F. Hydrologic/Inundation Analyses and Preliminary Design for Model River Basins

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F. HYDROLOGIC/INUNDATION ANALYSES AND PRELIMINARY DESIGN FOR MODEL RIVER BASINS

1 GENERAL

Hydrologic/inundation analyses and preliminary design for model river basins are conducted for six (6) model river basins as shown below. The preliminary design for each model river basin is conducted for the recommended plan.

- Ilog-Hilabangan River Basin
- Dungcaan River Basin
- Meycauayan River Basin
- Kinanliman River Basin
- Tuganay River Basin
- Dinanggasan River Basin

2 HYDROLOGIC ANALYSIS

2.1 Project Scale

The project scale is basically proposed to mitigate the flood damages of less than 20-year return period. However, if there exists the project scale adopted in the previous related study, this project scale is applied. The project scales adopted for respective river basins are shown in Table F.2.1. In this table, the previous studies are also described.

Table F.2.1 Project Scale and Previous Related Studies

Name of River Basins	Return Period	Previous Studies
Ilog-Hilabangan	25-year	Master Plan Report, Study on Ilog-Hilabangan River Basin Flood Control Project, 1991
Dungcaan	20-year	None
Meycauayan	30-year	Feasibility Study on Valenzuela-Obando-Meycauayan (VOM) Area Drainage System Improvement Project, 2001
Kinanliman	25-year	Detailed Design Report for the Pilot Project for Kinanliman River, Real, Quezon, 2007
Tuganay	25-year	Report on Preliminary Design of Liboganon River Dike Extension, 1998
Dinanggasan	20-year	Basic Study on Disaster Prevention and Reconstruction Project for Camiguin Island, Mindanao, Philippines, 2003*

*Note) * : This Basic Study did not refer to the project scale for flood control.*

2.2 Design Flood Discharge

2.2.1 Estimation Method of Design Flood Discharge

The design flood discharges are basically computed by the Specific Discharge Formula. Basically, this method is applied to a river basin with the basin area of 20 km^2 or more (Manual on Flood Control Planning, DPWH). The Specific Discharge Formula is shown below:

$$\mathbf{q = c \cdot A^{(A^{-0.048}-1)}}$$

where, q = specific discharge ($m^3/s/km^2$)
c = constant (refer to Table F.2.2)
A = catchment area (km^2)

Table F.2.2 Constants for Regional Specific Discharge Curve

Region	Return Period					
	2-year	5-year	10-year	25-year	50-year	100-year
Luzon	15.66	17.48	18.91	21.51	23.83	25.37
Visayas	6.12	7.77	9.36	11.81	14.52	17.47
Mindanao	8.02	9.15	10.06	11.60	12.80	14.00

However, if there exist the design discharges analyzed in the previous study, these design discharges are adopted. Table F.2.3 shows the methods of the design discharge estimation for respective model river basins.

Table F.2.3 Methods of the Design Discharge Estimation

Name of River Basins	Previous Studies	Remarks
Ilog-Hilabangan	Storage Function Model	Adopted method in the previous study
Dungcaan	Specific Discharge Formula	
Meycauayan	Quasi-Linear Runoff Model	Adopted method in the previous study
Kinanliman	Rational Formula	Adopted method in the previous study
Tuganay	Specific Discharge Formula	Specific Discharge Formula is modified based on the previous study.
Dinanggasan	Specific Discharge Formula	Calculation results are adjusted considering sediment content.

The design discharges applied in this Study are shown in the following sections.

2.2.2 Design Flood Discharges and Distribution

(1) Ilog-Hilabangan River

The design flood discharges are set with reference to the previous master plan. In the previous study, the Storage Function Model is applied as a runoff model. In the previous study, rainfall intensity - duration curve was prepared to develop a hyetograph model. Distribution of design flood discharge with 25-year return period is shown in Figure F.2.1.

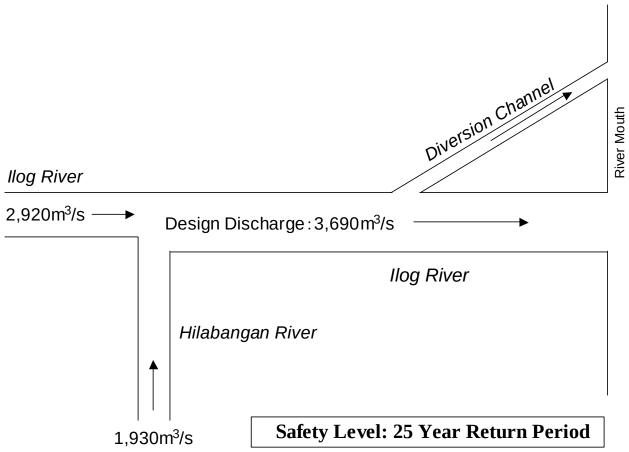


Figure F.2.1 Design Flood Distribution of Ilog-Hilabangan River

(2) Dungcaan River

The design flood discharges are calculated using the Specific Discharge Formula. Distribution of design flood discharge with 20-year return period is shown in Figure F.2.2.

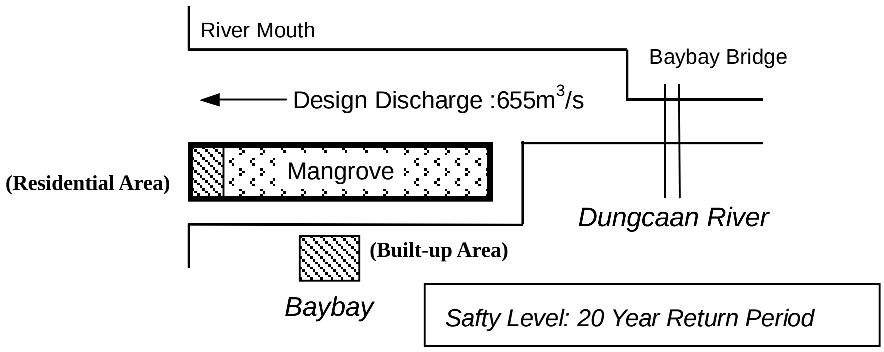
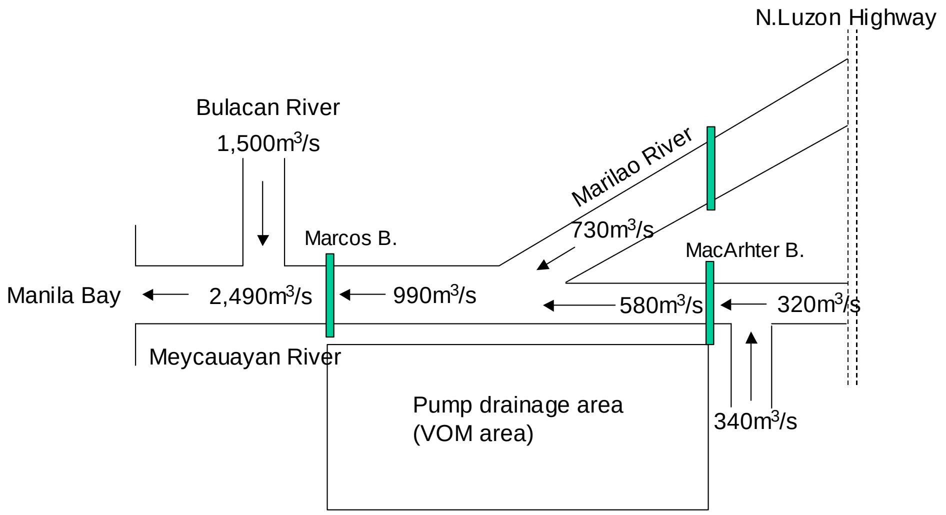


Figure F.2.2 Design Flood Distribution of Dungcaan River

(3) Meycauayan River

The design flood discharges are set with reference to the previous feasibility study. In the previous report, the design flood discharges were computed by the Quasi-Linear Runoff Model, which was developed to express runoff characteristics on variation of land uses. Distribution of design flood discharge for 30-year return period is shown in Figure F.2.3.

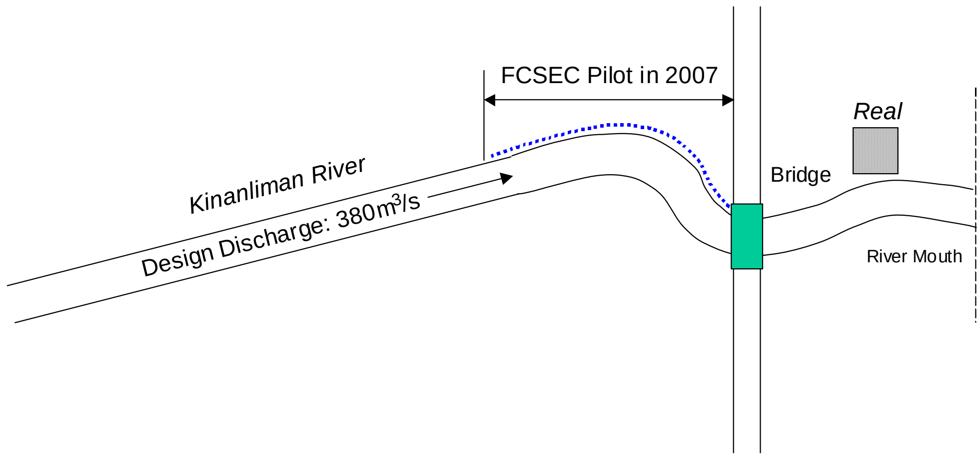


Safety Level: 30 Year Return Period

Figure F.2.3 Design Flood Distribution of Meycauayan River

(4) Kinanliman River

The design flood discharges are set with reference to the previous detailed design. In this detailed design, the flood discharge was calculated with the Rational Formula using the rainfall intensity duration curve of Infanta, Quezon. Since this river is of a debris flow stream, the flood discharge calculated with the Rational Formula is multiplied by 1.5 considering 50% sediment content. The distribution of design flood discharge for 25-year return period is shown in Figure F.2.4.



Safety Level: 25 Year Return Period

Figure F.2.4 Design Flood Distribution of Kinanliman River

(5) Tuganay River

Design discharges are calculated based on the Specific Discharge Formula. For this calculation, the constants are estimated based on the design discharges obtained in the previous preliminary design. The design discharges are estimated based on the following procedures:

① Constants are estimated by the Formula based on the design discharges of previous study and basin areas. In the previous study, flood discharges were calculated by the Unit Graph Method. The estimated constants are shown in Table F.2.4.

② The relationship between the basin areas and the constants is built based on the above data. The relationship is shown in Figure F.2.5.

③ From the relationship, the constant is estimated and specific discharge is calculated.

Table F.2.4 Constant Applied for Tuganay River

River	Catchment Area (km^2)	Discharge (m^3/s)	Constant
Tuganay and Anibongan	565.92	543	4.98
Ising	146.38	190	3.67

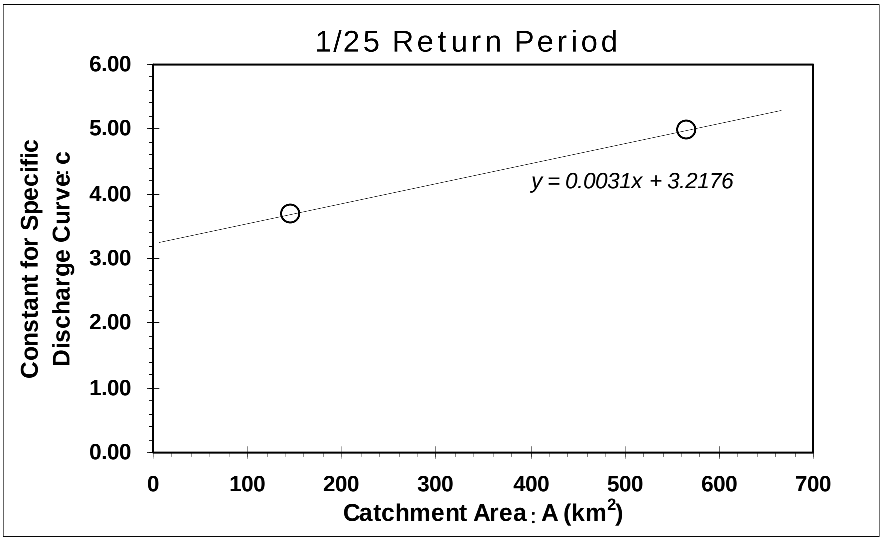


Figure F.2.5 Relationship between Catchment Area and Constant

In constructing a river system model, the Tuganay River Basin is firstly divided into several sub-basins. River channels connecting the sub-basins are set up together with computation points. Sub-basin areas are shown in Table F.2.5. The sub-basin divisions are shown in Figure F.2.6. Based on these data, the design flood discharges are calculated as shown in Table F.2.5.

Table F.2.5 Sub-Basin Areas and Design Discharges of Tuganay River

Reference Point	Total Aea (km^2)	Discharge (1/25)
TU-M1	572.29	548
TU-M2	565.92	543
TU-M3	416.29	420
TU-M4	317.32	339
TU-M5	232.36	267
TU-M6	105.07	150
TU-A1	145.39	189
TU-A2	116.62	162
TU-L1	80.54	124
TU-P1	82.05	126
TU-B1	88.77	133
IS-M1	172.11	214
IS-M2	146.38	190
IS-M3	143.98	188
IS-O1	16.90	40
IS-O2	13.45	33

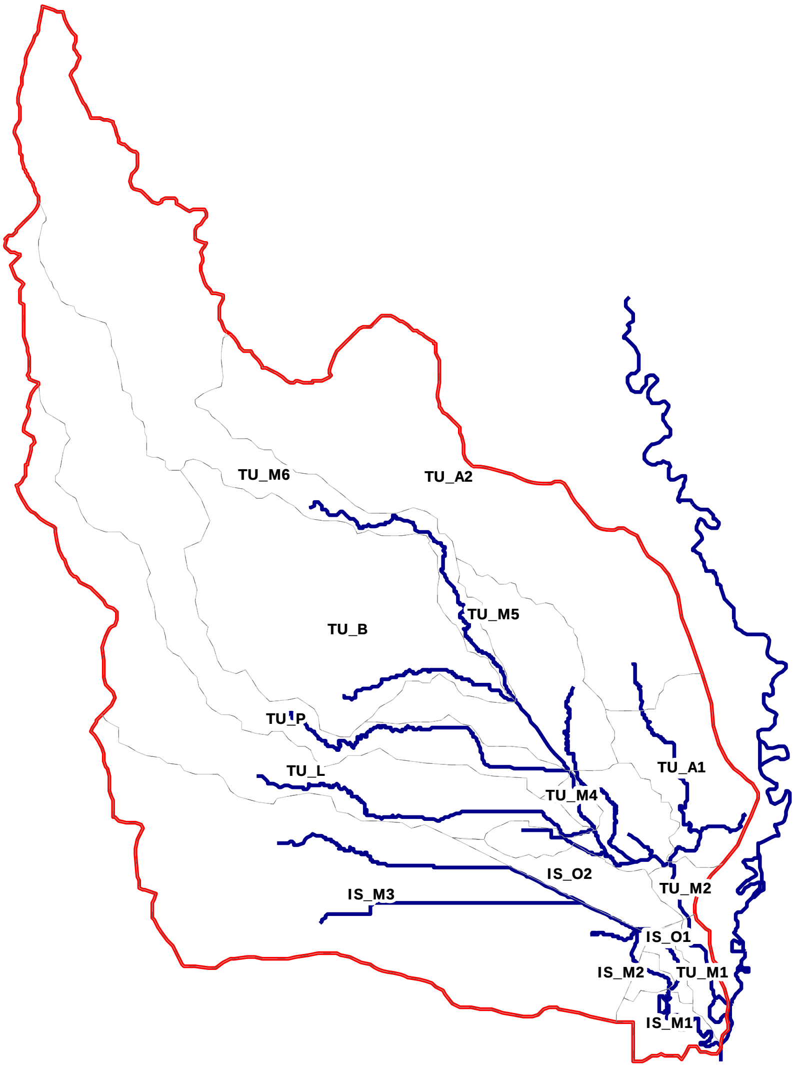


Figure F.2.6 Sub-basin Divisions of Tuganay River

The distribution of design discharge for 25-year return period is shown in Figure F.2.7.

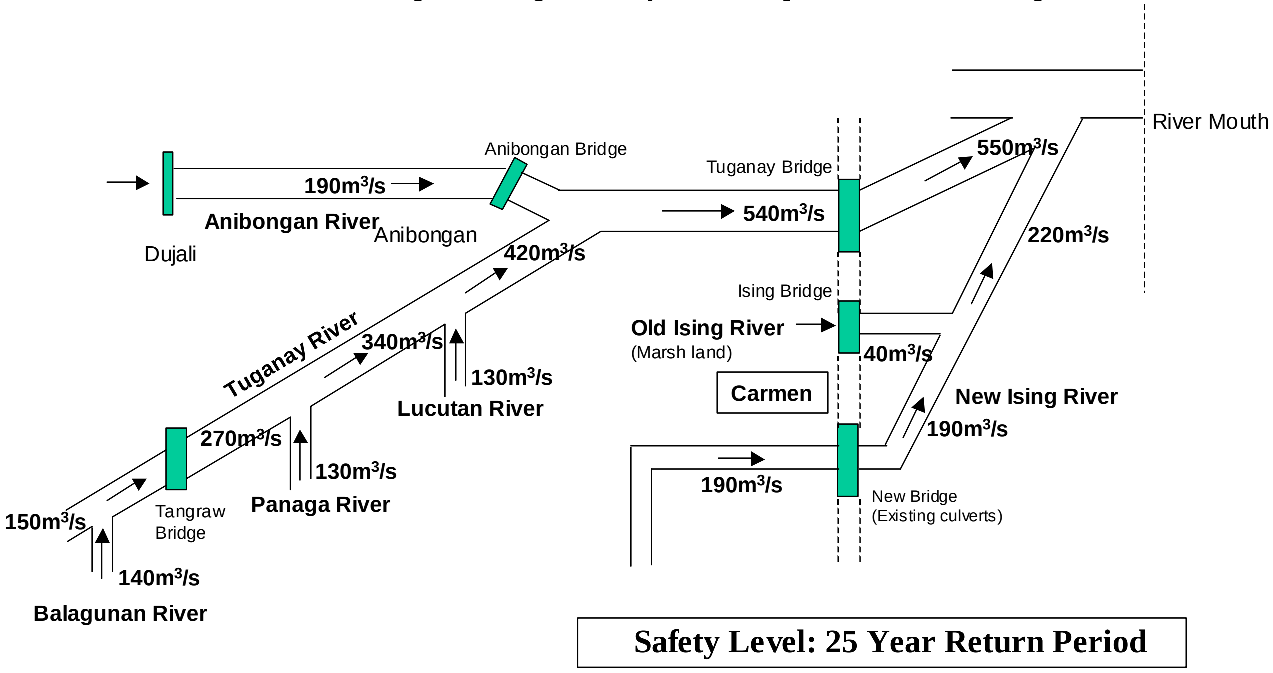


Figure F.2.7 Design Flood Distribution of Tuganay River

(6) Dinanggasan River

The design flood discharges are calculated based on the Specific Discharge Formula. Since this river is of a debris flow stream, calculated flood discharge is multiplied by 1.5 considering 50% sediment content. Distribution of design flood discharge for 20-year return period is shown in Figure F.2.8.

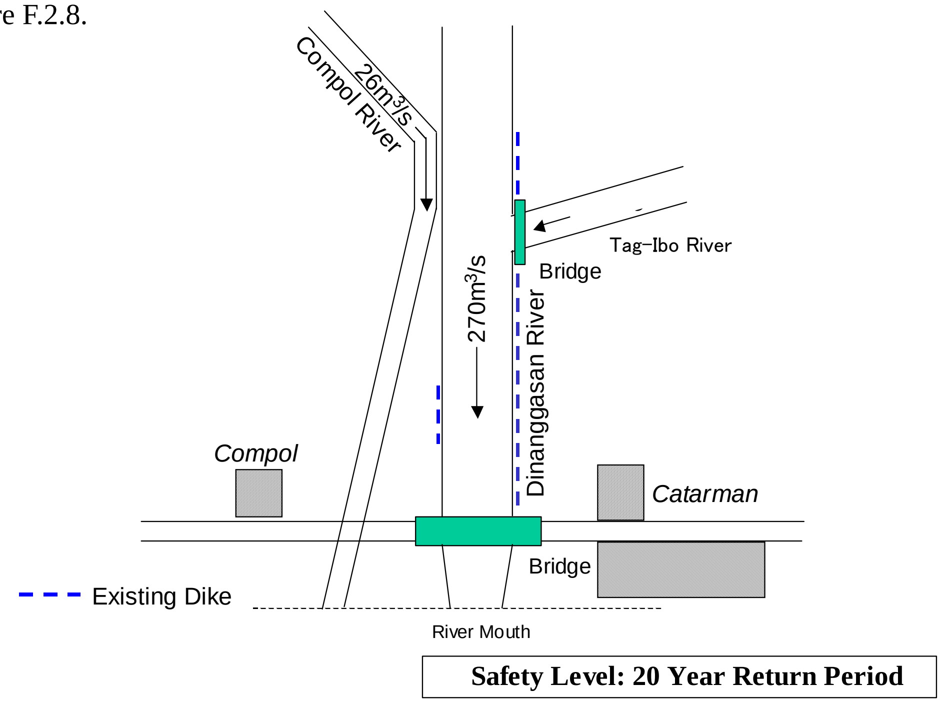


Figure F.2.8 Design Flood Distribution of Dinanggasan River

3 FLOOD INUNDATION

3.1 Flow Capacity

3.1.1 Calculation Method

The flow capacity analysis is conducted using HEC-RAS (US Army Corps of Engineers Hydrologic Engineering Center River Analysis System). HEC-RAS is a one-dimensional steady flow hydraulic model designed to aid channel flow analysis and floodplain determination. Flow capacity of the existing river channel is estimated to identify the reach where safety level is lacking and to consider possible alternative plans to accommodate the design discharge. In principle, flow capacity of the existing river channel is estimated by non-uniform flow method using newly obtained data on river cross sections. The calculation is conducted with reference to the manual of the DPWH, and the freeboard shown in the table below is taken into consideration.

Table F.3.1 Minimum Required Freeboard for Dike

Design Flood Discharge (m^3/s)	Freeboard (m)
Less than 200	0.6
200 and up to 500	0.8
500 and up to 2,000	1.0
2,000 and up to 5,000	1.2

The discharge, whose corresponding water level equals to the height, which is current ground elevation or dike elevation minus freeboard, is set as the flow capacity of the existing river channel.

3.1.2 River Cross Section Data

Flow capacities of the rivers are calculated using the cross section data. In this Study, river cross section survey was conducted in order to collect the necessary data. The survey point of each cross section is shown in the tables below.

Table F.3.2 Cross Section Survey Points

Ilog-Hilabangan River

Cross Section No.	Ilog River	Hilabangan River	Old Ilog River
CR1	0.96KP	---	0.37KP
CR2	5.68KP	---	6.05KP
CR3	12.91KP	---	---
CR4	18.00KP	---	---
CR5	20.24KP	---	---
CR6	---	7.81KP	---

Dungcaan River

Cross Section No.	Dungcaan River
CR1	0.14KP
CR2	0.88KP
CR3	1.66KP
CR4	2.69KP
CR5	3.58KP

Meycauayan River

Cross Section No.	Meycauayan River	Marilao River
CR1	5.06KP	---
CR2	8.80KP	---
CR3	9.89KP	0.42KP
CR4	13.64KP	---
CR5	12.94KP	1.06KP
CR6	---	3.58KP

Kinanliman River

Cross Section No.	Kinanliman River
CR1	0.00KP
CR2	0.39KP
CR3	0.68KP

Tuganay River

Cross Section No.	Tagum Libuganon River	Tuganay River	Anibongan River	Ising River	Old Ising River
CR1	0.62KP	---	---	---	---
CR2	---	7.69KP	---	11.61KP	3.27KP
CR3	---	10.02KP	---	15.30KP	---
CR4	---	16.23KP	5.31 KP	---	---
CR5	---	17.69KP	6.89 KP	---	---
CR6	---	20.23KP	10.74 KP	---	---

Dinanggasan River

Cross Section No.	Dinanggasan River
CR1	0.13KP
CR2	0.52KP
CR3	0.88KP
CR4	1.16KP
CR5	5.60KP

Note) KP means Kilometer Post, and figures attached to KP means the distance of cross section survey point from the river mouth.

3.1.3 Flow Capacity

Based on the method above mentioned, the flow capacities of the rivers are estimated as shown below.

Table F.3.3 Flow Capacity of Existing River Channel

Ilog-Hilabangan River

Location of Calculation	Flow Capacity (m^3/sec)
Ilog River (upstream portion)	290 - 800
Ilog River (downstream portion)	250 - 2,650
Old Ilog River	250
Hilabangan River	100

Dungcaan River

Location of Calculation	Flow Capacity (m^3/sec)
Downstream of Baybay Bridge	290

Meycauayan River

Location of Calculation	Flow Capacity (m^3/sec)
Meycayayan River (downstream of confluence point)	400
Meycauayan River (upstream of confluence point)	140
Meycauayan River (31.4KP)	330
Marilao River (upstream of confluence point)	240

Kinanliman River

Location of Calculation	Flow Capacity (m^3/sec)
Kinanliman River (bridge)	190

Tuganay River

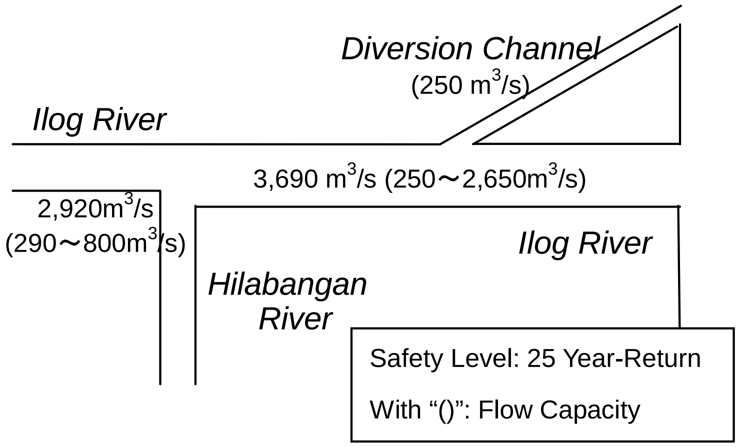
Location of Calculation	Flow Capacity (m^3/sec)
Tuganay River (upstream portion)	75
Tuganay River (Tuganay Bridge)	175
Anibongan River	20
Ising River	8

Dinanggasan River

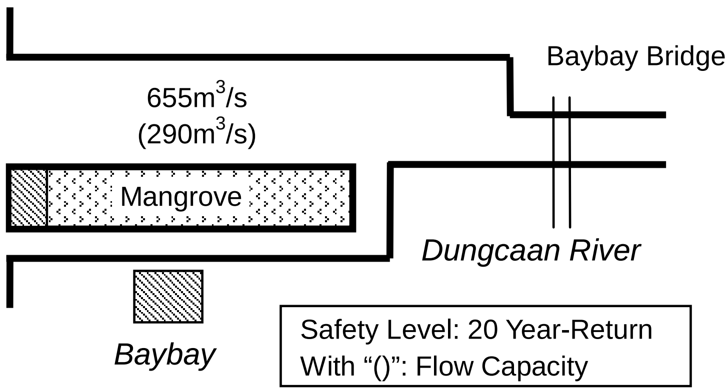
Location of Calculation	Flow Capacity (m^3/sec)
Dinanggasan River (upstream portion)	180

In order to understand the present condition of the rivers, the design flood discharges and the flow capacities are summarized in the following figures:

Ilog-Hilabangan River:



Dungcaan River:



Meycauayan River:

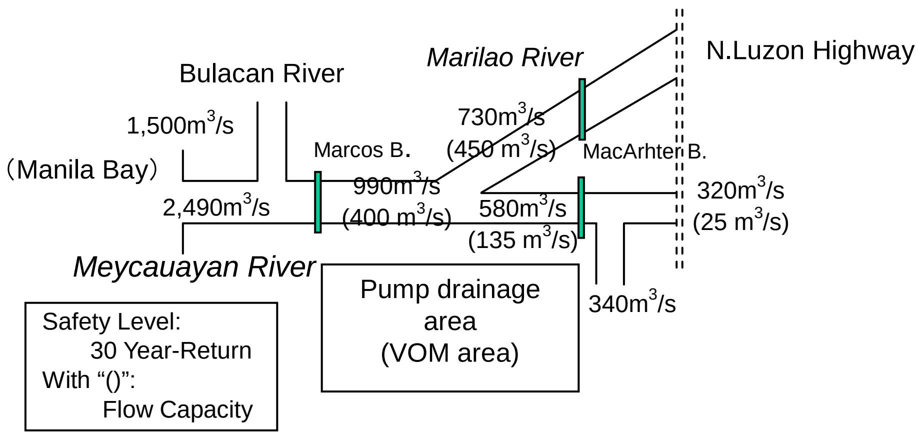
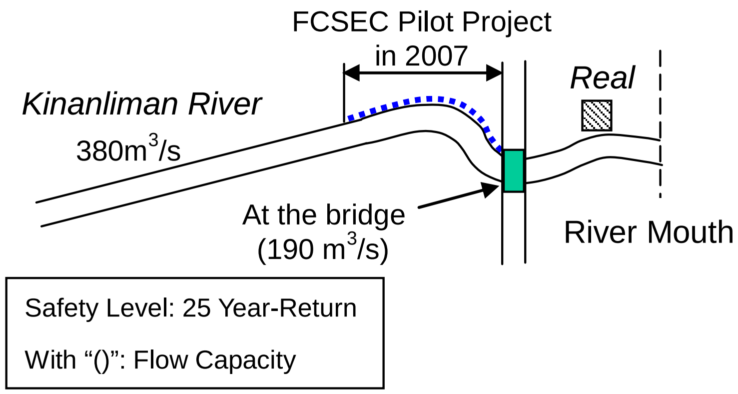
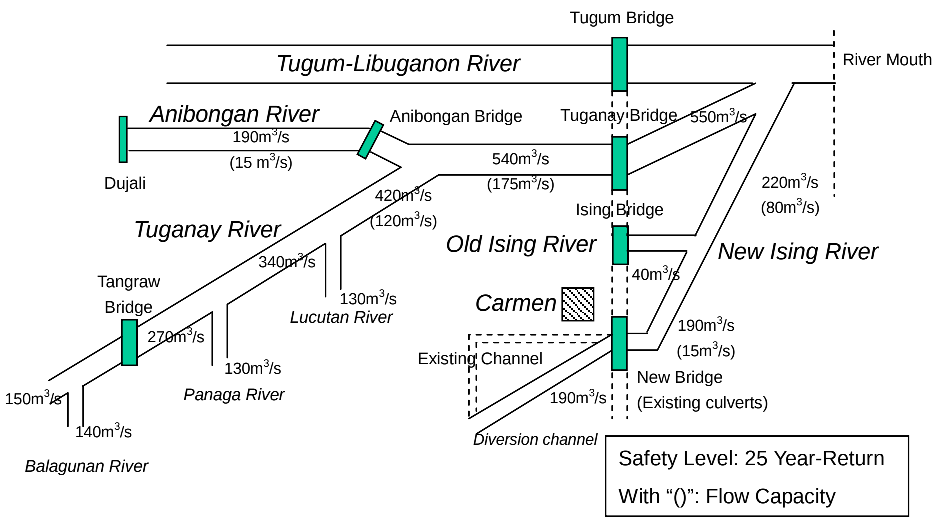


Figure F.3.1 Design Flood Discharges and Flow Capacities (1/2)

Kinanliman River:



Tuganay River:



Dinanggasan River:

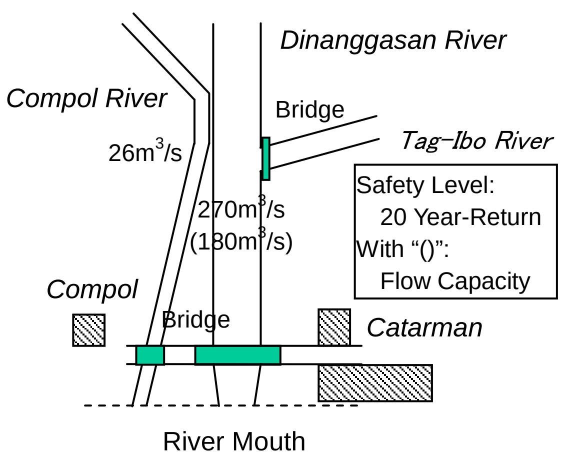


Figure F.3.1 Design Flood Discharges and Flow Capacities (2/2)

3.2 Flood Inundation Analysis

3.2.1 Analysis Method

Software of HRC-RAS and HEC-GeoRAS is used for flood inundation analysis. HEC-RAS is used for one-dimensional steady flow analysis, and HEC-GeoRAS is used for creation of cross section cut lines, flood inundation mapping and others. HEC-GeoRAS is the extension software of ArcGIS. For the flood inundation analysis, the following data are needed:

- DEM (Digital Elevation Model) data of the river system in the TIN (Triangulated Irregular Network) format
- Cross sectional survey data
- Design discharge data
- Hydraulic boundary data (river mouth water level, etc.)

The salient features of the flood inundation analysis are described below.

At first, DEM data are incorporated into HEC-GeoRAS and cross sectional data are created. Then, the water levels of the river are computed using HEC-RAS. Based on the water levels, water surface TIN is created, and flood inundation areas are mapped out using HEC-GeoRAS.

3.2.2 Hydrologic / Hydraulic Boundary

In principle, the water level at river mouth is set at MHWL (Mean Monthly Highest Water Level) of nearby tidal station with reference to the manual of the DPWH. However, if there is the water level adopted in the previous related study, this value is applied. The water level applied in this study is shown in the table below.

Table F.3.4 Water Level at River Mouth

River	W.L.	Reference Data
Ilog-Hilabangan	EL. +1.50 m	Mean High Water Spring Level with reference to the previous related study
Dungcaan	EL. +1.29 m	Mean Monthly Highest Water Level of the tidal station “Ormoc Pier, Leyte” with reference to the manual of the DPWH
Meycauayan	EL. +0.80 m	Mean High Water Spring Level with reference to the previous related study (Water Level at the confluence point with Marilao River is EL. +1.37 m)
Kinanliman	EL. +0.72 m	Mean High Water Spring Level with reference to the previous related study
Tuganay	EL. +0.78 m	Mean Higher High Water Level with reference to the previous related study (Water level at the confluence point with Libuganon River is EL. +1.35 m)
Dinanggasan	EL. +0.97 m	Mean Monthly Highest Water Level of the tidal station “Macabalan Port, Cagayan de Oro” with reference to the manual of the DPWH

3.2.3 Analysis Conditions

(1) Ilog-Hilabangan River Basin

Based on the calculation result of the flow capacities, the capabilities of the current river channel are insufficient for the design flood discharges. Therefore, inundation analysis is necessary in order to estimate the inundation area and relating data/information. On the other hand, the inundation analysis was conducted in the previous study using two-dimensional models. Compared the river width and profile prepared in the previous master plan with the new survey results (shown in Figure F.3.2), the river width and riverbed gradient of Ilog River are mostly alike. Based on this, there seems to occur no remarkable channel changes after the previous study. Therefore, it can be judged that there is no considerable differences in inundation area between the previous study and the present conditions. Hence, the results of the analysis done in the previous study are adopted in this Study considering the higher accuracy of the previous analysis.

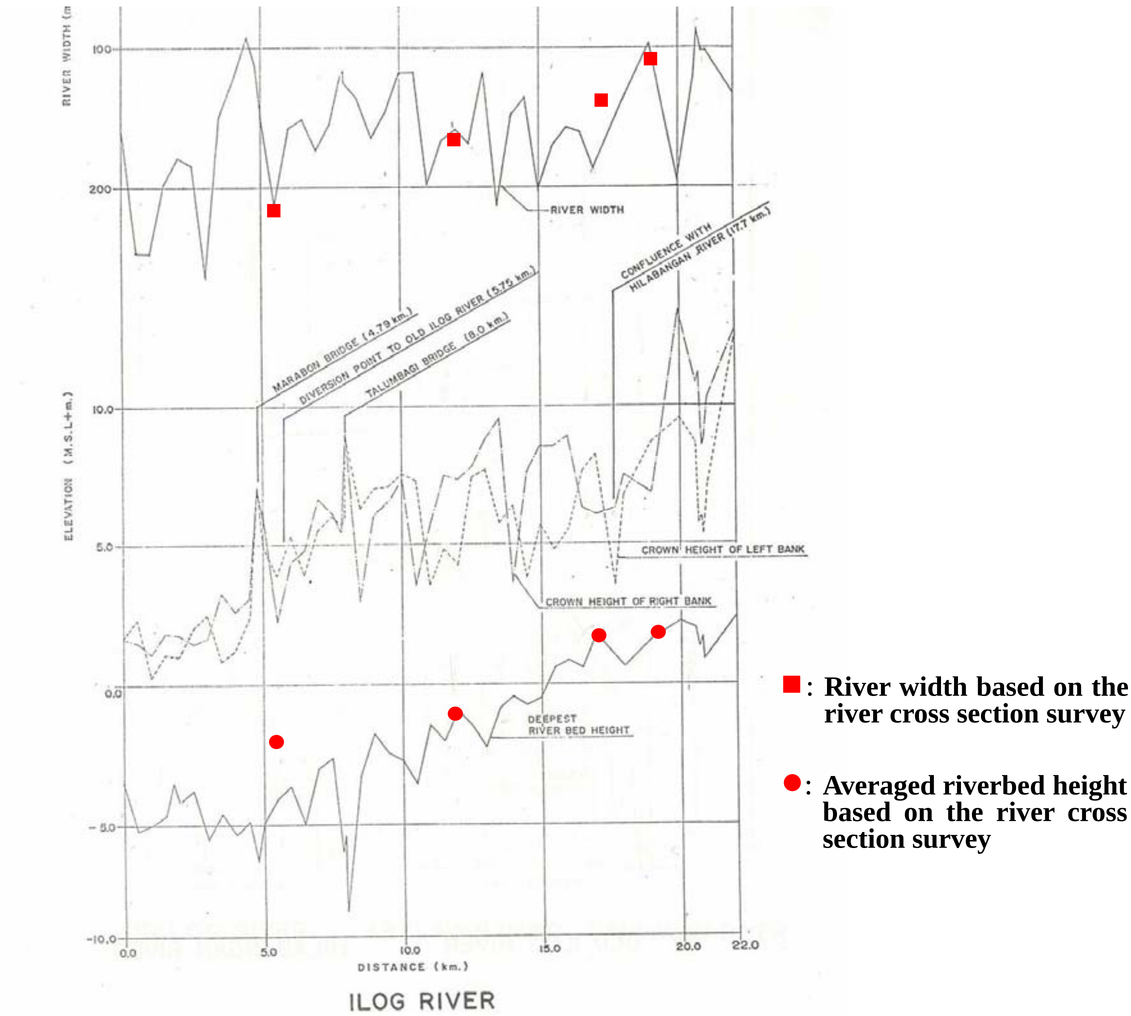


Figure F.3.2 River Profile of Ilog River

(2) Other Model River Basins

Based on the calculation results of the flow capacities, the capabilities of current river channels are insufficient for the design flood discharges. Therefore, inundation analyses are necessary in order to estimate the inundation areas and relevant information. The ranges of the analyses are studied based on the results of the field survey.

3.2.4 Adjustment of SRTM/NASA Data

The geographical feature data for the inundation analysis are SRTM/NASA. Since the altitude data of SRTM/NASA include the error compared with the actual evaluation, height adjustment of SRTM/NASA data is required. For this adjustment, the comparison between SRTM/NASA data and cross section survey data is carried out in order to identify the adjustment values and locations. The results of this adjustment are shown below.

Table F.3.5 Adjustment of SRTM/NASA Data

River	Adjusted Value	Adjusted SRTM/NASA Data
Dungcaan	–2.012 m	Built-up Area of Baybay on CR2
Meycauayan	–3.970 m	CR1～CR6
Kinanliman	–3.504 m	CR1～CR2
Tuganay	–2.150 m	Built-up Area of Carmen on CR2

3.2.5 Flood Inundation Area

The flood inundation area of each river basin is described below.

(1) Ilog-Hilabangan River

The flood inundation area is set with reference to the previous related study. The area is distributed over the whole low flat ground including the built-up areas of Kabankalan and Ilog, fish pond area and annual crop area. The total inundation area is estimated at 10,402 ha with a 25-year return period flood as shown below. The flood inundation area is shown in Figure F.3.3.

Table F.3.6 Flood Inundation Area of the Ilog-Hilabangan River Basin

(Unit:ha)

Land Use	Flood Scale (Return Period)
	25-year
Built-up Area	114.2
Fishpond	2,035.7
Annual Crop	6,710.7
Other	1,541.6
Total	10,402.1

(2) Dungcaan River

The flood inundation area consists of mangrove forest at around the river mouth, built-up area of the Baybay City and annual crop area in the upstream of the Bay-bay Bridge. The total inundation area is estimated at 173 ha with a 20-year return period flood as shown in the following table. The flood inundation map is shown in Figure F.3.4.

Table F.3.7 Flood Inundation Area of the Dungcaan River Basin

(Unit:ha)

Land Use	Flood Scale (Return Period)
	20-year
Built-up Area	13.0
Fishpond	0.0
Annual Crop	89.1
Other	70.5
Total	172.6

(3) Meycauayan River

Valenzuela, Obando, Meycauayan and Malabon are generally located at very low elevations, therefore, these areas are always under the menace of flood inundation. There are two types of flood in these areas. The one is channel overflow and the other is influence of high tide. Particularly, the flood inundation is remarkable in the downstream portion from the North Luzon Highway. The total inundation area is estimated at 5,222 ha with a 30-year return period flood as shown below. Figure F.3.5 shows the flood inundation area.

Table F.3.8 Flood Inundation Area of the Meycauayan River Basin

(Unit:ha)

Land Use	Flood Scale (Return Period): 30yr			
	VOM	Improvement Area	Other	Total
Built-up Area	804.2	352.8	157.8	1,314.8
Fishpond	741.5	92.0	2,830.7	3,664.2
Annual Crop	56.9	25.2	24.0	106.1
Other	0.0	93.7	42.8	136.5
Total	1,602.6	563.7	3,055.3	5,221.6

Note) The vacant holes nearest to the river channels in inundated area are included in the inundation area considering flood conditions.

(4) Kinanliman River

The water, which flows from the upper stream portion, has afflux at the narrow segment of the Bridge, and the flood is exerted on the built-up area of Real. The total inundation area is estimated at 13 ha with 25-year return period flood as tabulated below. Figure F.3.6 shows the flood inundation area.

Table F.3.9 Flood Inundation Area of the Kinanliman River Baisn

(Unit:ha)

Land Use	Flood Scale (Return Period)
	25-year
Built-up Area	8.4
Fishpond	0.0
Annual Crop	0.0
Other	4.2
Total	12.6

(5) Tuganay River

The flood inundation area spreads out in the low flat area, which includes the downstream of the Tuganay, Anibongan and Ising Rivers. The inundation area consists of the built-up areas of Carmen and Dujali, fishpond and annual crop areas. The total inundation area is estimated at 7,711 ha with 25-year return period flood as shown in Table F.3.10. Figure F.3.7 shows the flood inundation area.

Table F.3.10 Flood Inundation Area of the Tuganay River Basin

(Unit:ha)

Land Use	Flood Scale (Return Period)
	25-year
Built-up Area	154.5
Fishpond	391.2
Annual Crop	6,857.5
Other	307.4
Total	7,710.6

Note) The vacant holes nearest to the river channels in inundated area are included in the inundation area considering flood conditions.

(6) Dinanggasan River

The upper stream from the Bridge is the debris flow section with the riverbed gradient of 1/30 or more. Based on these characteristics, it is considered that the flood damages are mainly caused by sands and rocks with flash flood. Therefore, the damage area is estimated based on the potential area for debris flows shown in the previous study with due consideration of the topography and river conditions. The flood inundation area is roughly estimated as shown in Figure F.3.8. The total inundation area is estimated at around 147 ha as shown below.

Table F.3.11 Flood Inundation Area of the Dinanggasan River Basin

(Unit:ha)

Land Use	Flood Scale (Return Period)
	20-year
Built-up Area	6.0
Fishpond	0.0
Annual Crop	91.5
Other	49.3
Total	146.8

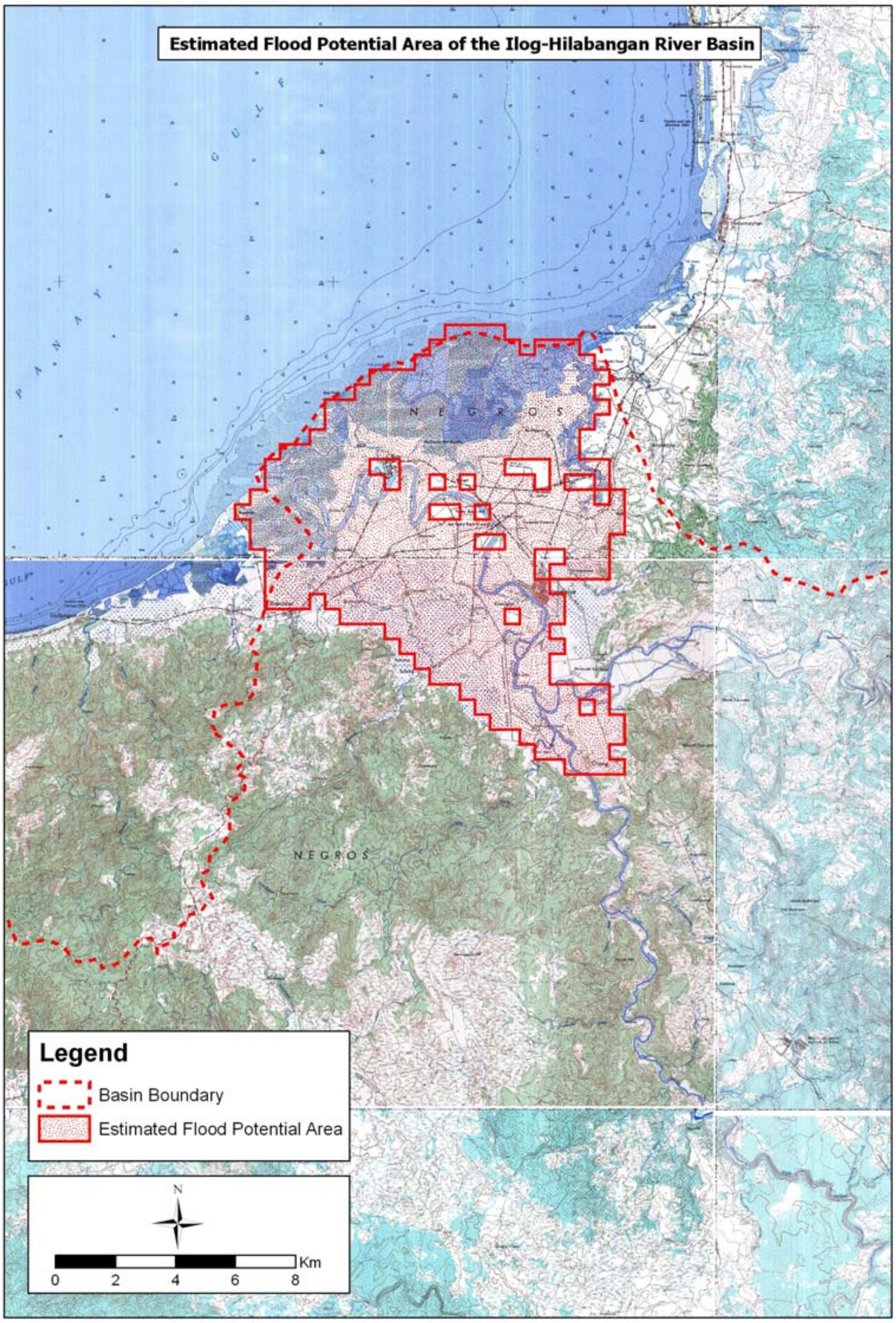


Figure F.3.3 Flood Inundation Area of the Ilog-Hilabangan River Basin

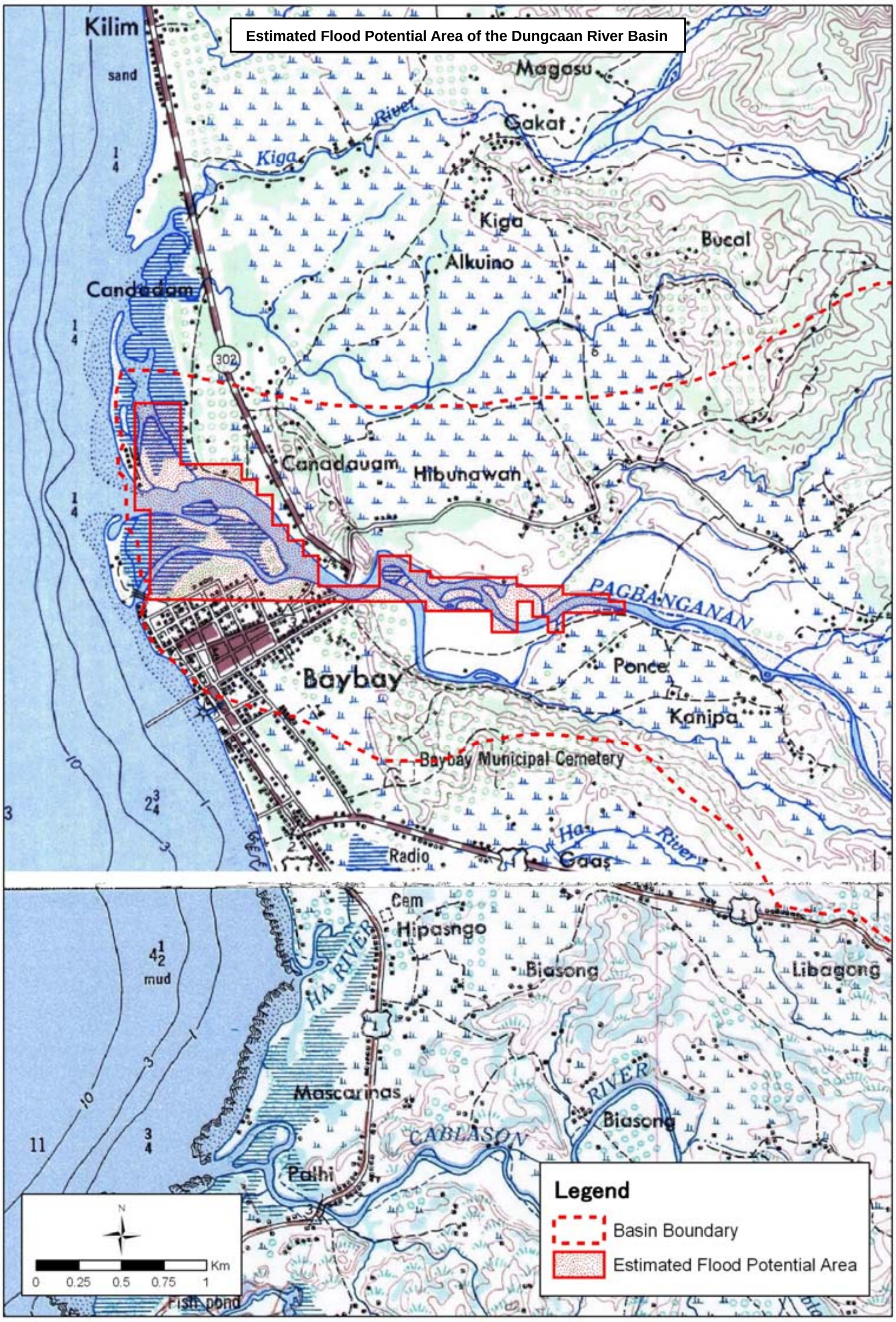


Figure F.3.4 Flood Inundation Area of the Dungcaan River Basin

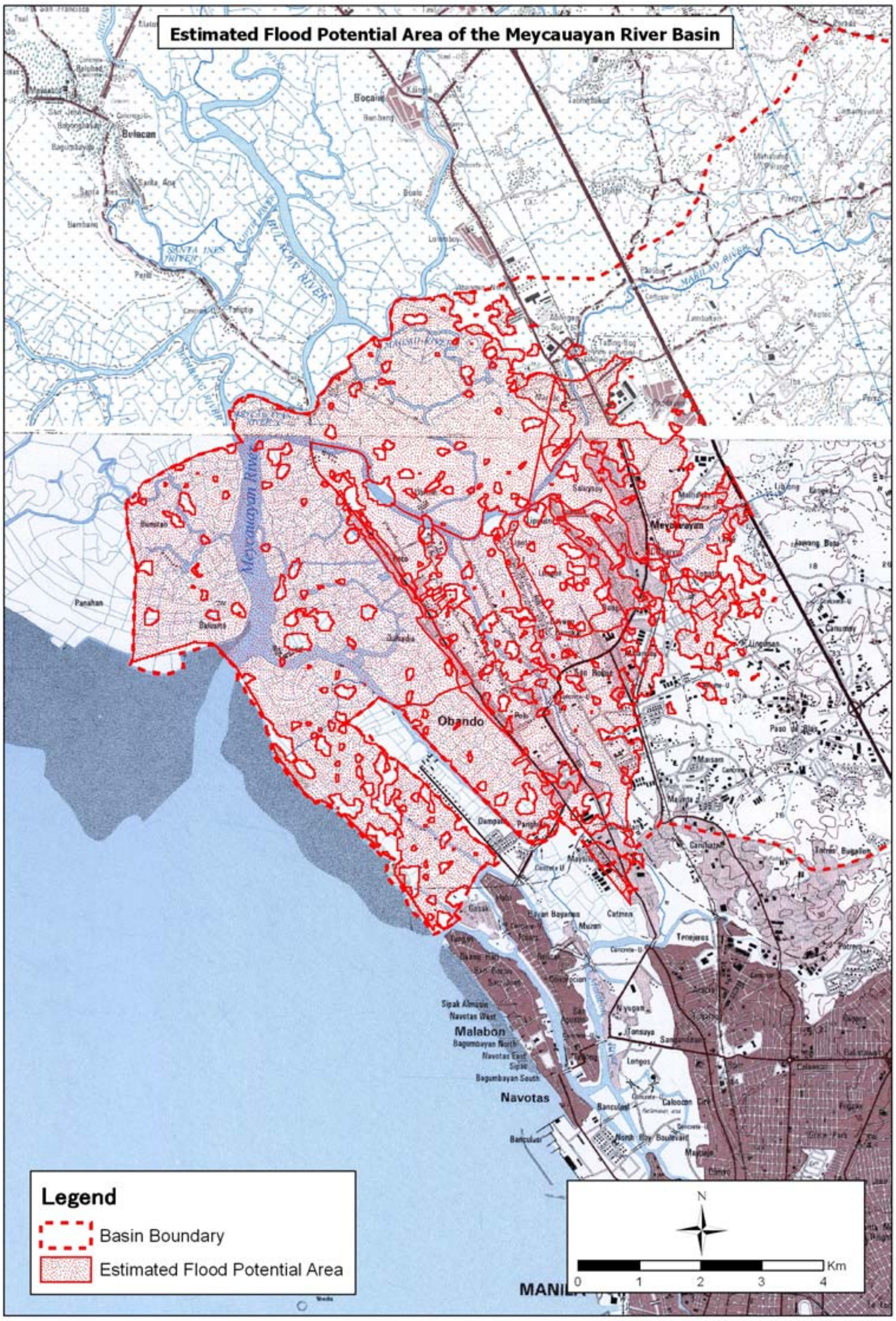


Figure F.3.5 Flood Inundation Area of the Meycauayan River Basin

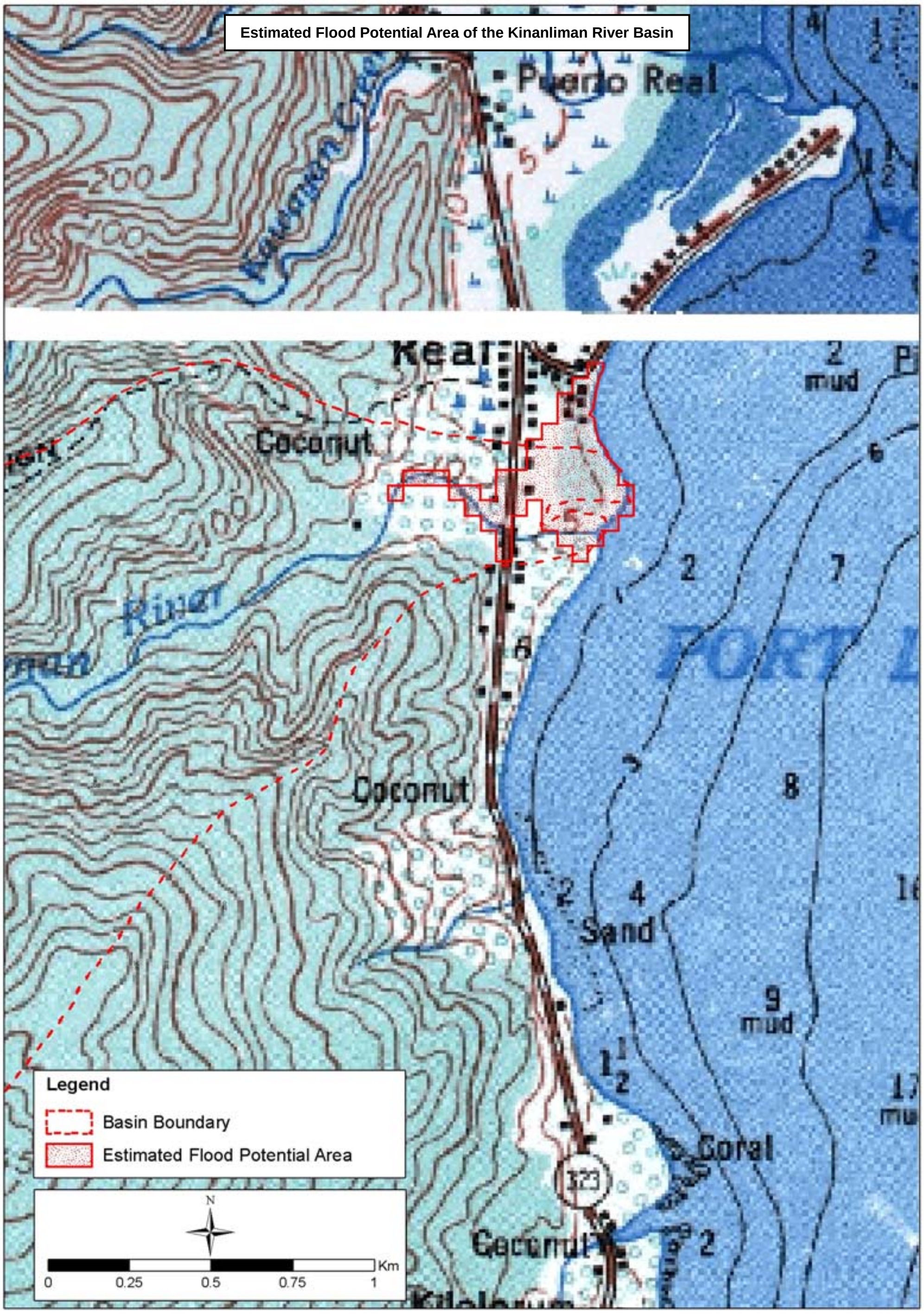


Figure F.3.6 Flood Inundation Area of the Kinanliman River Basin

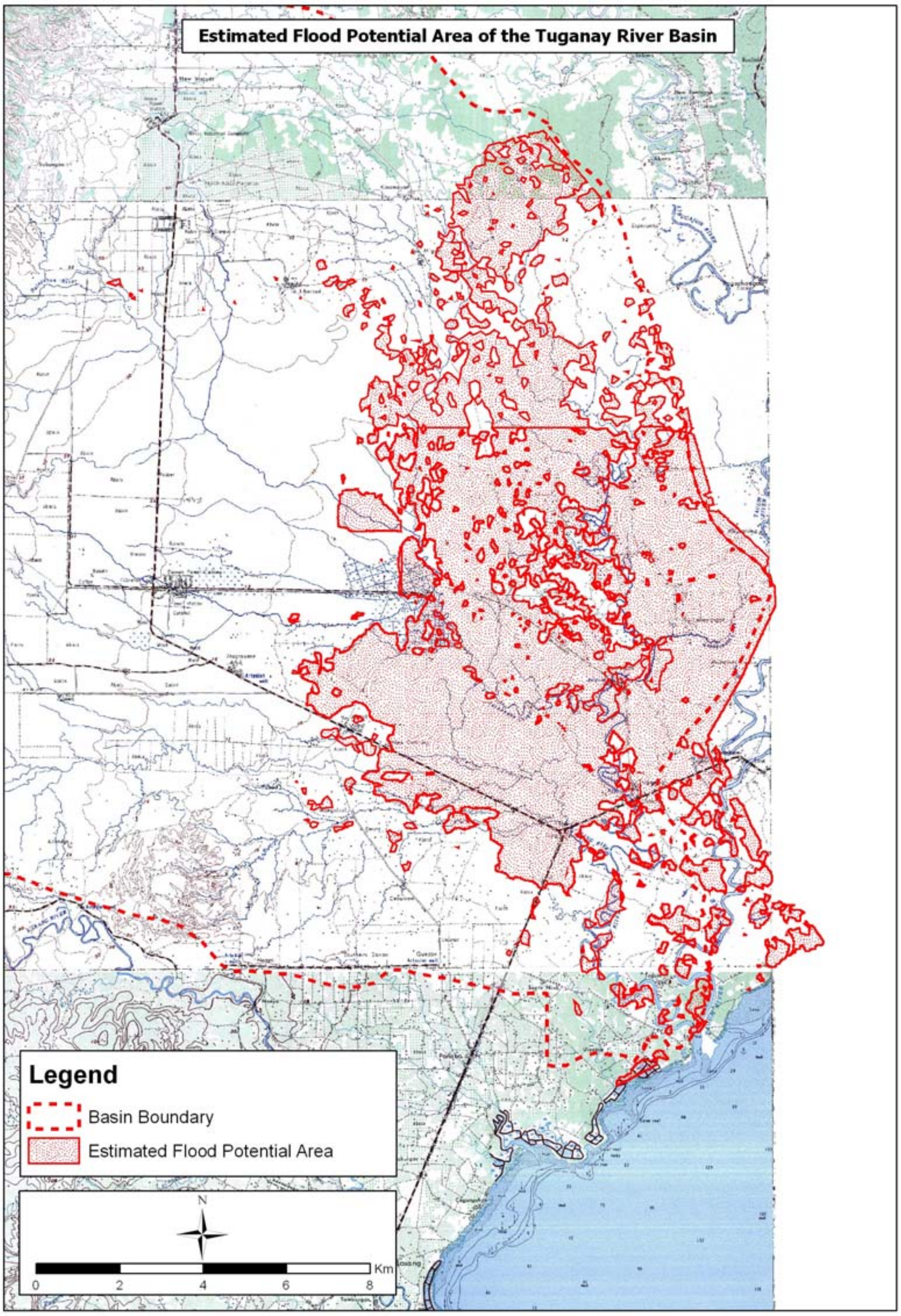


Figure F.3.7 Flood Inundation Area of the Tuganay River Basin

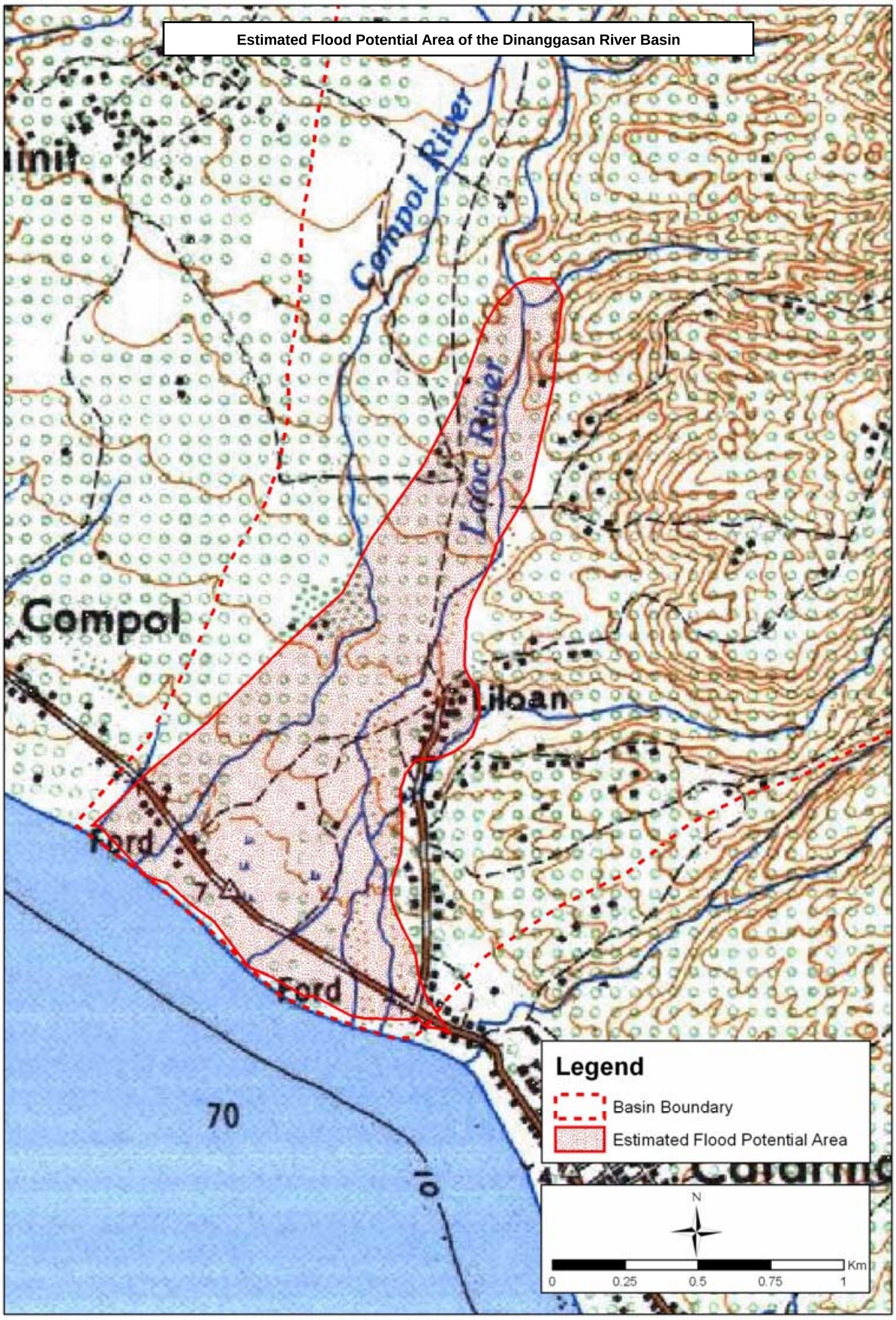


Figure F.3.8 Flood Inundation Area of the Dinanggasan River Basin

4 PRELIMINARY DESIGN OF MAIN STRUCTURAL MEASURES

4.1 Design Conditions

The design criteria are prepared mainly based on the "Manual on Design of Flood Control Structures, January 2005, DPWH", "Manual for River Works in Japan, Ministry of Land, Infrastructure and Transport, Japan" and others. The major design concepts are described below.

4.1.1 Channel Alignment

In order to minimize land acquisition, the channel will follow as much as possible the existing river alignment. However, the design alignment of river course should be composed of straight lines or large radius curves in order to provide a smooth flood flow in principle.

4.1.2 Longitudinal Profile and Cross Sections

(1) Design High Water Level

Design high water level is set, in principle, to correspond with the average ground elevation along the river course with due consideration of the maximum flood water level.

(2) Design Riverbed

Design riverbed profile principally follows the existing average riverbed profile to avoid unbalanced scouring and sedimentation as well as to minimize relocation and modification of existing river structures. Change in riverbed gradients between two reaches is set such that the ratio of riverbed gradients between the upper and lower stretches is less than 1:2 to ensure the stability of the river channel. In addition, the design riverbed should be determined in relation with the average velocity and high water level of river channel, considering dike stability and the flood damage potential in the hinterland of the channel.

(3) Cross Section

Cross section is designed conforming to the existing one in order to reduce land acquisition. In the narrow reaches, the river should be widened to confine the design discharge. In this river channel improvement design, the compound cross section type is applied to Ilog-Hilabangan River with large design discharges, and the single cross section type is applied to the other rivers. Regarding the slope of dike and revetment, 1:2.0 side slope is applied for excavation slope, and 1:3.0 side slope is applied for high banking of 4.0 m or more. On the other hand for Meycauayan and Dungcaan Rivers, 1:0.5 side slope revetment or vertical wall is applied according to the land use and housing conditions of the bank line.

4.1.3 Freeboard

Freeboard for embankment corresponding to design discharge is shown in Table F.3.1.

4.1.4 Manning's Roughness Coefficient for Improved Channel

If there is available figure of roughness coefficient adopted in the previous related study, this coefficient is applied in principle. Otherwise, the coefficient is preliminarily determined according to the plan and O/M condition. The roughness coefficient of each river is shown below.

Table F.4.1 Manning's Roughness Coefficient

River	River Channel
Ilog-Hilabangan	0.035
Dungcaan	0.045
Meycauayan	0.030*
Kinanliman	0.040*
Tuganay	0.040
Dinanggasan	0.040

*Note) *: value adopted in the previous related study*

4.2 Preliminary Design

4.2.1 Ilog-Hilabangan River

The river channel improvement works will be required for the following stretches of the river in order to attain the flood mitigation against the project scale of 25-year return period. The length and section for the improvement are tabulated in Table F.4.2. On the other hand, longitudinal profile and typical cross sections of the improvement are shown in Fig F-4-1.

Table F.4.2 River Channel Improvement of the Ilog-Hilabangan River Basin

Ilog River

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	7.0	3,690	7.0	360
2	7.0	16.0	3,690	9.0	290
3	16.0	20.0	2,920	4.0	220
TOTAL				20.0	

Hilabangan River

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	2.0	1,930	2.0	120
TOTAL				2.0	

Based on the above design, the basic layout of the main structural measures is presented in Figure F.4.1.

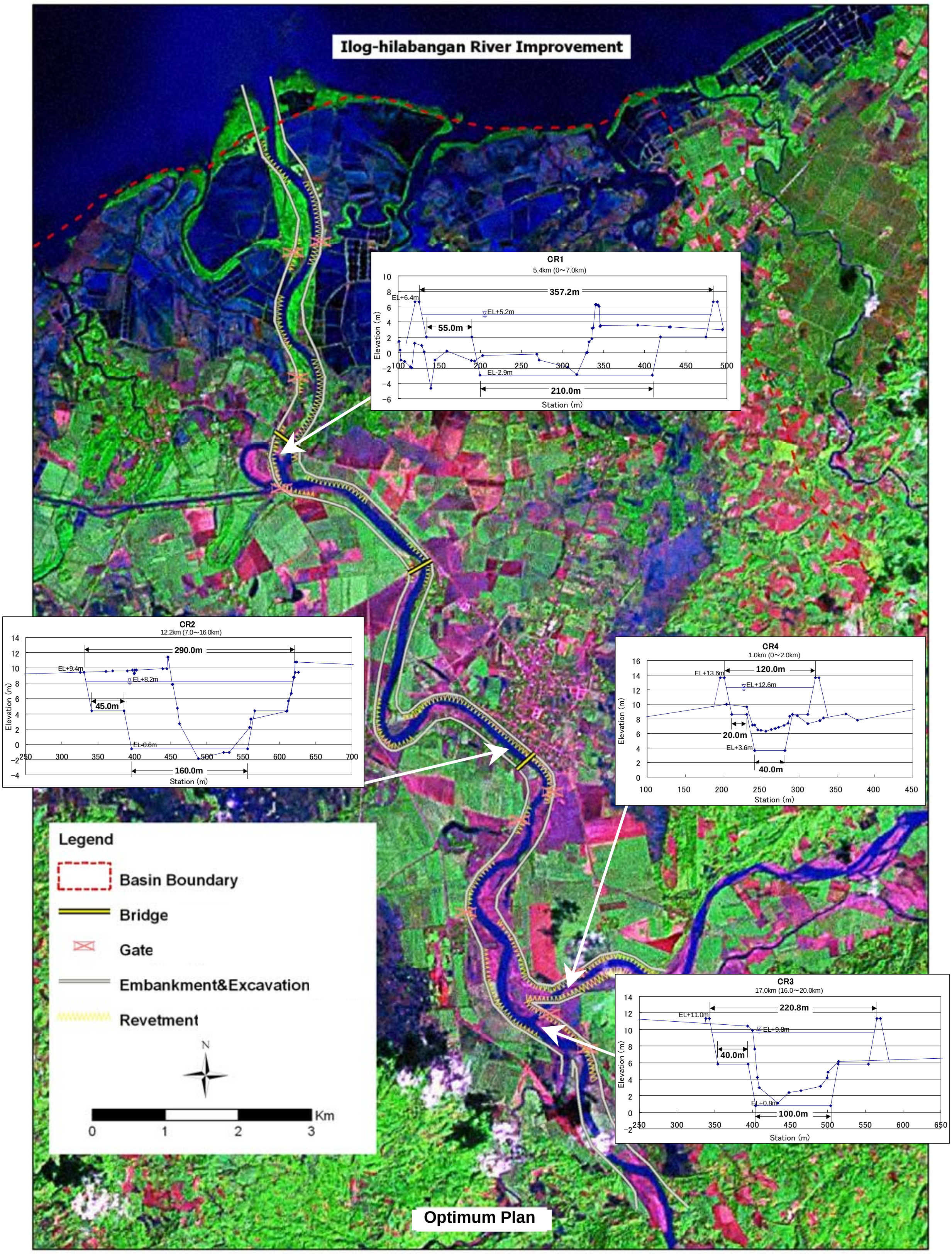


Figure F.4.1 Proposed Works of the Ilog-Hilabangan River Basin

4.2.2 Dungcaan River

The river channel improvement works will be required for the following stretches of the river in order to attain the flood mitigation against the project scale of 20-year return period. The length and section for the improvement are tabulated in Table F.4.3. On the other hand, longitudinal profile and typical cross sections of the improvement are shown in Fig.F-4-2.

Table F.4.3 River Channel Improvement of the Dungcaan River Basin

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	0.2	655	0.2	125
2	0.2	1.4	655	1.2	115
3	1.4	1.6	655	0.2	70
4	1.6	1.8	655	0.2	115
TOTAL				1.8	

Based on the above design, the basic layout of the main structural measures is presented in Figure F.4.2.

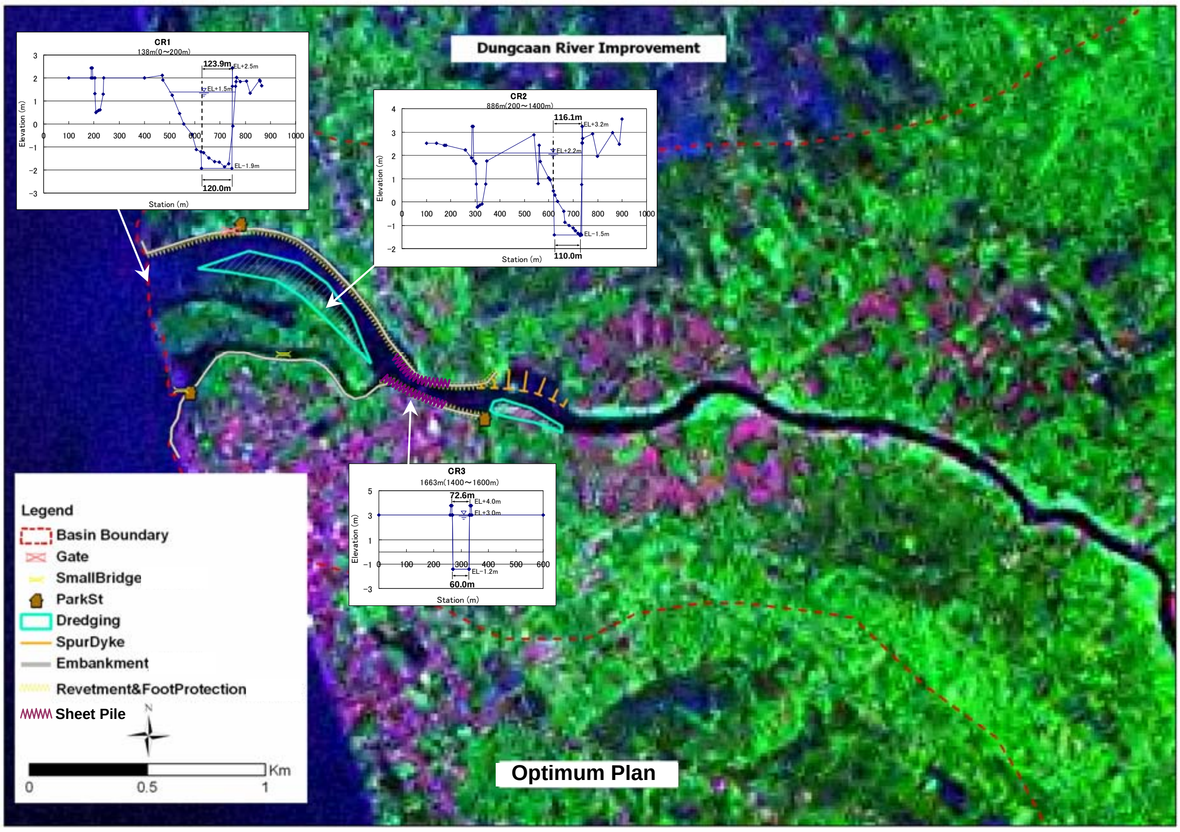


Figure F.4.2 Proposed Works of the Dungcaan River Basin

4.2.3 Meycauayan River

The river channel improvement works will be required the following stretches of the river in order to attain the flood mitigation against the project scale of 30-year return period. The length and section for the improvement are tabulated in Table F.4.4. On the other hand, longitudinal profile and typical cross sections of the improvement are shown in Fig.F-4-3 and Fig.F-4-4.

Table F.4.4 River Channel Improvement of the Meycauayan River Basin

Meycauayan River

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)	Remarks
	From	To				
1	5.0	9.5	580	4.5	-	Embankment Type
2	9.5	11.2	580	1.7	90	Embankment Type
3	11.2	12.2	580	1.0	40	Vertical Wall Type
4	12.2	13.6	320	1.4	50	Embankment Type
5	13.6	14.5	320	0.9	30	Vertical Wall Type
Total				9.5		

Marilao River

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)	Remarks
	From	To				
1	0.0	0.5	730	0.5	66	Embankment Type
2	0.5	1.0	730	0.5	30	Vertical Wall Type
3	1.0	2.0	730	1.0	50	Vertical Wall Type
4	2.0	3.5	730	1.5	45	Vertical Wall Type
5	3.5	4.5	730	1.0	30	Vertical Wall Type
Total				4.5		

The same work items proposed in the pervious F/S are adopted in the structural measures of the Meycauayan River Basin. Based on the above design, the basic layout of the main structural measures is presented in Figure F.4.3.

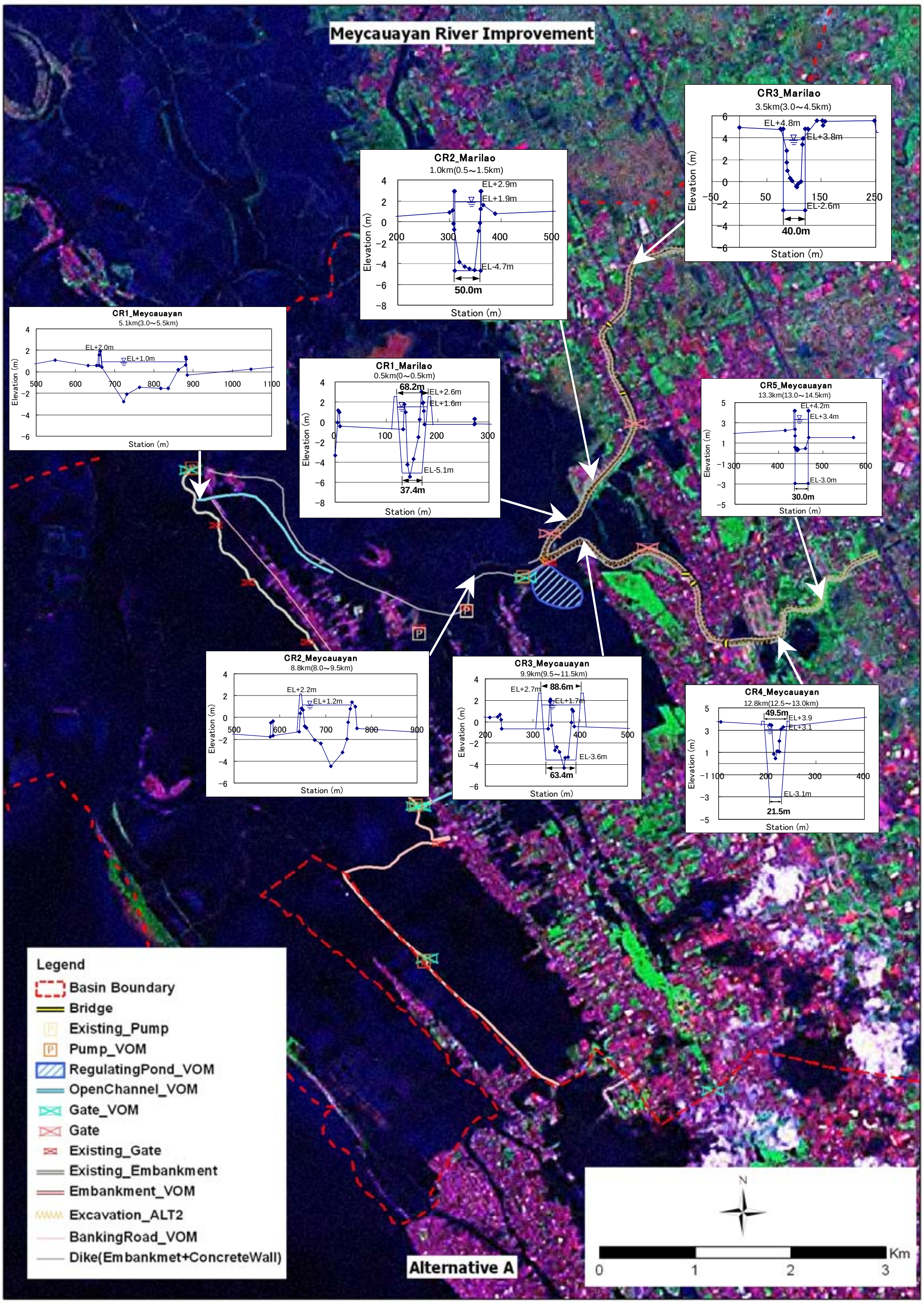


Figure F.4.3 Proposed Works of the Meycauayan River Basin

4.2.4 Kinanliman River

(1) River Channel Improvement

The river channel improvement works will be required the following stretches of the river in order to attain the flood mitigation against the project scale of 25-year return period. The length and section for the improvement are tabulated in Table F.4.5. On the other hand, longitudinal profile and typical cross sections of the improvement are shown in Fig.F-4-5.

Table F.4.5 River Channel Improvement of the Kinanliman River Basin

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	0.39	380	0.39	55
2	0.39	0.54	380	0.15	155
3	0.54	0.74	380	0.20	115
4	0.74	1.05	380	0.31	45
TOTAL				1.05	

(2) Sabo Dam

Referring to the previous FCSEC study, the salient features of the sabo dam is summarized, as shown below:

Table F.4.6 Salient Features of Sabo Dam of the Kinanliman River Basin

Dimension	Design Value
Dam Type	Permeable Type Dam
Storage Capacity (Thousand m^3)	16.2
Dam Height (m)	5.5
Dam Width (m)	85.0

Based on the above design, the basic layout of the main structural measures is presented in Figure F.4.4.

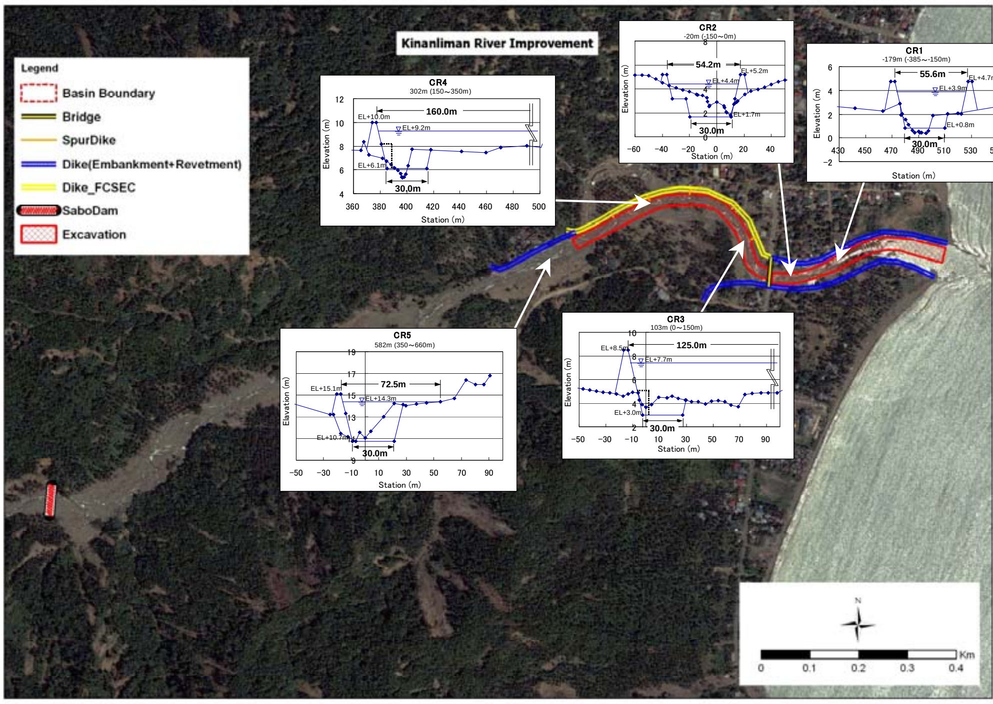


Figure F.4.4 Proposed Works of the Kinanliman River Basin

4.2.5 Tuganay River

(1) River Channel Improvement

The river channel improvement works will be required for the following stretches of the river in order to attain the flood mitigation against the project scale of 25-year return period. The length and section for the improvement are tabulated in Table F.4.7. On the other hand, longitudinal profile and typical cross sections of the improvement are shown in Figs. F-4-6 to F-4-8.

Table F.4.7 River Channel Improvement of the Tuganay River Basin

Tuganay River

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	9.0	340 - 350	9.0	60
2	9.0	15.0	220	6.0	60
3	15.0	21.0	270 - 340	6.0	55
TOTAL				21.0	

Anibongan River

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	6.5	190	6.5	65
2	6.5	10.0	190	3.5	60
TOTAL				10.0	

New Ising River

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	6.0	90 - 130	6.0	100
2	6.0	9.0	90	3.0	50
TOTAL				9.0	

Old Ising River

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	3.0	40	3.0	25
TOTAL				3.0	

(2) Retarding Basins

The retarding basins are planned for the Tuganay and New Ising Rivers. With the design discharge of 25-year return period, the regulation functions are examined to estimate the required capacities of the retarding basins. As a result, the required volumes and dike heights are preliminarily designed as shown below.

Table F.4.8 Dimension of Retarding Basins in the Tuganay River Basin

Dimensions	Tuganay River	New Ising River
Area of Retarding Basin (ha)	200	75
Storage Volume (MCM)	5.00	1.50
Required Capacity (MCM)	4.99	1.42
Surface Elevation (EL. m)	7.6	6.0
Dike Height (m)	3.1	2.3
Dike Length (m)	11,000	4,100

Based on the above design, the basic layout of the main structural measures is presented in Figure F.4.5.

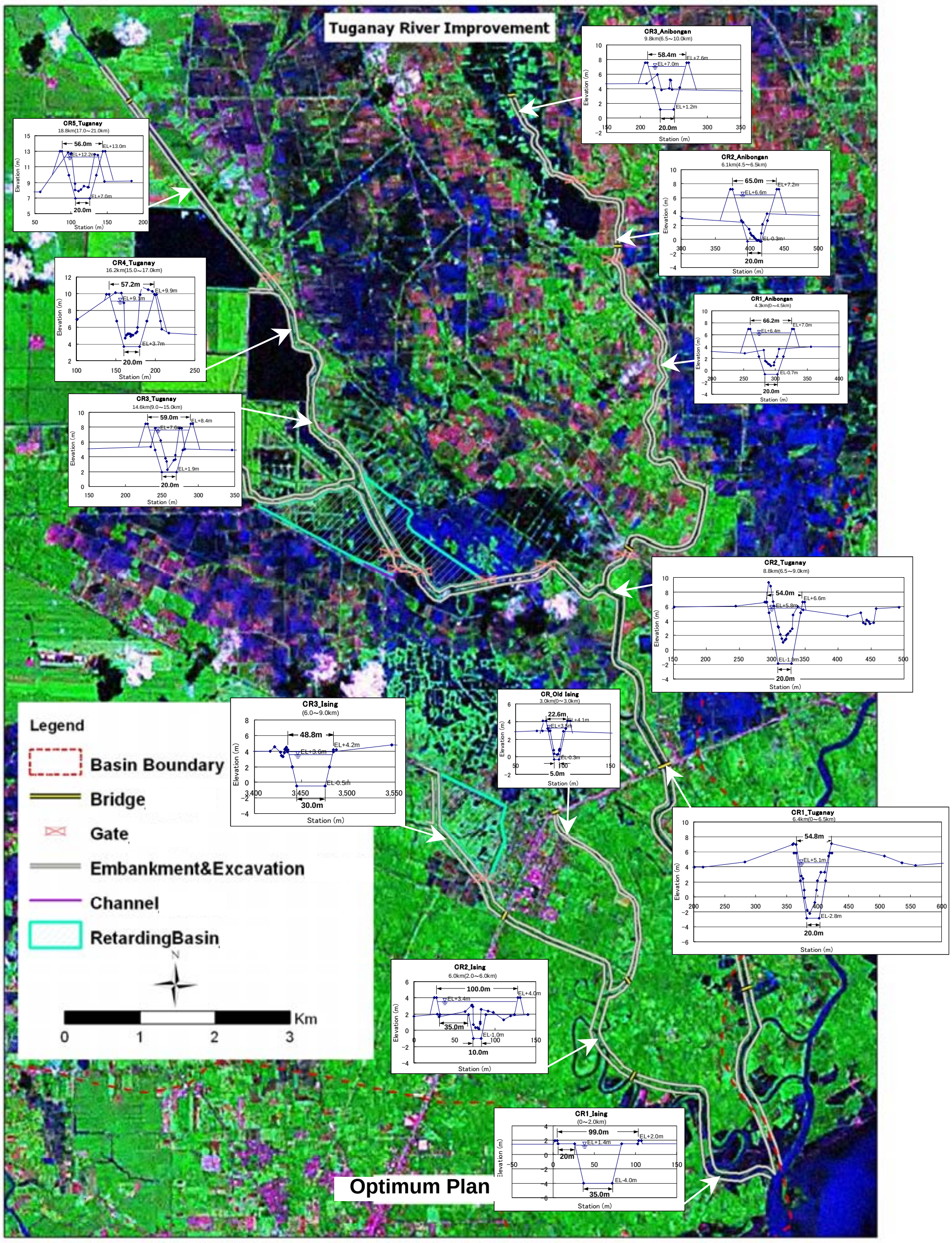


Figure F.4.5 Proposed Works of the Tuganay River Basin

4.2.6 Dinanggasan River

(1) River Channel Improvement

The river channel improvement works will be required for the following stretches of the river in order to attain the flood mitigation against the project scale of 20-year return period. The length and section for the improvement are tabulated in Table F.4.9. On the other hand, longitudinal profile and typical cross sections of the improvement are shown in Fig.F-4-9.

Table F.4.9 River Channel Improvement for the Dinanggasan River Basin

Stretch	Station Number		Design Discharge (m^3/s)	Length (km)	Width (m)
	From	To			
1	0	0.12	296	0.12	215
2	0.12	0.53	296	0.41	260
3	0.53	0.88	296	0.35	215
4	0.88	1.40	296	0.52	80
TOTAL				1.40*	

**: In addition to the above, training dike of 0.2km is planned for the right bank.*

(2) Sand Pocket and Sabo Dam

One (1) sabo dam and one (1) sand pocket are preliminary proposed in this plan. The main purpose of these sabo facilities is to catch the front of debris flow, the most dangerous portion of debris flow, in order to weaken its destructive power. The salient features of the planned sabo facilities are shown below.

Table F.4.10 Salient Features of the Sabo Facilities of the Dinanggasan River Basin

Dimension	Sabo Dam	Sand Pocket
Dam Type	Impermeable Type Dam	
Storage Capacity (Thousand m^3)	19.1	6.4
Dam Height (m)	8.0	5.5
Dam Width (m)	72.5	30.0

Based on the above design, the basic layout of the main structural measures is presented in Figure F.4.6.

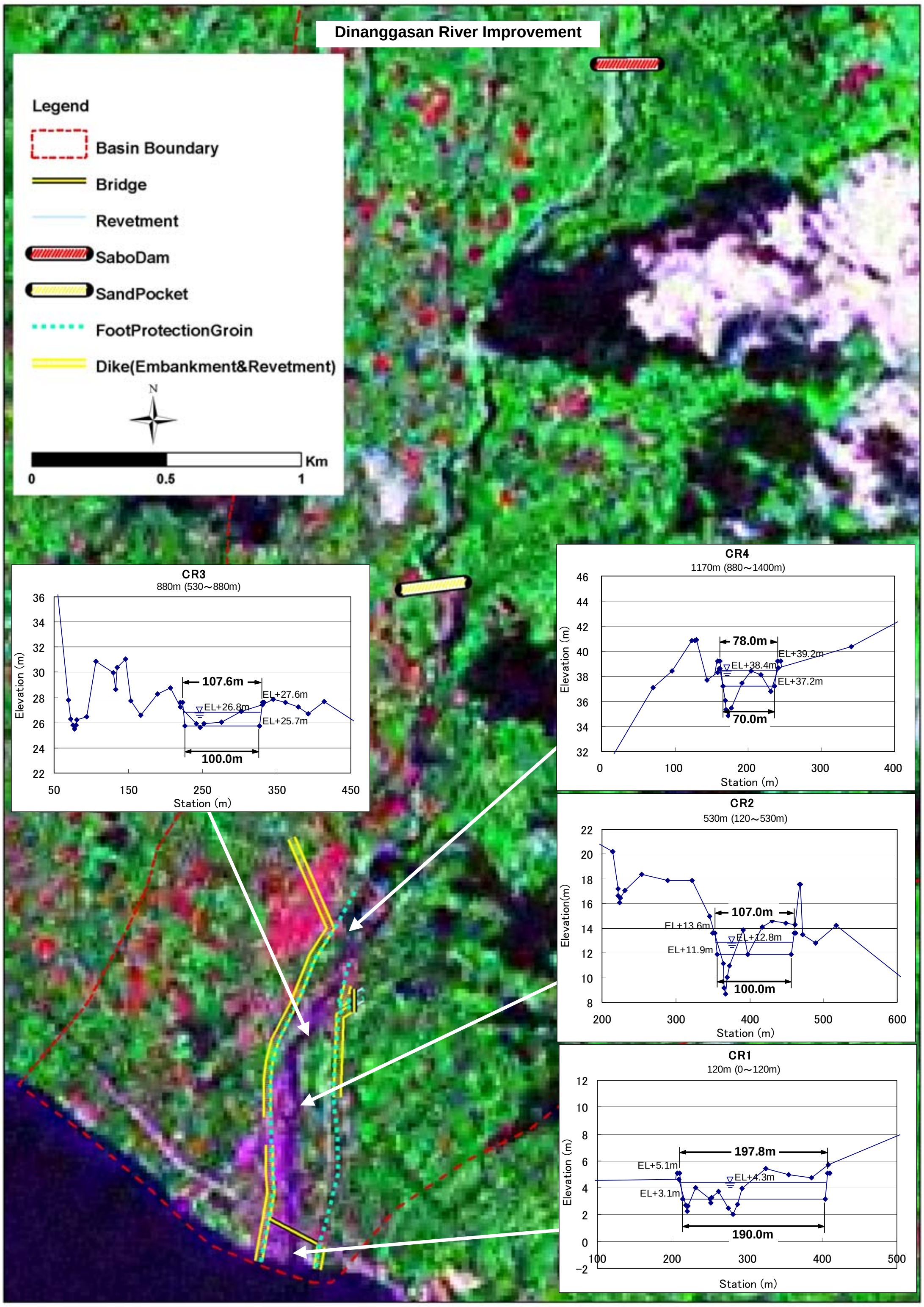
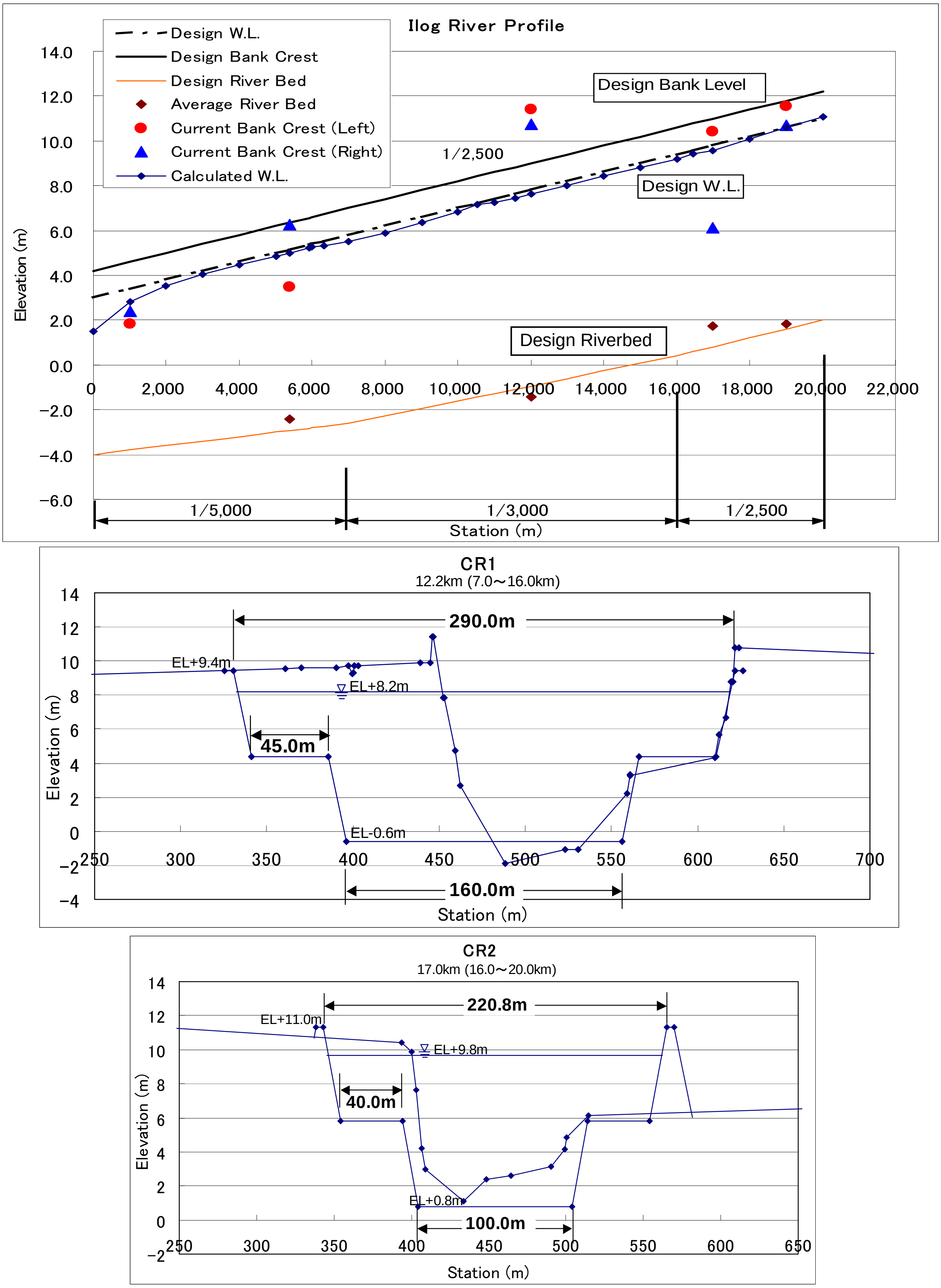
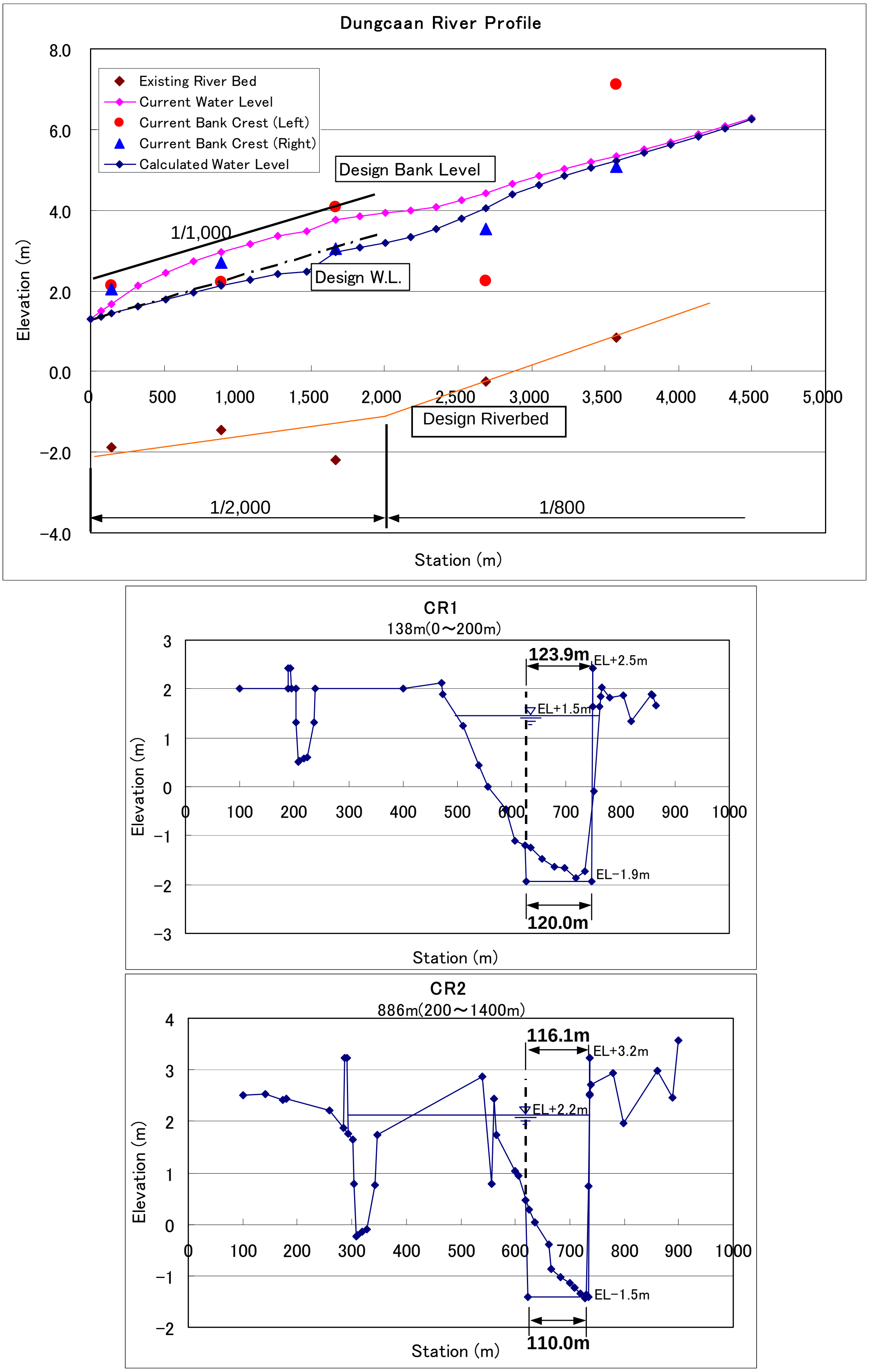


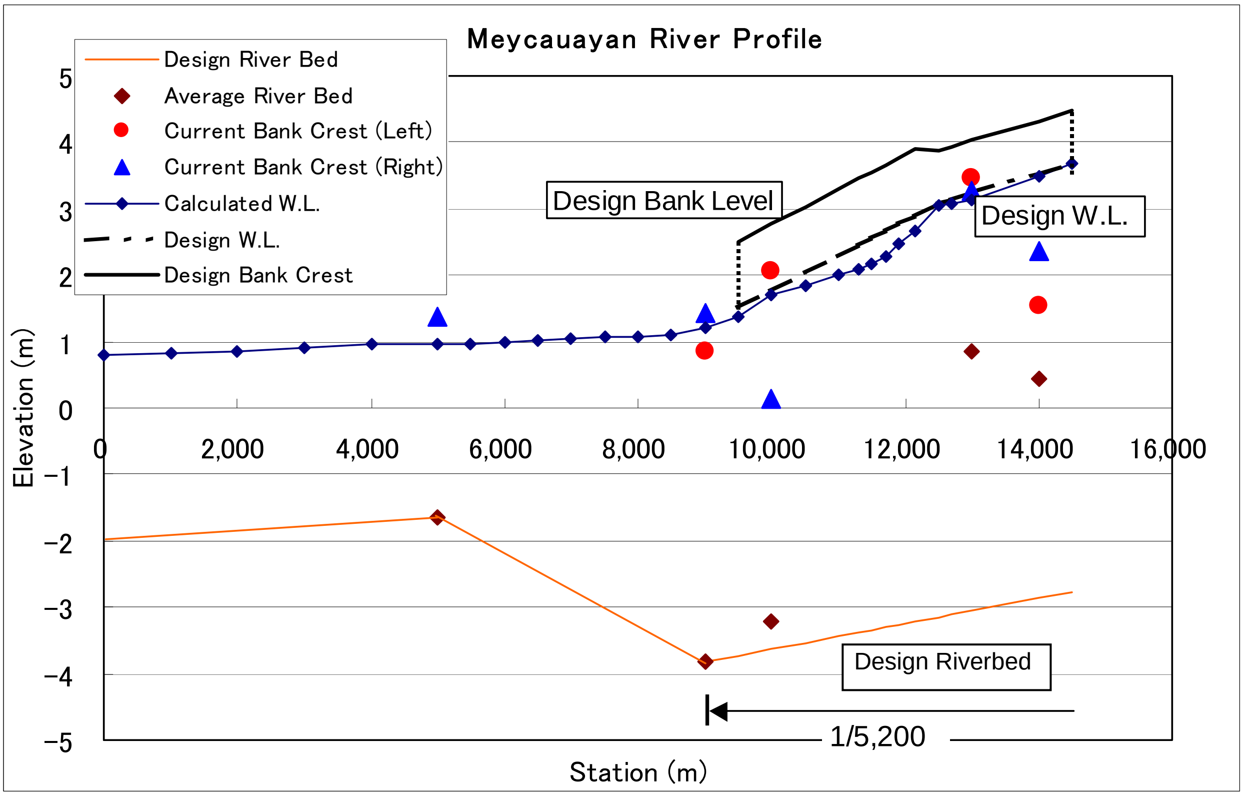
Figure F.4.6 Proposed Works of the Dinanggasan River Basin

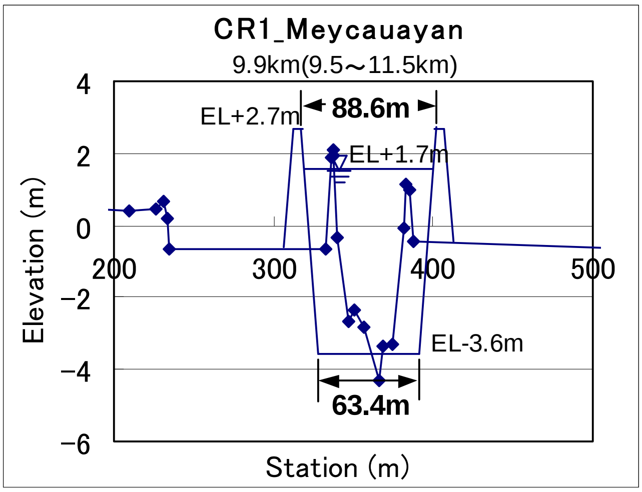


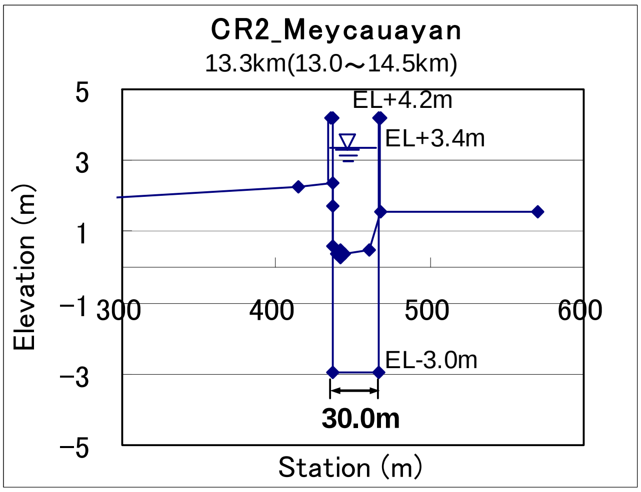
THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES	**Fig. F-4-1** **Longitudinal Profile and Typical Cross Sections of Ilog-Hilabangan River**
JAPAN INTERNATIONAL COOPERATION AGENCY	



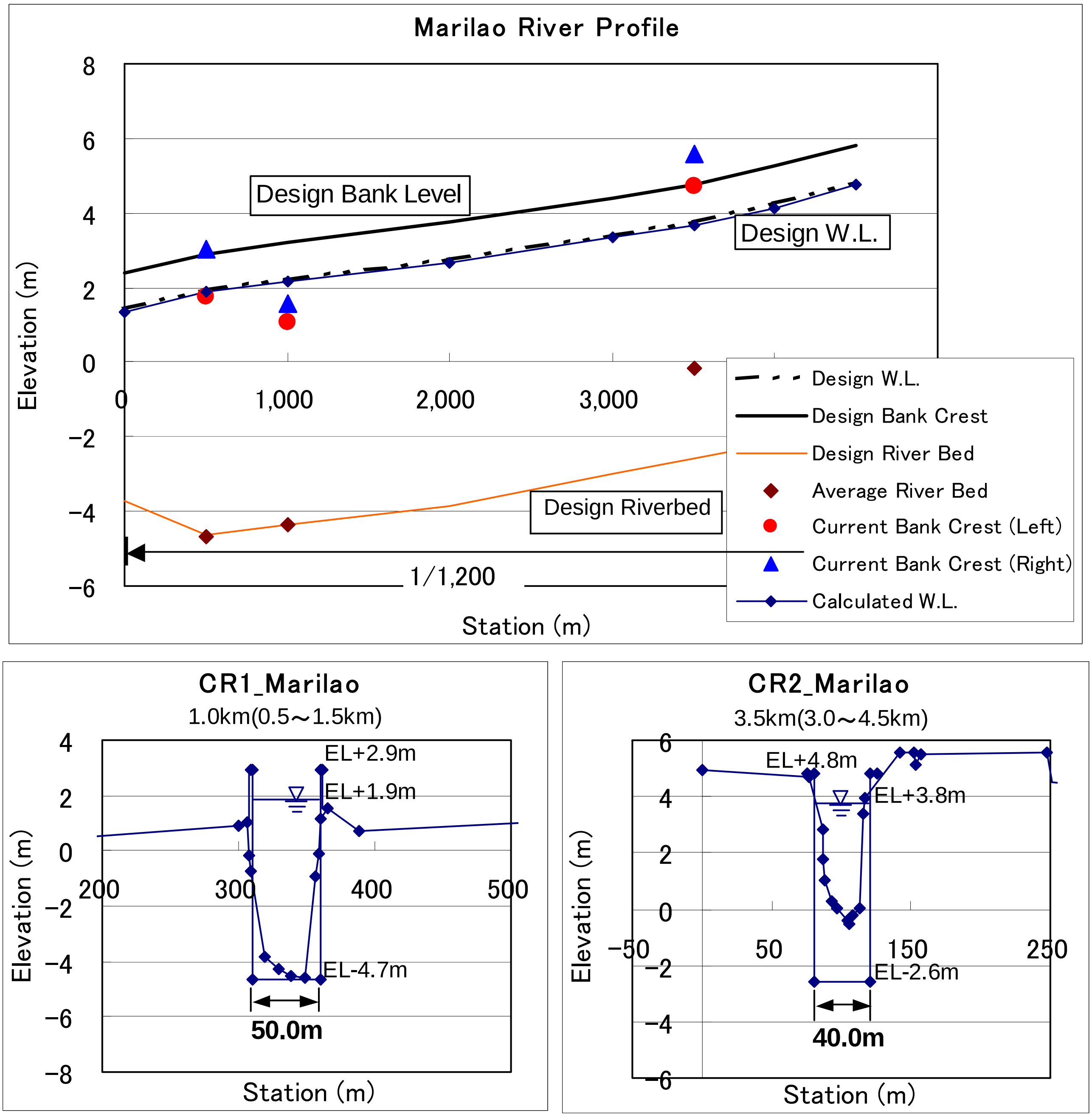
THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES	**Fig.F-4-2**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Longitudinal Profile and Typical Cross Sections of Dungcaan River**



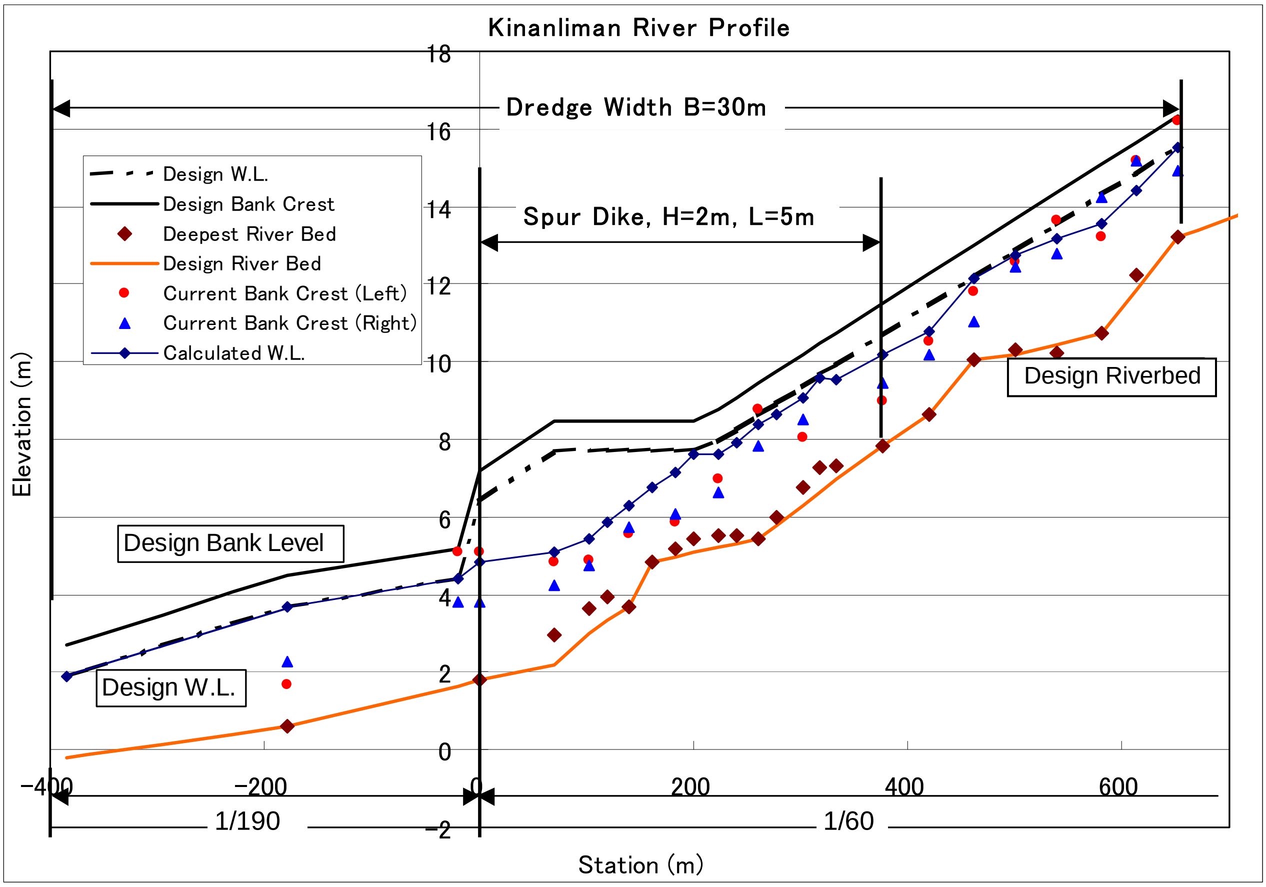


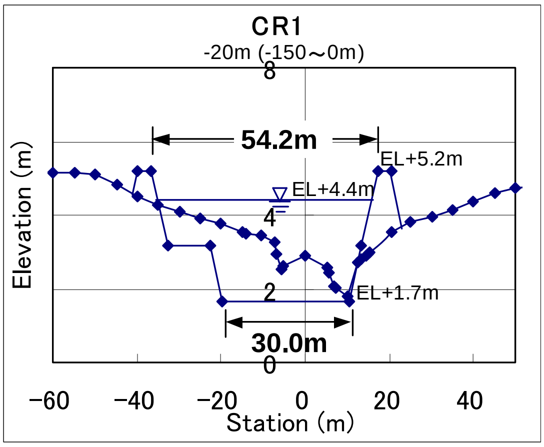


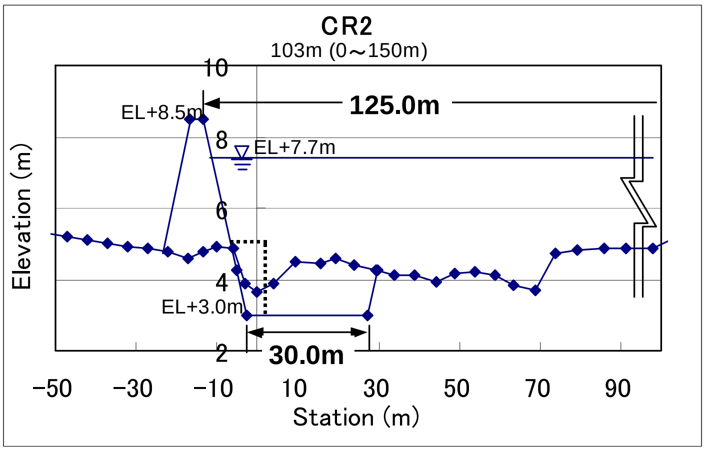
THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES	**Fig. F-4-3**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Longitudinal Profile and Typical Cross Sections of Meycauayan River**



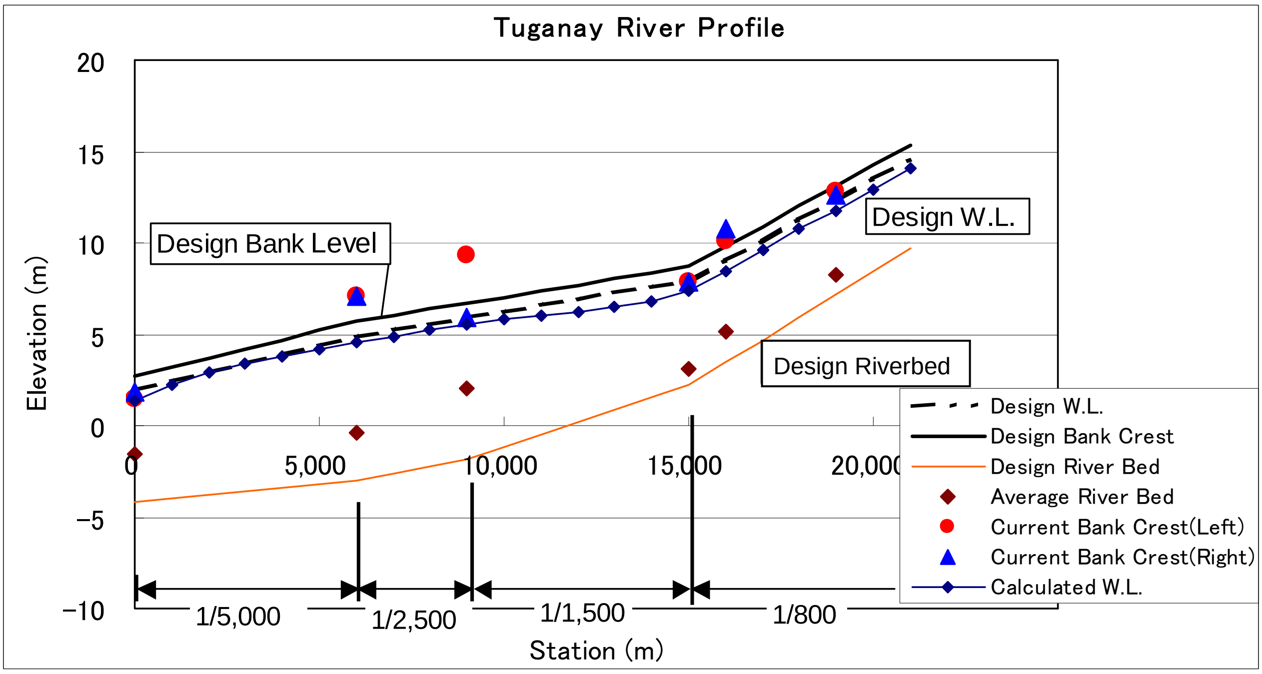
THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES	**Fig. F-4-4** **Longitudinal Profile and Typical Cross Sections of Marilao River**
JAPAN INTERNATIONAL COOPERATION AGENCY	

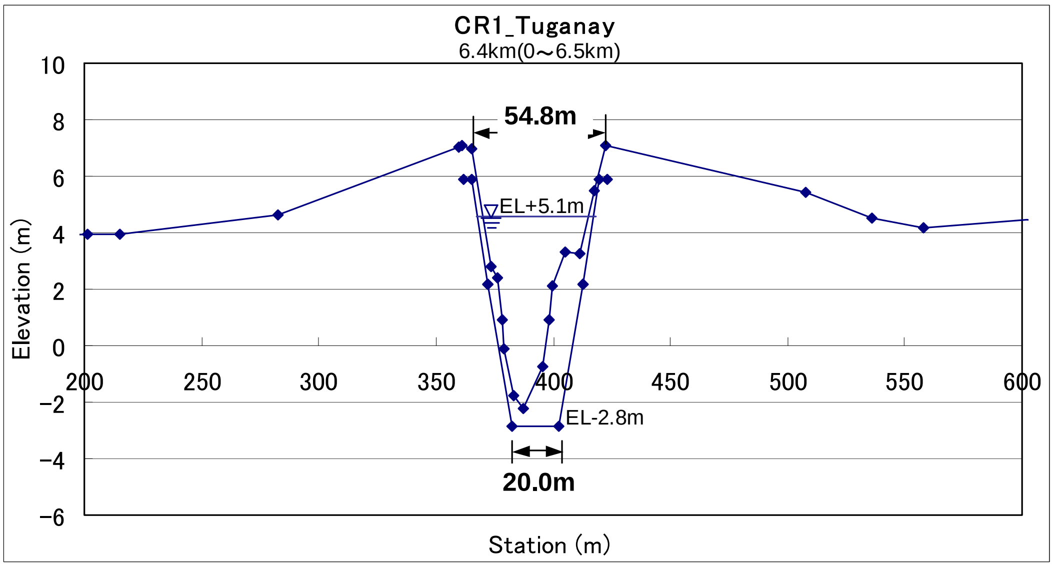


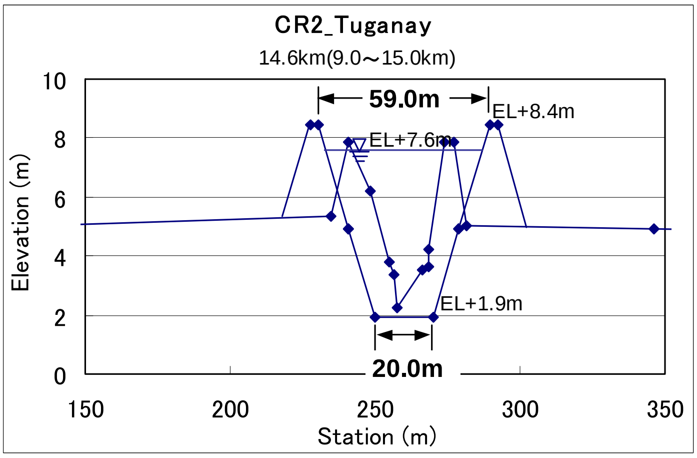




THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES	**Fig. F-4-5**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Longitudinal Profile and Typical Cross Sections of Kinanliman River**





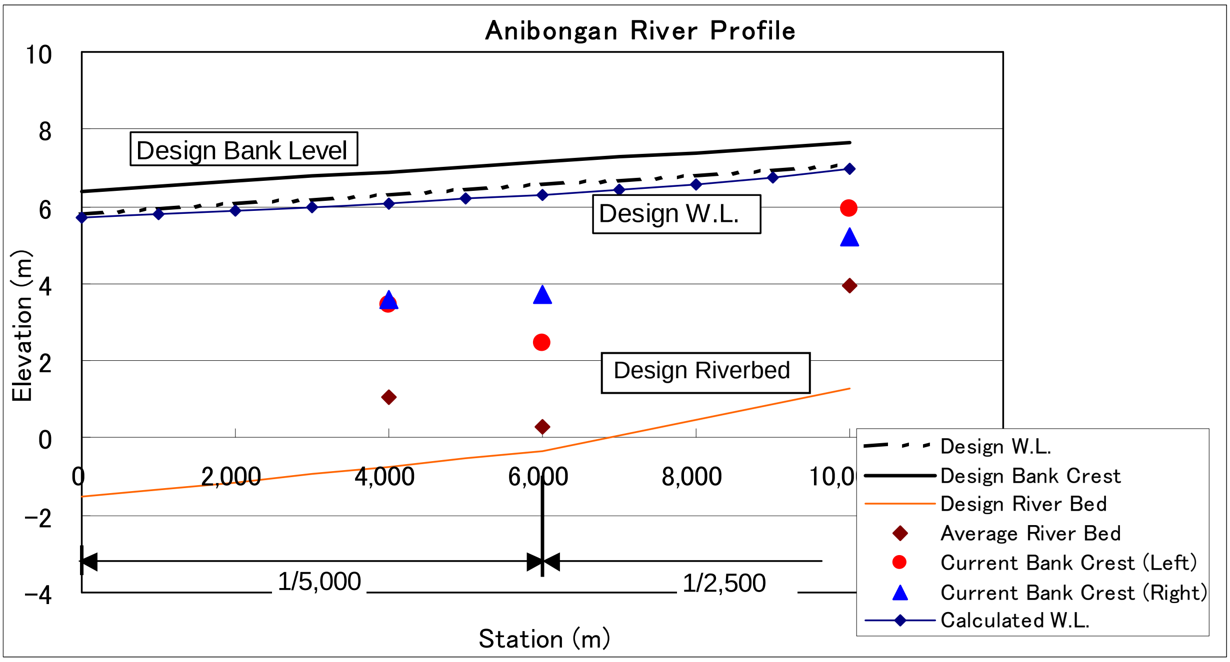


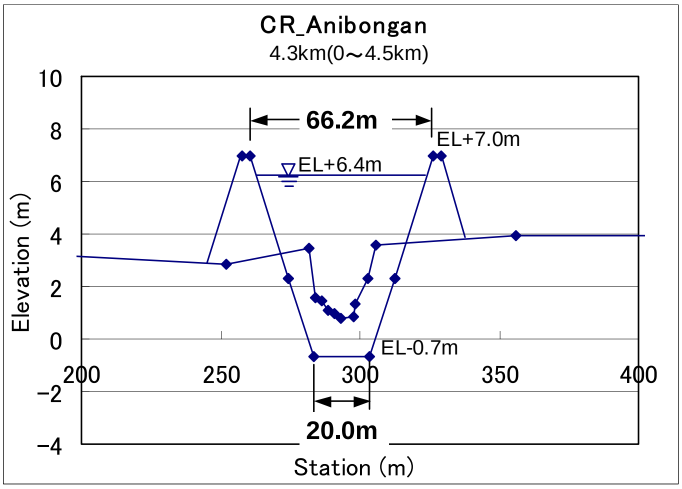
THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

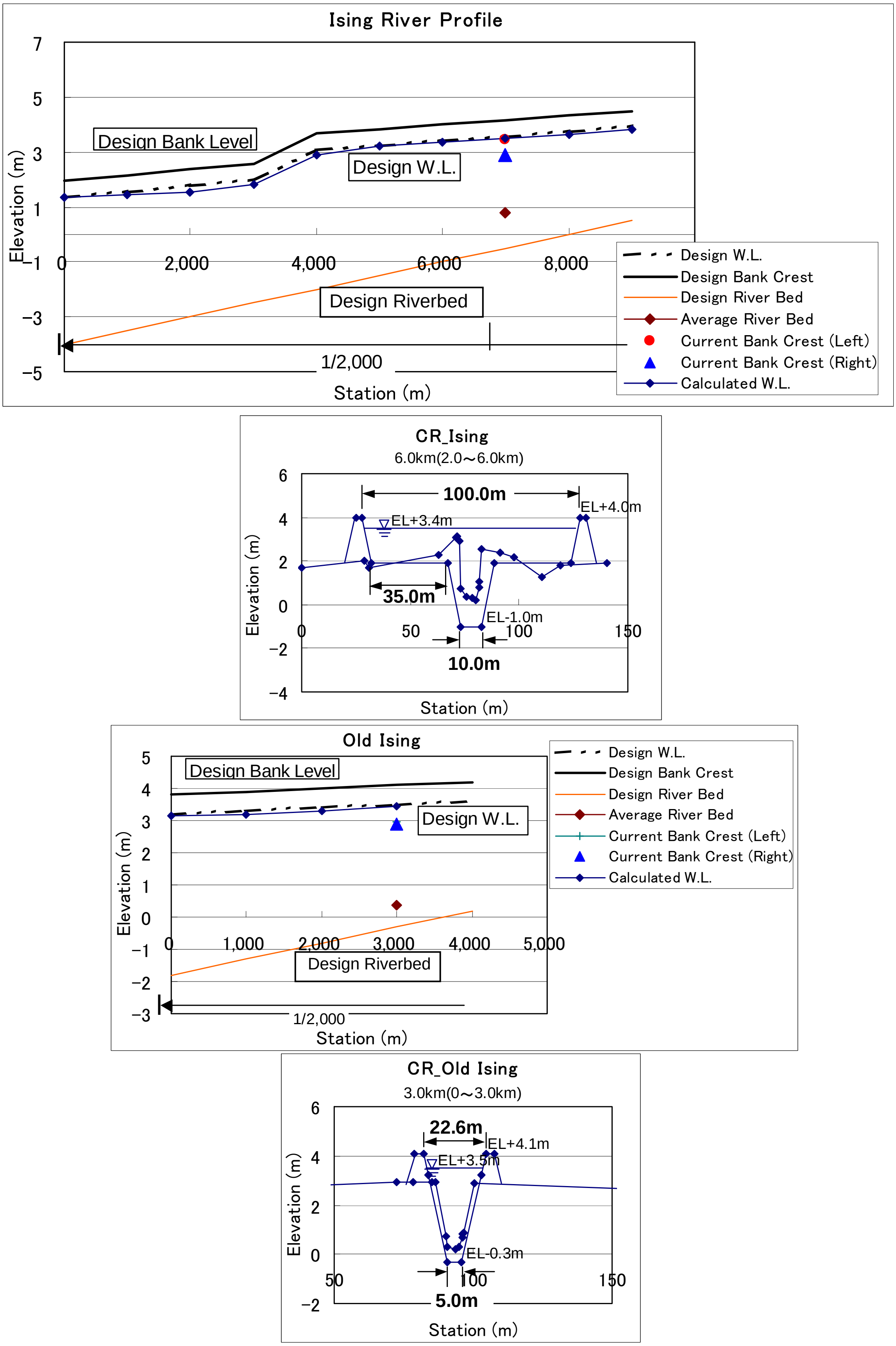
Fig. F-4-6

Longitudinal Profile and Typical Cross Sections of Tuganay River

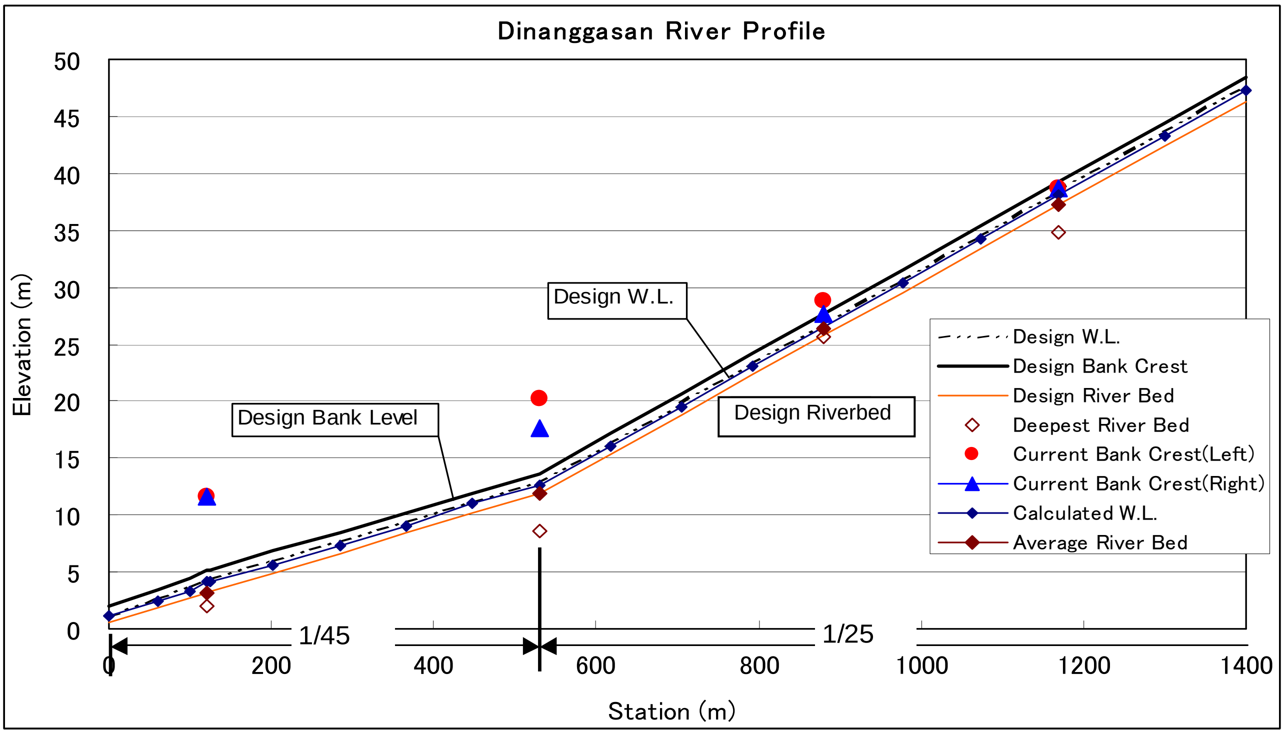


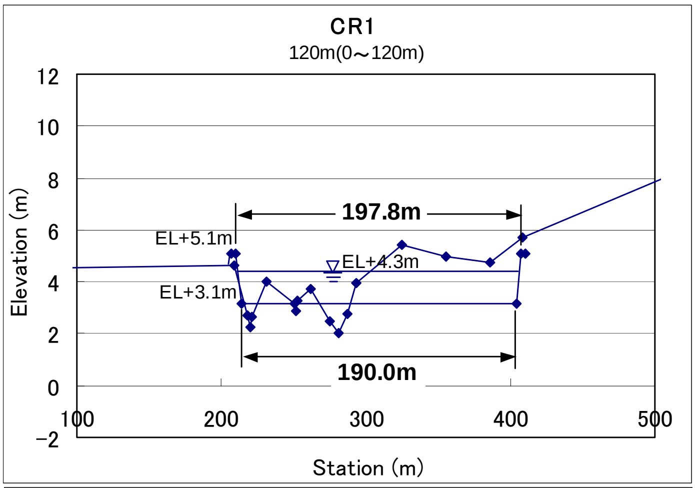


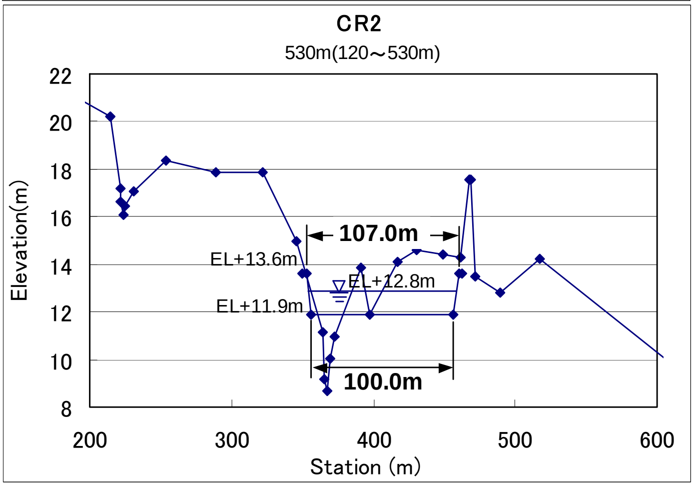
THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES	**Fig. F-4-7** **Longitudinal Profile and Typical Cross Section of Anibongan River**
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES	**Fig. F-4-8** **Longitudinal Profile and Typical Cross Sections of Ising River**
JAPAN INTERNATIONAL COOPERATION AGENCY	







THE STUDY ON THE NATIONWIDE FLOOD RISK ASSESSMENT AND THE FLOOD MITIGATION PLAN FOR THE SELECTED AREAS IN THE REPUBLIC OF THE PHILIPPINES	**Fig. F-4-9**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Longitudinal Profile and Typical Cross Sections of Dinanggasan River**