261

Source: JICA Study Team



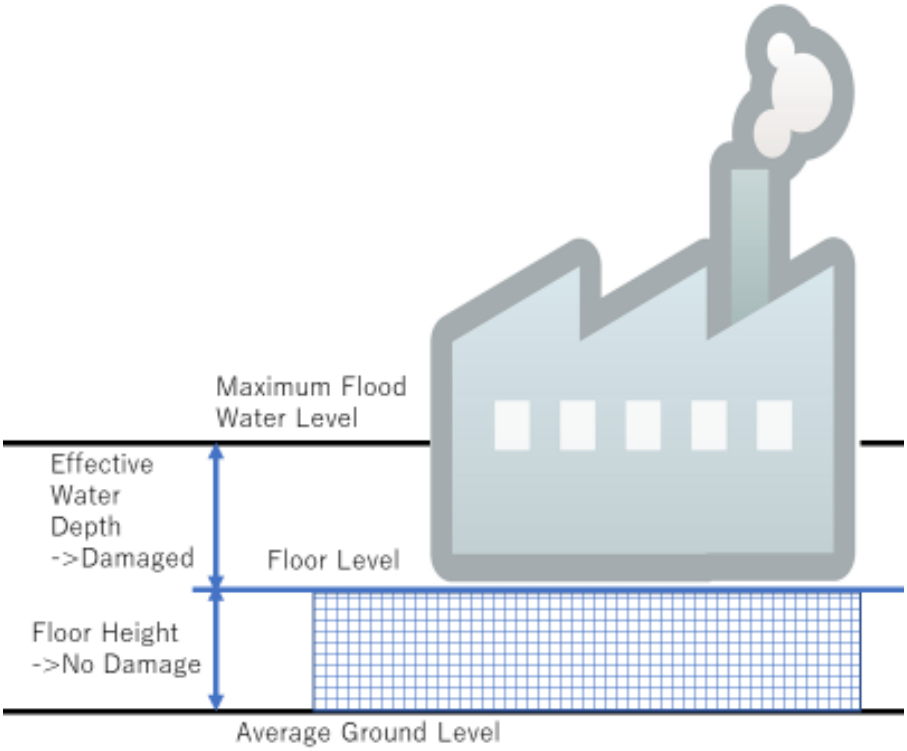
Source: JICA Study Team

Figure 9.3.2 Distribution map of assets (Thousand THB)

2) Estimation of the direct damage in the Manufacturing Sector

The amount of assets in the Manufacturing Sector has been specified by mesh owing to the Factory Data published by DIW. The direct damage to the assets, in the other words, the damage to the assets caused by the flood is estimated from the multiplication of the damage rate in the Draft of Economic Survey Manual for Water Control Projects of 2005 corresponding to the simulated inundation depth and the assets.

Throughout history Chao Phraya River Basin has had huge floods, so factories and houses are built with higher basement. "Flooring height" is defined the maximum height bringing no damage to factories and housings. In the JICA M/P in 2013, the Manufacturing Sector in the protected area has a flooring height as high as the inundation depth of the 2 year return period, and that out of the protected area has a flooring height as high as the inundation depth of the 2 year return period plus 50 cm. This Study accepts the same assumption.



Source: JICA Study Team

Figure 9.3.3 Conceptual diagram of water depth

Table 9.3.6 Water depth and Damage rate for factories

Inundation Depth	0 – 0.5m	0.5 – 1m	1 – 2m	2 – 3m	More than 3m
Damage Rate (Factory Assets)	0.232	0.453	0.789	0.966	0.995
Damage Rate (Stock Assets)	0.128	0.267	0.586	0.897	0.982

Source: "Draft Manual for economic survey on flood control" prepared by the Ministry of Land, Infrastructure, Transport and Tourism, Japan

(3) Estimation of Direct Damage in the Household Sector

1) Estimation of Assets in the Household Sector

The direct damage in the Household Sector is defined as the decrease of value of assets (housing/buildings, home appliances, private vehicles, etc.) caused by the flood, which is estimated in line with the process shown below,

【Estimation Process for Household Assets】

- Estimate the asset value of housing and household goods per household by province, and estimate the household assets by mesh
- In this estimation, the housing assets per household are assumed to be equal to the cost to build the housing.
- The composition of past years of housings is constant in the project period and all housings' depreciation rate is 50%, which means that the housing asset per household is constant in the project period and is 50% of the cost for building.
- The first process to estimate the housing asset is to calculate the average building cost per household for each housing type by province from "standard total floor area by housing type" and "building cost per unit floor area by housing type by building material.
- However, in the estimation of the number of households in each mesh, it is difficult to take into account the difference among housing types and housing material; the average cost of all housing types and housing materials is estimated.
- The number of houses of each housing type and housing material by province in NSO "The 2010 Population and Housing Census" and the building cost by housing type and housing material are used for the estimation of total building cost by province.
- It is assumed that high-rise buildings are damaged only to their first floor, and the building cost of mansions and apartments in the targeted 24 provinces is divided by the average number of floors in a building in each province.
- From the total building cost of each province and total number of households in each province, average building cost per household in all kinds of housing types and housing materials is estimated.
- The 50% of that figure is the average housing asset of each province.
- Total household goods assets is estimated by province from "the ownership ratio of household goods" (TV, VCD/DVD player, PC, Refrigerators, Microwaves, Laundry Machines, Air Conditioners, Private Vehicles, Motorcycles) in the NSO "The 2010 Population and Housing Census", "the standard commodity price" published by the Ministry of Commerce of Thailand,

and the total number of households by province. Household goods assets per household is calculated by dividing the total household goods assets by the total number of households by province.

- As with housing assets, household goods assets, only the first floor is damaged when the building is high rise. Therefore, household goods assets in all high rises in each province are divided by average number floors in a building.
- Moreover, the amount of household goods assets of each household is constant in the project period and the depreciation rate is 50% the same as the housing assets.

Table 9.3.7 Household Assets in each province (Unit: Mil THB)

	Housing Assets	Household Goods Assets	Total Household Assets
Ang Thong	20,648	22,181	42,829
Auttaradit	22,818	26,681	49,499
BKK	475,283	720,366	1,195,649
Chachoengsao	43,102	47,571	90,673
Chainat	22,809	26,408	49,217
Kampaengphet	41,819	47,198	89,017
Lopburi	61,062	64,107	125,169
Nakhon Sawan	19,937	21,097	41,034
Nakorn Pathom	83,578	92,310	175,889
Nakornnayok	72,760	82,635	155,395
Nonthaburi	151,109	231,519	382,628
Pathum Thani	116,735	203,830	320,566
Phichit	32,918	37,357	70,275
Phitsanulok	63,214	67,594	130,808
Phra Nakhon Si Ayutthaya	33,776	75,131	108,906
Ratchaburi	64,167	62,676	126,844
Samut Prakan	107,319	181,395	288,714
Samut Sakhon	33,609	61,309	94,919
Samut Songkham	11,292	15,020	26,312
Saraburi	57,499	57,547	115,047
Sing Buri	15,432	16,468	31,900
Sukhothai	37,719	44,054	81,773
Suphan Buri	61,213	59,811	121,024
Uthai Thani	19,608	22,434	42,042
Total	1,669,427	2,286,703	3,956,130

Source: JICA Study Team

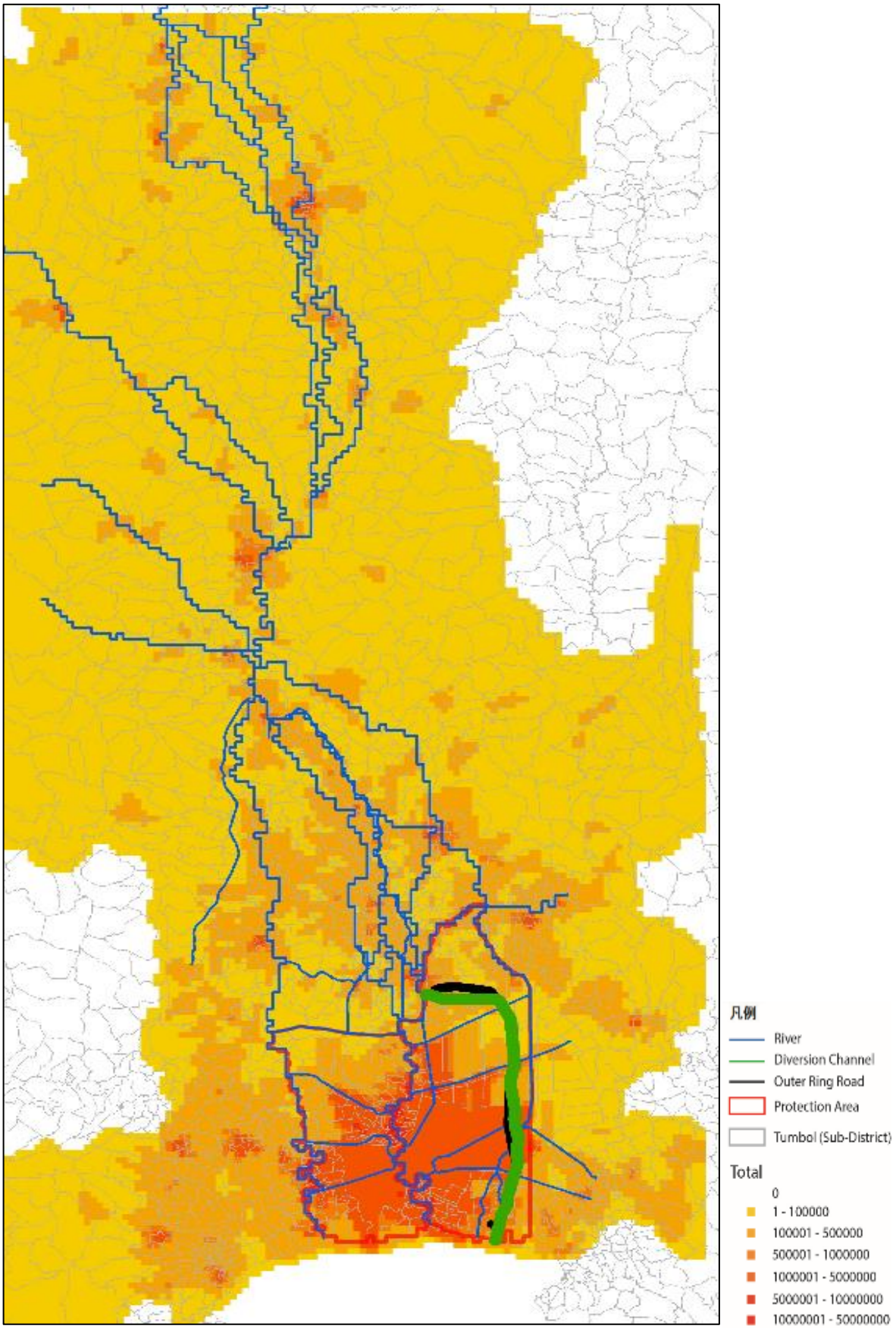
- With the unit amount of housing assets and household goods assets as estimated above, the area of Tombons included in the mesh and number of households in the Tombon, the amount of housing assets and household goods assets are calculated by mesh
- The area of each mesh is not the same as that of the Tombon. Some meshes may include more than one Tombons, so assets in households should be estimated by Tombon.
- First, the number of households per square meter is calculated from the number of households in a Tombon and the area of the Tombon as published by the Department of Provincial Administration.

- From the area and the number of households per square meter of each Tombon, and the number of households in the mesh by Tombon, the total number of households is estimated by summing the number of households in the mesh.
- The housing and household goods assets in each mesh are estimated from the number of households in each mesh and the housing and household goods assets of each province
- When the mesh includes several provinces, housing and household goods assets per household in each province where the mesh belongs to can be the unit price.

Table 9.3.8 Asset per household in each province

	Total Household Assets	Households	Household Assets per Household
Ang Thong	42,829	70,239	0.61
Auttaradit	49,499	115,961	0.43
BKK	1,195,649	820,068	1.46
Chachoengsao	90,673	563,584	0.16
Chainat	49,217	122,364	0.40
Kampaengphet	89,017	560,660	0.16
Lopburi	125,169	491,282	0.25
Nakhon Sawan	41,034	544,439	0.08
Nakorn Pathom	175,889	787,177	0.22
Nakornnayok	155,395	382,451	0.41
Nonthaburi	382,628	217,214	1.76
Pathum Thani	320,566	429,440	0.75
Phichit	70,275	128,653	0.55
Phitsanulok	130,808	196,655	0.67
Phra Nakhon Si Ayutthaya	108,906	510,104	0.21
Ratchaburi	126,844	438,466	0.29
Samut Prakan	288,714	173,160	1.67
Samut Sakhon	94,919	136,571	0.70
Samut Songkham	26,312	8,581	3.07
Saraburi	115,047	242,444	0.47
Sing Buri	31,900	60,243	0.53
Sukhothai	81,773	120,764	0.68
Suphan Buri	121,024	614,120	0.20
Uthai Thani	42,042	204,482	0.21
Total	3,956,130	7,939,122	0.50

Source: JICA Study Team



Source: JICA Study Team

Figure 9.3.4 Distribution of household assets in Thailand

2) Estimation of Direct Damage in Household Sector

As with the Manufacturing Sector, the Household Sector should consider the floor height to estimate its direct damage.

Generally, the floor height in the Household Sector is higher than that in the Manufacturing Sector, and the floor height in the Household Sector is the depth of water at a 5 year return period plus 50 cm.

Table 9.3.9 Water depth and damage rate for households

Inundation	0 – 0.5m	0.5 – 1m	1 – 2m	2 – 3m	More than 3m
Damage Rate (Housing Assets)	0.092	0.119	0.266	0.580	0.834
Damage Rate (Household Assets)	0.145	0.326	0.508	0.928	0.991

Source: "Draft Manual for economic survey on flood control" prepared by the Ministry of Land, Infrastructure, Transport and Tourism, Japan

3) Direct Damage in other than Manufacturing and Household Sectors and Indirect Damage in all Sectors.

From the breakdown of damages in the 2011 flood and estimated direct damage in the Manufacturing and Household Sectors, the direct damage in other than Manufacturing and Household Sectors is estimated.

Indirect damage is estimated from the direct damage and direct/indirect ratio in each sector in the 2011 flood.

Table 9.3.10 Sectorial flood damage in 2011

Unit: Mil THB

Sub Sector	Disaster Effects			Ownership	
	Damage	Losses	Total	Public	Private
Infrastructure					
Water Resources Management	8,715	–	**8,715**	8,715	–
Transport	23,538	6,938	**30,476**	30,326	150
Telecommunication	1,290	2,558	**3,848**	1,597	2,251
Electricity	3,186	5,716	**8,901**	5,385	3,517
Water Supply and Sanitation	3,497	1,984	**5,481**	5,481	
Production					
Agriculture, Livestock and Fishery	5,666	34,715	**40,381**	–	40,381
Manufacturing	513,881	493,258	**1,007,139**	–	1,007,139
Tourism	5,134	89,673	**94,808**	403	94,405
Finance and Banking	–	115,276	**115,276**	74,076	41,200
Social					
Health	1,684	2,133	**3,817**	1,627	2,190
Education	13,051	1,798	**14,849**	10,614	4,235
Housing	45,908	37,889	**83,797**	–	83,797
Cultural Heritage	4,429	3,076	**7,505**	3,041	4,463
Cross Cutting					
Environment	375	176	**551**	212	339
TOTAL	**630,354**	**795,191**	**1,425,544**	**141,477**	**1,284,066**

Source: DALA estimates, NESDB, and Ministry of Industry.
Note: Losses for each sector include higher expenditures due to floods.

Source : World Bank "Thai Flood 2011 Rapid Assessment for Resilient Recovery and Reconstruction Planning – overview"

Table 9.3.11 Manufacturing & housing and other sector ratios indirect damage of 2011 flood, Direct Damage and Indirect Damage Ratio in each sector

Flood damage in 2011（Mil THB）	Direct Damage		Indirect Damage		Other Sector - Manufacturing & Housing Ratio	Direct/Indirect Ratio
Infrastructure						
Water Resource Management	8,715	1.4%	0	0.0%	0.02	0.00
Transport	23,538	3.7%	6,938	0.9%	0.04	0.29
Telecommunication	1,290	0.2%	2,558	0.3%	0.00	1.98
Electricity	3,186	0.5%	5,716	0.7%	0.01	1.79
Water Supply and Sanitation	3,497	0.6%	1,984	0.2%	0.01	0.57
Productive						
Agriculture, Livestock and Fishery	5,666	0.9%	34715	4.4%	0.01	6.13
Manufacturing	513,881	81.5 %	493,258	62.0%	0.92	0.96
Tourism	5,134	0.8%	89,673	11.3%	0.01	17.47
Finance & Banking	0	0.0%	115,276	14.5%	0.00	-
Social						
Health	1,684	0.3%	2,133	0.3%	0.00	1.27
Social						
Education	13,051	2.1%	1,798	0.2%	0.02	0.14
Housing	45,908	7.3%	37,889	4.8%	0.08	0.83
Cultural Heritage	4,429	0.7%	3,076	0.4%	0.01	0.69
Cross Cutting						
Environment	375	0.1%	176	0.0%	0.00	0.47
Total	630,354	100%	795,190	100%	1.13	1.26

(4) Calculation of the project cost

1) Project cost of the Diversion Channel

Table 9.3.12 shows the result of the cost estimation of the project cost of the Diversion Channel.

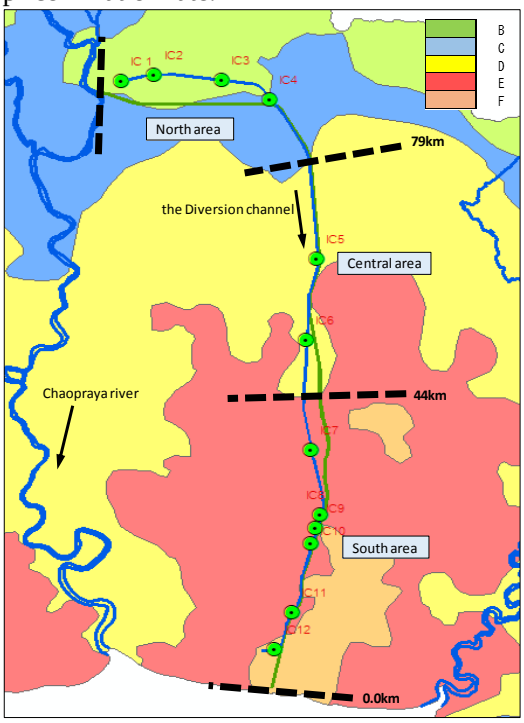
Table 9.3.12 Project cost of the Diversion Channel

	Cost (Million THB)	memo
Construction Cost	71,949	a)
Engineering Cost / Construction Control	5,756	b) = a) *0.08
Project Management Cost / Processing	2,158	c) = a) *0.03
Value Added Tax	0	d)
Land Cost / Compensation	52,450	e)
Project Cost	132,314	f) = a) + b) + c) + e)

Source: JICA Study Team

In the estimation, the conditions shown below are assumed;

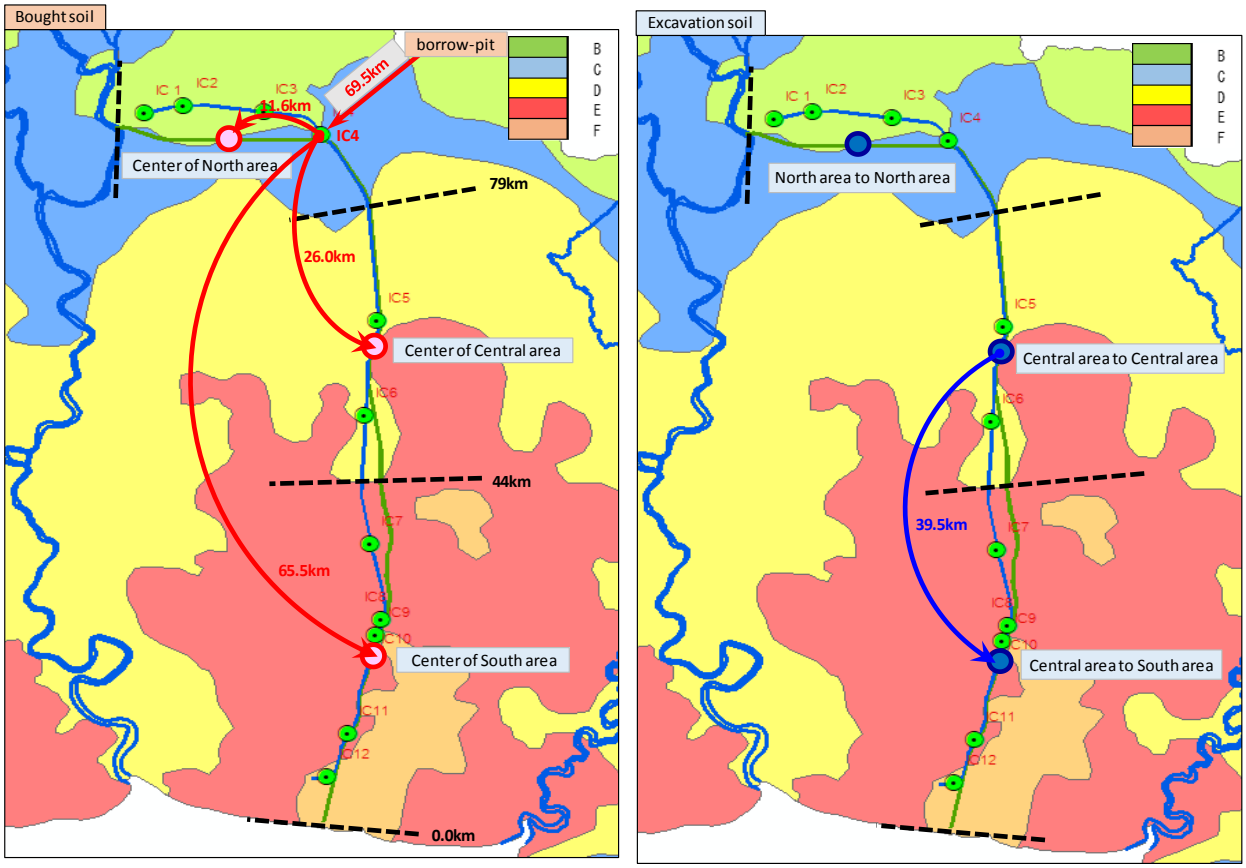
- The project zone is divided into 3 zones (Northern part, Central part and Southern part) by soil condition, and the construction cost in each zone is estimated in line with the need for soil strengthening of each zone.
- The construction cost estimation is divided into the estimation of the cost of the Diversion Channel itself and that of facilities: gates, siphons, etc.
- A transportation cost is assumed for the excavated soil from the project site to disposal sites.
- Factor F is set at 13 %
- The land acquisition cost is estimated based on the latest data from the Treasury Department of the Ministry of Finance.
- The other cost items are estimated by multiplying those estimations in the Master Plan of 2013 with the price inflation rate.



Source: JICA Study Team

Figure 9.3.5 Zone division of the Diversion Channel investment

A transportation cost is assumed by the distance between the borrow pit and IC4 and the distance between IC4 and each site. Excavated soil from the northern area is to be used for the Diversion Channel embankment in the northern area. Excavated soil from the central area is to be used for the Diversion Channel embankment in the central area. In the southern area, the transportation cost from the central area to the southern area was summated. The transportation distance is from the halfway point of the central area to the halfway point of the southern area



Transport distance of purchased soil

Transport distance of excavated soil

Source : JICA Study Team

Figure 9.3.6 Transportation distance of bought soil and excavated soil

The breakdown of the construction cost of the Diversion Channel and its facilities are shown on the next page.

Table 9.3.13 Result of cost estimation of the Diversion Channel

Items			Quantity	Unit	Unit price (THB)	Amount (THB)		Remark
Earthwork	Excavation		58,783,824	m^3	20	1,175,676,480	44,795,262,061	a)
	Embankment	Mixing / Compaction (V)	16,004,910	m^3	292.2	4,676,634,702		
		Purchased sand for mixing (V/3)	5,334,970	m^3	135	720,221,085		
		Purchase sand transportation (Sand pit → Interchange 4)	5,334,970	m^3	240	1,280,393,040		
		Purchased sand transportation (Interchange 4 → Excavation yard)	5,334,970	m^3		995,262,785		
	Remained soil disposal	Remained soil disposal	38,231,309	m^3	282	10,781,229,138		
		Excavated soil	*58,783,824*	*m^3*				
		Utilize excavated soil	*-10,669,939*	*m^3*				
		Road embanking material	*-9,882,576*	*m^3*				
Planting work		Sodding	3,786,795	m^2	65	246,141,675		
Crest Pavement (2 lanes 10m width)		Under layer roadbed T=200mm	437,432	m^3	118.8	51,966,922		
		Upper layer roadbed T=150mm	308,729	m^3	313.6	96,817,414		
		Surface layer t=150mm	292,101	m^3	930.0	271,653,930		
Soil Stabilization		SCC (Soil Cement Column)	16,695,704	m^3	1,200	20,034,844,800		
		PVD (Prefabricated Vertical Drain)	42,938,001	m	90	3,864,420,090		
Boxculvert		Interchange 11 (4 places)	4	sites	150,000,000	600,000,000		
Factor F（Indirect construction cost rate)							5,823,384,068	b)=a)×0.13
Construction cost (Diversion Channel)							50,618,646,129	c)=a)+b)
Facility structure	Road bridge		27,000	m^2	82,000	2,214,000,000	18,876,624,000	d)
	Railway bridge		677,000	m	800	541,600,000		
	Gate	Upstream end, Downstream end	2	place		5,466,000,000		
	Syphon	14 places	1	set		7,429,000,000		
	Lock gate		1	set		2,500,000,000		
	General work	4% of the above				726,024,000		
Factor F（Indirect construction cost rate)							2,453,961,120	e)=d)×0.13
Construction cost (Facility structure)							21,330,585,120	f)=d)+e)
Construction cost							71,949,231,249	g)=c)+f)
Engineering Cost / Construction Control							5,755,938,500	h)=g)×0.08
Project Management Cost / Processing							2,158,476,937	i)=g)×0.03
Value added Tax							0	
Land Cost / Compensation							52,450,447,449	j)
Project cost							132,314,094,135	k)=g)+h)+i)+j)

The project cost including Engineering Cost / Construction adjustment Cost 5,756 Mil B and Project Management Cost / Processing 2,158 Mil B will be 132,314 Mil B.

Source JICA Study Team

2) Project cost of The outer ring road

The result of the estimation of the road construction cost is shown in Table 9.3.13.

The project cost of the outer ring road was estimated in the Feasibility Study conducted by DOH from 2006 to 2008. However, when development of the Diversion Channel and the Outer Ring Road is combined and the estimated cost in the Feasibility Study is reviewed since the road structure is changed as shown in "2.4.3 the Outer Ring Road". Moreover, the number of construction inputs and the unit costs in the Feasibility Study are also reviewed to reflect those changes caused by the change of road structure and inflation between 2008 to 2017

The method to review the unit price of construction inputs is given below;

i. When a Cost Breakdown exists

When the cost breakdown in the Feasibility Study by DOH exists, i.e. ground treatment, and pavement, those unit costs are revised by replacing the unit costs of the construction materials, labor and operations adopted in the Feasibility Study to the latest ones.

ii. When the Cost Breakdown does not exist

When the cost breakdown in the Feasibility Study by DOH does not exist, i.e. bridges, unit costs are revised by using "adjustment factors", which are calculated from multiplying the cost increase of construction materials, labor and operations by the general ratio of each cost to the construction cost of each facility.

The result of the estimation is shown below;

Table 9.3.14 Road construction cost

	① This Study	② After F/S Review	③ F/S 2011
Direct Construction Cost	48,629	45,162	26,073
Indirect Construction Cost	6,322	5,871	3,500
Construction Cost	54,951	51,033	29,573

Indirect construction cost is estimated multiplying direct construction cost by Factor-F(0.13 Unit : Mil. THB

Source: JICA Study Team

Road cost and facility cost includes increment of construction cost of interchange and crossing bridge, accompanying integrated construction with diversion channel. These costs are currently accounted for as DOH expenses.

At the stage when the implementation of the integrated project became clear, it is presumed that consultation with DOH and others will progress regarding cost sharing with RID of DOH and measures to further reduce construction cost of road project cost.

Table 9.3.15 Calculation result of road project cost

		Combined Project				2020		2021		2022		2023		2024		2025		TOTAL
		Quantity	Unit	Unit Price (TBH)	Amount	14,251,315,758		14,251,315,758		11,195,620,692		12,032,834,967		14,981,830,546		16,740,355,356		83,453,273,076
Main Road (Fill Section)																		
RC Pavement	t=25cm	1,277,208	m2	930.0	1,187,803,440									296,950,860	296,950,860	296,950,860	296,950,860	1,187,803,440
Sand Bed	t=10cm	1,277,208	m2	137.0	174,977,496									43,744,374	43,744,374	43,744,374	43,744,374	174,977,496
AC Shoulder	t=5cm	729,700	m2	195.0	142,291,500									35,572,875	35,572,875	35,572,875	35,572,875	142,291,500
Upper Base-course	t=20cm (Crushed Stone)	220,969	m3	313.6	69,300,298								17,325,074	17,325,074	17,325,074	17,325,074		69,300,298
Lower Base-course	t=15cm (Laterite)	97,861	m3	118.8	11,629,807							3,876,602	3,876,602	3,876,602				11,629,807
Subgrade and Embankment	t=245cm (Selected Soil)	2,889,954	m3	101.7	294,925,281						98,308,427	98,308,427	98,308,427					294,925,281
Mixing Material	Sand for Mixing	4,487,362	m3	135.0	603,093,898					201,031,299	201,031,299	201,031,299						603,093,898
	Cement (7%)	42,599	ton	2700.0	115,017,700									38,339,233	38,339,233	38,339,233		115,017,700
	Quick Lime (5%)	120,553	ton	2700.0	325,494,396									108,498,132	108,498,132	108,498,132		325,494,396
Mixing Cost	Mixing Plant (8 sets)	13,402,087	m3	292.2	3,916,089,709					559,441,387	559,441,387	559,441,387	559,441,387	559,441,387	559,441,387	559,441,387		3,916,089,709
Transport Cost : Bollow Pit→IC-4	t=20cm (Crushed Stone)	220,969	m3	361.3	79,833,890									26,611,297	26,611,297	26,611,297		79,833,890
	t=15cm (Laterite)	97,861	m3	369.9	36,108,681								12,034,560	12,034,560	12,034,560			36,103,681
	t=245cm (Selected Soil)	2,889,954	m3	369.9	1,069,874,082							356,624,694	356,624,694	356,624,694				1,069,874,082
	Sand for Mixing	4,487,362	m3	240.9	1,076,008,861					358,669,620	358,669,620	358,669,620						1,076,008,861
Transport Cost : IC-4→Site	t=20cm (Crushed Stone)	220,969	m3	155.8	34,426,344									11,475,448	11,475,448	11,475,448		34,426,344
	t=15cm (Laterite)	97,861	m3	52.4	5,126,364								1,708,788	1,708,788	1,708,788			5,126,364
	t=245cm (Selected Soil)	2,889,954	m3	52.4	151,511,487							50,637,162	50,637,162	50,637,162				151,511,487
	Sand for Mixing	4,487,362	m3	162.5	725,930,272					241,976,757	241,976,757	241,976,757						725,930,272
PVD STA 56+579~83+790	1.0m*1.0m	22,641	m	96,558	2,186,169,678					1,093,084,839	1,093,084,839							2,186,169,678
PVD STA 35+500~56+579	2.0m*2.0m	20,069	m	19,950	400,376,550					200,188,275	200,188,275							400,376,550
Planting, Fence, etc.					410,802,649												410,802,649	410,802,649
Main Road (Viaduct)																		
STA 83+700~97+112	8 lanes	13,412	m	1,001,743	13,435,378,574					1,919,339,796	1,919,339,796	1,919,339,796	1,919,339,796	1,919,339,796	1,919,339,796	1,919,339,796		13,435,378,574
Service Road																		
Inside of Ring Road R.O.W	2 lane	36,024	m	3,550	127,885,200							25,577,040	25,577,040	25,577,040	25,577,040	25,577,040		127,885,200
Inside of Diversion C. R.O.W	2 lane	31,290	m	3,550	111,079,500								22,215,900	22,215,900	22,215,900	22,215,900	22,215,900	111,079,500
Other Facilities																		
Bridge on Diversion Channel	STA21+015	820	m	774,000	634,680,000								126,936,000	126,936,000	126,936,000	126,936,000	126,936,000	634,680,000
Bridge on other channel and road					1,882,962,690					268,994,670	268,994,670	268,994,670	268,994,670	268,994,670	268,994,670	268,994,670		1,882,962,690
Existing Road Bridges	I Girder	3,200	m	269,510	862,752,000							143,792,000	143,792,000	143,792,000	143,792,000	143,792,000	143,792,000	862,752,000
(Additional for Diversion Channel)	180m extension	320	m	269,510	86,275,200							14,379,200	14,379,200	14,379,200	14,379,200	14,379,200	14,379,200	86,275,200
	Segmental Girder	612	m	516,000	315,792,000							63,158,400	63,158,400	63,158,400	63,158,400	63,158,400		315,792,000
Existing Road Underpass (w=6m)	Community Road	486	m	68,112	33,102,432					8,275,608	8,275,608	8,275,608	8,275,608					33,102,432
Existing Road Overpass (w=6m)	Additional for Combine	8,370	m	109,650	917,770,500										305,923,500	305,923,500	305,923,500	917,770,500
Interchange	11 nos.				10,937,796,480								2,187,559,296	2,187,559,296	2,187,559,296	2,187,559,296	2,187,559,296	10,937,796,480
(Additional for Diversion Channel)	Additional for Combine				1,734,716,251								346,943,250	346,943,250	346,943,250	346,943,250	346,943,250	1,734,716,251
Box Culvert	for small irrigation channels	6,504	m	33,000	214,632,000					53,658,000	53,658,000	53,658,000	53,658,000					214,632,000
Service Area					154,440,000											77,220,000	77,220,000	154,440,000
Motorway Facility Buildings					1,153,812,000											576,906,000	576,906,000	1,153,812,000
Toll Collection and Safty System					2,348,760,000											1,174,380,000	1,174,380,000	2,348,760,000
Sign, Marking, Guide Post					367,360,000												367,360,000	367,360,000
Environment Mitigation Cost	Noise Barrier etc.				292,504,129												292,504,129	292,504,129
Sub-total					48,628,886,337	0	0	0	0	4,904,660,202	5,002,968,579	4,367,740,663	6,280,785,896	6,681,736,040	5,376,521,091	8,391,288,732	6,428,190,034	48,628,886,337
Factor F (13% without VAT)		13	%		6,321,755,224	0	0	0	0	637,605,833	650,385,928	567,806,286	816,502,161	868,625,585	854,947,741	1,090,867,885	835,014,704	6,321,755,224
Construction Cost Total					54,950,641,561	0	0	0	0	5,542,266,085	5,653,354,507	4,935,546,950	7,097,288,017	7,550,361,725	7,431,468,821	9,482,150,618	7,258,204,738	54,950,641,561
Land Aquisition and Compensation		6,908,035	m2	4.129	28,502,631,515	7,125,657,879	7,125,657,879	7,125,657,879	7,125,657,879									28,502,631,515
TOTAL PROJECT COST					83,453,273,076	7,125,657,879	7,125,657,879	7,125,657,879	7,125,657,879	5,542,266,085	5,653,354,507	4,935,546,950	7,097,288,017	7,550,361,725	7,431,468,821	9,482,150,618	7,258,204,738	83,453,273,076

Source : JICA Study Team

The completion of the outer ring road(Eastern Area) is assumed at the end of 2025, based on the assumptions in the Feasibility Study by DOH in 2009 the operation and maintenance cost from 2026 and beyond is estimated as shown below.

i. Routine Maintenance

The routine maintenance includes the cost for the patrol for targeted roads, cleaning, and small-scale improvement. Referring to the record from DOH, it is assumed that the daily operation and maintenance cost for four-lane roads is 0.40 Mil THB/km.

ii. Periodical Maintenance

Since the outer ring road(Eastern Area) adopts concrete pavement, 0.12 Mil THB/km is assumed as a eplacement cost of joint sealing for four-lane roads every three years.

Based on those assumptions, the annual routine maintenance cost and periodical maintenance cost are calculated and shown in table bellow.

Table 9.3.16 Maintenance cost of the 3rd Outer Ring Road

Routine Maintenance	Nos. of lane	Maintenance Cost(mil. Bht)/km	Length (km)	Routine Maintenance Cost (Mil. Bht. per year)
Service Road	2	0.40	67.31	26.93
Main Road (Embankment)	4	0.80	44.60	35.68
Main Road (Embankment)	6	1.20	39.20	47.03
Main Road (Elevated)	6	1.20	13.32	15.99
Total				**125.62**
Periodical Maintenance	Nos. of lane	Maintenance Cost(mil. Bht)/km	Length (km)	Periodical Maintenance Cost (Mil. Bht. per every 3 year)
Service Road	2	0.12	67.31	8.08
Main Road (Embankment)	4	0.24	44.60	10.70
Main Road (Embankment)	6	0.36	39.20	14.11
Main Road (Elevated)	6	0.36	13.32	4.80
Total				**37.69**

Source: JICA Study Team

(5) Project Evaluation

1) Economic Evaluation: Preconditions

- The variance of return periods of floods in this economic evaluation is 2-year, 3-year. 5-year, 10-year, 30-year, 50-year and 100-year, and the damage in each return period is estimated in the with and without cases. Then the damage reduction (Dm) between the With-case and Without-case for each return period is calculated.
- The annual average damage reduction (dm) is calculated by multiplying the interval average damage reduction ([Dm+Dm-1]/2) with the interval probability of flood occurrence (Nm-Nm+1). The total damage reduction owing to the Diversion Channel is the cumulative total of the annual damage reduction of all intervals.

Table 9.3.17 Benefit calculation table

Return Period	Probability	Flood Damage			Interval Average Damage Reduction	Interval Probability	Benefit
		① With-case	② Without-case	③ Damage Reduction (①－②)			
Q_0	N_0			$D_0(=0)$	$\frac{D_0+D_1}{2}$	N_0-N_1	$d_1 = (N_0-N_1) \times \frac{D_0+D_1}{2}$
Q_1	N_1			D_1	$\frac{D_1+D_2}{2}$	N_1-N_2	$d_2 = (N_1-N_2) \times \frac{D_1+D_2}{2}$
Q_2	N_2			D_2	⋮	⋮	⋮
⋮				⋮	$\frac{D_{m-1}+D_m}{2}$	N_m-N_{m+1}	$d_m = (N_{m-1}-N_m) \times \frac{D_{m-1}+D_m}{2}$
Q_m	N_m			D_m			

Source: JICA Study Team

- The construction period is projected to be the 5 years from 2021 to 2015, and no benefits accrue during the construction period, but the benefit occurs from 2026. The targeted period for evaluation is the 40 years from 2021 to 2060, but it is assumed that the benefit and Operation and Maintenance cost will continue even after 2060. Therefore, the residual value to occur is added to the benefit and cost.
- The social discount rate adopted generally in Thailand is 12%, so 12% is adopted also in this project evaluation.
- Economic growth in the targeted period is also incorporated in the calculation.
- The predicted real annual economic growth rate in Thailand as given in the IMF "World Economic Outlook (April 2017)" is a low 3% from 2017 to 2020 and 3% for 2021 and beyond.

Table 9.3.18 Prediction of the real economic growth rate of Thailand

Year	2017	2018	2019	2020	2021 and beyond
Real Economic Growth Rate	3.0%	3.3%	3.2%	3.1%	3%

Source: JICA Study Team

Based on the prediction of the IMF, the real economic growth rate in the targeted period is assumed to be 3%, and annual benefit and cost for operation and maintenance will increase in line with the economic growth.

2) Annual Benefit

The flood damage of With-case and Without-case in each return period is shown in the next table;

Table 9.3.19 Annual Benefit: manufacturing sector

Return Period	Occurrence Probability	With-case (Mil THB)	Without-case (Mil THB)	Damage Reduction (Mil THB)	Interval Average Damage Reduction (Mil THB)	Interval Occurrence Probability	Annual Benefit
1-year	1.000	0	0	0			
					0	0.5	
2-year	0.500	0	0	0			
					4,484	0.167	747
3-year	0.333	277,133	268,166	8,967			
					29,483	0.133	3,931
5-year	0.250	523,502	473,504	49,998			
					53,730	0.100	5,373
10-year	0.100	773,357	715,896	57,461			
					88,359	0.067	5,891
30-year	0.033	1,174,601	1,055,343	119,258			
					130,631	0.013	1,742
50-year	0.020	1,303,110	1,161,105	142,005			
					161,122	0.010	1,611
100-year	0.010	1,539,306	1,359,067	180,239			
						Total	19,295

Source: JICA Study Team

Table 9.3.20 Annual Benefit: household sector

Return Period	Occurrence Probability	With-case (Mil THB)	Without-case (Mil THB)	Damage Reduction (Mil THB)	Interval Average Damage Reduction (Mil THB)	Interval Occurrence Probability	Annual Benefit
1-year	1.000	0	0	0			
					0	0.5	0
2-year	0.500	0	0	0			
					0	0.167	0
3-year	0.333	17	17	0			
					0	0.133	0
5-year	0.250	0		0			
					1,657	0.100	166
10-year	0.100	16,485	13,172	3,313			
					43,025	0.067	2,868
30-year	0.033	144,440	61,704	82,737			
					82,454	0.013	1,099
50-year	0.020	194,814	112,643	82,171			
					92,175	0.010	922
100-year	0.010	349,763	247,584	102,179			
						Total	5,055

Source: JICA Study Team

In the benefit evaluation of sectors other than the Manufacturing sector and Household sector, as mentioned already, the ratio of the other sectors' total damage to the Manufacturing sector and Household sector's total damage in the 2011 flood is used. The estimation formula is shown below;

$$\text{Flood Damage Reduction in SectorsOther than Manufacturing Sector and Household Sector}$$

$$= \frac{\text{Flood Damage in Other Sectors in 2011 Flood}}{\text{Flood Damage in the Manufacturing Sector and Household Sector in 2011 Flood}} \times \text{Estimated Flood Damage Reduction by the Diversion Channel in the Manufacturing Sector and Household Sector}$$

$$= 0.307 \times \text{Estimated Flood Damage Reduction by the Diversion Channel in the Manufacturing Sector and Household Sector}$$

The estimated benefit in sectors other than the Manufacturing Sector and Household sector is 13,105 Mil THB.

To summarize the above, the total annual benefit from the Diversion Channel will be 31,774 Mil THB.

3) Net Present Value (NPV)、Economic Internal Return Rate (EIRR)、Cost-Benefit Ratio (B/C)

The total project cost excluding operation and maintenance cost of the Diversion Channel is 132,314 Mil THB which is assumed to be distributed uniformly from 2021 when the land acquisition and construction start and continue to 2025 when the Diversion Channel is completed.

After 2026, the costs of the operation and maintenance of the Diversion Channel will be 1% of the project cost, 1,323 Mil THB a year to begin with, but they will increase in line with the real economic growth (3% annually).

Meanwhile, the annual benefit of the Diversion Channel, 31,774 Mil THB will rise every year from the beginning of usage in 2026, and the benefit will increase in line with the real economic growth (3% annually). Therefore, the benefit in 2026 will be 41,458 Mil THB because of the real economic growth since 2017.

The benefit and cost in the targeted period for evaluation, from 2021 to 2060, is chronologically shown below. The benefit and cost in 2060 include the terminal values after 2061 based on the assumption that the benefit and cost for operation and maintenance will continue to occur after 2060; the terminal value of the benefit and maintenance cost is calculated by dividing them by the discount rate (12%).

Table 9.3.21 Cost Benefit Analysis

Unit : Mil THB

Year	Benefit			Cost		
	Benefit	Present Value	Residual Value	Benefit	Present Value	Residual Value
2021	0	0		29,784	18,928	
2022	0	0		29,784	16,900	
2023	0	0		29,784	15,090	
2024	0	0		29,784	13,473	
2025	0	0		29,784	12,029	
2026	41,458	14,950		1,489	537	
2027	42,702	13,749		1,534	494	
2028	43,983	12,644		1,580	454	
2029	45,302	11,628		1,627	418	
2030	46,661	10,694		1,676	384	
2031	48,061	9,834		1,726	353	
2032	49,503	9,044		1,778	325	
2033	50,988	8,317		1,832	299	
2034	52,518	7,649		1,886	275	
2035	54,093	7,034		1,943	253	
2036	55,716	6,469		2,001	232	
2037	57,388	5,949		2,061	214	
2038	59,109	5,471		2,123	197	
2039	60,882	5,031		2,187	181	
2040	62,709	4,627		2,253	166	
2041	64,590	4,255		2,320	153	
2042	66,528	3,913		2,390	141	
2043	68,524	3,599		2,461	129	
2044	70,579	3,310		2,535	119	
2045	72,697	3,044		2,611	109	
2046	74,878	2,799		2,690	101	
2047	77,124	2,574		2,770	92	
2048	79,438	2,367		2,853	85	
2049	81,821	2,177		2,939	78	
2050	84,276	2,002		3,027	72	
2051	86,804	1,841		3,118	66	
2052	89,408	1,693		3,212	61	
2053	92,090	1,557		3,308	56	
2054	94,853	1,432		3,407	51	
2055	97,698	1,317		3,509	47	
2056	100,629	1,211		3,615	44	
2057	103,648	1,114		3,723	40	
2058	106,758	1,024		3,835	37	
2059	109,960	942		3,950	34	
2060	113,259	866	7,220	4,068	31	259
Total		183,351			83,006	

Net Present Value	100,345
Cost Benefit Ratio	2.21
Economic Internal Rate of Return	20.7%

Source: JICA Study Team

The Net Present Value (NPV) of the Diversion Channel in 2017 is calculated with the formula shown below; NPV is the sum of the difference between the benefit Bn and cost Cn in each year (n) discounted by the years from 2017.

$$\mathrm{NPV} = \sum_{n=2017}^{2060} \frac{B_n - C_n}{(1+r)^{n-2017}}$$

The result of the estimation is shown in the Table below; the NPV of the Diversion Channel is 77, 190 Mil THB, the EIRR is 17.3%, the B/C is 1.75.

Table 9.3.22 Economic index

Index	Value
Net Present Value (NPV)	100,345 Mil THB
Economic Internal Return Rate (EIRR)	20.7 %
Benefit-Cost Ratio (B/C)	2.21

Source: JICA Study Team

The EIRR exceeds not only the social discount rate (12%), but also 15% which is required generally for public works in Thailand. Moreover, the B/C is also far beyond 1, so it is concluded that the Diversion Channel is a sufficiently efficient socio-economic investment and it is highly feasible as a public works.

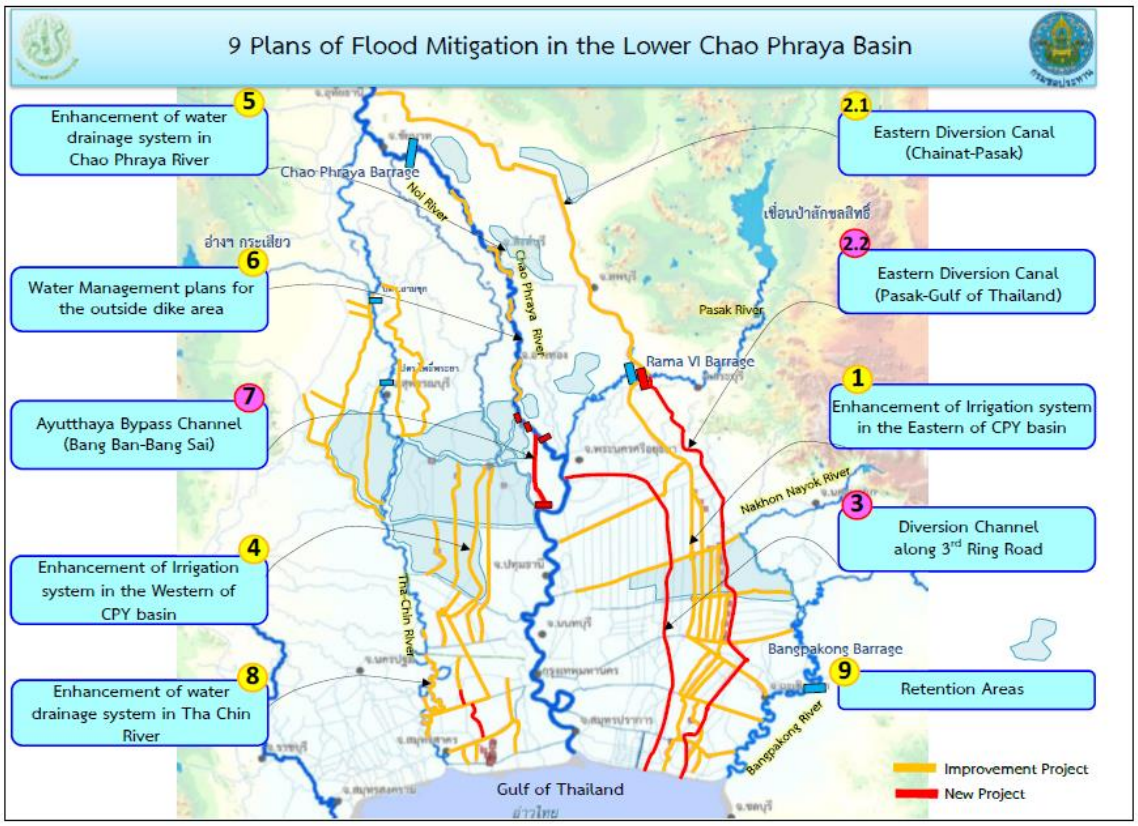
CHAPTER 10 RID'S PLAN AND JICA'S OPINION

10.1 RID Plan

10.1.1 Summary of RID Plan

RID has been discussing about flood management by taking the flood in 2011 as defense target, including planning of diversion channel on both sides, and has proposed following 9 projects to the Cabinet.

1. Enhancement of Irrigation System in the Eastern of CPY Basin
2-1. Eastern Diversion Canal (Chainat-Pasak (CP))
2-2. Eastern Diversion Canal (Pasak-Gulf of Thailand (PGT))
3. Diversion Channel along the outer ring road
4. Enhancement of Irrigation system in the Western of CPY basin
5. Enhancement of water drainage system in Chao Phraya River
6. Water Management plans for the outside dike area
7. Ayutthaya Bypass Channel (Bang Ban-Bang Sai)
8. Enhancement of water drainage system in Tha Chin River
9. Retention Areas



Source : RID Presentation

Figure 10.1.1 Location of 9 Projects（RID Plan）

Nine projects of RID are judged to be feasible from the viewpoint of the environment and society. Under these projects, RID has set the discharge 3,795 m^3/s in C2 (Nakhon Sawan) with assumption of discharge capacity 2,800 m^3/s, which is expected not to cause damages in the downstream of the Chao Phraya River. This concept of distribution of discharge to downstream of rivers or channels is similar to irrigation plans. Incidentally, according to the explanation of RID, the scale of this discharge (3,795 m^3/s) is 25 years probability.

Figure 10.1.2 discharge distribution in RID Plan

10.1.2 Prioritized Projects in RID Plan

4 of above-mentioned 9 projects are prioritized by RID in following order because of their high budget requirement. They are supposed capable to increase discharge capacity and reduce the peak flood. Summary and current situation for implementation of these project is described below, based on information provided by RID. RID is planning to implement them in the priority order.

Prioritized Project 1 : Ayutthaya Bypass Channel (Bang Ban-Bang Sai) (7)
Prioritized Project 2 : Eastern Diversion Canal (Chainat-Pasak) (2-1)
Prioritized Project 3 : Areas Eastern Diversion Canal (Pasak-Gulf of Thailand) (2-2)
Prioritized Project 4 : Diversion Channel along the outer ring road (3)

(1) Prioritized Project 1 : Ayutthaya Bypass Channel (Bang Ban-Bang Sai)

This project can solve bottle-neck problem of Chao Phraya River at Phra Nakhon Si Ayutthaya province where flood repeats every year. This project was approved in principle by the Cabinet for project preparation phase and under details design phase.

(2) Prioritized Project 2：Eastern Diversion Canal (Chainat-Pasak)

This canal is a drainage canal parallel with irrigation canal. It can reduce flow rate at upstream Chao Phraya Diversion Dam of 800m^3/s. Project can be implemented with no land acquisition or resettlement because of sufficient right-of-way according to RID. Survey and details design work will be conducted in 2019.

(3) Prioritized Project 3：Eastern Diversion Canal (Pasak-Gulf of Thailand)

This project can prevent and mitigate flood from Nakhon Sawan province to gulf of Thailand. Protected area of this project can cover the area of the Outer Ring Road Diversion Channel dose. Longitudinal slope of canal bottom is 1:10,000-1:25,000 so that water can be drained by gravity. Besides, water flow in and out can be well controlled because the project is equipped with regulator including Chao Phraya Diversion Dam, and Pasak Diversion Dam (New Rama VI diversion dam). This project can reduce peak flood both Chao Phraya River and Pasak River. Therefore it can be used more frequently than the Outer Ring Road Diversion Channel. Project cost and compensation of this project is lower than the Outer Ring Road Diversion Channel project, which is supposed to be feasible for investment with B/C ratio of 1.49 and EIRR of 17.22%. F/S study and EIA have been completed. (However, RID did not provide any evidence for these conclusion.)

(4) Prioritized Project 4：Diversion Channel along the Outer Ring Road

The the Outer Ring Road Diversion Channel Project, which is under preliminary F/S study together with JICA Survey Team, is considered as the 4th one. Next step, RID will propose for implementation after the Pre-F/S.

10.2 JICA's Opinion

Following issues on RID' plan are pointed out by JICA.

1. Problem of RID Plan
2. Comparison of economic advantage between "Outer Ring Road Diversion Channel (DC)" and "Chainat-Pasak Channel (CP) with Eastern Diversion Channel (PGT)"
3. Correct Order of project implementation

10.2.1 Problem of RID's Plan

(1) Problem of the 9 projects

Problem of the 9 projects are pointed out as follows.

- Definition of target discharge (Basic Flood Discharge)

There is no study process for defining "Basic Flood Discharge" such as:

- Defining target rainfall
- Defining target flood
- Assuming no overflow from the river upstream than observation point
- Design discharge distribution to the flood control facilities

There is no study process for defining "Design Discharge Distribution" such as:

- Estimation of discharge capacity of the river
- Against Design Flood, considering the optimal place for facilities such as river improvement, dams, detention area, and drainage channels
- Set the optimal discharge allocation for each flood control facility

A flow chart of flood control planning in Japan (Figure 4.2.1) is provided for RID to understand these two problems.

- Comprehensive project evaluation of RID nine projects
- Costs benefit ratio for the whole nine projects has not been calculated although some projects' cost benefit ratios have been calculated. The nine projects have been submitted to the Cabinet without evaluation for the necessity of the whole nine projects.

The nine projects are selected only by easiness of implementation without technical study process. And values of RID's design discharge are simply sum-up.

What is worse, it is impossible for us to judge how large the target flood scale is, or by which means flood can be controlled, nor whether the prioritized project is the optimal one, because there is no comprehensive economic evaluation of the 9 projects.

In one word, it is far from a flood control plan that is based on engineering approaches.

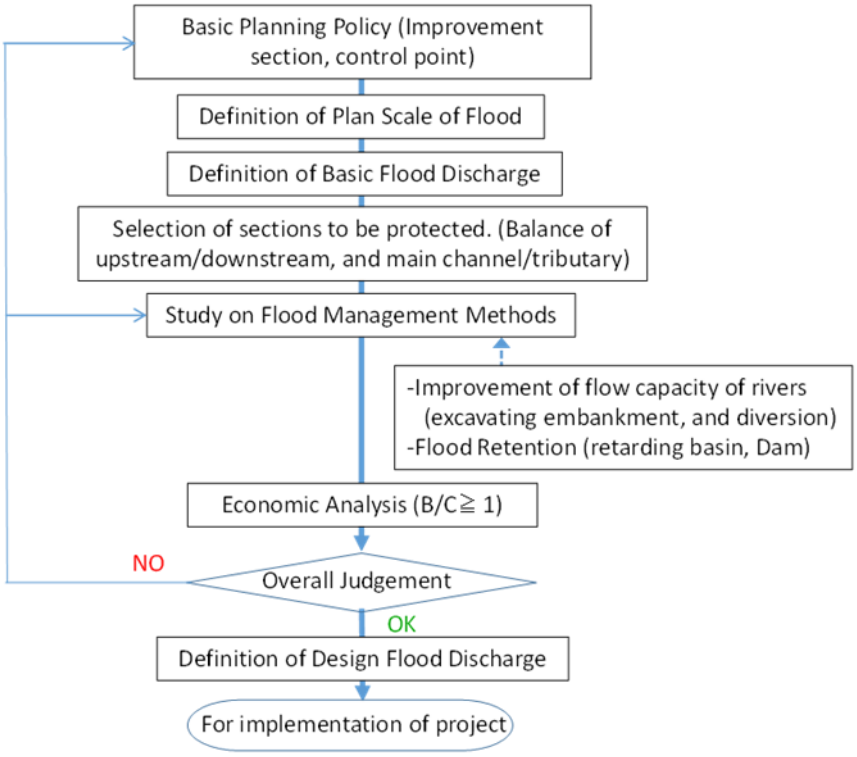


Figure 10.2.1 Flow chart of flood control planning in Japan

JICA Master Plan is the result of study according to the above procedure.

Key points are shown below.

1) Plan scale: 2011 flood scale (= 100-year return period)
2) Most effective plan with protected area and controlled inundation area, considering asset distribution in the whole river basin
3) Combination with "Improvement of dam operation" and "Dyke heightening in weak part of downstream of Chao Phraya River" which are low cost, but early and highly effective

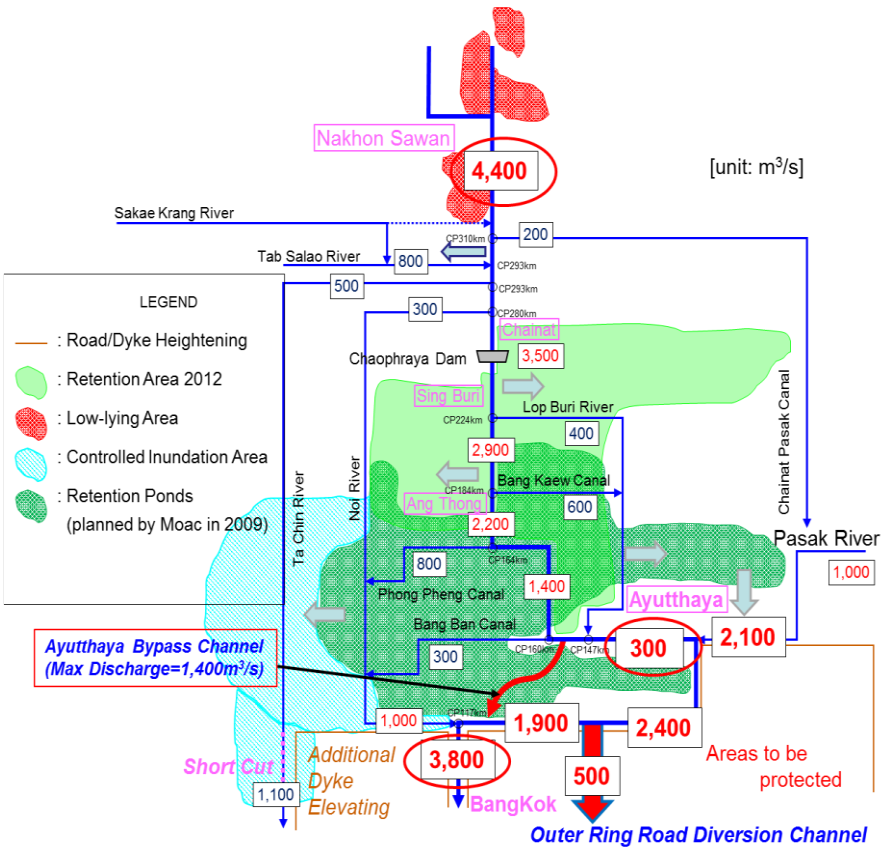


Figure 10.2.2 JICA Master Plan

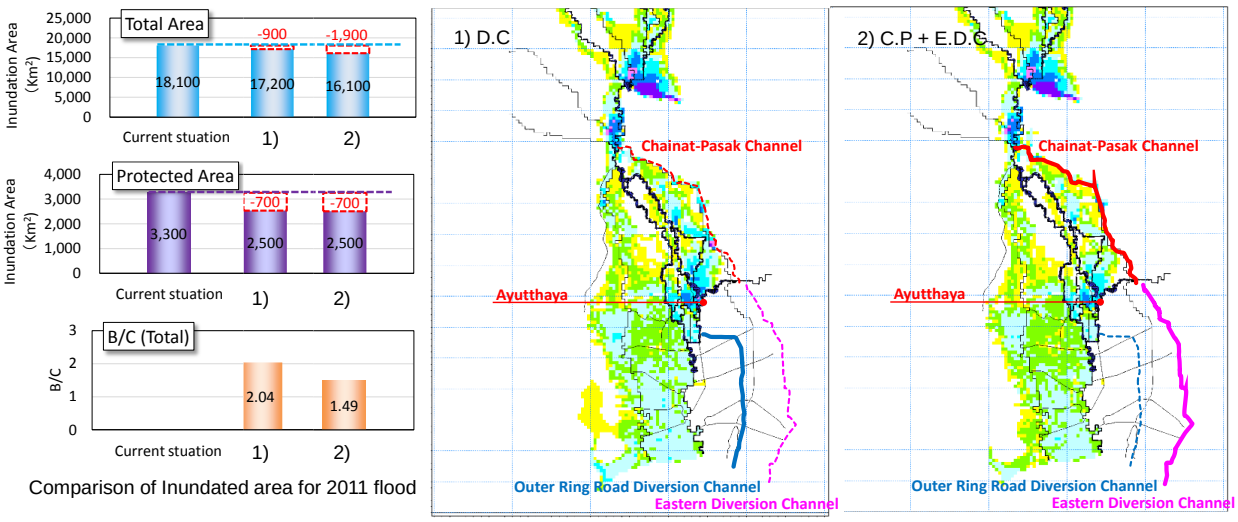
(2) Comparison of Economic Advantage between DC and CP + PGT

1) Economic Advantage

The following is a comparison of Economic Advantage between DC and CP + PGT:

- Economic evaluation on DC: B/C=2.04, EIRR＝19.5％ while Economic evaluation on CP+PGT: B/C=1.49、EIRR=13.9％. DC is better in Economic evaluation.
- As an estimated result, DC may have shorter construction period, and mitigate the inundation at earlier stage, thus the DC should be implemented with a higher priority.
- Besides, as pointed out at meetings, "Improvement of dam operation" and "Dyke heightening in weak part of downstream of Chao Phraya River" have a better and quicker effect with less cost which should be implemented with the highest priority.

In a nutshell, with shorter construction period and faster effect, DC is far more effective rather than CP+PGT.



Comparison of Inundated area for 2011 flood

※Both cases are simulated based on the conditions that "Improvement of dam operation" and "Dyke heightening in the weak part of downstream of the Chao Phraya River" are implemented.

※ Both cases are the combination of constructing Ayutthaya Bypass

Figure 10.2.3 Project effectiveness (inundation mitigation)

Table 10.2.1 Project effectiveness (economic view)

Alternative	Length (km)	Cost (Mil.THB)	Construction Period (year)	B/C
1) D.C.	111	165,695	5	2.04
2) C.P.+E.D.C	270	293,487	15	1.49

Cost includes the cost for Ayutthaya Bypass

2) Inundated Area

(a) Precondition of implementation

Beside of current condition, "Improvement of dam operation" and "Dyke heightening in weak part of downstream of Chao Phraya River" are regarded implemented as precondition for the simulation to compare the effectiveness between D.C. and C.P. + PGT, because they can be conducted in short time under present situation.

- Improvement of dam operation : operation proposed in JICA MP for Bhumipol Dam and Sirikit Dam.
- Dyke heightening in weak part of downstream of Chao Phraya River : as proposed in JICA MP
- Catchment condition : Road R9 regarded as constructed (set as embankment)

(b) Condition of Discharge allocation

In RID's plan, observed data of flood in 2011 was applied as upstream flow rate, and discharge distribution to C.P. + PGT. Was set fixed. We modified these conditions based on following view.

- Upstream flow rate : In RID plan, flow rate was underestimated because inundation had already happened where the upstream flow rate was applied. Therefore, a non-inundated point is set as the upstream.
- Discharge distribution : Fixed discharge means the water level at diversion point in non-flood season has to be raised up to HWL, which is overestimated. Therefore, a linear discharge based on flood scale is applied. Specifically, discharge will start when the flood rate reaches annual flood scale of 600m^3/s. And it will increase linearly to 800m^3/s when flood rate reaches the design peak of 3800m^3/s.

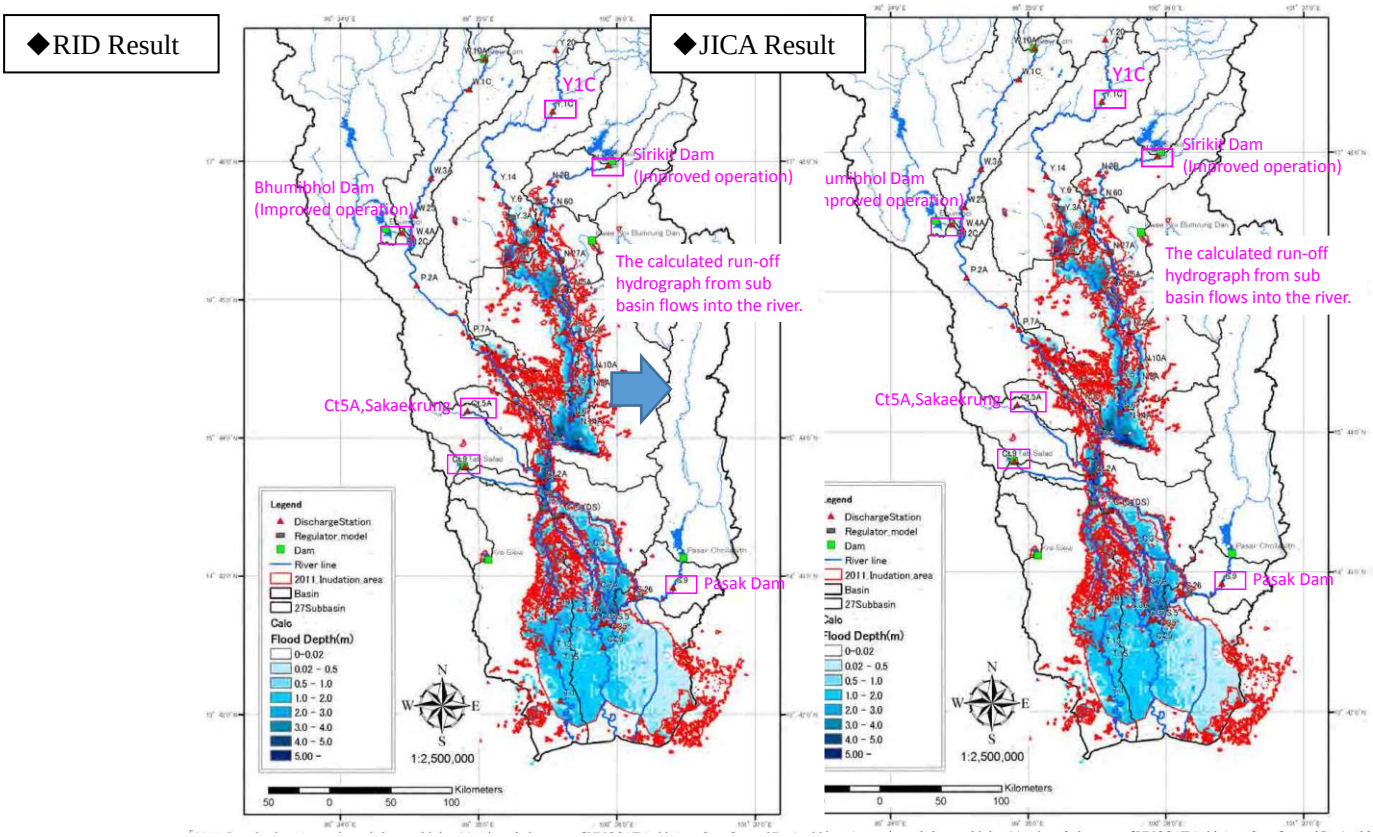


Figure 10.2.4 Upstream point change

Figure 10.2.5 Outflow Discharage of Chainat-Pasak in RID plan

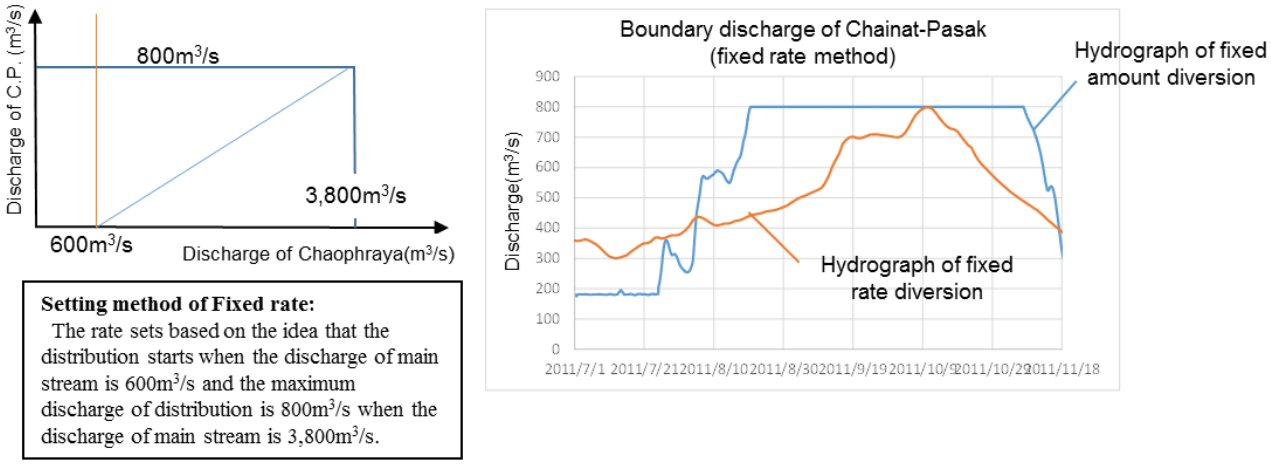


Figure 10.2.6 Change of discharge distribution

(c) Inundated area by return period

Simulated inundation area is shown below by return period. Inundated map is shown in next pages.

Table 10.2.2 Inundated area by return period

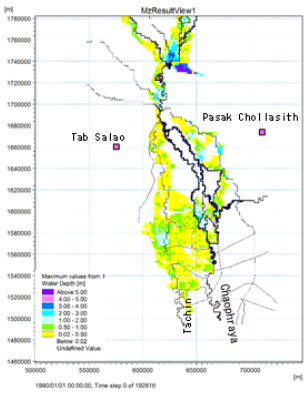
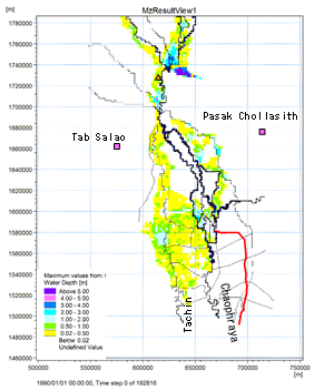
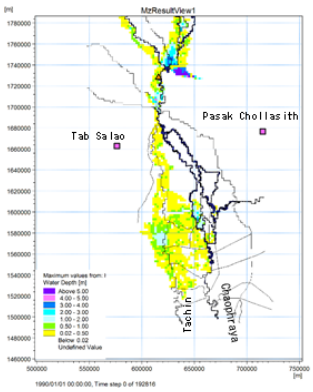
Total Area [Unit:km²]

Case		Without Case		D.C.500		C.P. + E.D.C.	
Revise		+R9		+R9+DC banking		+R9	
Additional Countermeasure	Ayuttaya	×		○		○	
	D.C.	×		○ (500m³/s fixed)		×	
	C.P. widening	×		×		○ (fixed rate)	
	E.D.C.	×		×		○ (fixed rate)	
100 years		18,071	—	17,165	-907	16,140	-1,931
50 years		17,169	—	16,436	-733	15,780	-1,389
30 years		16,213	—	15,772	-441	14,634	-1,579
10 years		12,606	—	12,400	-206	10,971	-1,635
5 years		11,720	—	11,521	-198	10,048	-1,672
3 years		10,517	—	10,084	-433	8,675	-1,842
2 years		8,910	—	8,619	-291	7,360	-1,550

Protected Area [Unit:km²]

Case		Without Case		D.C.500		C.P. + E.D.C.	
Revise		+R9		+R9+DC banking		+R9	
Additional Countermeasure	Ayuttaya	×		○		○	
	D.C.	×		○ (500m³/s fixed)		×	
	C.P. widening	×		×		○ (fixed rate)	
	E.D.C.	×		×		○ (fixed rate)	
100 years		3,258	—	2,537	-721	2,510	-748
50 years		2,889	—	2,519	-370	2,502	-387
30 years		2,828	—	2,507	-321	2,485	-343
10 years		2,396	—	2,314	-82	2,194	-202
5 years		2,226	—	2,068	-158	1,798	-428
3 years		1,744	—	1,388	-355	1,135	-609
2 years		1,116	—	960	-156	879	-237

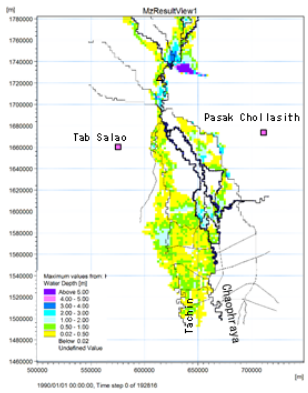
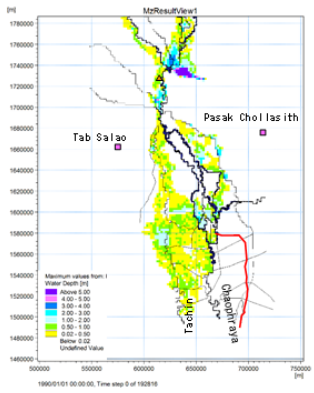
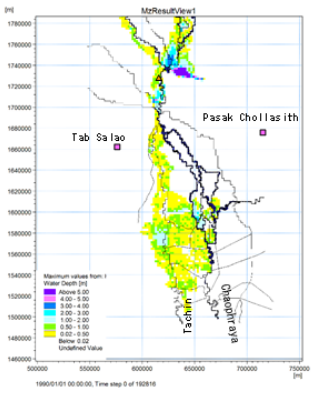
Table Inundated map (2-year return period)

Case_0 (Without)	Case_A (D.C. 500)	Case_C (C.P. + E.D.C.)
Ayuttaya : ×	Ayuttaya : ○	Ayuttaya : ○
D.C. : ×	D.C. : ○ (500m^3/s fixed)+banking	D.C. : ×
C.P.widening : ×	C.P.widening : ×	C.P.widening : ○ (800m^3/s fixed)
E.D.C. : ×	E.D.C. : ×	E.D.C. : ○ (600m^3/s fixed)
		
Inundation area (Total) : 8,910	Inundation area (Total) : 8,619	Inundation area (Total) : 7,360
Inundation area (PA) : 1,116	Inundation area (PA) : 960	Inundation area (PA) : 879

[km^2]

Figure 10.2.7 Inundated map（2-year return period）

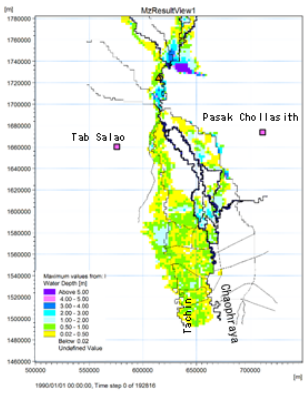
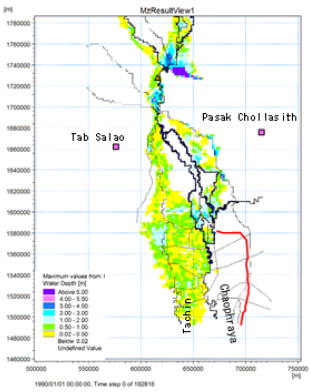
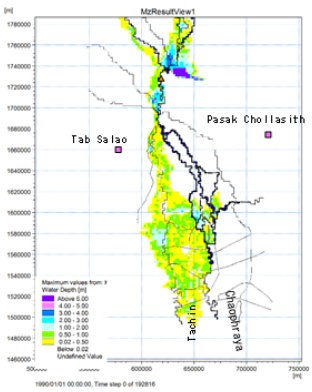
Table Inundated map (3-year return period)

Case_0 (Without)	Case_A (D.C. 500)	Case_C (C.P. + E.D.C.)
Ayuttaya : ×	Ayuttaya : ○	Ayuttaya : ○
D.C. : ×	D.C. : ○ (500m^3/s fixed)	D.C. : ×
C.P.widening : ×	C.P.widening : ×	C.P.widening : ○ (800m^3/s fixed)
E.D.C. : ×	E.D.C. : ×	E.D.C. : ○ (600m^3/s fixed)
		
Inundation area (Total) : 10,517	Inundation area (Total) : 10,084	Inundation area (Total) : 8,675
Inundation area (PA) : 1,744	Inundation area (PA) : 1,388	Inundation area (PA) : 1,135

[km^2]

Figure 10.2.8 Inundated map（3-year return period）

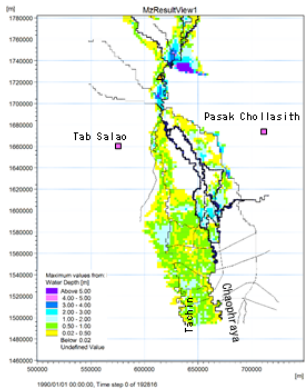
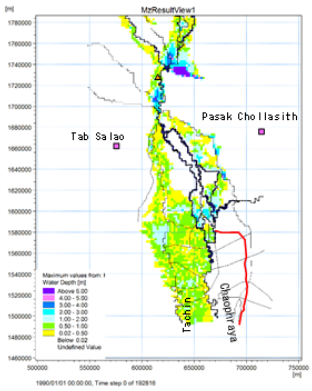
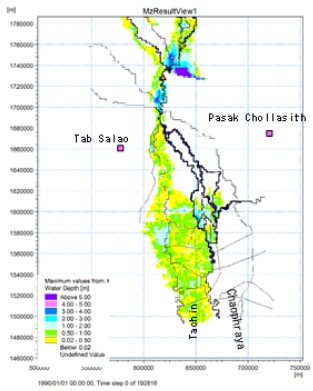
Table Inundated map (5-year return period)

Case_0 (Without)	Case_A (D.C. 500)	Case_C (C.P. + E.D.C.)
Ayuttaya : ×	Ayuttaya : ○	Ayuttaya : ○
D.C. : ×	D.C. : ○ (500m^3/s fixed)	D.C. : ×
C.P.widening : ×	C.P.widening : ×	C.P.widening : ○ (800m^3/s fixed)
E.D.C. : ×	E.D.C. : ×	E.D.C. : ○ (600m^3/s fixed)
		
Inundation area (Total) : 11,720	Inundation area (Total) : 11,521	Inundation area (Total) : 10,048
Inundation area (PA) : 2,226	Inundation area (PA) : 2,068	Inundation area (PA) : 1,798

[km^2]

Figure 10.2.9 Inundated map（5-year return period）

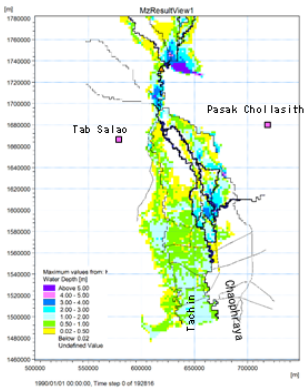
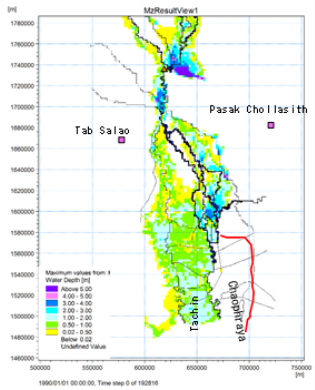
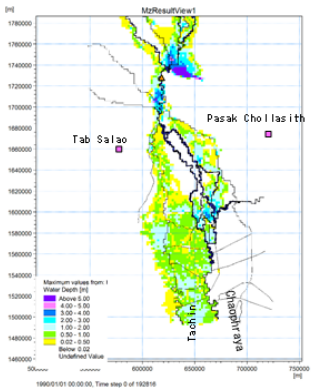
Table Inundated map (10-year return period)

Case_0 (Without)	Case_A (D.C. 500)	Case_C (C.P. + E.D.C.)
Ayuttaya : ×	Ayuttaya : ○	Ayuttaya : ○
D.C. : ×	D.C. : ○ (500m^3/s fixed)	D.C. : ×
C.P.widening : ×	C.P.widening : ×	C.P.widening : ○ (800m^3/s fixed)
E.D.C. : ×	E.D.C. : ×	E.D.C. : ○ (600m^3/s fixed)
		
Inundation area (Total) : 12,606	Inundation area (Total) : 12,400	Inundation area (Total) : 10,971
Inundation area (PA) : 2,396	Inundation area (PA) : 2,314	Inundation area (PA) : 2,194

[km^2]

Figure 10.2.10 Inundated map（10-year return period）

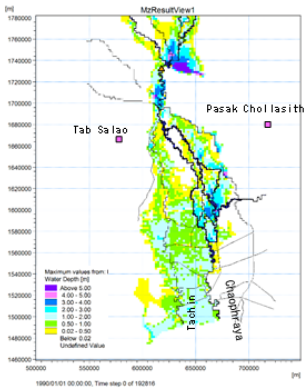
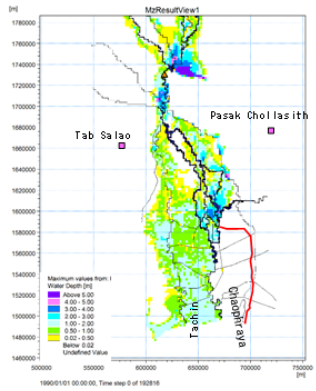
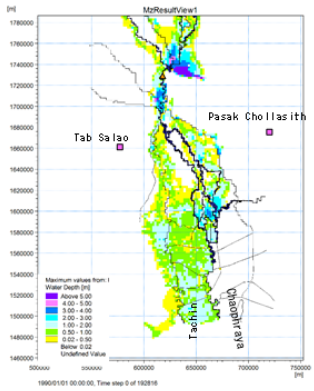
Table Inundated map (30-year return period)

Case_0 (Without)	Case_A (D.C. 500)	Case_C (C.P. + E.D.C.)
Ayuttaya : ×	Ayuttaya : ○	Ayuttaya : ○
D.C. : ×	D.C. : ○ (500m^3/s fixed)	D.C. : ×
C.P.widening : ×	C.P.widening : ×	C.P.widening : ○ (800m^3/s fixed)
E.D.C. : ×	E.D.C. : ×	E.D.C. : ○ (600m^3/s fixed)
		
Inundation area (Total) : 16,213	Inundation area (Total) : 15,772	Inundation area (Total) : 14,634
Inundation area (PA) : 2,828	Inundation area (PA) : 2,507	Inundation area (PA) : 2,485

[km^2]

Figure 10.2.11 Inundated map（30-year return period）

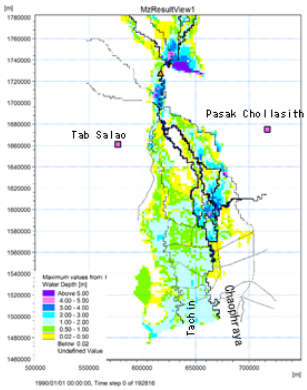
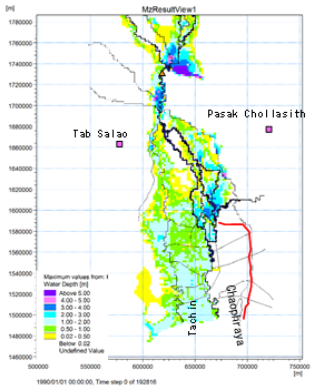
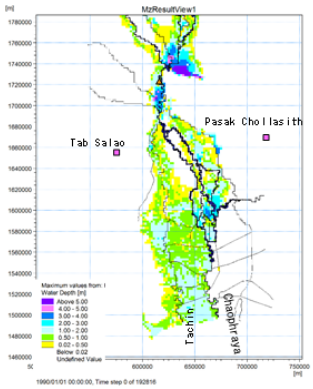
Table Inundated map (50-year return period)

Case_0 (Without)	Case_A (D.C. 500)	Case_C (C.P. + E.D.C.)
Ayuttaya : ×	Ayuttaya : ○	Ayuttaya : ○
D.C. : ×	D.C. : ○ (500m^3/s fixed)	D.C. : ×
C.P.widening : ×	C.P.widening : ×	C.P.widening : ○ (800m^3/s fixed)
E.D.C. : ×	E.D.C. : ×	E.D.C. : ○ (600m^3/s fixed)
		
Inundation area (Total) : 17,169	Inundation area (Total) : 16,436	Inundation area (Total) : 15,780
Inundation area (PA) : 2,889	Inundation area (PA) : 2,519	Inundation area (PA) : 2,502

[km^2]

Figure 10.2.12 Inundated map（50-year return period）

Table Inundated map (100-year return period)

Case_0 (Without)	Case_A (D.C. 500)	Case_C (C.P. + E.D.C.)
Ayuttaya : ×	Ayuttaya : ○	Ayuttaya : ○
D.C. : ×	D.C. : ○ (500m^3/s fixed)	D.C. : ×
C.P.widening : ×	C.P.widening : ×	C.P.widening : ○ (800m^3/s fixed)
E.D.C. : ×	E.D.C. : ×	E.D.C. : ○ (600m^3/s fixed)
		
Inundation area (Total) : 18,071	Inundation area (Total) : 17,165	Inundation area (Total) : 16,140
Inundation area (PA) : 3,258	Inundation area (PA) : 2,537	Inundation area (PA) : 2,510

[km^2]

Figure 10.2.13 Inundated map（100-year return period）

(3) Correct Order of project implementation

1) Problem of implementing Ayutthaya Bypass prior to DC

JICA Survey Team has pointed out following concerns for many times; nevertheless RID is looking forward to implement AB and PGT first.

- It is common sense to implement projects from the downstream side.
- Under current condition of river and facilities, it is definitely inappropriate to implement AB or PGT before DC.

If AB is completed without improving dam operation or Dyke heightening in weak part of downstream of Chao Phraya River first, huge problem will happen when 2011 scale flood strikes again. As shown in the figure below, water level near the diversion point of AB will decrease, however, in Chao Phraya River it will be even higher than that before the construction of AB, which makes it more dangerous for the downstream area than 2011. In another word, once implementing project in wrong order, RID is going to expose people living downstream to worse situation. RID explained that this is not a problem since gate will be installed on AB and it will be closed during large-scale flood. However, it is doubtful if they can successfully close the gate in the situation that the flood is occurring in upper stream of Ayutthaya Bypass. It should be proved based on practical situation instead of unrealistic logic.

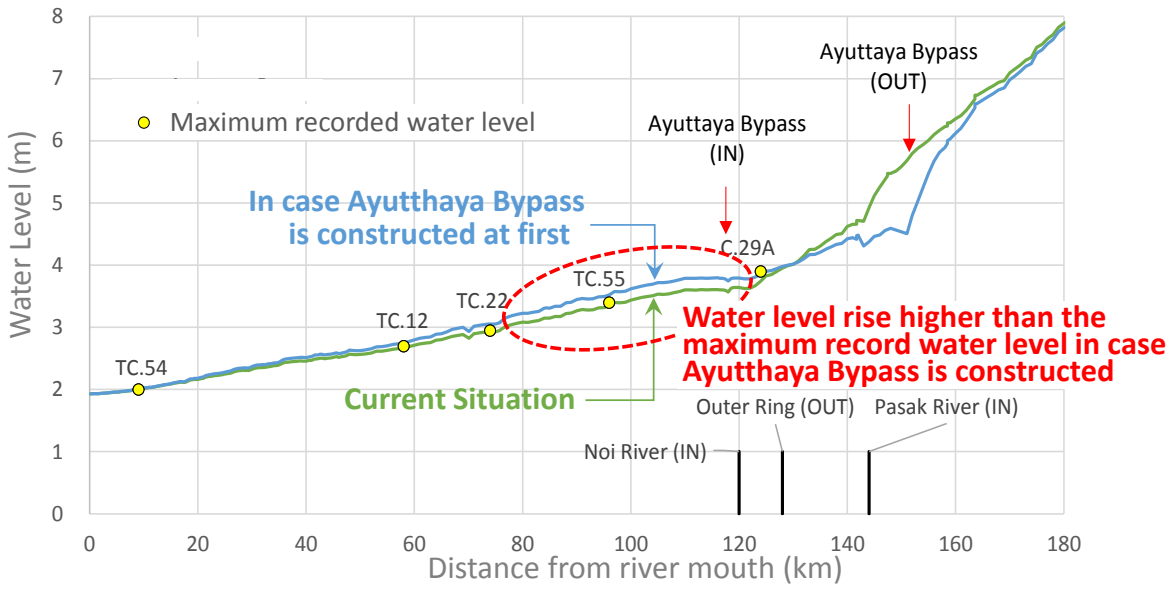


Figure 10.2.14 Comparison of water level for 2011 Flood with and without Ayutthaya Bypass

2) Problem of implementing CP prior to DC

Problem of implementing CP prior to DC is described as follows. The following figure indicates the results of inundation analysis. The analysis assumes the situation where the Chainat-Pasak Channel is completed first after "Improvement of dam operation" and "Dyke heightening in weak part of downstream of Chao Phraya River" If 2011-scale floods occurs, flood damages can be mitigated in some areas by the channel.

However, flood will occur in areas where were not flooded before. The downstream basin will suffer from serious flood damages more than without the channel. Therefore, the project should not be implemented first.

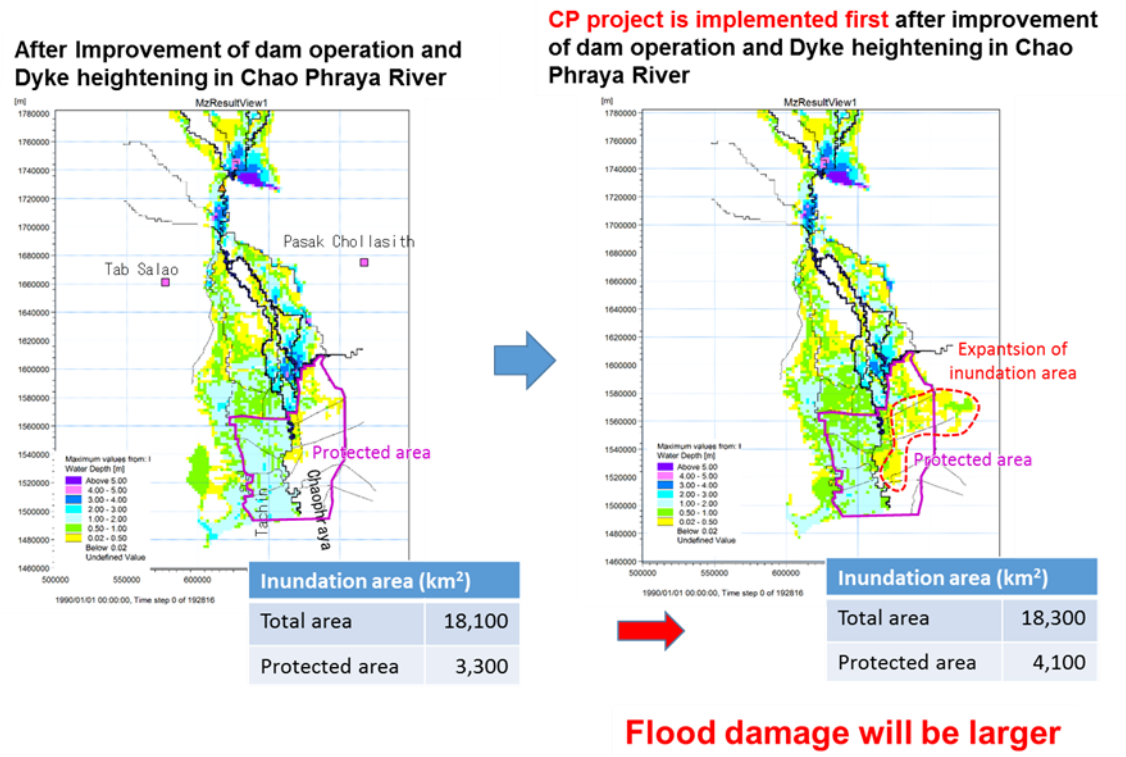


Figure 10.2.15 Comparison of inundation area

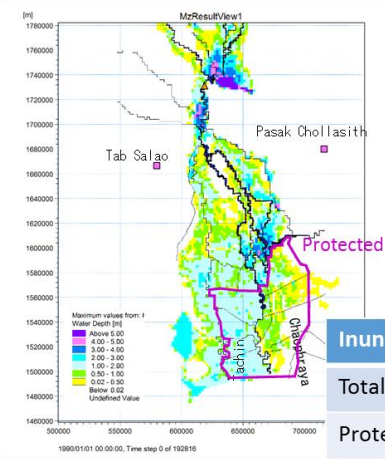
3) First priority project that should be implemented by RID

Firstly,RID should implement following projects that RID can lead to implement. These projects can mitigate inundation area largely with a relatively small cost.

- Improvement of dam operation during flooding time
- Dyke heightening in weak part of downstream of Chao Phraya River

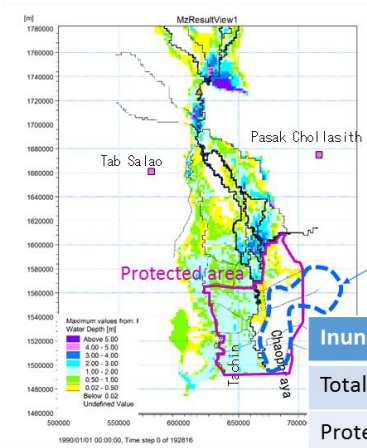
The effect of these projects against 2011 flood is shown in Fig 7. Above two projects have been proposed in JICA Master Plan which RID should give highest priority.

Current situation



Inundation area (km²)	
Total area	20,700
Protected area	4,500

After Improvement of dam operation and Dyke heightening in Chao Phraya River



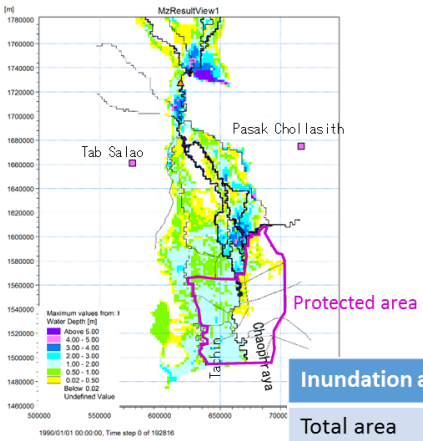
Inundation area (km²)	
Total area	18,100
Protected area	3,300

Figure 10.2.16 Effect of Improvement of dam operation and Dyke heightening in downstream of Chao Phraya River

4) Project effect of Diversion Channel and Ayutthaya Bypass

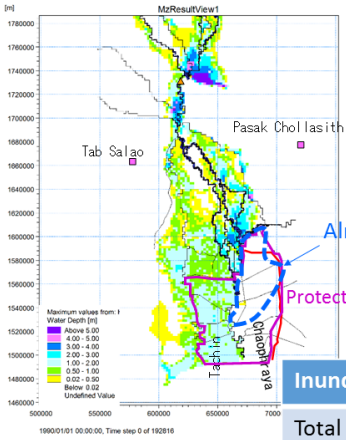
RID should implement the DC Project after completion of "Improvement of dam operation" and "Dyke heightening in weak part of downstream of Chao Phraya River" as described in 1). By completing DC together with Ayutthaya Bypass, the inundation area will be greatly reduced. These effect is shown in the following figure. However Ayutthaya Bypass should not be implemented prior to the completion of DC.

After Improvement of dam operation and Dyke heightening in Chao Phraya River



Inundation area (km²)	
Total area	18,100
Protected area	3,300

After completion of DC and AB addition to the condition in the left figure



Inundation area (km²)	
Total area	17,200
Protected area	2,500

Figure 10.2.17 Effect of Diversion Channel and Ayutthaya Bypass

10.2.2 Economic comparison

(1) Target index of economic comparison

Benefit over Cost (B/C) and Economic Internal Rate of Return are selected as target index to explain JICA Survey Team's plan is the most appropriate flood management plan for Chao Praya River.

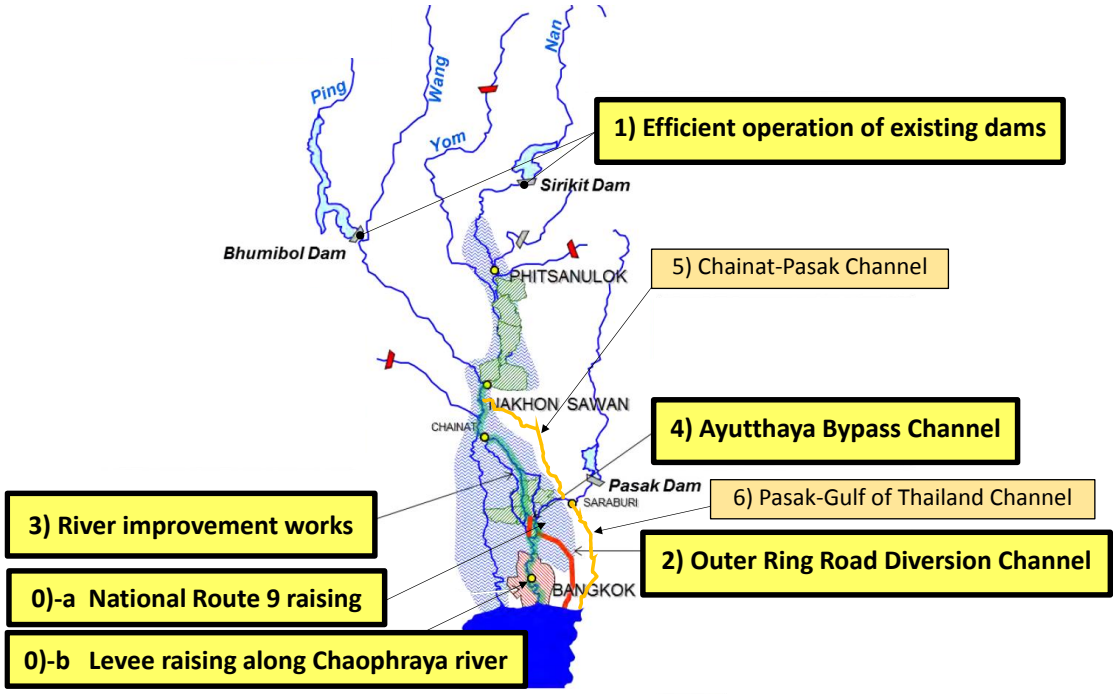
＜Case 1＞ : DC and AB are implemented, supposed as the highest priority by JICA Survey Team

＜Case 2＞ : AB and PGT (Chainat-Pasak and Pasak-Gulf of Thailand) are implemented as prioritized by RID

Table 10.2.3 Comparative case of cost benefit analysis

Flood Control Measures	＜Case 1＞		＜Case 2＞	
	with measures	without measures	with measures	without measures
0)-a National Route 9 raising	●	●	●	●
0)-b Levee raising along Chao Phraya river	-	●	-	●
1) Efficient operartion of existing dams	-	●	-	●
2) Outer Ring Road Diversion Channel	-	●	-	-
3) River improvement (include Ta Chin river)	-	-	-	-
4) Ayutthaya Bypass Channel	-	●	-	●
5) Eastern Diversion Channel (Chainat-Pasak Channel)	-	-	-	●
6) Eastern Diversion Channel (Pasak-Gulf of Thailand)	-	-	-	●

Source : JICA Study Team



Source : JICA MP

Figure 10.2.18 Candidate area for implementing measures against floods

(2) Cost

According to RID, project cost is estimated to be 35,000MB for PGT (CP), 70,000MB for PGT (PG) and 16,000MB for AB. However, they (hereinafter as “Cost 1”) are found obviously just construction cost after checking the estimation basis provided by RID. JICA Survey Team has recalculated it and the result (hereinafter as “Cost 2”) is 40,000MB for PGT (CP), 84,500MB for PGT (PG), and 18,500MB for AB. Therefore, the differences between Cost 1 and Cost 2 are 40,000MB for PGT (CP), 14,500MB for PGT (PG), and 900MB for AB among which construction cost of CP and PG shows a significant difference from RID’s result, indicating a low reliability of RID’s estimation.

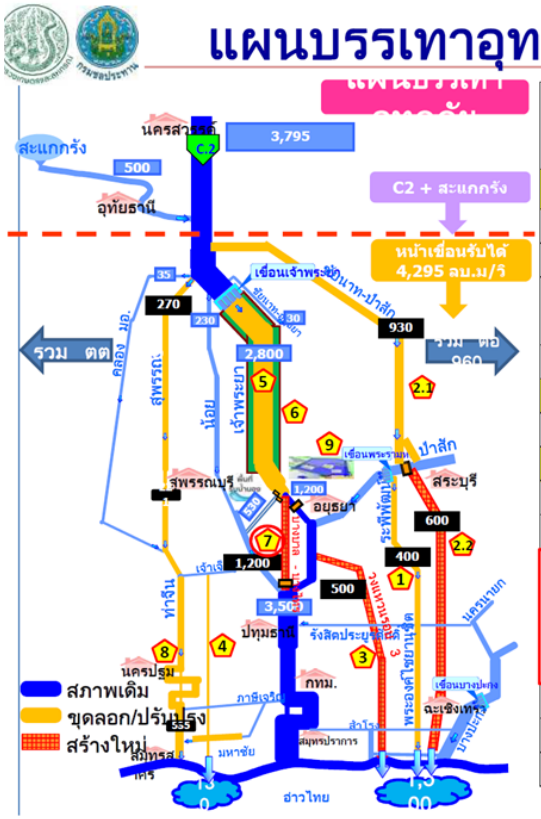
Therefore, project cost is determined as follows:

JICA result for PGT (CP) and PGT (PG) (CP: 120,071MB, PG: 140,035MB)

Project Cost for AB (33,382MB), calculated by taking RID’s value (17,600MB) as construction cost

Project cost shown in following table does not consist of land acquisition cost.

Table 10.2.4 Project cost of RID 9 projects (Offered from RID)



No.	Project	Budget (mB)
Chao Phraya East		
1	Irrigation in Chao Phraya East	62,000
2	Drainage in Chao Phraya East	
	2.1 Chainat – Pasak Channel	35,000
	2.2 Pasak – Gulf of Thailand Channel	70,000
3	Outer Ring Road Diversion Channel	
Chao Phraya West		
4	Irrigation in Chao Phraya East	31,000
Chao Phraya Main		
5	Increase of Drainage Capacity	2,400
6	Water Management outside Dykes	7,000
7	Bangban – Bangsai (Ayutthaya Bypass)	17,600
	Bangban – Bang Luang Gate	819
	Bypass Channel 22.4 km	14,181
	Ayutthaya Barrage (Downstream)	1,000
8	Increase of Drainage Capacity in Tha Chin	2,600
9	Increase of Storage Area	
รวมทั้งสิ้น		227,600

Chainat-Pasak C. 35,000MB

Pasak-Gulf of T. C. 70,000MB

Ayutthaya Bypass 16,000MB

Source : Documents presented from RID in September 2017

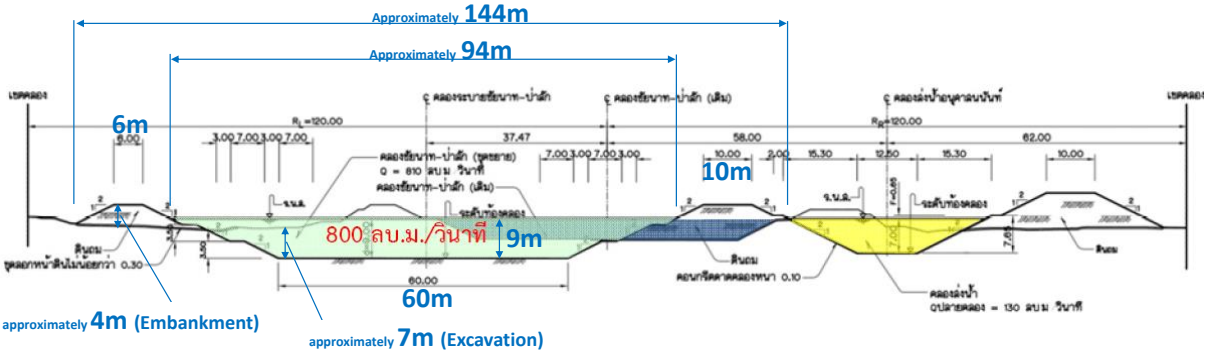
Note) Project cost for AB in the Table is 17,600MB. 3 lines below are the breakdown, including 819MB for Bang-Bang Luang Gate, 14,181MB for Bypass Channel (22.4km), and 1,000MB for Ayutthaya Barrage (Downstream). Contingency is counted as 10% of above 3 items.

Table 10.2.5 Approximate project cost calculated by the JICA study team

		Chainat-Pasak Channel				Pasak-Gulf of Thailand Channel				Ayutthaya Bypass Channel			
Construction Cost				75,075	a)			84,337	a)			16,000	a)
Engineering Cost &Construction Control				6,006	b)=a)*0.08			6,747	b)=a)*0.08			1,280	b)=a)*0.08
Project Management Cost& Processing				2,252	c)=a)*0.03			2,530	c)=a)*0.03			480	c)=a)*0.03
Valque added tax				0	d)			0	d)			0	d)
Land cost &Compensation				36,738	e)			46,421	e)			15,622	e)
Project Cost				120,071	f)=a)+b)+c)+e)			140,035	f)=a)+b)+c)+e)			33,382	f)=a)+b)+c)+e)
Breakdown of Construction Cost	*Breakdown Items*	*Quantity*	*Unit Price (THB)*	*Amount (MB)*	*Remark*	*Quantity*	*Unit Price (THB)*	*Amount (MB)*	*Remark*	*Quantity*	*Unit Price (THB)*	*Amount (MB)*	*Remark*
	Excavation	*72,463,160*	*20*	*1,449*		*50,418,900*	*20*	*1,008*		*24,080,000*	*20*	*482*	
	Embankment	*15,057,280*	*479*	*7,218*		*14,677,200*	*479*	*7,036*		*974,400*	*479*	*467*	
	Soil disposal	*72,463,160*	*282*	*20,435*		*50,418,900*	*282*	*14,218*		*24,080,000*	*282*	*6,791*	
	Soil Stabilization			*14,473*	*2)*			*29,260*	*1)*			*4,823*	*1)*
	Facility cost			*22,863*	*1)*			*23,111*	*1)*			*3,809*	*1)*
	Sub total			*66,438*				*74,634*				*16,372*	
	Factor F			*8,637*				*9,702*				*2,128*	
	Total			*75,075*				*84,337*				*18,500*	

1) Estimated cost based on the assumption that cost per unit length is similar to the estimated cost about Outer Ring Diversion Channel
2) Estimated cost based on the assumption that cost per unit length is half of the estimated cost about Outer Ring Diversion Channel

Source : JICA Study Team

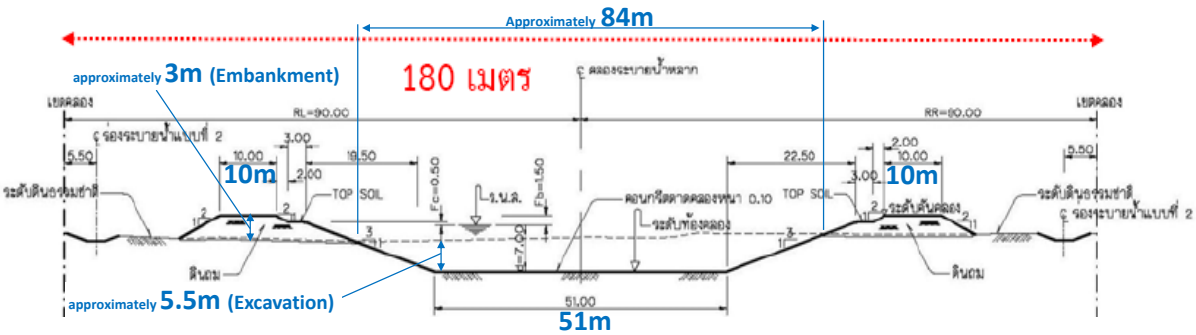


Chainat-Pasak Channel cross section

Source : 2017.10.27 RID document

Source ：Documents presented from RID in September 2017

Figure 10.2.19 Basis for calculating project cost (Chainat Pasak Channel)



Eastern Diversion Channel cross section

Source : 2017.10.27 RID document

Source ：Documents presented from RID in September 2017

Figure 10.2.20 Basis for calculating project cost (Pasak-Gulf of Thailand)

The project cost of each case is shown as follows.

Table 10.2.6 Comparison of Project Cost

Project Name	Project Cost (MB)		
		Case 1	Case 2
Outer Ring Road Diversion Channel (DC)	132,314	●	
Ayutthaya Bypass (AB)	33,382	●	●
Chainat-Pasak Channel (CP)	120,071		●
Pasak-Gulf of Thailand Channel (PG)	140,035		●
Total		165,695	293,487

Source : JICA Study Team

(3) Annual Benefit

Annual benefit for case 1 and case 2 are estimated as follows.

Table 10.2.7 Annual Benefit (Case 1)

Factory

Return Period (Year)	Damage Reduction			Interval Average Damage Reduction (Mil THB)	Interval Occurrence Probability	Interval Benefit (Mil THB)	Annual Benefit (Mil THB) (Direct damage reduction)
	Without-Case (Mil THB)	With-Case (Mil THB)	Damage Reduction (Mil THB)				
1	0		0	0	0.500	0	0
2	0	0	0	16,376	0.167	2,729	2,729
3	97,600	64,849	32,752	28,045	0.133	3,739	6,469
5	155,183	131,845	23,338	25,167	0.100	2,517	8,985
10	201,203	174,207	26,996	46,977	0.067	3,132	12,117
30	435,043	368,085	66,958	69,708	0.013	929	13,047
50	526,940	454,483	72,457	85,306	0.010	853	13,900
100	594,632	496,477	98,155				

a) Annual Benefit (Direct damage reduction of factory)	13,900
b)=a)×c) Annual Benefit (Indirect damage reduction of factory)	13,342
c) Ratio of Indirect to direct damage	0.960

Household

Return Period (Year)	Damage Reduction			Interval Average Damage Reduction (Mil THB)	Interval Occurrence Probability	Interval Benefit (Mil THB)	Annual Benefit (Mil THB) (Accumulation)
	Without-Case (Mil THB)	With-Case (Mil THB)	Damage Reduction (Mil THB)				
1	0	0	0	0	0.500	0	0
2	0	0	0	0	0.167	0	0
3	0	0	0	0	0.133	0	0
5	0	0	0	407	0.100	41	41
10	1,851	1,037	815	10,072	0.067	671	712
30	84,282	64,953	19,329	15,521	0.013	207	919
50	132,655	120,941	11,713	17,986	0.010	180	1,099
100	163,008	138,750	24,258				

d) Annual Benefit (Direct damage reduction of household)	1,099
e)=d)×f) Annual Benefit (Indirect damage reduction of household)	907
f) Ratio of Indirect to direct damage	0.825
g) Annual Benefit (Direct damage reduction of others)	1,891
h) Annual Benefit (Indirect damage reduction of others)	7,083
i)= Σ{a),b),d),e),g),h)} Annual Benefit	38,222

Source : JICA Study Team

Table 10.2.8 Annual Benefit （Case 2）

Factory

Return Period (Year)	Damage Reduction			Interval Average Damage Reduction (Mil THB)	Interval Occurrence Probability	Interval Benefit (Mil THB)	Annual Benefit (Mil THB) (Direct damage reduction)
	Without-Case (Mil THB)	With-Case (Mil THB)	Damage Reduction (Mil THB)				
1	0	0	0				
2	0	0	0	0	0.500	0	0
3	97,600	41,326	56,274	28,137	0.167	4,690	4,690
5	155,183	101,153	54,029	55,152	0.133	7,354	12,043
10	201,203	150,414	50,789	52,409	0.100	5,241	17,284
30	435,043	310,246	124,797	87,793	0.067	5,853	23,137
50	526,940	360,857	166,083	145,440	0.013	1,939	25,076
100	594,632	416,238	178,394	172,238	0.010	1,722	26,798

a) Annual Benefit（Direct damage reduction of factory）	26,798
b)=a)×c) Annual Benefit（Indirect damage reduction of factory）	25,723
c) Ratio of Indirect to direct damage	0.960

Household

Return Period (Year)	Damage Reduction			Interval Average Damage Reduction (Mil THB)	Interval Occurrence Probability	Interval Benefit (Mil THB)	Annual Benefit (Mil THB) (Accumulation)
	Without-Case (Mil THB)	With-Case (Mil THB)	Damage Reduction (Mil THB)				
1	0	0	0				
2	0	0	0	0	0.500	0	0
3	0	0	0	0	0.167	0	0
5	0	0	0	0	0.133	0	0
10	1,851	385	1,467	733	0.100	73	73
30	84,282	34,189	50,093	25,780	0.067	1,719	1,792
50	132,655	61,260	71,395	60,744	0.013	810	2,602
100	163,008	87,526	75,481	73,438	0.010	734	3,336

d) Annual Benefit（Direct damage reduction of household）	3,336
e)=d)×f) Annual Benefit（Indirect damage reduction of household）	2,754
f) Ratio of Indirect to direct damage	0.825
g) Annual Benefit（Direct damage reduction of others）	3,799
h) Annual Benefit（Indirect damage reduction of others）	14,156
i)= Σ{a),b),d),e),g),h)} Annual Benefit	76,566

Source：JICA Study Team

(4) Cost benefit analysis

Calculation result of cost benefit ratio are shown below. As a conclusion, DC・AB (Case 1) recommended by JICA Survey Team shows cost benefit ratio of 2.04 and economic internal rate of return (EIRR) of 19.5 %, while cost benefit ratio of AB+PGT (CP & PG), shown as Case 2, is 1.49 and EIRR is 13.9 %.

Table 10.2.9 Cost benefit analysis

<Case 1>

Unit : Mil THB

Year	Benefit			Cost		
	Benefit	Net Value	Residual Value	Cost	Net Value	Residual Value
2021	0	0		37,298	23,704	
2022	0	0		38,417	21,799	
2023	0	0		39,570	20,047	
2024	0	0		40,757	18,436	
2025	0	0		41,980	16,955	
2026	49,870	17,984		1,865	673	
2027	51,367	16,539		1,921	618	
2028	52,908	15,210		1,978	569	
2029	54,495	13,987		2,038	523	
2030	56,130	12,863		2,099	481	
2031	57,813	11,830		2,162	442	
2032	59,548	10,879		2,227	407	
2033	61,334	10,005		2,294	374	
2034	63,174	9,201		2,362	344	
2035	65,070	8,462		2,433	316	
2036	67,022	7,782		2,506	291	
2037	69,032	7,156		2,581	268	
2038	71,103	6,581		2,659	246	
2039	73,236	6,052		2,739	226	
2040	75,433	5,566		2,821	208	
2041	77,696	5,119		2,905	191	
2042	80,027	4,707		2,993	176	
2043	82,428	4,329		3,082	162	
2044	84,901	3,981		3,175	149	
2045	87,448	3,661		3,270	137	
2046	90,072	3,367		3,368	126	
2047	92,774	3,097		3,469	116	
2048	95,557	2,848		3,573	106	
2049	98,424	2,619		3,681	98	
2050	101,376	2,408		3,791	90	
2051	104,418	2,215		3,905	83	
2052	107,550	2,037		4,022	76	
2053	110,777	1,873		4,143	70	
2054	114,100	1,723		4,267	64	
2055	117,523	1,584		4,395	59	
2056	121,049	1,457		4,527	54	
2057	124,680	1,340		4,662	50	
2058	128,420	1,232		4,802	46	
2059	132,273	1,133		4,946	42	
2060	136,241	1,042	11,580	5,095	39	433
Total		223,451			109,298	

Net Present Value	114,153
Cost Benefit Ratio	2.04
Economic Internal Rate of Return	19.5%

<Case 2>

Unit : Mil THB

Year	Benefit			Cost		
	Benefit	Net Value	Residual Value	Cost	Net Value	Residual Value
2021	0	0		22,022	13,995	
2022	0	0		22,682	12,870	
2023	0	0		23,363	11,836	
2024	0	0		24,064	10,885	
2025	0	0		24,785	10,010	
2026	0	0		25,529	9,206	
2027	0	0		26,295	8,466	
2028	0	0		27,084	7,786	
2029	0	0		27,896	7,160	
2030	0	0		28,733	6,585	
2031	0	0		29,595	6,056	
2032	0	0		30,483	5,569	
2033	0	0		31,397	5,122	
2034	0	0		32,339	4,710	
2035	0	0		33,310	4,332	
2036	134,259	15,588		3,303	384	
2037	138,287	14,336		3,402	353	
2038	142,436	13,184		3,504	324	
2039	146,709	12,124		3,610	298	
2040	151,110	11,150		3,718	274	
2041	155,644	10,254		3,829	252	
2042	160,313	9,430		3,944	232	
2043	165,122	8,672		4,063	213	
2044	170,076	7,975		4,184	196	
2045	175,178	7,335		4,310	180	
2046	180,434	6,745		4,439	166	
2047	185,847	6,203		4,572	153	
2048	191,422	5,705		4,710	140	
2049	197,165	5,246		4,851	129	
2050	203,079	4,825		4,996	119	
2051	209,172	4,437		5,146	109	
2052	215,447	4,080		5,301	100	
2053	221,910	3,753		5,460	92	
2054	228,568	3,451		5,624	85	
2055	235,425	3,174		5,792	78	
2056	242,488	2,919		5,966	72	
2057	249,762	2,684		6,145	66	
2058	257,255	2,468		6,329	61	
2059	264,973	2,270		6,519	56	
2060	272,922	2,088	23,196	6,715	51	571
Total		193,294			129,345	

Net Present Value	63,949
Cost Benefit Ratio	1.49
Economic Internal Rate of Return	13.9%

Source : JICA Study Team