THE REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS (DPWH)
DAVAO CITY

PROJECT FOR MASTER PLAN AND FEASIBILITY STUDY ON FLOOD CONTROL AND DRAINAGE IN DAVAO CITY

FINAL REPORT
(2 of 2)

JULY 2023

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
PACIFIC CONSULTANTS CO., LTD.

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Foreign Exchange Rate:
Master Plan
US$ 1 = JPY 126
PHP 1 = US$ 0.0192
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FINAL REPORT (2 of 2)
ON
THE PROJECT FOR MASTER PLAN AND FEASIBILITY STUDY ON FLOOD CONTROL AND DRAINAGE IN DAVAO CITY

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ABBREVIATIONS AND TERMINOLOGY

ADB	Asian Development Bank
AIDS	Acquired Immunodeficiency Syndrome
ASU	Ancillary Services Unit
B/C	Benefit／Cost
BDRRMC	Barangay Disaster Risk Reduction Management Council
BFAR	Bureau of Fisheries and Aquatic Resources
BM	Benchmark
BOC	Bureau of Construction
BOD	Bureau of Design
BWPDC	Bukidnon Watershed Protection and Development Council
CAD	Computer Aided Design
CADT	Certificate of Ancestral Domain Title
CCAM	Climate Change Adaptation, Mitigation
CCC	Climate Change Composition
CCTV	Closed-Circuit TeleVision
CDRRMC	City Disaster Risk Reduction Management Council
CDRRMO	City Disaster Risk Reduction Management Office
CENRO	City Environment & Natural Resources Office
CEO	City Engineering Office
CESO	Career Executive Service Officer
CIP	Conservation International Philippines
CLUP	Comprehensive Land Use Plan
CNC	Certificate of NonCoverage
C/P	Counterpart
CPDO	City Planning Development Office
CSSDO	City Social Services Development Office
DAO	DENR Administrative Order
DCDRRMO	Davao City Disaster Risk Reduction Management Office
DCCEO	Davao City City Engineering Office
DCPDO	Davao City Planning Development Office
DCWMC	Davao City Watershed Management Council
DGMC	Davao Gulf Management Council
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DEO	District Engineering Office
DFL	Danger Flood Level
DGCS	Design Guideline, Criteria and Standards
DIAS	Data Integration & Analysis System
DILG	Department of Interior and Local Government
DOST	Department of Science and Technology
DOTr	Department of Transportation
DPWH	Department of Public Works and Highways
DRBFFWC	Davao River Basin Flood Forecasting and Warning Center
DRRM	Disaster Risk Reduction and Management
DSM	Digital Surface Model
DSWD	Department of Social Welfare and Development
DTM	Digital Terrain Model
ECA	Environmental Critical Areas
ECC	Environmental Certificate Clearance
ECP	Environmental Critical Projects
EIRR	Economic Internal Rate of Return
EISS	Environmental Impact Statement System
EMB	Environmental Management Bureau

ENPV	Economic Net Present Value
EORC	Earth Observation Research Center
ESSD	Environmental and Social. Safeguards Division
FC	Foreign Cost
FCMC	Flood Control and Management Cluster
FCMO	Flood Control Management Office
FFWC	Flood Forecasting and Warning Center
F/S	Feasibility Study
GCP	Ground Control Point
GHG	Greenhouse Gas
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GSMaP	Global Satellite Mapping of Precipitation
HEC-HMS	Hydrologic Engineering Center- Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HIV	Human Immunodeficiency Virus
HWL	High Water Level
ICC	Investment Coordination Committee
ICHARM	International Centre for Water Hazard and Risk Management
IDIS	Interface Development Interventions Inc.
IEC	Information, Education, and Communication
IEE	Initial Environmental Examination
IFSAR	Interferometric Synthetic Aperture Radar
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
ISF	Informal Settler Family
ITR	Interim Report
IUCN	International Union for Conservation of Nature
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
JICS	Japan International Cooperation System
JMA	Japan Meteorological Agency
JPT	JICA Project Team
JPY	Japanese Yen
JRA	Japanese Re-Analysis
JST	Japan Standard Time
KBA	Key Biodiversity Area
KEC	Korean Engineering Company
LC	Local Cost
LDRRMF	Local Disaster Risk Reduction and Management Fund
LGU	Local Government Unit
LiDAR	Light Detection and Ranging
MCM	Million Cubic Meters
MDRRMC	Municipality Disaster Risk Reduction Management Council
MGB	Mines and Geosciences Bureau
MHW	Mean High Water
MHHW	Mean Higher High Water
MinDA	Mindanao Development Authority
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MLW	Mean Low Water
MLLW	Mean Lower Low Water
M/M	Minutes of Meetings
M/P	Master Plan
MSL	Mean Sea Level
MRP	Mindanao Railway Project

NAMRIA	National Mapping and Resource Information Authority
NCCAP	National Climate Change Action Plan
NCIP	National Commission on Indigenous Peoples
NDC	Nationally Determined Contribution
NDRRMF	National Disaster Risk Reduction and Management Fund
NDRRMP	National Disaster Risk Reduction and Management Plan
NEDA	National Economic Development Authority
NEPC	National Environmental Protection Council
NFSCC	National Framework Strategy on Climate Change
NGO	Non Governmental Organization
NHA	National Housing Authority
NIA	National Irrigation Administration
NOAA	National Oceanic and Atmospheric Administration
NSO	National Statistics Office
NWRB	National Water Resources Board
NWSA	National Water Security Act
OCD	Office of Civil Defense
ODA	Official Development Assistance
OIC	Officer in Charge
OJT	On-the-Job Training
ORI	Ortho-Rectified Image
PAGASA	Philippine Atmospheric Geophysical and Astronomical Services Administration
PCUP	Presidential Commission for the Urban Poor
PD	Presidential Decrees
PD	Project Description
PDRRMC	Provincial Disaster Risk Reduction Management Council
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PHP	Philippine Peso
PIA	Project Impact Analysis
PPA	Philippine Ports Authority
PPD	Project Preparation Division
PRECIS	Providing Regional Climates for Impacts Studies
PRS	Philippine Reference System
PSCG	Pre-stressed Concrete Girder
RAP	RoW Action Plan / Resettlement Action Plan
RBCO	River Basin Control Office
RCDP	Regional Cities Development Project
RCM	Regional Climate Model
RCP	Representative Concentration Pathways
R/D	Record of Discussion
RDC	Regional Development Council
RO	Regional Office
ROW	Right-Of-Way
RTK	Real Time Kinematic
SCS	Soil Conservation Service
SEA	Strategic Environmental Assessment
SLR	Sea Level Rise
SLSC	Standard Least-Squares Criterion
SRTM	Shuttle Radar Topography Mission
SWAN	Simulating WAves Nearshore
SWMM	Storm Water Management Model
TDD	Tagum - Davao - Digos
TGBM	Tide Gauge Benchmark
TOR	Terms of Reference
TWG	Technical Working Group
UAV	Unmanned Aerial Vehicle

UP	University of the Philippines
UPMO	Unified Project Management Office
US$	United States Dollar
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
UTM	Universal Transverse Mercator
WGS	World Geodetic System

Chapter 4 Feasibility Study

4.1 Priority Project and Preliminary Design of Structural Measures Targeted for Feasibility Study for Riverine Flood in Davao River

4.1.1 Priority Project of Structural Measures Targeted for Feasibility Study for Riverine Flood in Davao River

(1) Overview of Priority Project (Structural Measure) Target for Feasibility Study

As described in Chapter 3 Master Plan, the priority project constitutes riverbed dredging, retarding ponds, and cut-off channels at the meandering portion of the river.

Riverbed dredging work executes dredging of the existing river in the stretch from the river mouth to 23km upstream as much as maintaining the stability of the existing rive structures.

Retarding ponds work installs 3 retarding ponds out of 7 retarding ponds that are planned in M/P. The 3 retarding ponds, which are RP 08, RP 09, and RP 11, have been determined by constructibility, the number of relocation houses and earthwork volume for installation of a unit control volume (see Table 4.1.1).

Cut-off at the meandering portion of the river executes cut-off work from STA 6+500 to STA 12+700, which the river is meandering continuously.

Solving the riverine flood caused by approximately 10-year scale floods is the target of the project, and these countermeasures would be executed for reaching the target.

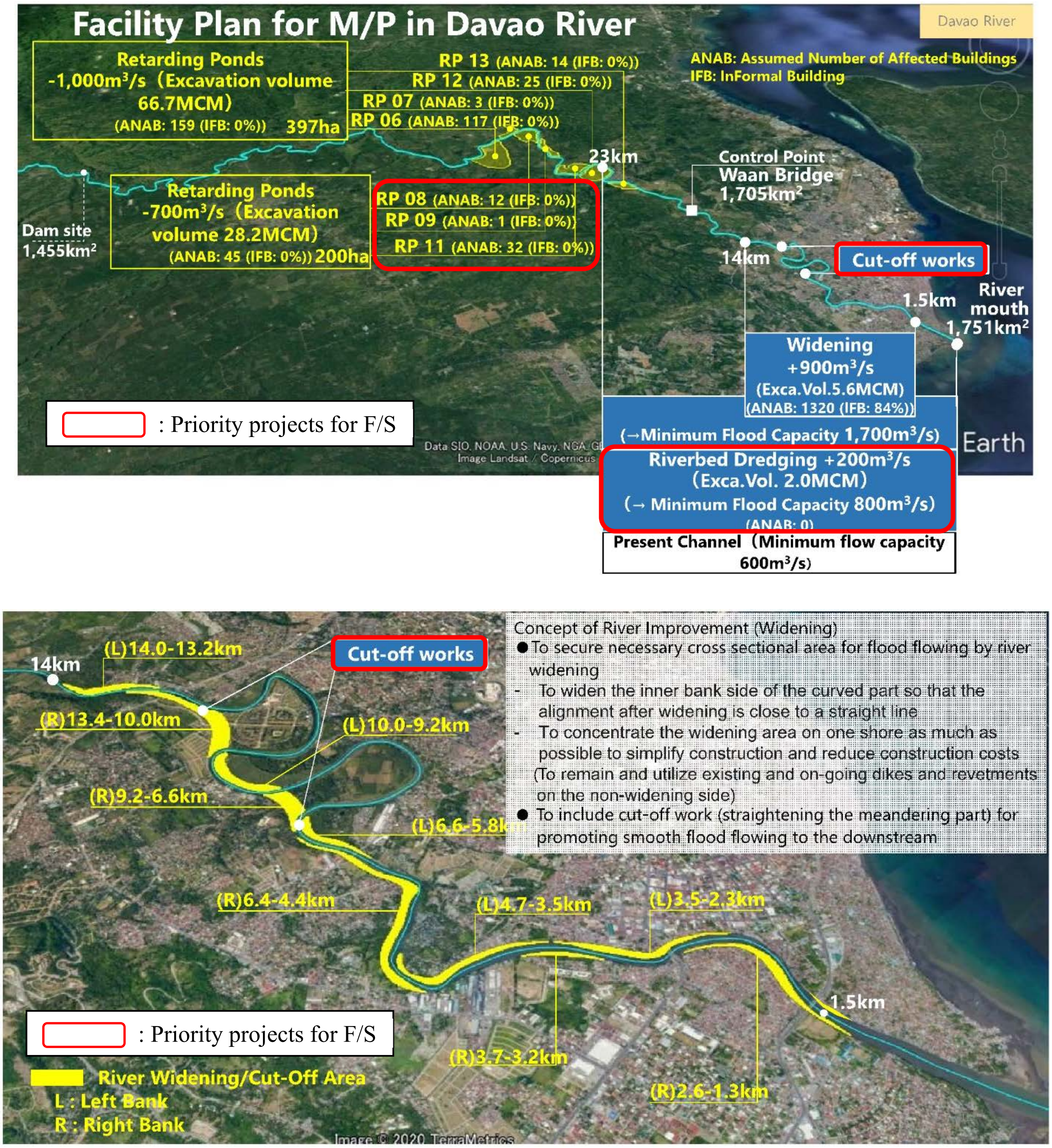
Table 4.1.1 Priority Projects Targeted for Feasibility Study

Item	Target Portion	Remarks
Riverbed Dredging	STA 0+500 – STA 23+000 (L=18.0km) (Target Area of Riverine Flood Control)	STA 0+000 would be excluded since that is located in Davao Bay. The extension of the dredging works reflects the cut-off work.
Retarding Ponds	RP 08 (Right-bank side of STA 29+000), RP 09 (Left-bank side of STA 27+200), RP 11 (Left-bank side of STA 23+800)	
Cut-off Channels	STA 6+500 – STA 12+700 (L=1.3km)	The extension of the Cut-off works would be the portion from STA 6+500 to STA 9+260 and STA 9+870 to STA 12+675.

Source: Project Team

(2) Target Area of Priority Project (Structural Measure) Target for Feasibility Study

The target area of the priority project for the feasibility study is shown in Figure 4.1.1.



Source: Project Team

Figure 4.1.1 Conceptual Drawing of Priority Project for F/S

4.1.2 Additional Topographic and River Surveys for Structure Measures of the Priority Project Targeted for Feasibility Study for Riverine Flood in Davao River

(1) Outline of Additional Topographic and River Survey

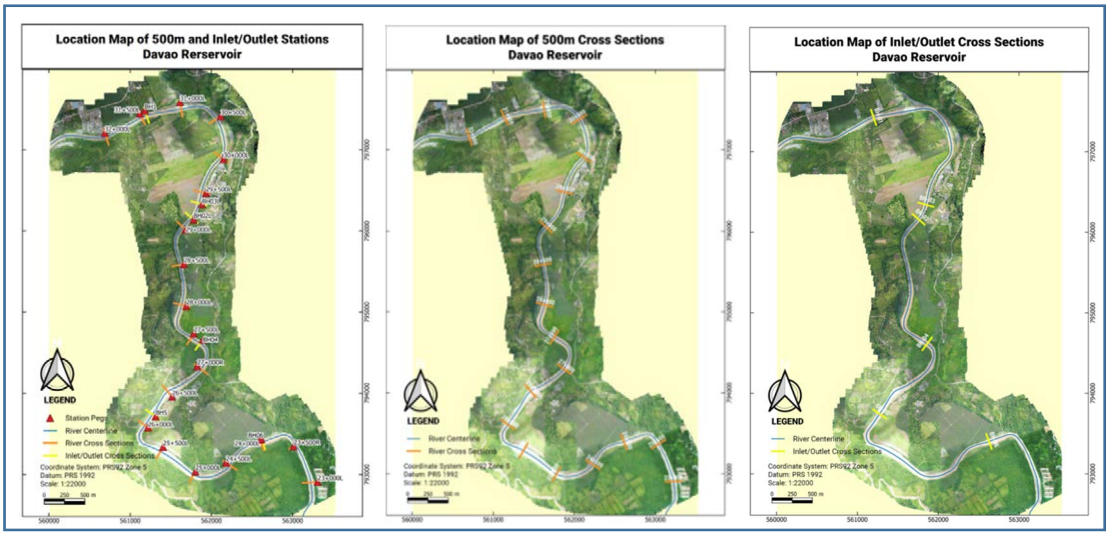
For the facilities (Retarding Ponds) subject to F/S as a priority project in the Davao River, the additional topograhic and river survey were condacted on the Reservoir Area. The survey works was subcontracted to a local survey firm and carried out during the period from April 2021 to August 2021 in accordance with the terms, conditions, requirements of the Sub-contract Agreement and Terms of Reference (TOR) under the supervision of the JICA Project Team.. The work items and quantity are as Table 4.1.2.

Table 4.1.2 Work Item and Work Quantity (Additional Topographic and River Survey)

Work Item	Quantity
1. River and Topographic Survey of F/S Targeted Structure (Reservoir Area)	
1.1 River Longitudinal Survey (Station No. 23+000 – 32+000)	9 km
1.2 River Cross Sectional (C/S) Survey (Interval of C/S : 500m pitch, Width : 200m)	19 sections
1.3 River Cross Sectional Survey on Inlet and Outlet (Site:3, Width: 200m)	6 sections
1.4 Ortho-photo Mapping by UAV(including GCP survey:10points)	500 ha

Source : Project Team

The TOR was prepared making reference to "Specifications of Overseas Surveying Works for Development Study by JICA in 1982". In addition, the survey standard of the TOR was used the map coordinate system (Horizontal Datum:PRS92, Map Projection System: PTM coordinates) and the elevation (Mean Sea Level of Philippines) of NAMRIA.



Source : Project Team

Figure 4.1.2 Location of Topographic and River Survey on the Reservoir Area (River Cross section Points, Longitudinal & Cross Sectional Survey and Outlet and Inlet Cross Sectional Survey)

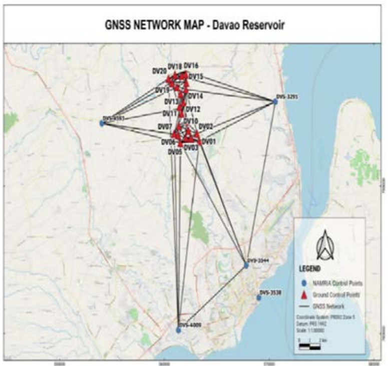
(2) Topographic and River Survey on Reservoir Area

The topographic and river survey on the reservoir area of the Davao River (Station No. 23+000 – 32+000) consists the setting up of river cross section points, river longitudinal survey, river cross sectional survey and ortho-photo mapping were conducted. Information on survey location maps, surveying methods and output covering the reservoir area are as follows.

1) Setting up of River Cross Section Points

19 river cross section points were set up at 500 m pitches along the Davao River (Station No. 23+000 – 32+000) and 6 river cross section points were set up at inlet/outlet of the Reservoir Area. Setting up of the river cross section points were carried out by GCP survey from NAMRIA GCPs and Benchmarks, and it obtained the geo-coordinates and elevation of the river C/S points. Accuracy coordinates and elevation for setting up of river crossing are as follows.

・Accuracy of coordinates : 1/8,000 (From NAMRIA GCP and closed loop by GNSS travers)
・Accuracy of elevation : 40mm√ km （From NAMRIA Benchmarks, Levelled twice）



DAVAO RESERVOIR CROSS SECTION POINTS

STATION	NORTHING	EASTING	ELEVATION
23+000L	792908.789	563307.532	19.477
23+500R	793348.167	563013.270	12.897
24+000L	793430.684	562597.801	14.846
24+500L	793146.048	562179.588	16.160
25+000L	793035.975	561803.066	16.190
25+500L	793340.317	561405.035	22.604
26+000L	793581.877	561218.598	21.871
26+500L	793955.529	561515.752	22.717
27+000R	794332.277	561824.407	24.029
27+500L	794734.585	561783.563	24.909
28+000L	795074.373	561691.456	26.518
28+500L	795591.006	561662.304	25.941
29+000L	796019.225	561683.595	25.758
29+500L	796468.886	561933.727	25.330
30+000L	796888.932	562148.784	27.630
30+500L	797413.972	562115.575	22.538
31+000L	797587.206	561613.540	26.294
31+500L	797445.806	561118.847	32.692
32+000L	797207.513	560687.684	33.017

DAVAO RESERVOIR INLET/OUTLET CROSS SECTION POINTS

STATION	NORTHING	EASTING	ELEVATION
BH01	797484.053	561180.196	32.077
BH02L	796142.310	561780.092	20.317
BH03L	796332.502	561884.985	23.837
BH04	794660.115	561895.079	23.312
BH5	793717.325	561314.310	22.792
BH06	793436.689	562615.576	15.113

Source : Project Team

Figure 4.1.3 Location Map of River Cross Section Points and its data on the Reservoir Area

2) River Longitudinal Survey

River longitudinal survey were carried out to obtain the coordinates and elevation of the river canter line of Davao River (Station No. 23+000 – 32+000). The location map of the river longitudinal survey is shown in Figure 4.1.2. Accuracy of the survey from a river cross section points is as follows.

・Accuracy of coordinates : ±3 cm /Riparian area, ±5 cm/Water area
・Accuracy of elevation : ±3 cm /Riparian area, ±5 cm/Water area

3) River Cross Sectional Survey

The River Cross Sectional Survey was carried out to obtain geo-coordinate and elevation of the river cross section of Davao River (19 sections, width: 200 m) and inlet/outlet of the Reservoir Area (6 sections, width: 200 m). The location map of the river cross sectional survey is shown in Figure 4.1.2. Accuracy of the survey from river cross section points is as follows.

・Accuracy of coordinates : ±3 cm /Riparian area, ±5 cm/Water area
・Accuracy of elevation : ±3 cm /Riparian area, ±5 cm/Water area

4) Ortho-photo Mapping by UAV

Ortho-photo mapping by UAV were carry out covering the Reservoir Area of Davao River (Station No. 23+000 – 32+000). Ground resolution of aerial photos by UAV measurement was 10 cm and coverage area was 500ha. Ortho-photos were prepared using coordinates and elevation data of additional GCP Survey.

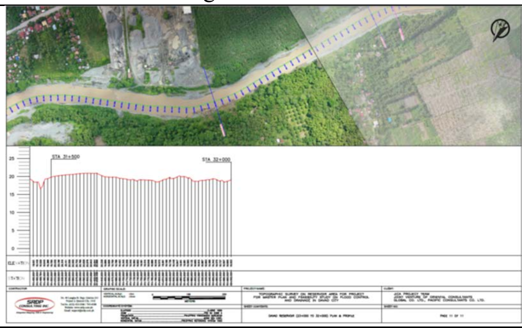
5) Output

Output is as follows:

Table 4.1.3 List of Output and Quantity (Reservoir Area)

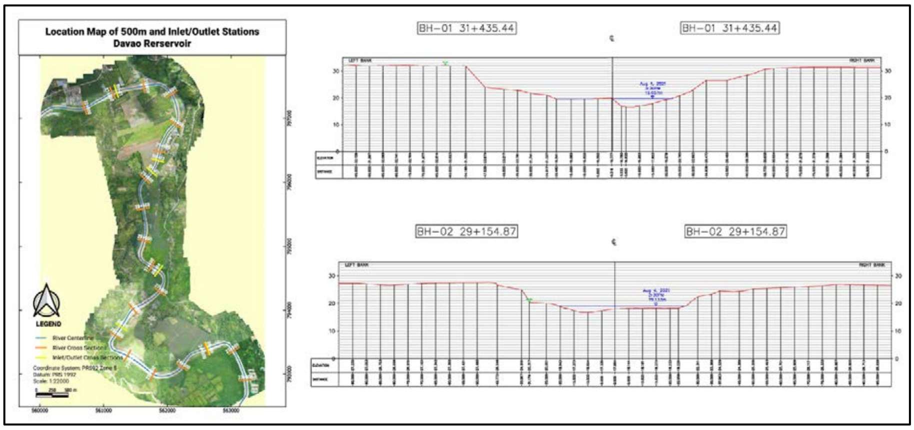
Output	Quantity (Hard & Soft Copy)	
1. River and Topographic Survey of F/S Targeted Structure (Reservoir Area)	**A4 size**	**A3 size**
1.1 Survey Mark Description of 100m Station No. Pegs	2sets	-
1.2 River Longitudinal Survey Data	1set	-
1.3 River Profile Section Data	2set	1set
1.4 River Cross Sectional Survey Data	2sets	-
1.5 River Cross Section Data	2set	1set
1.6 Cross Sectional Survey Data (Inlet/Outlet)	2sets	-
1.7 Cross Sectional Survey Data (Inlet/Outlet)	2set	1set
1.8 Ortho-photo Mapping by UAV and GPS Data	1set	-
1.9 Ortho-photo Map Data	2set	1set
1.10 Survey Report	2sets	-

Source：Project Team

23km Starting Point of Profile Section	Davao River	32km Ending Points of Profile Section
		

Source: Project Team

Figure 4.1.4 River Longitudinal Sections (Reservoir Area)



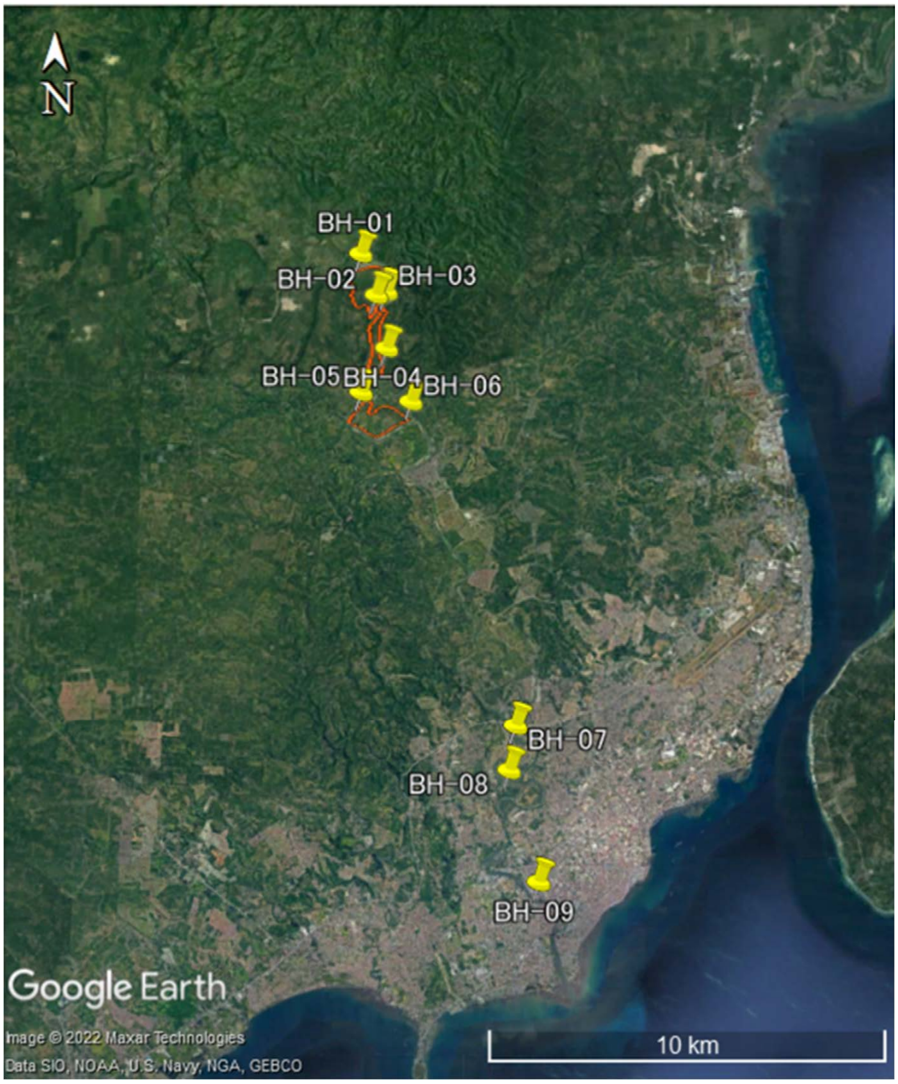
Source：Project Team

Figure 4.1.5 Ortho-photo and River Cross Sections (Reservoir Area)

4.1.3 Geotechnical Investigation for Structure Measures of the Priority Project Targeted for Feasibility Study for Riverine Flood in Davao River

(1) Outline of Geotechnical Investigation

Geotechnical investigations were carried out for the preliminary design of structures for the priority projects listed in the feasibility study. A total of six boreholes (BH01 to BH06) were drilled at inlet/outlet locations of the retarding ponds (RP08, RP09 and RP11), together with two other locations (BH07 to BH08) in the upstream and downstream sections of the cut-off channel. (BH09 is omitted from this section as it is a pre-F/S structure location).



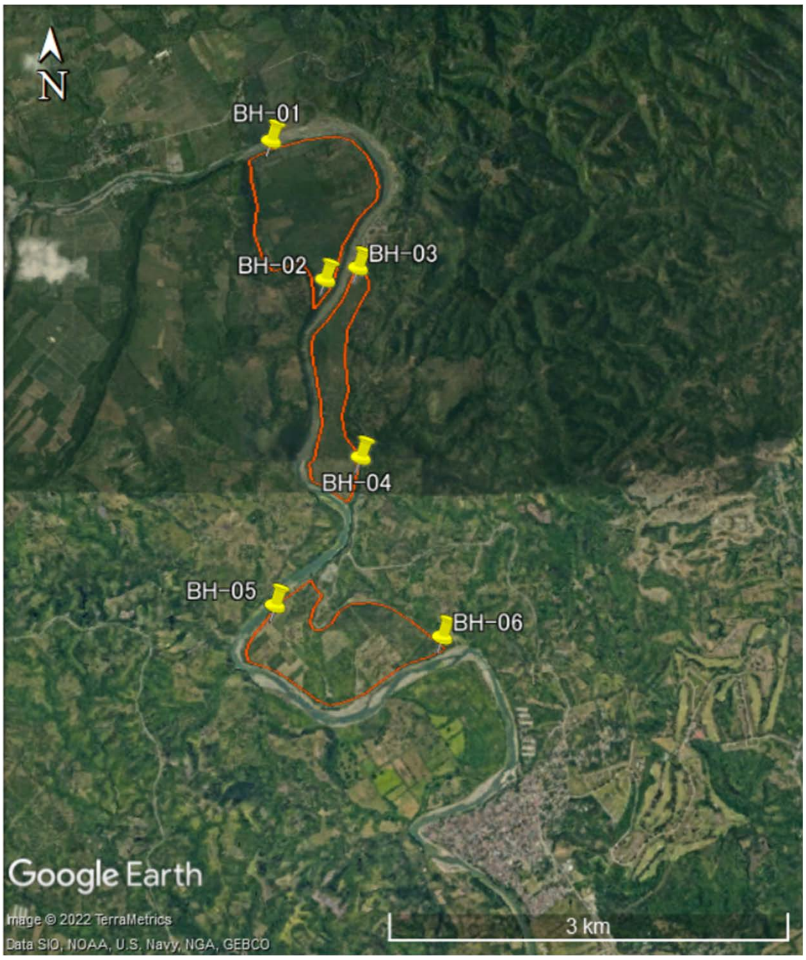
Source: Project Team

Figure 4.1.6 Geotechnical survey location maps for priority projects for F/S (BH-1-BH-8)

Table 4.1.4 List of Geotechnical survey location for priority projects for F/S (BH-1-BH-8).

No.	Coordinate Location		Description with type of structure assumed
	N	E	
BH-1	7°12'33.97"N	125°33'20.34"E	Retarding Pond RP08 (Inlet location)
BH-2	7°11'59.61"N	125°33'35.77"E	Retarding Pond RP08 (Outlet location)
BH-3	7°11'57.14"N	125°33'41.92"E	Retarding Pond RP09 (Inlet location)
BH-4	7°11'10.34"N	125°33'42.34"E	Retarding Pond RP09 (Outlet location)
BH-5	7°10'45.94"N	125°33'33.18"E	Retarding Pond RP11 (Inlet location)
BH-6	7°10'30.58"N	125°34'6.42"E	Retarding Pond RP11 (Outlet location)
BH-7	7° 6'0.88"N	125°35'38.43"E	Cut-off channel upstream section (revetment / embankment)
BH-8	7° 5'25.38"N	125°35'33.88"E	Cut-off channel downstream section (revetment / embankment)
BH-9	7° 4'8.12"N	125°35'49.24"E	Channel Widening (revetment / embankment) *Pre-F/S project

Source: Project Team



Source: Project Team

Figure 4.1.7 Geotechnical survey location maps for priority projects for F/S (BH-1-BH-6)

Source: Project Team

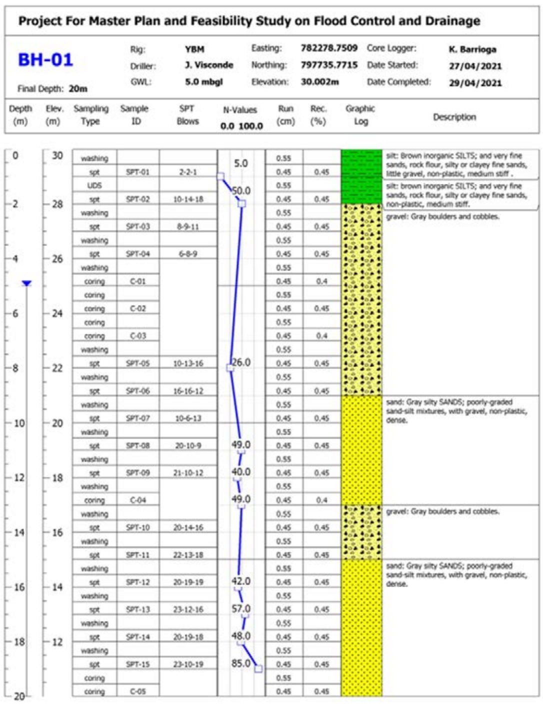
Figure 4.1.8 Geotechnical survey location maps for priority projects for F/S (BH-7-BH-8)

(2) Geotechnical Investigation on Reservoir Area

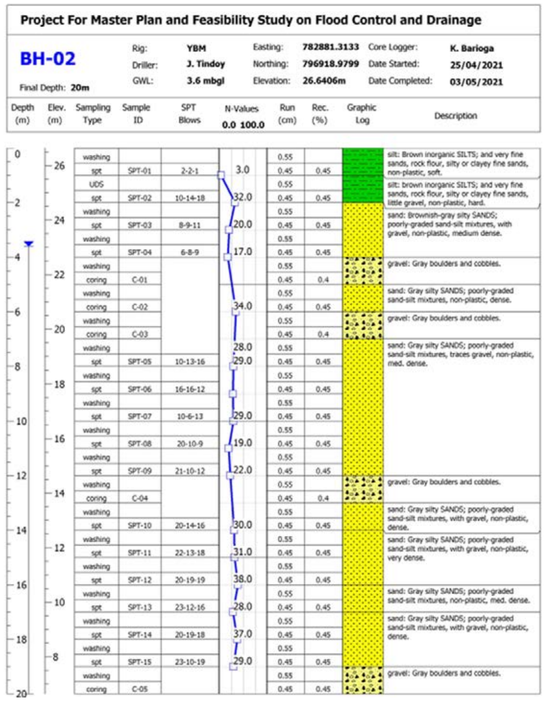
The results of the geotechnical investigations at the retarding pond (RP08, RP09 and RP11) locations are shown below.

1) Retarding Pond: RP08

At the retarding pond: RP08, BH-01 and BH-02 were drilled near the inlet and outlet location respectively. The average N value of the sand layer is more than 40 in BH-1 and more than 20 in BH-2, indicating that those sand layers are firm.



BH-01 (RP08 Inlet)



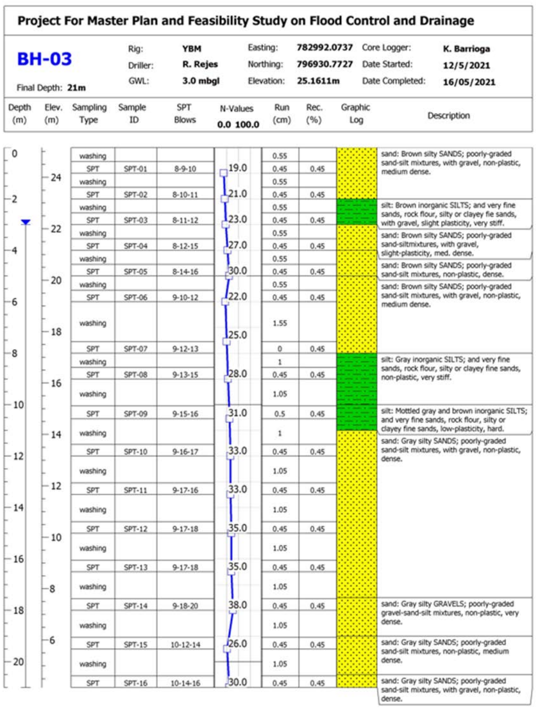
BH-02 (RP08 Outlet)

Source: Project Team

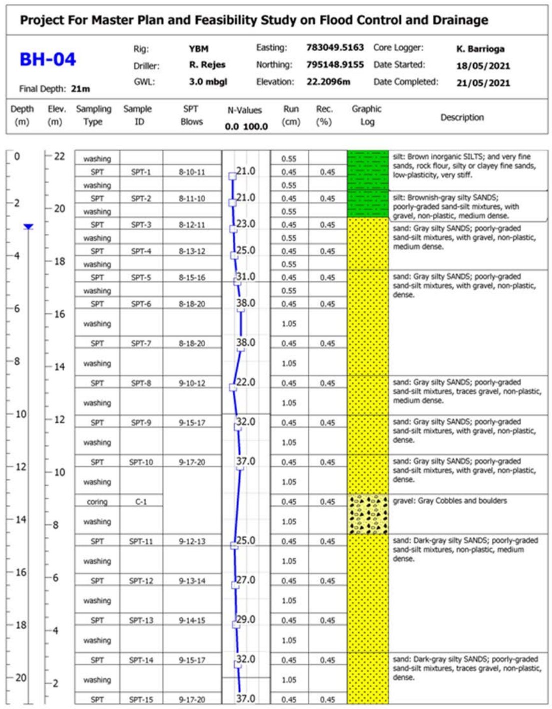
Figure 4.1.9 Geotechnical survey results (BH-01, BH-02)

2) Retarding Pond: RP09

At the retarding pond: RP09, BH-03 and BH-04 were drilled near the inlet and outlet location respectively. Compared to the geotechnical survey results at the retarding pond: RP08 in the upstream, the presence of gravel layers is limited, and it is instead dominated by sand layers (N-values = 20-40) and silt layers (N-values = 20 and above). The silt layers also have large N-values and are firm, with no presence of soft ground.



BH-03 (RP09 Inlet)



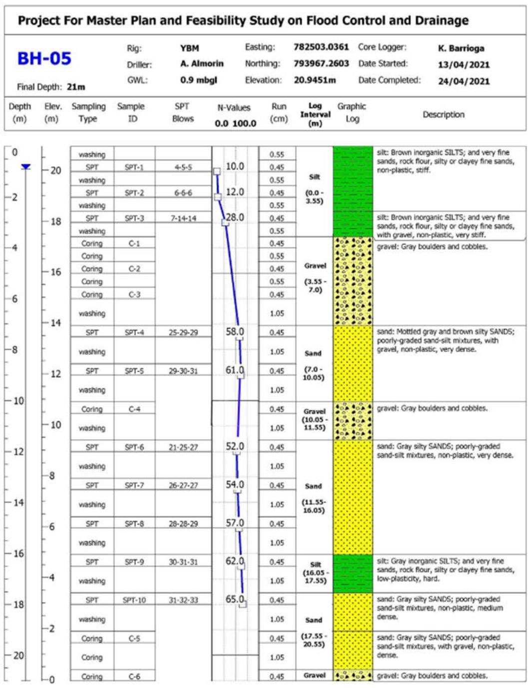
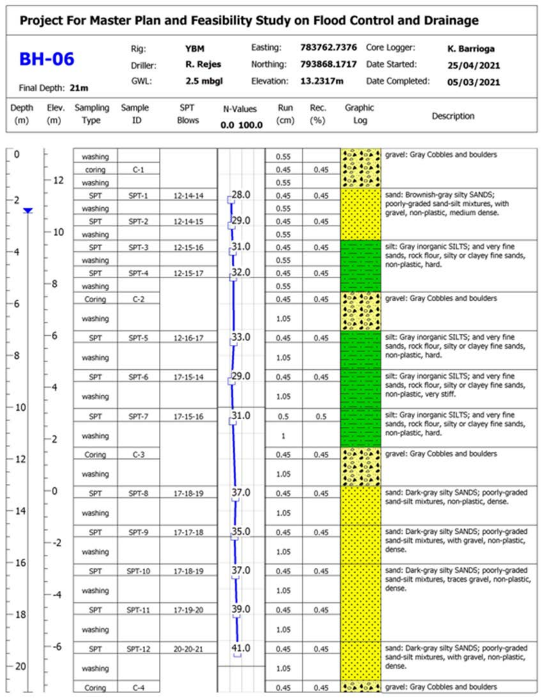
BH-04 (RP09 Outlet)

Source: Project Team

Figure 4.1.10 Geotechnical survey results (BH-03, BH-04)

3) Retarding Pond: RP11

At the retarding pond: RP11, BH-05 and BH-06 were drilled near the inlet and outlet location respectively. Both locations are composed of alternating layers of gravel, sand and silt layers. The N-values of silt layers are above 10 at the surface of BH-05 and above 20 for those distributed deeper, and there is no soft ground. The N-values of the sand layers also show values above 50 in BH-05 and above 30 in BH-06.

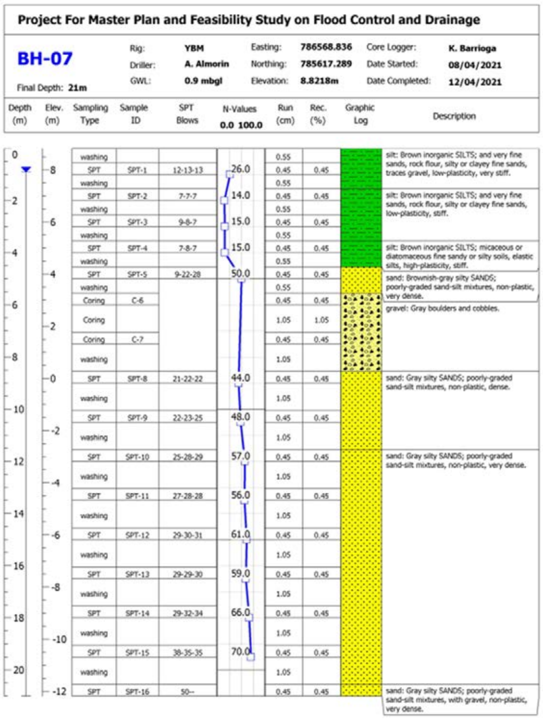
	
BH-05 (RP11 Inlet)	BH-06 (RP11 Outlet)

Source: Project Team

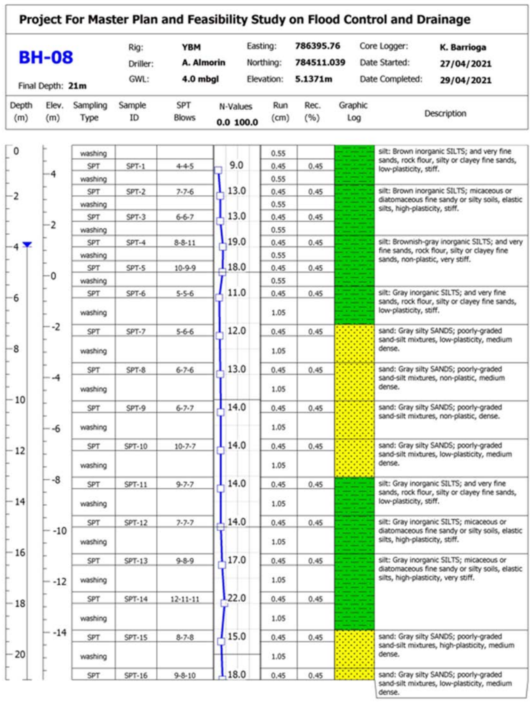
Figure 4.1.11 Geotechnical survey results (BH-05, BH-06)

4) Cut-off Channel Location

At cut-off channel locations, BH-07 was drilled in the upstream section and BH-08 in the downstream section. In the upstream section, BH-07, a silt layer (N value = 14-26) is observed at a depth of about 4 m below the surface, and a sand layer (average N value >50) at deeper depths. In BH-08, silt layers (N-value = 10-20) with a thickness of 6-7 m are seen at the surface and at a depth of 10 m and deeper. There is no soft ground in any of these locations.



BH-07 (Cut-off channel (upstream))



BH-08 (Cut-off channel (downstream))

Source: Project Team

Figure 4.1.12 Geotechnical survey results (BH-07, BH-08)

4.1.4 Hydraulic Study and Setting of Design Conditions for Priority Project (Structural Measure) Target for Feasibility Study

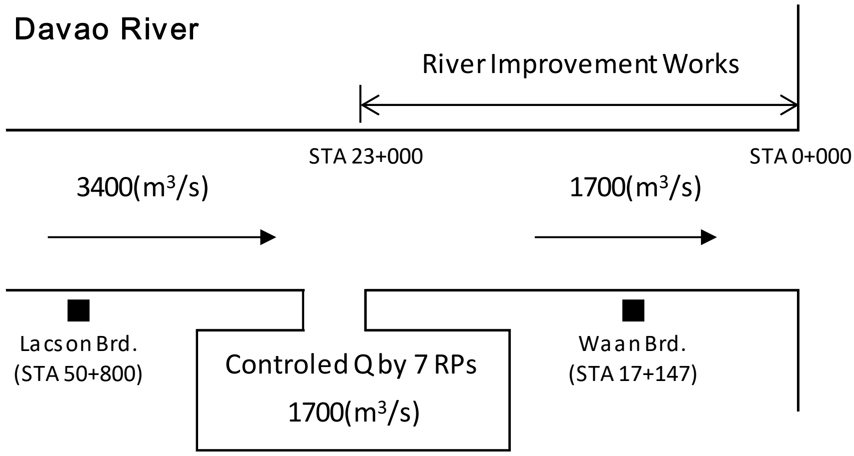
The study of the items indicated below would be carried out for setting the design conditions for the project for F/S.

- ✓ Design river shape (design alignment, design profile, and typical design cross-section)
- ✓ Extent of riverbed dredging (each surveyed cross-section)
- ✓ Water level conditions of retarding ponds (channel water level of inlet/outlet, overflow dike crest level, drainage channel bed level)
- ✓ Design river channel for cut-off reach (typical design cross-section)

(1) Design River Shape

The flood control safety level that is ensured by executing the priority project for F/S would be 5-year to 10-year scale floods. In order to avoid rework for M/P, the design river channel shall be considered with the 100-year scale flood as the target scale for M/P.

As described in Chapter 3 Master Plan, the riverine flood measure in M/P is planned that the design flood discharge of the river channel is 1,700 m^3/s out of the basic design flood discharge of 3,400 m^3/s for the target river reach, which is from STA 0+000 to STA 23+000, and the remaining 1,700 m^3/s would be controlled by retarding ponds. Since the flow capacity of the existing river is 600 m^3/s, as a result of comparison with alternatives of riverbank heightening and channel widening, river channel widening is proposed for flowing 1,700 m^3/s safely by design channel. The way of setting the design river channel is shown below.



Source: Project Team

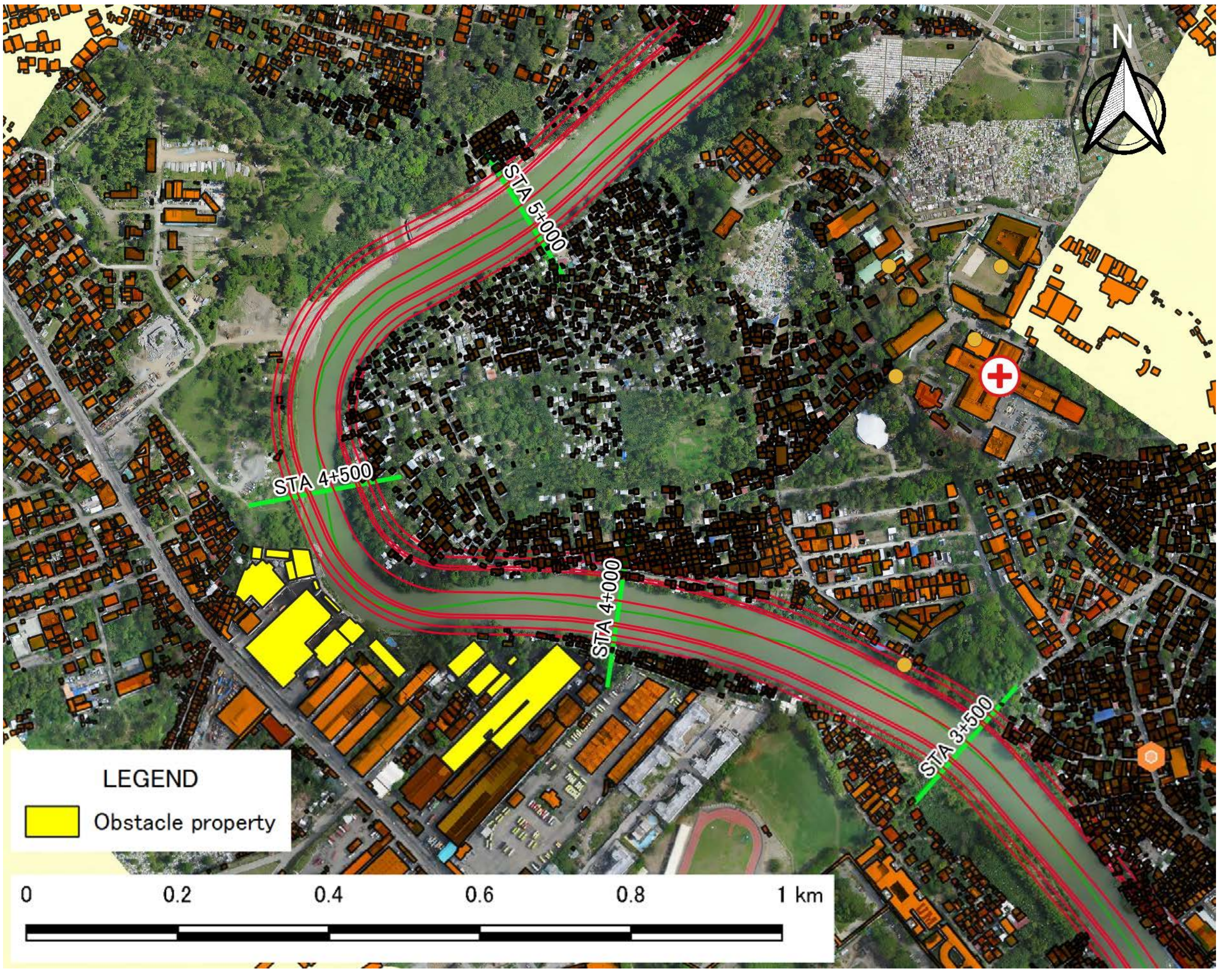
Figure 4.1.13 Design Flood Discharge Distribution of Davao River (100-year scale flood)

1) Plan View Designing

The design alignment of the river channel is set with respect to the existing channel while considering the number of relocation houses due to river improvement work, utilization of the existing revetment, construction period, and project cost, and keeping in mind the widening by one side bank construction. For the river meandering section from STA 6+500 to STA 12+700, cut-off work is applied, and the design river alignment is set to connect smoothly with the existing river channel (see Figure 4.1.14). In addition, as a result of interviews with relevant agencies through C/P regarding compensation properties in the case of river channel widening, it was concluded that it would be difficult to relocate or compensate for the factories on the right bank of STA 4+000 to STA 4+500. Based on this, a comprehensive judgment shall be made in setting the design river alignment. (See Figure 4.1.15).

Source: Project Team

Figure 4.1.14 Design River Alignment of Cut-off Portion



Source: Project Team

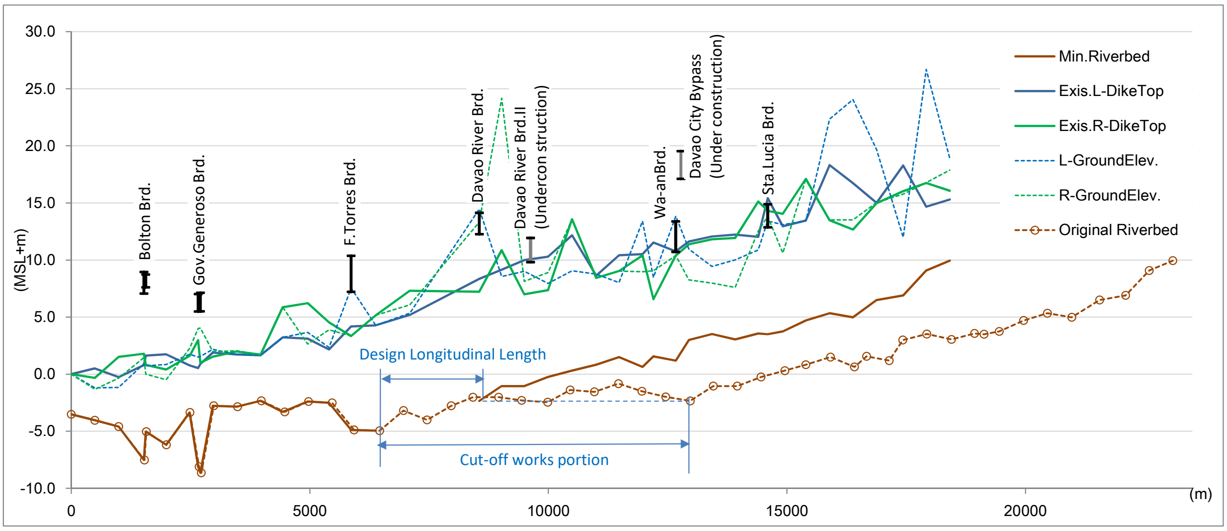
Figure 4.1.15 Location of Obstructive Property along Davao River

2) Longitudinal Profile Designing

The design riverbed elevation and gradient should be generally the same as that of the existing river channel, without major changes to the riverbed gradient or excavation of the riverbed, from the viewpoint of ensuring the stability of the riverbed elevation and biological habitat. The existing longitudinal profile of the target reach can be roughly divided into a downstream section (tidal reach), a midstream section, and an upstream section. The cut-off portion locates in the midstream section, and its length is shorter than that of the existing channel. Therefore, the design profile should be determined in consideration of the stability of the riverbed and the continuity of the biological habitat.

The design river channel is planned to be widened to increase the flow area, and the design high water level is set based on the present ground level. However, since the river mouth needs to be safe even at the high tide level, the design embankment level (revetment height) shall be set for the higher of the design high water level and the design high tide level. In addition, a total of eight bridges (six existing bridges and two bridges under construction) would be constructed in the subject reach. (Here, a bridge in the cut-off portion (near STA 8+500) would also be constructed by DEO, but this bridge is not included in the subject reach.) In order to avoid impacts on the roadside caused by the river widening work, basically, the height of the design water level plus freeboard shall be lower than the height of the bridge girders.

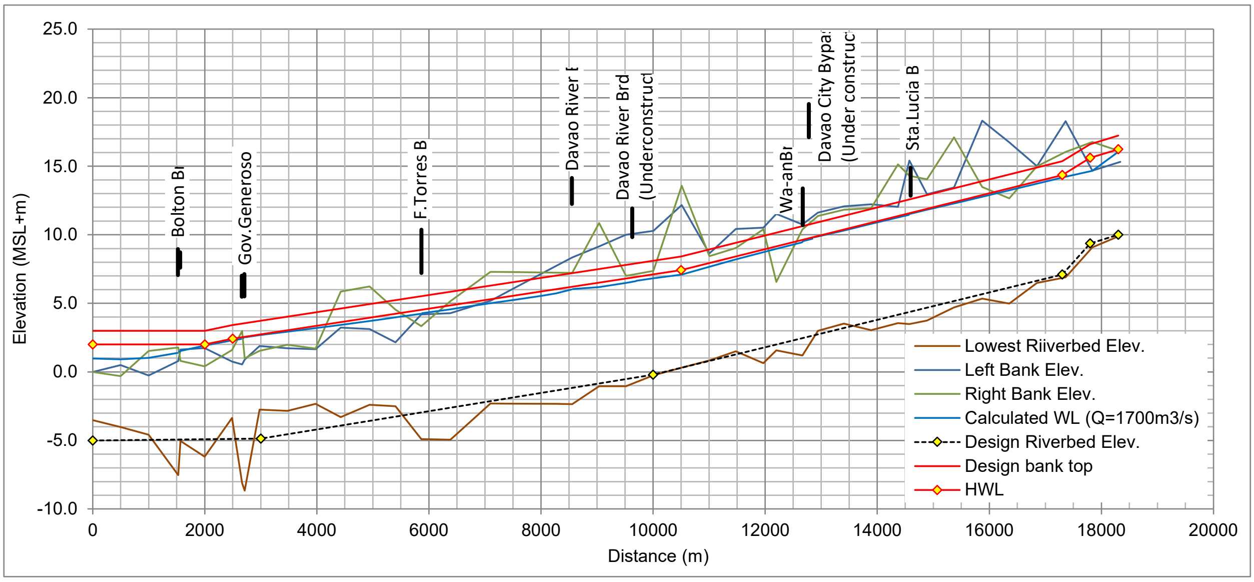
Figure 4.1.16 shows the existing longitudinal profile reflecting the cut-off reach that is set in the design alignment. Based on this, the design profile would be set according to the above-mentioned policy.



Source: Project Team

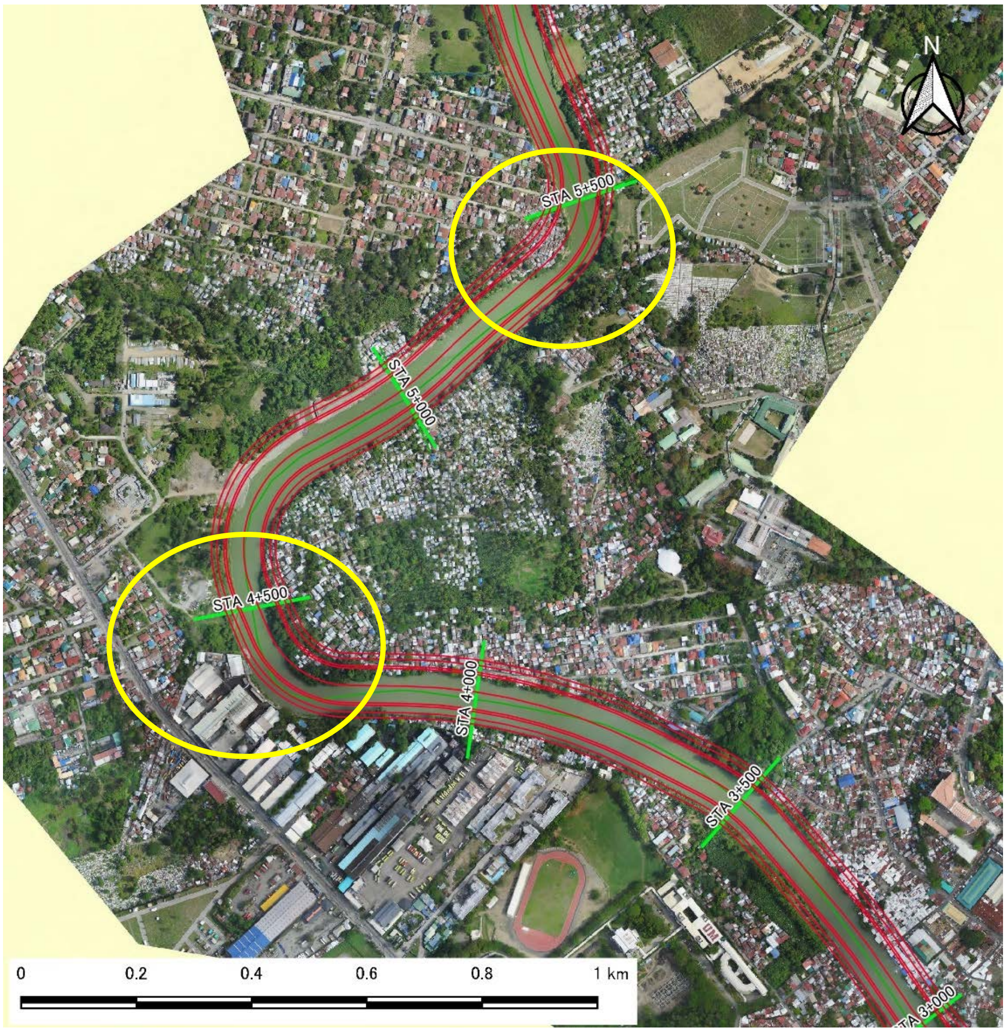
Figure 4.1.16 River Profile after Cut-off Work

Based on the present deepest riverbed profile after the shortcut, as shown in Figure 4.1.17 the target section (STA 0+000 - STA 23+000: L≒18.3 km) was divided into the downstream (tidal reach), midstream, and upstream sections, and the design longitudinal gradient was set. The present riverbed level between the Gov. Generoso bridge and the F. Torres bridge is higher than that of the upstream reach of the F. Torres bridge. This is presumably thought to be due to a decrease in flow velocity immediately upstream of STA 5+500 and around STA 4+500 since the existing river width of these portions is locally narrow as shown in Figure 4.1.18, resulting in localized bed sedimentation. (Conversely, local scouring of the riverbed was observed at the narrow sections based on the results of the longitudinal river survey.) Since these localized narrow sections would be eliminated by river improvement, the design riverbed gradient was set in this section as well as in the section upstream of the F. Torres Bridge, referring to the existing ground level. Although the excavation of 1.0m to 1.5m in this section would cause temporary loss of habitat for organisms living in the riverbed, the habitat would be maintained both upstream and downstream and continuity would be ensured, therefore habitat is expected to recover after the river improvement works.



Source: Project Team

Figure 4.1.17 Design River Profile of Davao River



Source: Project Team

Figure 4.1.18 Existing River Width around STA 4+500 – STA 5+500 of Davao River

Around STA 22+500 (17.8 km from the river mouth), exposed rocks in the channel are shown and the riverbed is fixed (see Figure 4.1.19), therefore, the design riverbed level has been set to maintain the existing riverbed in this stretch.

Regarding the design riverbank level, the design water depth has been set at 7.2 m (design riverbank level is to be added 1.0 m freeboard to this), which is generally the same level as the existing riverbank shoulder. For near the river mouth, the design riverbank level shall be adopted the higher one by comparing the HWL with the storm surge embankment height (MSL+3.00m). HWL has been set by the calculated river water considering the backwater effect, with the condition of the downstream end water level as the mean high water level (MHHW) of MSL+0.981m (considering future rise due to climate change) the channel applies the typical design cross-section.

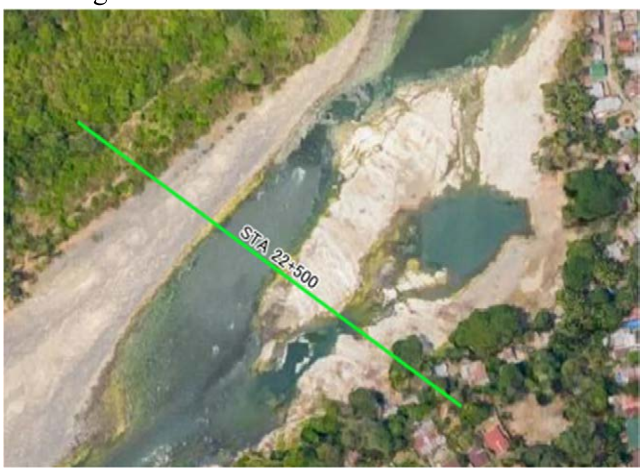
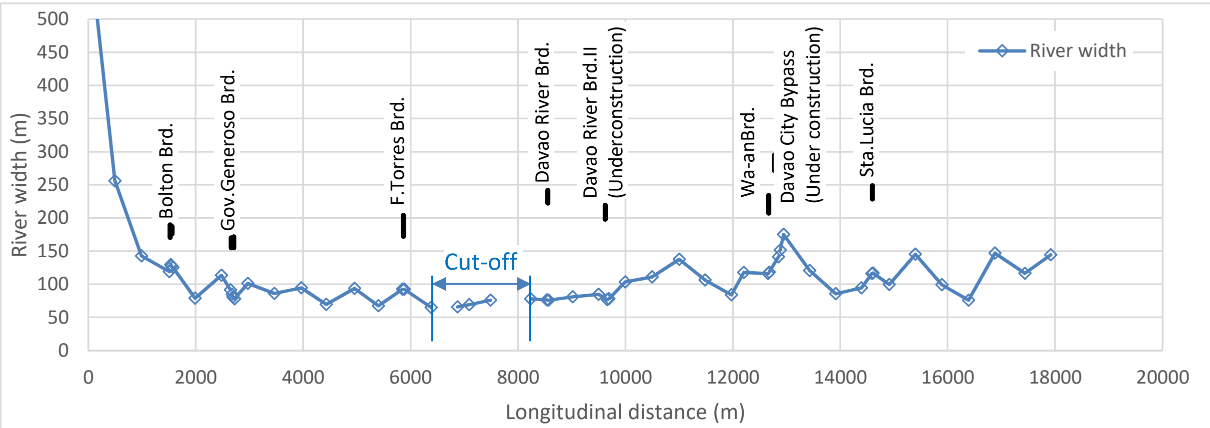


Figure 4.1.19 Exposed Rocks at STA 22+500 of Davao River

3) Typical Design Cross-section

The typical design cross-section is set for each design longitudinal gradient by uniform flow calculation based on the condition that the design flood discharge is constant for the subjected section. In order to increase the river flow area by widening the channel, if the entire riverbed is flattened, the velocity of flow acting on the riverbed during outflow will be too low, which will reduce the effect of the riverbed fluctuation and cause excessive growth of vegetation and tree growth in the river channel, and then may have a negative impact on the flow capacity. Therefore, a standard cross-section with a double-sectional shape is used as a reference for the average width of the existing riverbed in each section where a standard cross-section is applied. The downstream reach (STA 0+000 - STA 3+000), which is affected by backwater, shall be set separately by non-uniform flow calculation.

In addition, there are many houses along the river from the river mouth to about STA 14+000 (around 9.5 km from the river mouth), and future development is planned in the land use plan upstream to the upstream end (STA 23+000) of the subjected section. Hence, in order to minimize the social impact of the river training work as much as possible, a riverbank slope (high water revetment) of 1:1.5 was used as the standard slope for the typical cross-section. However, for the low channel, a slope of 1:2.0 is used to create a natural waterfront in the hope of maintaining a good biological habitat. After setting the typical cross-section, the gradient of riverbank slope should be made sloping and access paths to the water edge should be considered appropriately, based on the available land.



Source: Project Team

Figure 4.1.20 Longitudinal Profile of Existing River Width of Davao River

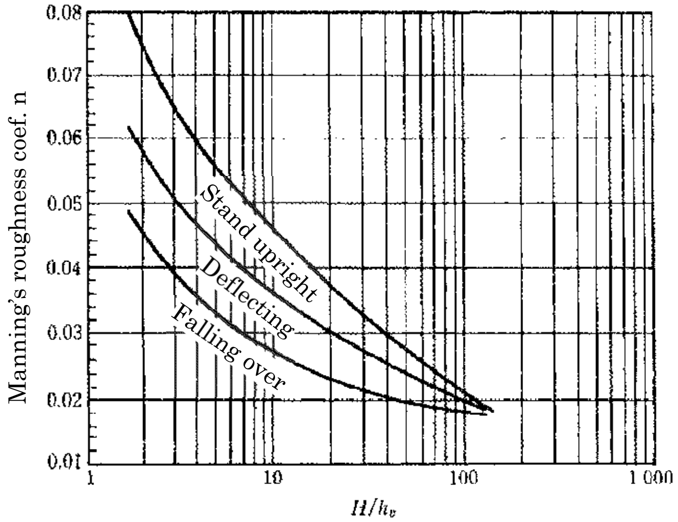
The roughness coefficient of the design channel is set by the composite roughness coefficient calculated by setting the roughness of riverbed, high water channel, and riverbank respectively. The roughness coefficient of the riverbed is calculated with Manning-Strickler's formula shown below applying the riverbed material survey result (30 cm below the surface).

$$n = \frac{{H_d}^{1/6}}{\sqrt{g} \times \psi} \qquad \psi = 6.0 + 5.75 \times log\frac{H_d}{2.5 d_R}$$

Where, H_d: design water depth (m), d_R: representative grain size of riverbed material (D60) (m)

If the calculated roughness coefficient is less than 0.020, it shall be 0.020.

The roughness coefficient of the high water channel is set by reading the corresponding value in the Figure 4.1.21 with setting design water depth on the high water channel (H), average vegetation height (hv), and its lodging condition during flooding. And, the roughness coefficient of the riverbank is set by the corresponding bank structure referring Table 4.1.5.



Source: Basic Policy for Disaster Rehabilitation to Protect Beautiful Mountains and Rivers, MLIT

Figure 4.1.21 Relationship between Grass Condition in Running Water and Roughness Coefficient

Table 4.1.5 Riverbank Structure and Roughness Coefficient

Structure of bank protection	Manning's roughness
Wedge block (ks=0.04)	0.024
Articulated concrete mattress (ks=0.08)	0.027
Gabion (gravel size=app.20cm)	0.032
Sodding with 20cm height grasses	0.032
Wooden fence (gravel size=15-20cm)	0.030
Stone masonry (φ=app.30cm), water depth (2-4m)	0.025
Stone masonry (φ=app.40cm), water depth (2m)	0.027
Stone masonry (φ=app.40cm), water depth (3-4m)	0.026
Stone masonry (φ=app.50cm), water depth (2-3m)	0.028
Stone masonry (φ=app.50cm), water depth (4m)	0.027

Source: Basic Policy for Disaster Rehabilitation to Protect Beautiful Mountains and Rivers, MLIT

Applying the roughness coefficient of each portion set following the above description, the composite roughness coefficient that is calculated by the formula below for each design riverbed slope is shown in Table 4.1.6.

$$N = \left\{ \frac{\sum_{i=1} \left({n_i}^{3/2} \cdot S_i \right)}{S} \right\}^{2/3}$$

Where,
n_i : Roughness coefficient Portion i
Si : Wetted perimeter length of portion i

Table 4.1.6 Roughness Coefficient of Design River Channel

	Low-water channel bed	Low-water channel bank	High-water channel floor	High-water channel bank	Composite roughness (N)
STA 3+500 – STA 14+500	n=0.020 S=60.00 (m)	n=0.032 S=8.94 (m)	n=0.022 S=24.20 (m)	n=0.024 S=18.75 (m)	n=0.022
STA 15+000 – STA 21+500	n=0.024 S=48.00 (m)	n=0.032 S=8.94 (m)	n=0.022 S=17.6 (m)	n=0.024 S=18.75 (m)	n=0.025

Source: Project Team

Meanwhile, DPWH standards do not mention regarding roughness coefficient of the design channel though, it says that the standard roughness coefficient of the general river is to be a range of 0.030 to 0.035. Based on this, the roughness coefficient of the design river channel is set at 0.030 though the calculated composite roughness coefficient is less than 0.030.

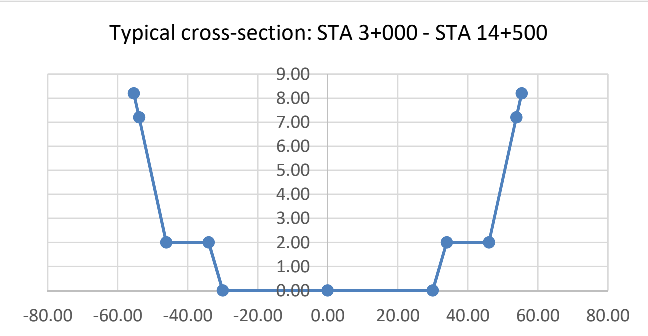
Table 4.1.7 Roughness Coefficient of Design River Channel

Channel Conditions	*Coefficient of Roughness*
General waterway	*0.030 – 0.035*
Rapid river of wide and shallow river	*0.040 – 0.050*
Temporary waterway excavated without timbering	*0.035*
Three-sided lined channel	*0.025*
River tunnel	*0.023*

Source: Technical Standards and Guidelines for Planning of Flood Control Structures, DPWH

Based on the condition above mentioned, the typical design cross-section for each section was determined by uniform flow calculation as shown below.

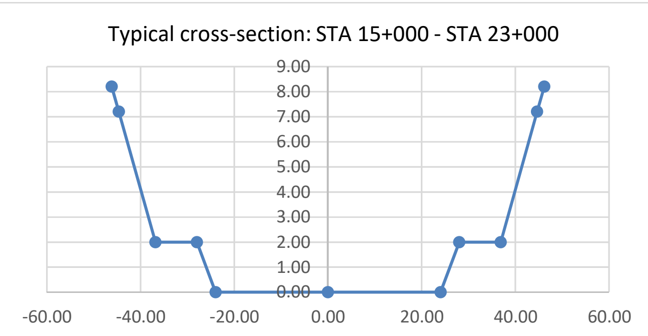
Table 4.1.8 Calculation Sheet of Typical Design Cross-section (STA 3+000 – STA 14+500)



Chanle width:	110.8
Channle water depth:	7.2
low-water channel bed width:	60.0
low-water channel bank slope:	1:2.0
high-water channel bank slope:	1:1.5
Wetted primeter:	111.89
Channel flow area:	648.0
Manning's n:	0.030
Chanle bed gradient:	1/1500
Flow velocity:	2.78
Flow capacity:	1798.55

Source: Project Team

Table 4.1.9 Calculation Sheet of Typical Design Cross-section (STA 14+500 – STA 23+000)

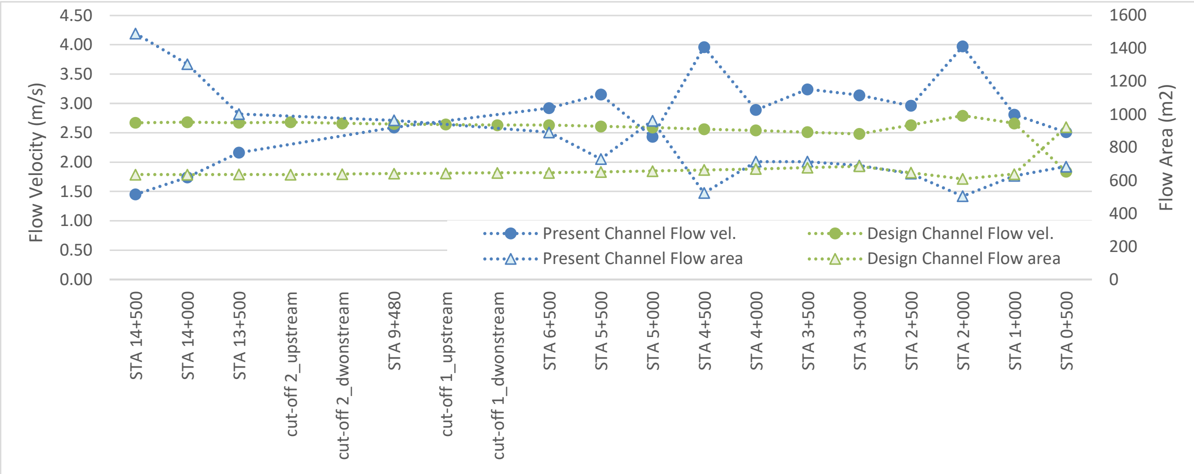


Chanle width:	92.3
Channle water depth:	7.2
low-water channel bed width:	48.0
low-water channel bank slope:	1:2.0
high-water channel bank slope:	1:1.5
Wetted primeter:	93.39
Channel flow area:	527.8
Manning's n:	0.030
Chanle bed gradient:	1/1000
Flow velocity:	3.34
Flow capacity:	1765.16

Source: Project Team

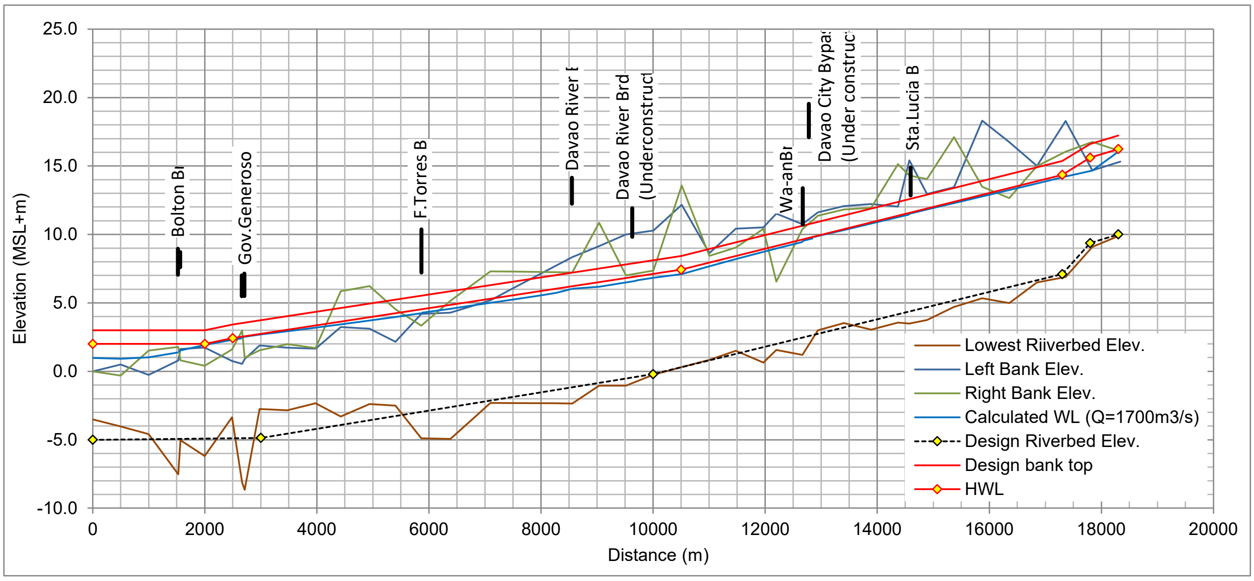
For the section downstream from STA 3 + 000, which is considered to be greatly affected by the backwater from the river mouth, HWL is set by non-uniform flow calculation based on the same cross-section as the STA 3+000 --STA 14+500 section, but STA 1+000 and STA 0+500, the riverbed width of the low waterway will be 80m and 190m respectively in consideration of the existing river channel width. Since STA 0+000 is located in Davao Bay, the design cross-section would not be set.

Applying the design river channel that reflects the above-mentioned design alignment, design longitudinal slope, and typical design cross-section, the water level in the condition of running design flood discharge was calculated, and the HWL was set to envelop this. The set HWL and design riverbank height are shown in Figure 4.1.23. Here, in order to understand the effect of the cut-off on the river channel flow velocity, the changes in the flow velocity near the cut-off reach were compared between the existing river and design river. In the downstream side cut-off reach (STA 6+500 – STA 9+000), the flow velocity decreased by using the design river channel, but the flow velocity increased in the upstream side cut-off (STA 10+040 – STA 12+500). It is considered that this is because the river flow area of the existing river channel exceeds the design river channel, and in general, since even if the river flow area of the existing river channel is larger than the design river channel, it shall not reduce its flow area by improving the river channel. Therefore, it is not expected that the riverbed would become unstable due to the implementation of M/P. However, river channel monitoring should be carried out as normal management work, and if a tendency for riverbed decline is observed, countermeasures shall be considered.



Source: Project Team

Figure 4.1.22 Velocity and Flow Area Longitudinal Profile of Cut-off Reach



Source: Project Team

Figure 4.1.23 Design Longitudinal Profile of Davao River

(2) Riverbed Dredging

1) Determination of Dredging Area

As described in Section 4.1.4(1), the design riverbed has been set generally the same as the existing riverbed gradient. Therefore, target portion of river dredging would be the portion of gentle slope riverbank of the existing river. Here, since reshape of river channel by dredging work is a tentative river improvement, if a riverbank protection were installed, it would need to be removed in the future river improvement work in line with M/P. Hence, the riverbank slope applies to 1:2.0, which is stable under the running water condition.

While the downstream section that proceeds riverbed sedimentation due to the effect of the existing narrower portion is planned to dredge up to about 2m. The slope of low waterway riverbank would be 1:2.0 as the same as design channel of M/P.

Here, the following related standards are established for the implementation of riverbed dredging work. The summary of the description of the river channel dredging of each standard is shown below.

“DPWH ORDER 139, Series of 2014”

- River channel dredging purposes increasing the flow capacity of rivers and reducing flood damage, and DPWH would directly supervise the work.
- Conduct riverbed material survey (200m pitch), sediment production and transportation analysis, and dredging slope stability analysis.
- Obtaining CNC or ECC from the DENR Environmental Management Bureau as an environmental impact assessment
- Formulate a design report including the above survey / examination, a geological survey report, a quantity calculation report, and a construction plan (including the designation of a dumping site).
- Secure a distance of 10m from the existing structure.

“DENR ADMINISTARATIVE ORDER No. 2020-07: Feb 27, 2020”

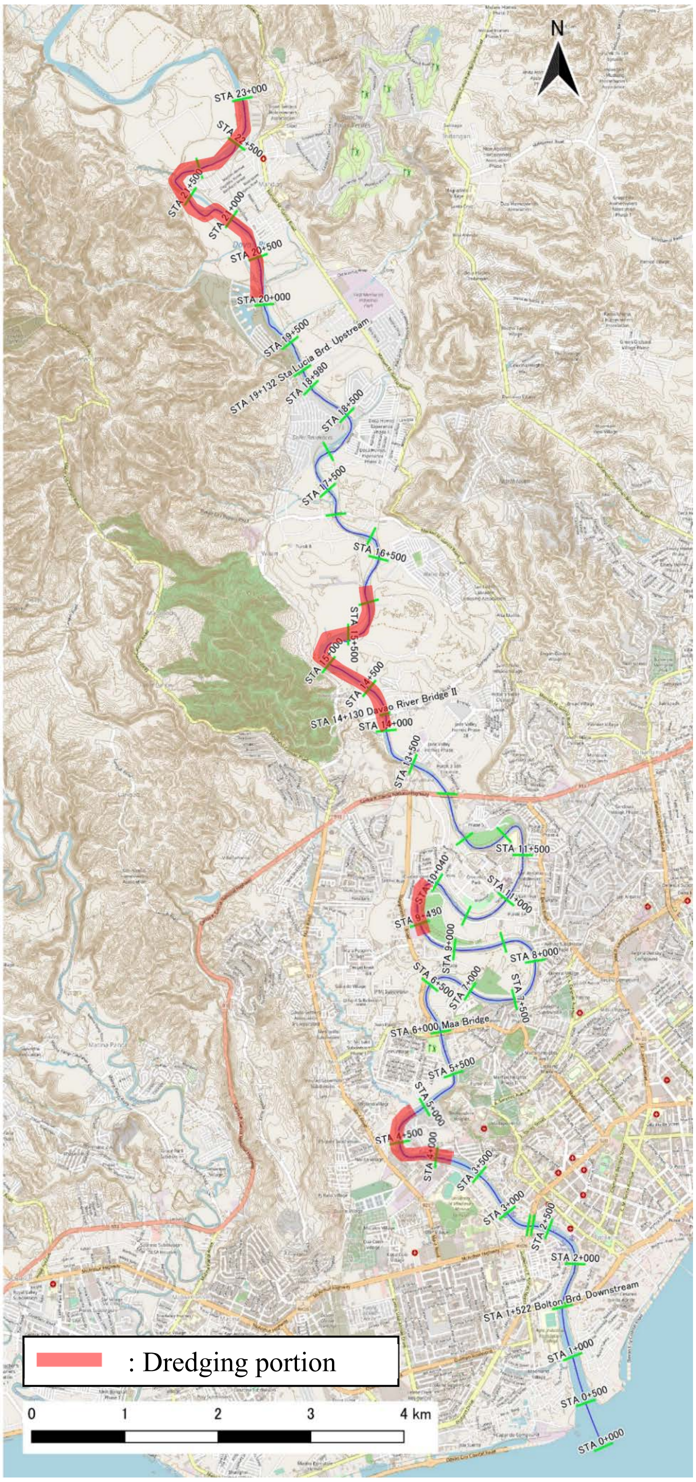
- This is an ordinance on dredging activities carried out by the private sector, and dredging activities by the private sector can only be carried out in the section (River Dredging Zone) specified in the DPWH dredging plan.

“JOINT MEMORANDUM CIRCULAR No. 01, Series of 2019: Mar. 14, 2019”

- This is an ordinance related to the application for permission for dredging, and the target is not only the private sector but also public institutions such as DPWH and LGU.
- For existing structures, secure a 10m separation as a buffer zone. However, in case of the river width is narrow and it is difficult to secure a buffer zone, this does not apply if safety is shown by slope stability analysis.
- Do not dredge within a stretch of 1km upstream and downstream from the bridge. However, this does not apply if appropriate analysis shows that dredging does not affect the stability of the bridge and the permission of the relevant organizations is obtained.

In accordance with the above orders and regulations, the distance from the existing structure at each cross-section shall be at least 10m. Regarding the conservation stretch of 1km upstream and downstream of the bridge in "JOINT MEMORANDUM CIRCULAR No. 01, Series of 2019: Mar. 14, 2019", the description that dredging shall not be performed in principle limits the section where river channel dredging can be performed. If exactly follow this, since the dredging reach would be limited (see Figure 4.1.24), the effect of reducing the flooding damage cannot be expected. Therefore, a non-uniform flow calculation is examined when the range where dredging is not performed is shorter than 1 km, and the result of the calculations is compared hydraulic specifications (water depth and flow velocity) with the not dredging the range of 1 km upstream and downstream of the bridge.

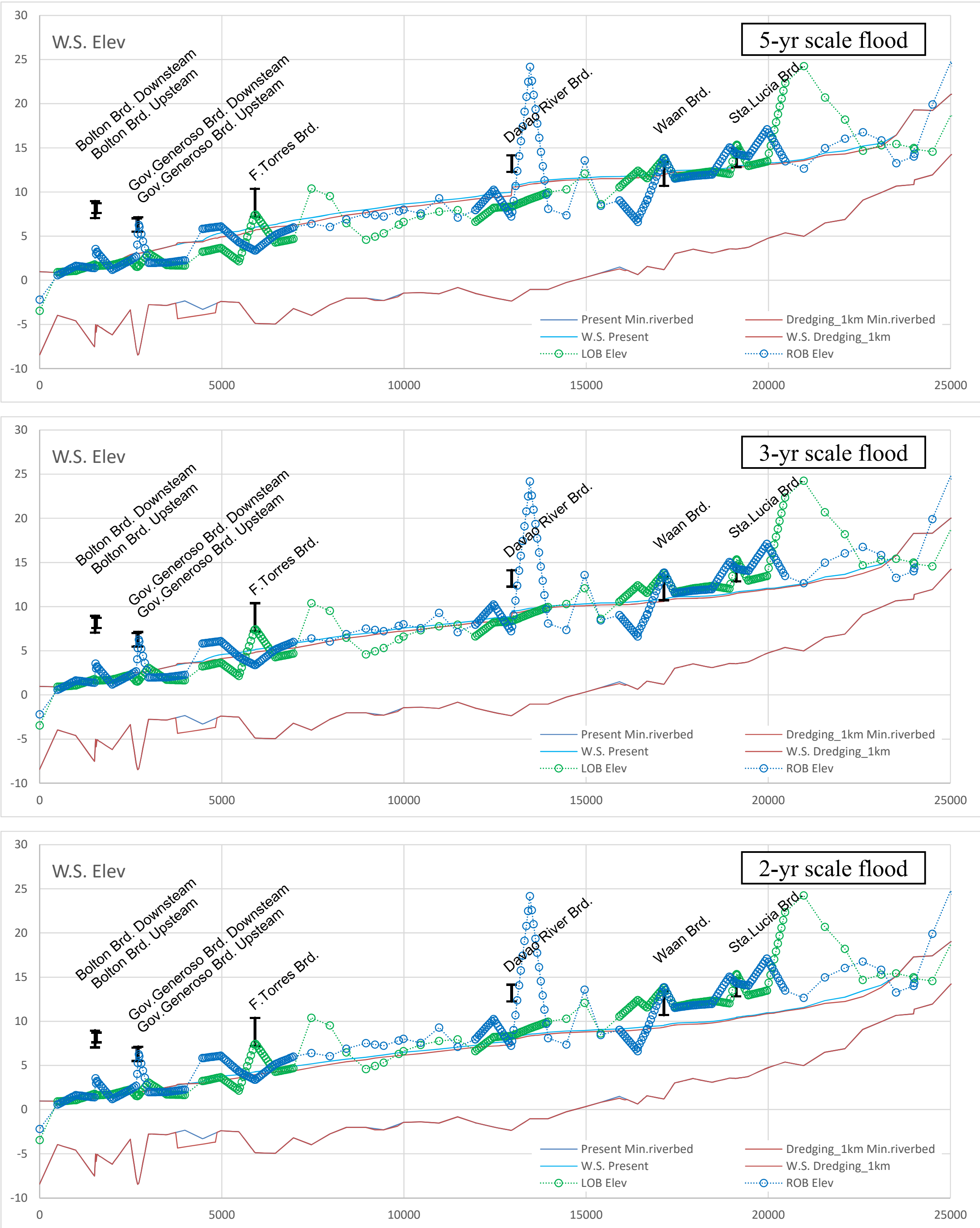
By the way, since it is out of scope of this project specification quantity to carry out studies and surveys that satisfy the above orders and regulations, additional studies and surveys are required to be performed by the RO or DEO, which is the implementing body, when carrying out river channel dredging. Therefore, this study is a study at the F/S stage and is positioned as a reference for future river channel dredging plan formulation.



Source: Project Team

Figure 4.1.24 Dredging Portion in case of 1km Conservation Stretch from Existing Bridges

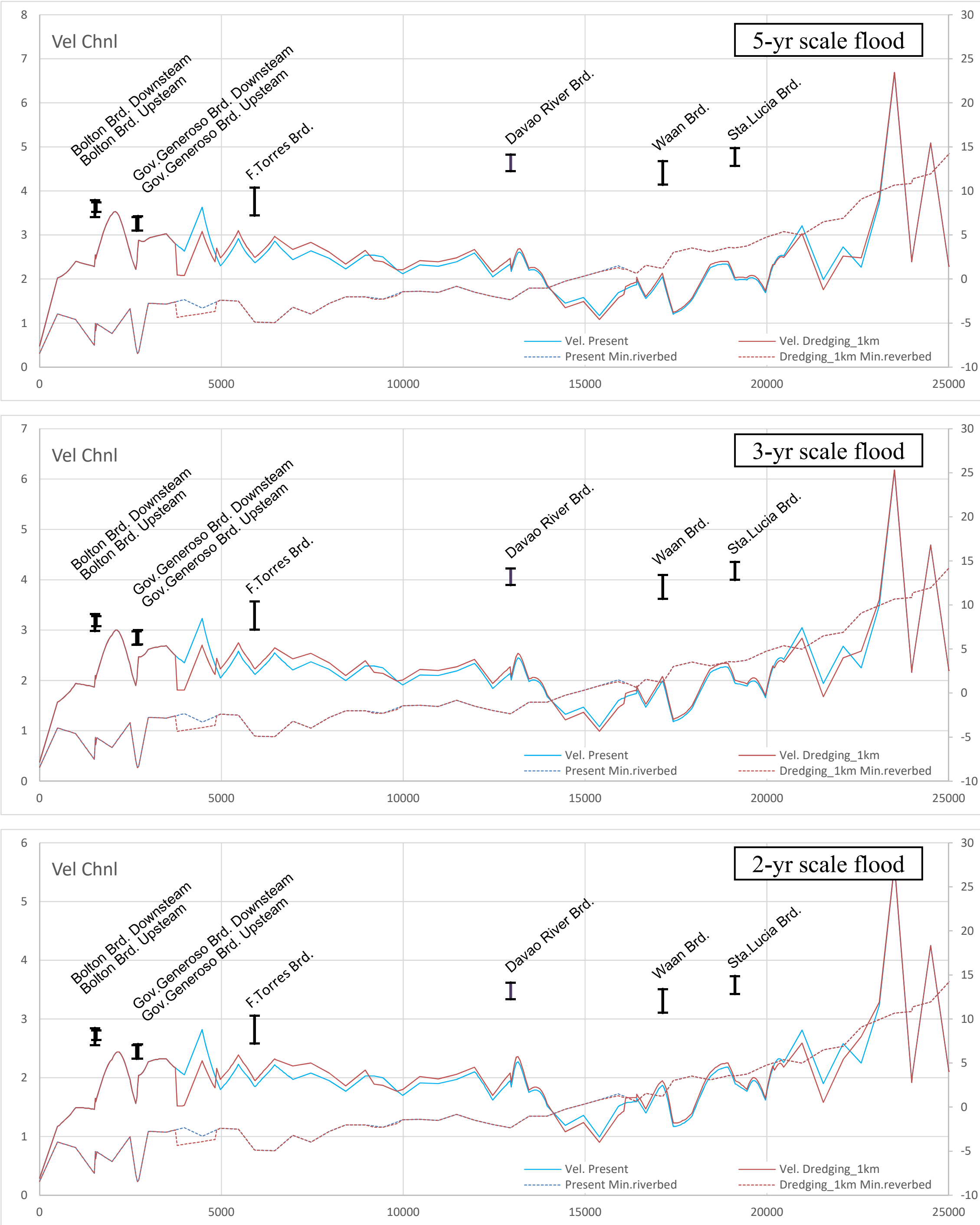
Figure 4.1.25 shows the comparison of water level between the existing river channel and the dredging river channel that is not performed dredging work at the conservation stretch of 1km both upstream and downstream from the existing bridges with each flood scale. It is recognized that the water level is going down, especially at the portion from 4.5km to 13km by the dredging work.



Source: Project Team

Figure 4.1.25 Water Level of Existing River and Dredging River with 1km Conservation Stretch of Existing Bridges
(above: 5-yr scale flood, middle: 5-yr scale flood, below: 5-yr scale flood)

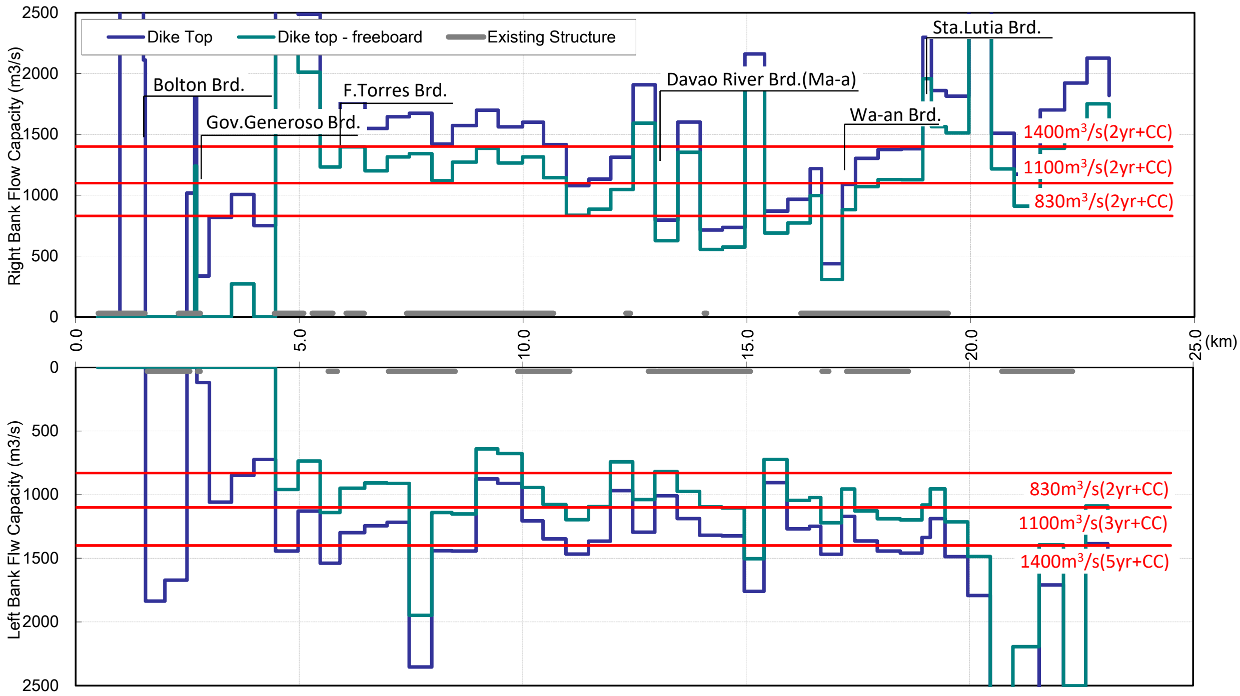
Similarly, Figure 4.1.26 shows the comparison of flow velocity between the existing river channel and the dredging river channel that is not performed dredging work at the conservation stretch of 1km both upstream and downstream from the existing bridges with each flood scale. It is recognized that the flow velocity is going up, especially at the portion from 4.5km to 13km that the lowering of water level by the dredging work is comparatively large.



Source: Project Team

Figure 4.1.26 Flow Velocity of Existing River and Dredging River with 1km Conservation Stretch of Existing Bridges (above: 5-yr scale flood, middle: 5-yr scale flood, below: 5-yr scale flood)

Now, the flow capacity of the existing river channel with dredging the whole reach including the portion of existing bridge sections is shown in Figure 4.1.27. The flow capacity with dredging the whole reach is approximately 800 m^3/s, which is corresponding to the run-off discharge by 2-yr scale flood considering climate change; 830 m^3/s. In general, hydraulic specifications, such as water level and flow velocity, would increase following flow discharge. Thus, the study of the effect due to the variation of conservation stretch on hydraulic specifications is carried out by targeting to 2-yr scale flood.

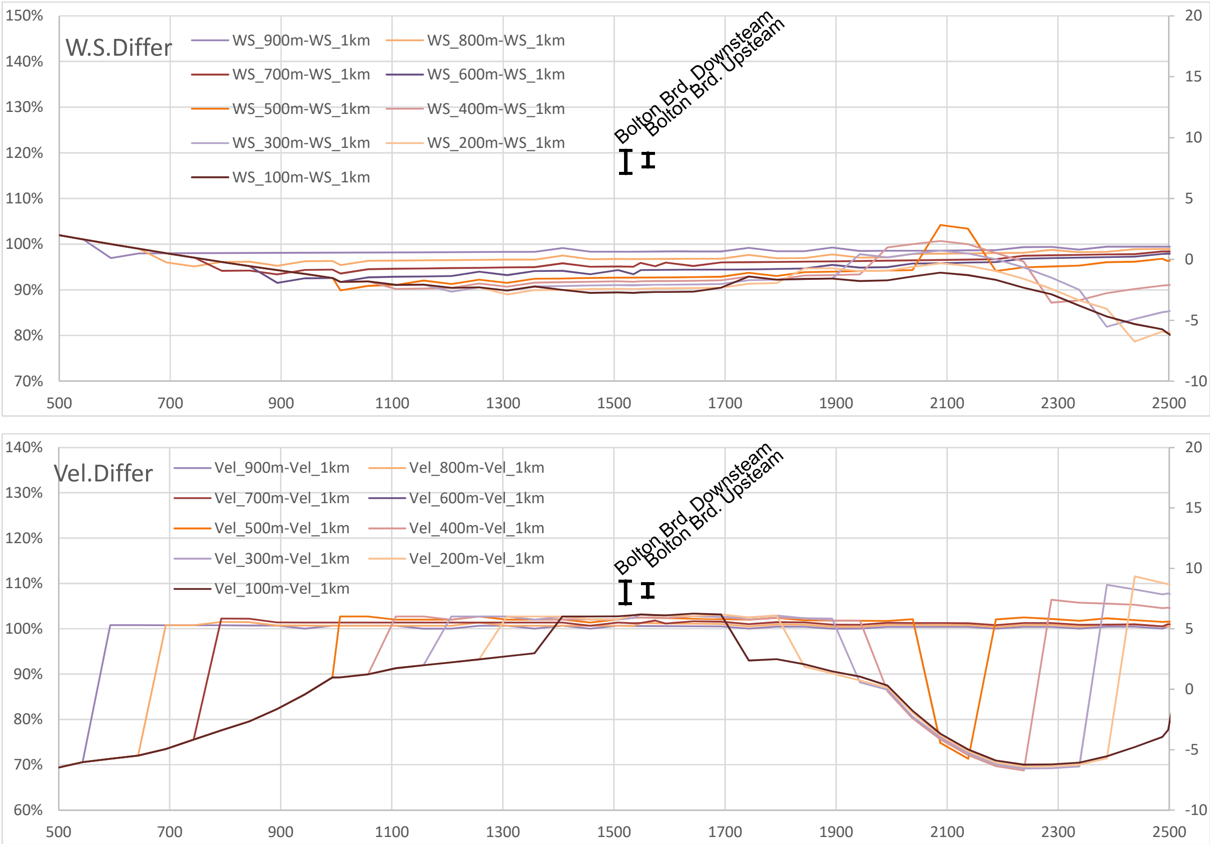


Source: Project Team

Figure 4.1.27 Flow Capacity of the River with Whole Reach Dredging

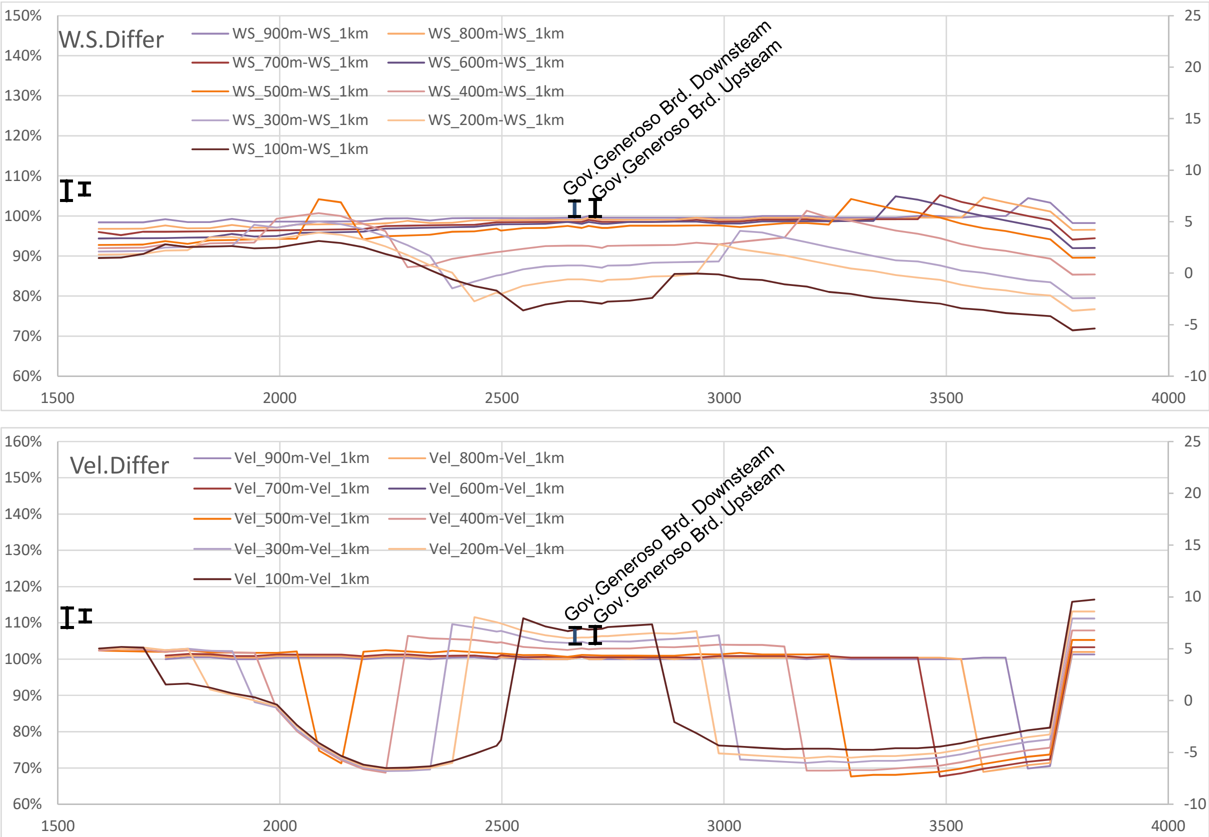
As written above, represented by the 2-yr scale flood, the variation rate of water level and flow velocity, which is compared with the river channel with preserving 1km upstream and downstream of existing bridges, in cases of shortened conservation stretch are shown below (the figures indicate the section of about 1km upstream and downstream of each existing bridge).

In most cases, the water levels of the river channel with shortened conservation stretch are lower than that of the river channel with preserving 1km upstream and downstream of existing bridges because of the increase of flow area. Meanwhile, the increase in flow velocity is significant at the sections of the Gov.Generoso Bridge and F.Torres Bridge, however, these variation rates are less than 20%.



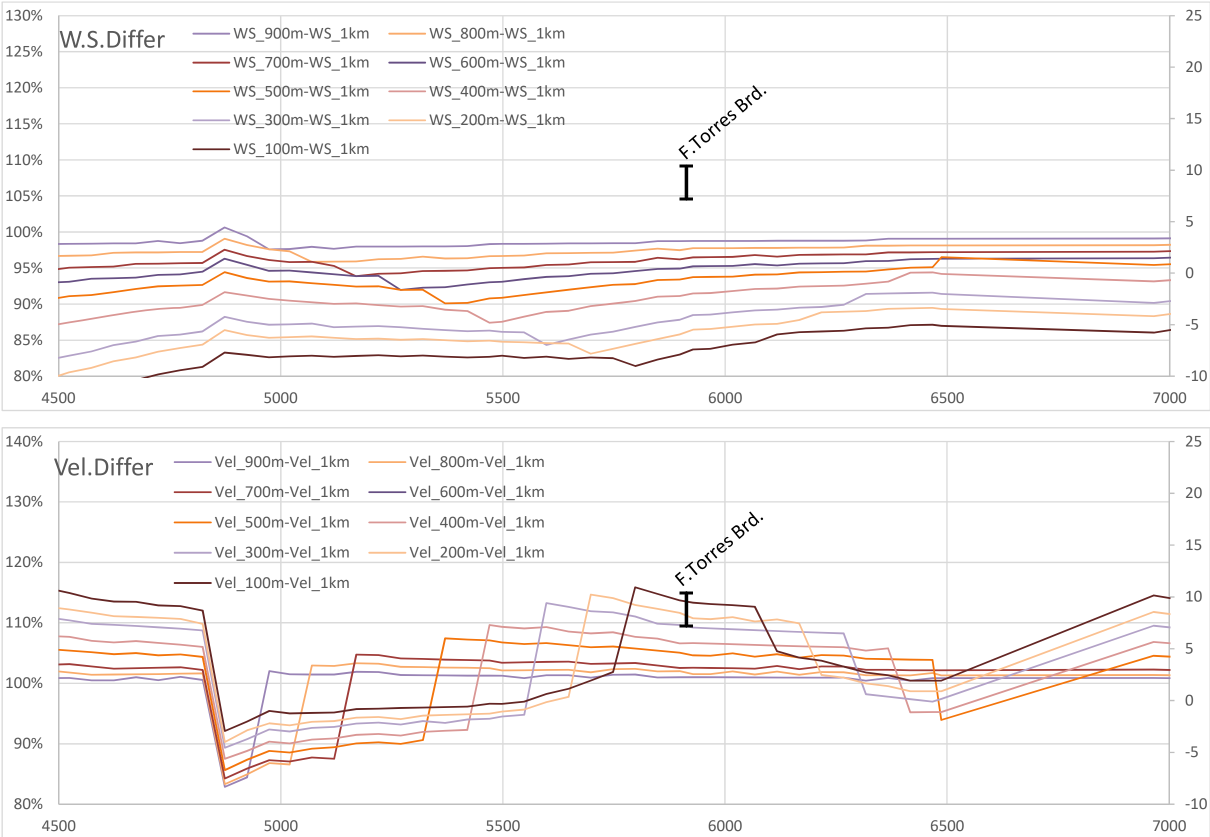
Source: Project Team

Figure 4.1.28 Variation of Hydraulic Value due to Dredging Reach (Bolton Bridge) (2-yr scale flood) (above: water depth, below: flow velocity)



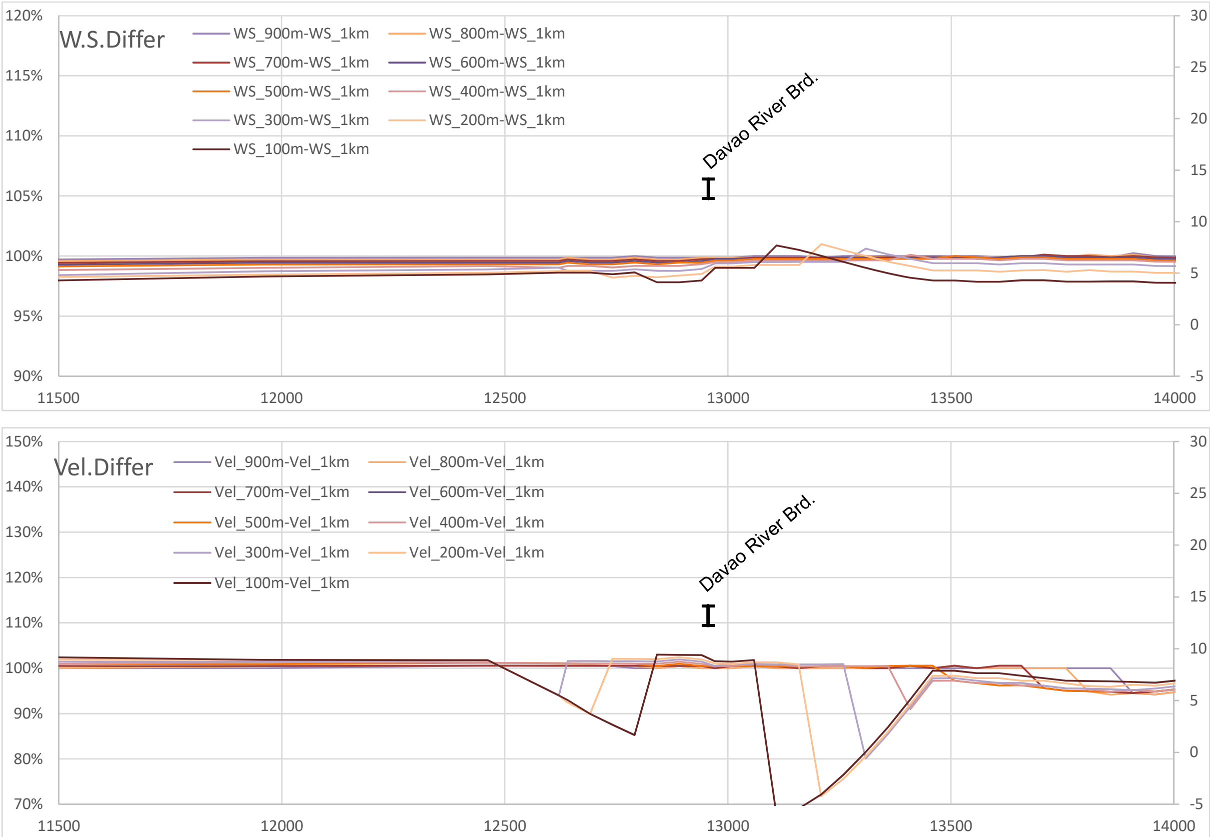
Source: Project Team

Figure 4.1.29 Variation of Hydraulic Value due to Dredging Reach (Gov.Generoso Bridge) (2-yr scale flood) (above: water depth, below: flow velocity)



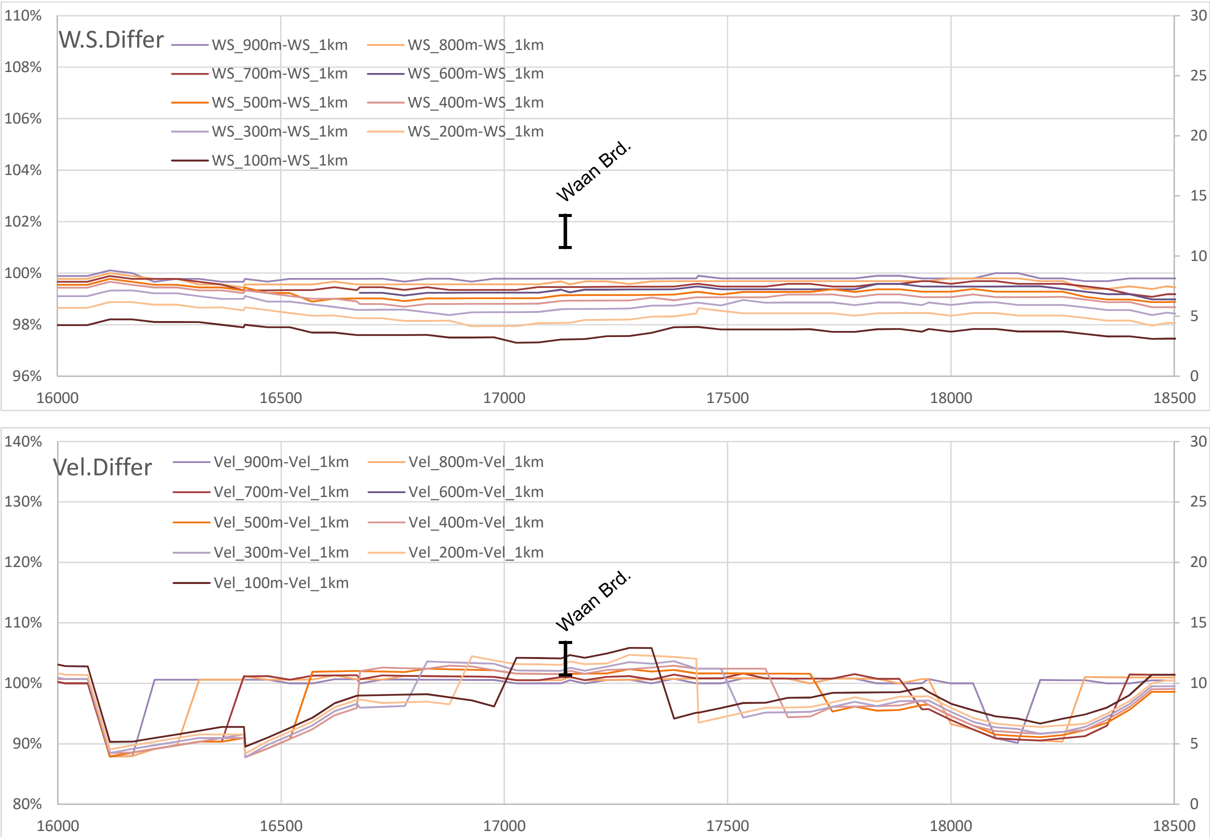
Source: Project Team

Figure 4.1.30 Variation of Hydraulic Value due to Dredging Reach (F.Torres Bridge) (2-yr scale flood) (above: water depth, below: flow velocity)



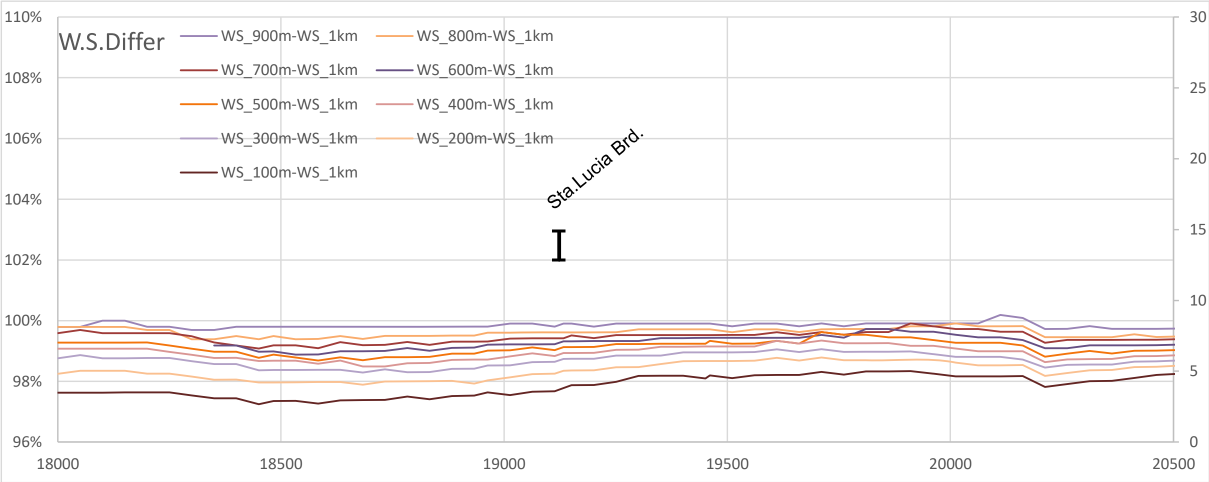
Source: Project Team

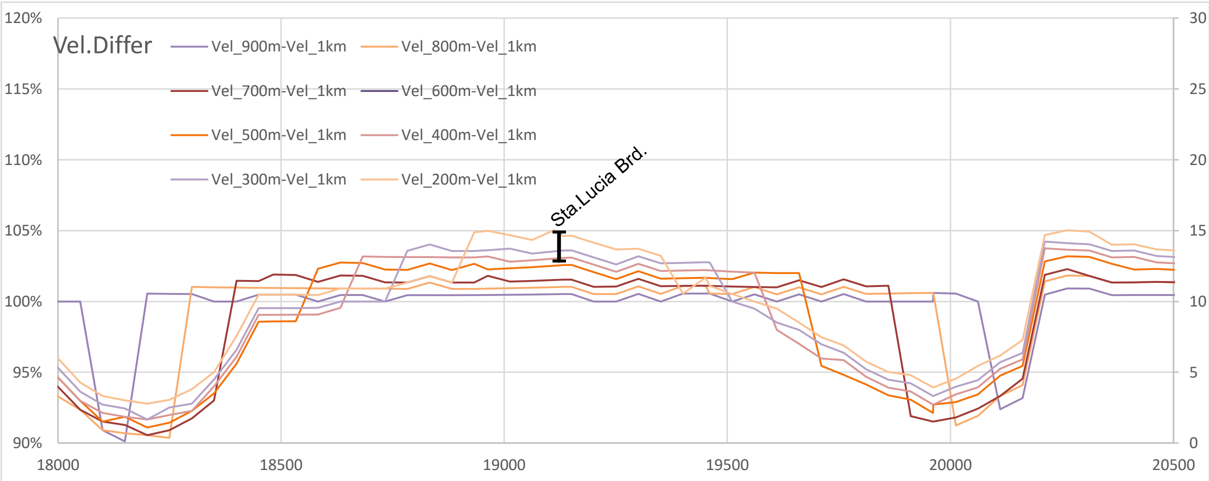
Figure 4.1.31 Variation of Hydraulic Value due to Dredging Reach (Davao River Bridge) (2-yr scale flood) (above: water depth, below: flow velocity)



Source: Project Team

Figure 4.1.32 Variation of Hydraulic Value due to Dredging Reach (Waan Bridge) (2-yr scale flood) (above: water depth, below: flow velocity)



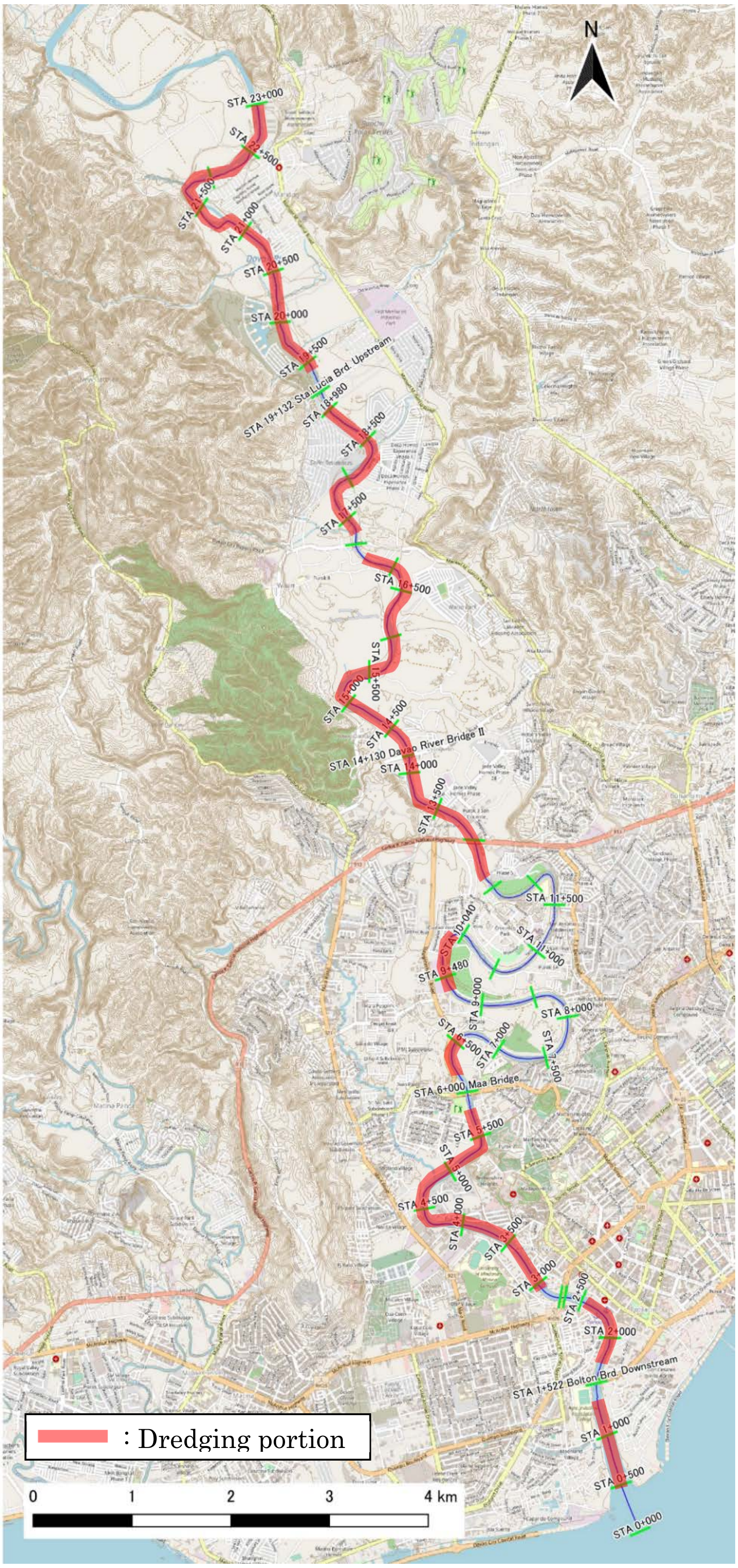


Source: Project Team

Figure 4.1.33 Variation of Hydraulic Value due to Dredging Reach (Sta.Lucia Bridge) (2-yr scale flood) (above: water depth, below: flow velocity)

As shown above, comparing with the case of preserving 1km upstream and downstream of existing bridges, the increasing ratio is less than 20% even in the case of 100m conservation stretch, and it can be said there is no significant effect of shortened the conservation stretch.

In addition to the study above, from the aspect of the flood security level including the other target works in F/S, cut-off channel and retarding ponds, as a result of the comparison of conservation stretch (refer to Section 4.1.5), the area of conservation stretch for the existing bridges is determined 100m upstream and downstream of the bridges in this project. Here, since the Davao River Bridge obstructs the flow area very much and it is expected significant reduction of inundation area by dredging this cross-section, the cross-section of the Davao River Bridge shall not have any conservation stretch with the premise that riverbed protection would be installed to preserve the stability of bridge piers.



Source: Project Team

Figure 4.1.34 Dredging Portion in case of 100m Conservation Stretch

2) Procedures of River Channel Dredging

The procedure of river channel dredging would be determined depends on the site condition. Major procedures of dredging are as shown below, and it shall be selected properly corresponding the site condition since each procedure is effective respectively for earlier expression of flood mitigation, countermeasure of re-sedimentation, and reduction of burden on the environment.

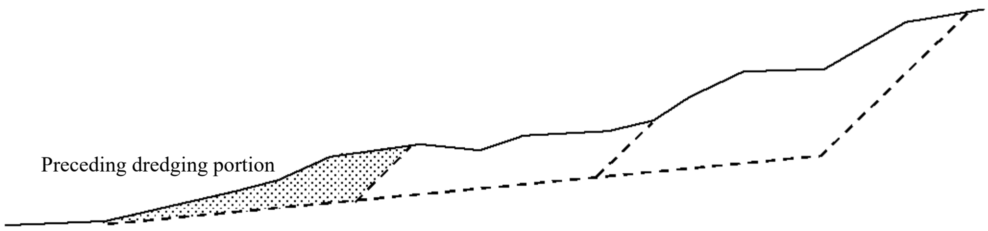
i. Stripe dredging : Dredging in a stripe shape from a location close to the waterway (early expression of flood mitigation effect)

ii. Slice dredging : Dredging is carried out sequentially from the top of the ground (measures against re-sedimentation)

iii. Vase dredging : Dredging while remaining the ground at the water's edge as a cofferdam (reduction of burden on the environment)

i. Stripe dredging

- This is a dredging procedure that aims to realize the flood mitigation effect earlier by proceeding with excavation in a stripe shape from the location close to the waterway.
- This is an effective procedure when the construction period is multi-year.
- In underwater construction, since it is easy to sediment again at the dredged site, sufficient consideration is required before adopting this procedure.

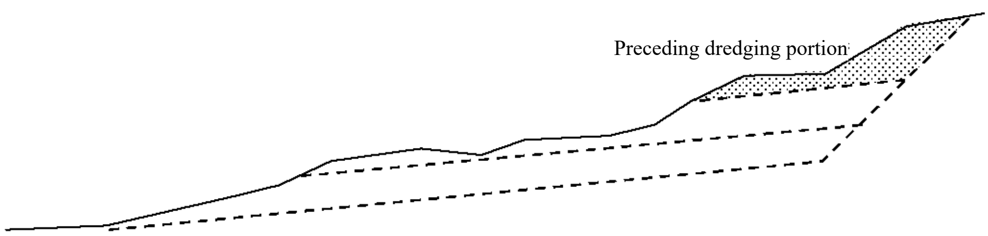


Source: "Design Guideline for River Structure", MLIT Chubu Regional Development Bureau

Figure 4.1.35 Conceptual Drawing of Stripe Dredging

ii. Slice dredging

- This is a dredging procedure that is able to dredge re-accumulated sand at the next construction by proceeding with dredging from the top of the ground.
- This is an effective procedure for underwater construction, which requires multi-years construction period.
- Since the early expression of flood mitigation effects cannot be expected, it is necessary to give sufficient consideration when adopting it in places where flood mitigation priority is high.

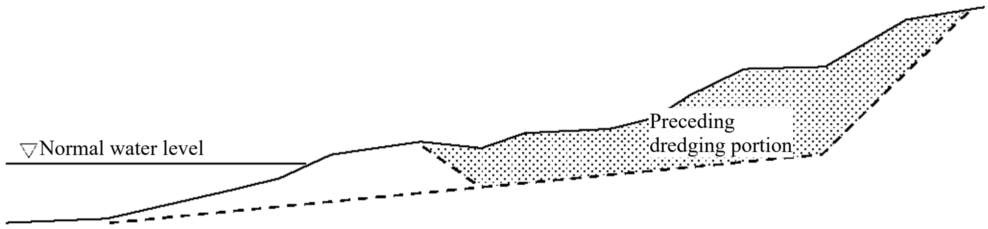


Source: "Design Guideline for River Structure", MLIT Chubu Regional Development Bureau

Figure 4.1.36 Conceptual Drawing of Slice Dredging

iii. Vase dredging

- This is a dredging procedure that minimizes the outflow of turbid water during construction by excavating the ground near the waterway at the end.
- This is an effective procedure for on-land construction in a single year.



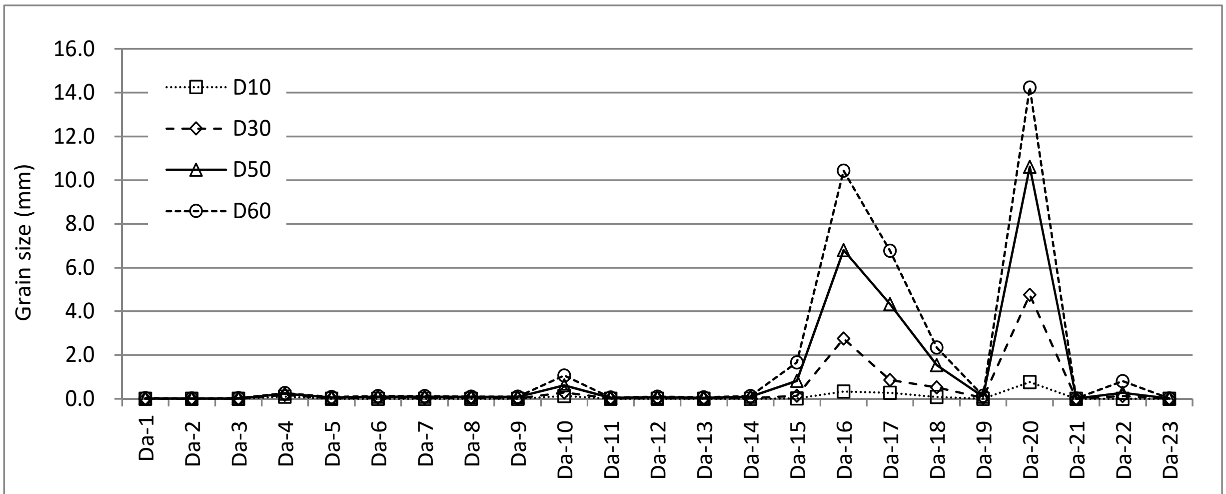
Source: "Design Guideline for River Structure", MLIT Chubu Regional Development Bureau

Figure 4.1.37 Conceptual Drawing of Vase Dredging

3) Soil Condition

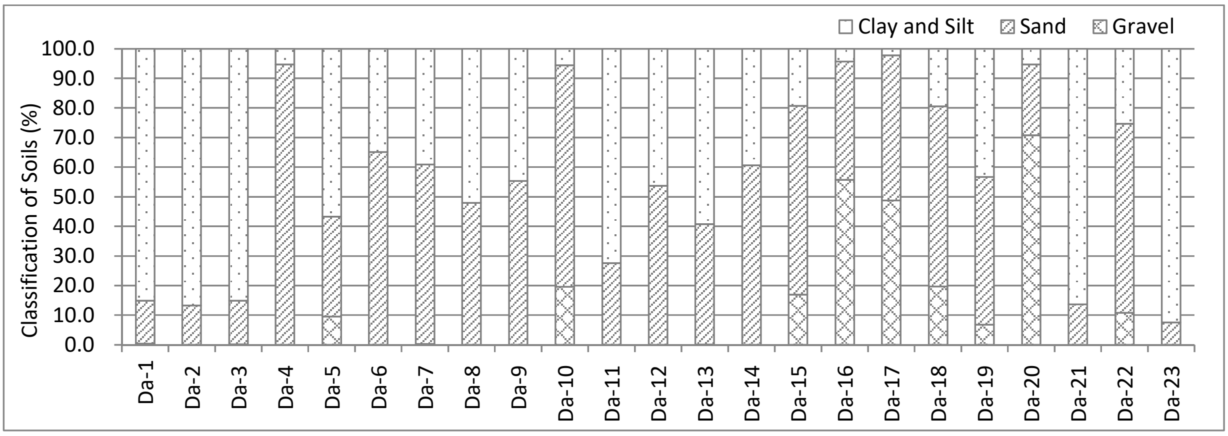
The efficiency of dredging work, wear of parts, etc. vary considerably depending on the soil condition. Since it directly affects the construction unit price, construction method, and construction period, it is important to investigate the soil condition in the dredging plan area in advance. In particular, when considering the diversion of dredged soil, it is necessary to confirm the distribution of soil and examine the mud drainage order.

To grasp the soil condition, it is desirable to carry out core boring and standard penetration test, but it can be simplified by conducting surface soil survey. For the target section of river channel dredging (STA 0+500 – STA 23+000), the result of the riverbed material survey that conducted in this project is applied. As shown in Figure 4.1.38 and Figure 4.1.39, the riverbed material from the estuary to around 15 km is mainly composed of clay, silt, and sand. Although the ratio of gravel increases from around 15 km to the upstream, it can be judged that dredging work by the construction method for standard sandy soil is possible.



Source: Project Team

Figure 4.1.38 Riverbed Material Survey Result in Davao River (Passage Particle Size)



Source: Project Team

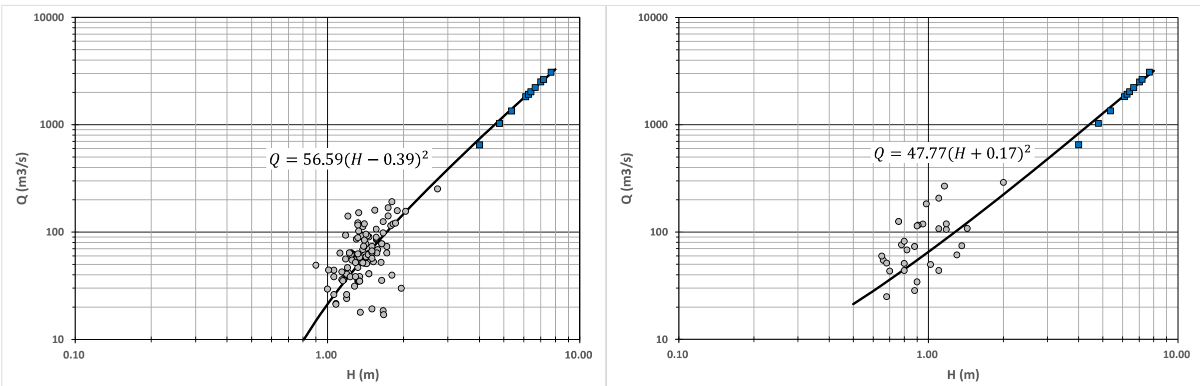
Figure 4.1.39 Riverbed Material Survey Result in Davao River (Soil Distribution)

4) Hydraulic Condition

For dredging work, it is necessary to investigate the flow conditions (normal water level, etc., past highest/lowest water), flow velocity, etc. near the dredging site, and consider the construction plan, and evacuation site and method in an emergency.

The Lacson station has been installed as a water level/flow discharge gauging station in the Davao River. Since the Lacson station is located upstream of the dredging target section (about 50.8 km from the river mouth), the flow conditions at the Lacson station are utilized for calculation of the flow condition at the upstream end of the dredging target section (SAT 23+000) by basin rate method. According to the runoff analysis model constructed in the M/P study, the upstream area of the Lacson station is 1,512.53 km^2 and the upstream area of STA 23+000 is 1,706.52 km^2. Meanwhile, The DPWH has a catchment area of 1,469.0 km^2 at the Lacson station, which is different from the value obtained by the runoff analysis model. Since the estimation of flow condition at the dredging target section by basin ratio is the purpose of this study, the value of the runoff analysis model is applied.

Regarding the daily average water level data of the Lacson station (2005 – 2017: 13 years), the highest and lowest water levels and flow regime (95-day water level, normal water level, low water level, droughty level) of each year are organized. And the flow discharge corresponding to the daily average water level data was calculated by the H-Q formula created based on the observation records of the Lacson station from 2001 to 2017 at the time of flooding. Here, since a difference of about 30 cm was recognized in the flow regime (water level) between 2015 and 2016 (see Table 4.1.10), H-Q formulas were created before 2015 and after 2016, respectively. Figure 4.1.40 shows the H-Q formulas, and Table 4.1.11 shows the flow conditions at the Lacson station and the conversion values at the upstream end of the river channel dredging section (STA 23+000).



Source: Project Team

Figure 4.1.40 H-Q Formula at Lacson Station in Davao River (left: 2005-2015, right: 2016-)

Table 4.1.10 Davao River Flow Regime Water Level Table

Year	Max. (m)	High Discharge (m)	Normal Discharge (m)	Low Discharge (m)	Drought Discharge (m)	Min. (m)	Mean (m)
		95th day	185th day	275th day	355th day		
2005	2.99	1.50	1.33	1.20	0.91	0.85	1.38
2006	3.32	1.63	1.36	1.23	1.07	0.95	1.47
2007	3.44	1.71	1.38	1.25	1.03	0.87	1.52
2008	3.86	1.79	1.55	1.36	1.15	0.97	1.66
2009	3.13	1.93	1.65	1.48	1.21	0.97	1.77
2010	3.58	1.88	1.63	1.43	1.07	0.89	1.71
2011	3.47	1.94	1.61	1.40	1.26	1.15	1.78
2012	3.68	1.64	1.41	1.31	1.12	1.02	1.56
2013	4.16	1.61	1.39	1.26	1.10	1.07	1.50
2014	2.99	1.52	1.34	1.28	1.10	1.05	1.45
2015	3.47	1.44	1.29	1.18	1.06	0.96	1.39
2016	3.00	1.24	1.03	0.89	0.67	0.58	1.10
2017	2.88	1.28	1.11	0.88	0.65	0.32	1.14
2018	2.03	1.11	0.88	0.68	0.59	0.57	0.95
Ave. at Lacson ($1512.53km^2$)	3.29	1.59	1.35	1.20	1.00	0.87	1.46

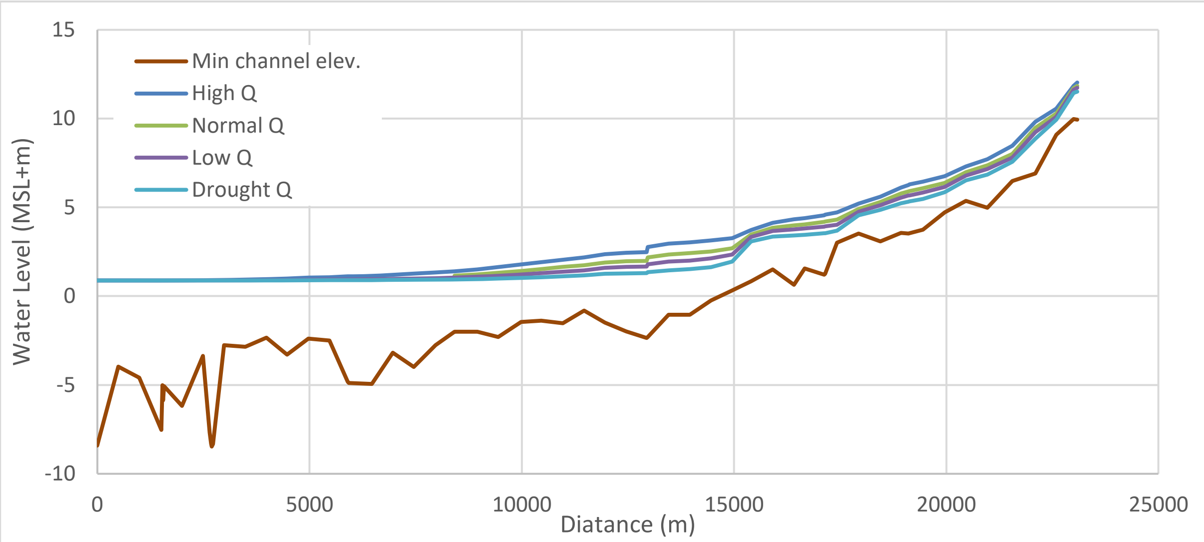
Source: Project Team

Table 4.1.11 Davao River Flow Regime Discharge Table

Year	Max. (m^3/s)	High Discharge (m^3/s)	Normal Discharge (m^3/s)	Low Discharge (m^3/s)	Drought Discharge (m^3/s)	Min. (m^3/s)	Mean (m^3/s)	River Regime Coefficient
		95th day	185th day	275th day	355th day			
2005	383.59	70.17	50.38	37.45	15.51	12.16	55.54	31.55
2006	487.00	87.51	53.63	40.26	26.44	17.97	66.78	27.10
2007	527.66	99.13	55.86	42.20	23.43	13.23	72.62	39.89
2008	682.80	111.47	76.61	53.63	32.99	19.27	92.16	35.44
2009	425.96	134.82	90.34	67.67	38.38	19.27	108.58	22.11
2010	577.15	126.23	87.51	61.62	26.44	14.35	98.61	40.23
2011	538.08	136.58	84.71	58.13	43.18	32.99	109.14	16.31
2012	613.87	88.92	59.28	48.26	30.45	22.71	77.40	27.03
2013	805.84	84.71	56.99	43.18	28.81	26.44	69.98	30.48
2014	383.59	72.71	51.45	45.18	28.81	24.91	64.43	15.40
2015	538.08	62.81	46.20	35.63	25.67	18.61	56.60	28.91
2016	479.36	94.68	68.54	53.45	33.53	26.72	77.25	17.94
2017	443.73	100.13	78.00	52.45	31.95	11.37	81.81	39.03
2018	230.74	78.00	52.45	34.34	27.44	26.01	60.01	8.87
Ave. at Lacson ($1512.53km^2$)	508.39	96.28	65.14	48.10	29.50	20.43	77.92	24.89
Ave. at Lacson ($1706.52km^2$)	573.59	108.62	73.49	54.27	33.28	23.05	87.92	24.89

Source: Project Team

Utilizing the Table, the water levels at the dredging section corresponding to each flow discharge of 95-day water, normal water, low water, and droughty water is calculated. Runoff discharge by the basin along the dredging section is obtained with basin ratio as same as the calculation method of discharge at the upstream end of the dredging section. Here, the river condition for this study is the existing river channel that is not executed the cut-off work yet with considering the work schedule. Also, the water level at the estuary as the downstream end of the calculation applies MSL+0.881m that is the high tide level (MHHW) before affected by climate change.



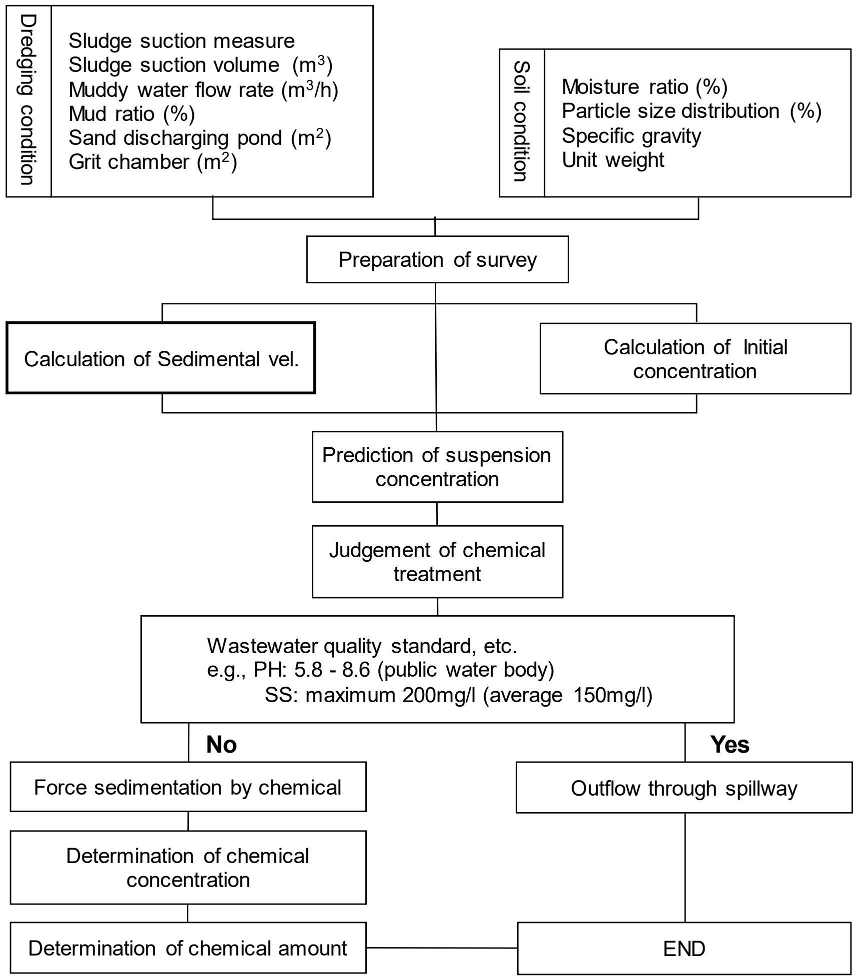
Source: Project Team

Figure 4.1.41 Longitudinal Profile of Water Level for Flow Regime of Davao River

5) Turbid Water Measure

Regarding the generation of turbid water due to dredging of river channel, it is required to take measures to reduce the burden on the environment as much as possible. Since specific measures against turbid water will be implemented by the contractor, the procedure for examining measures against turbid water is shown here.

When the construction is undertaken from land, the slice dredging and vase dredging shown in "2)Procedures of River Channel Dredging" would be applied to control the generation of turbid water and the inflow into rivers. When the construction is undertaken underwater such as riverbed dredging, the suspension concentration is predicted from the dredging conditions set by the equipment used after understanding the soil conditions. If the expected suspension concentration is excessive in light of water quality standards, forced sedimentation with a chemical is performed. In addition to the installation of turbid water diffusion prevention membranes in settling basins and sand drainage areas, dust fences would be installed as necessary to prevent artificial alteration of plant habitats due to the outflow of seeds and alike.



Source: "Design Guideline for River Structure", MLIT Chubu Regional Development Bureau

Figure 4.1.42 Example Flowchart for Turbid Water Measure

6) Flow Capacity after Dredging Work

Based on the consideration up to the previous section, the dredging area of each cross-section is set, and then the flow capacity of the river after dredging work is calculated.

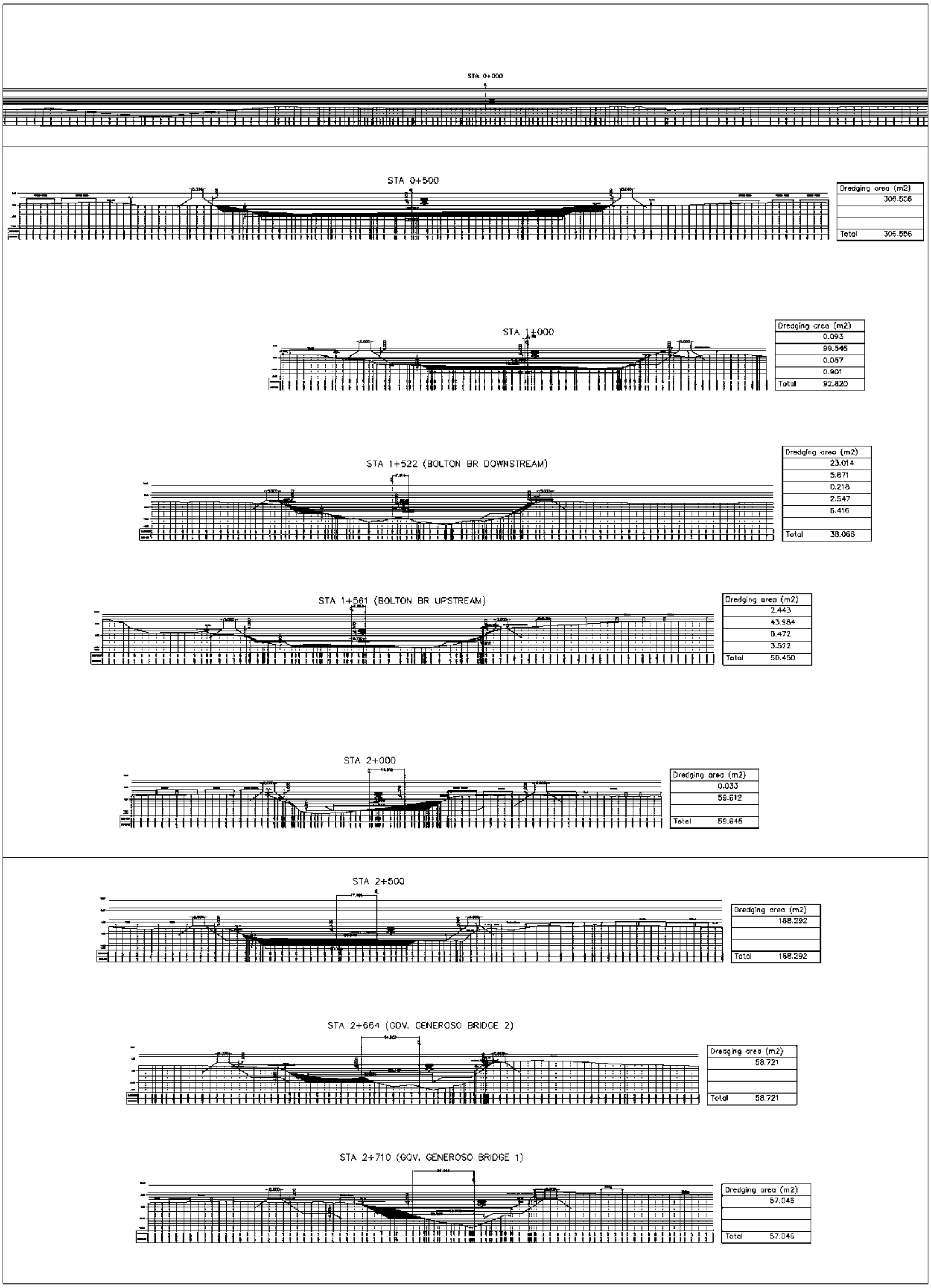
- **Cross-section**

The applied river channel shape is dredged river channel that is created by modifying the outcome of the river topographical survey as shown in Table 4.1.12.

Table 4.1.12 Applied River Topographical Survey Result

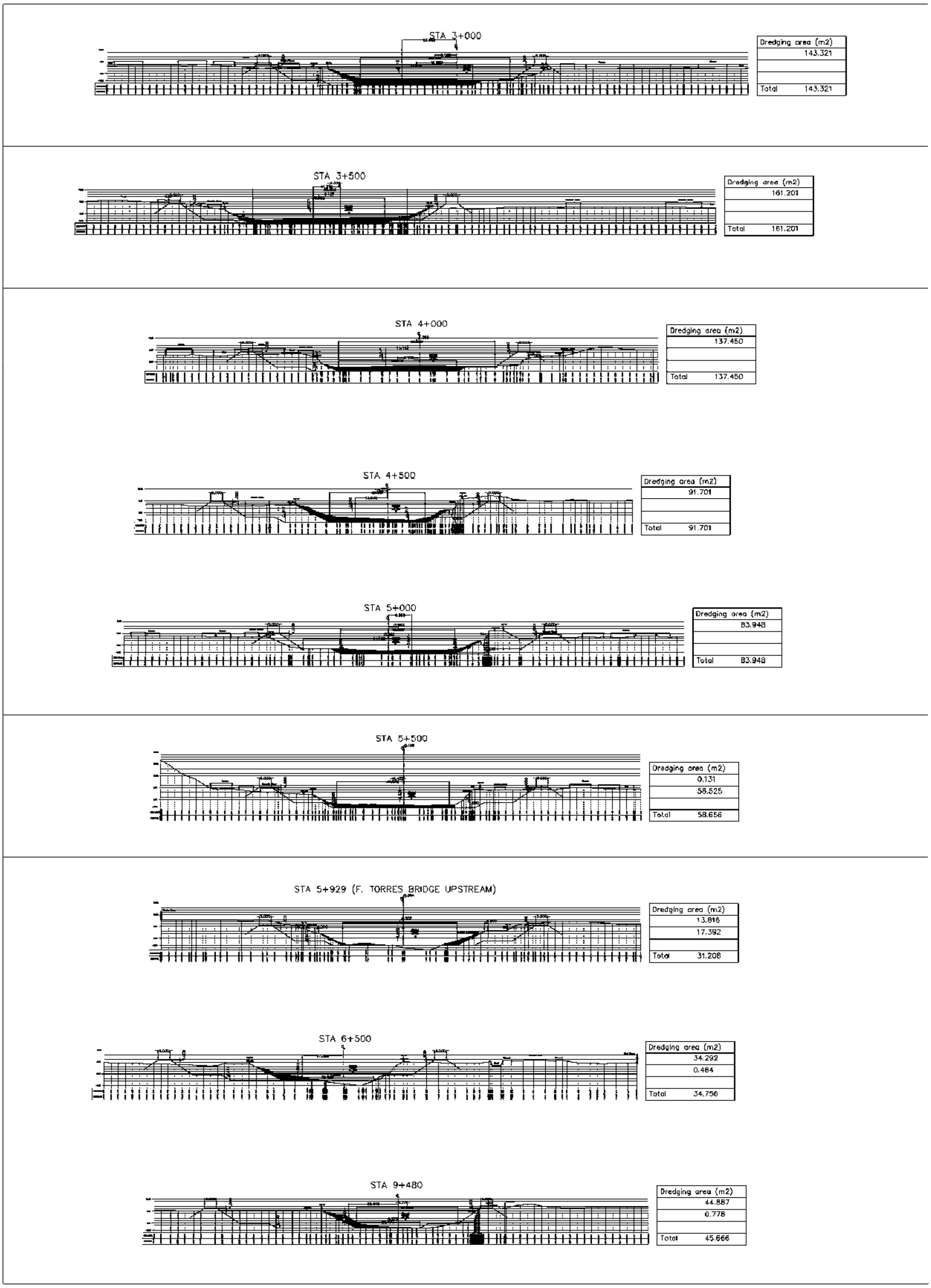
River	River Station of caculation reach	Reach length (km)	Number of cross-section	Survey date
Davao	STA 0+000 ~ STA 23+000	23.09	52	Apr.2019

Source: Project Team



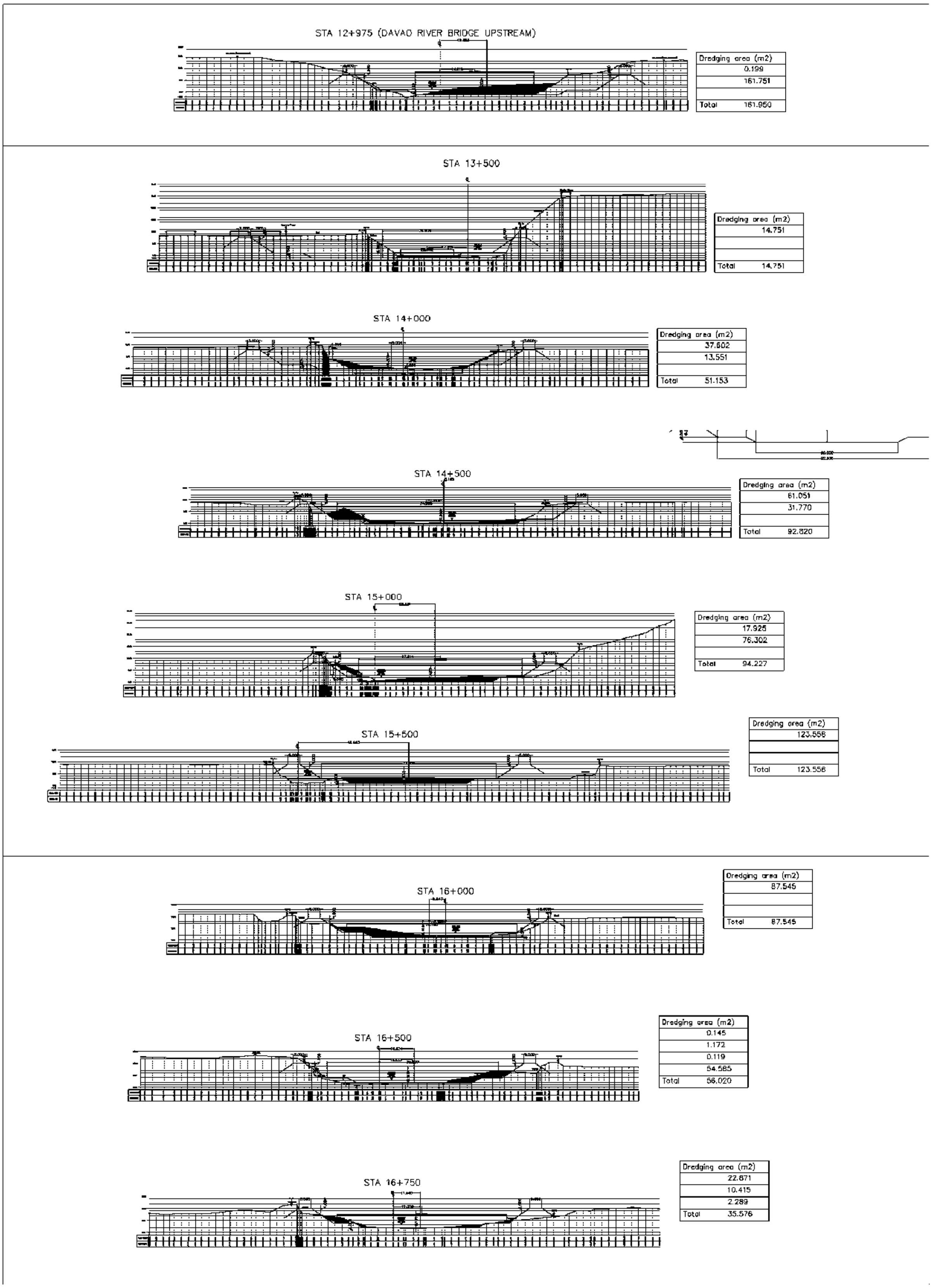
Source: Project Team

Figure 4.1.43(1) Davao River Dredged Channel Cross-section



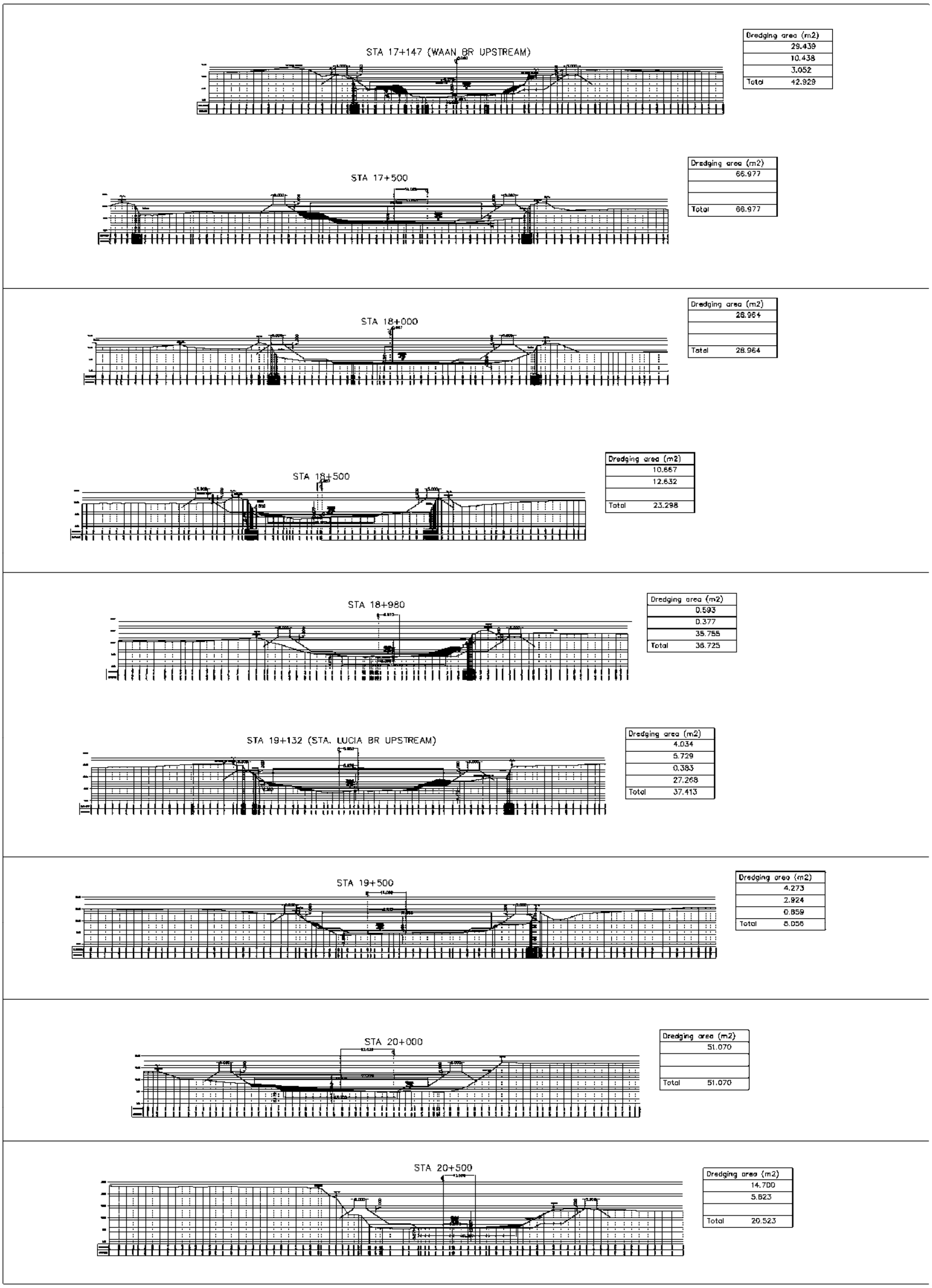
Source: Project Team

Figure 4.1.43(2) Davao River Dredged Channel Cross-section



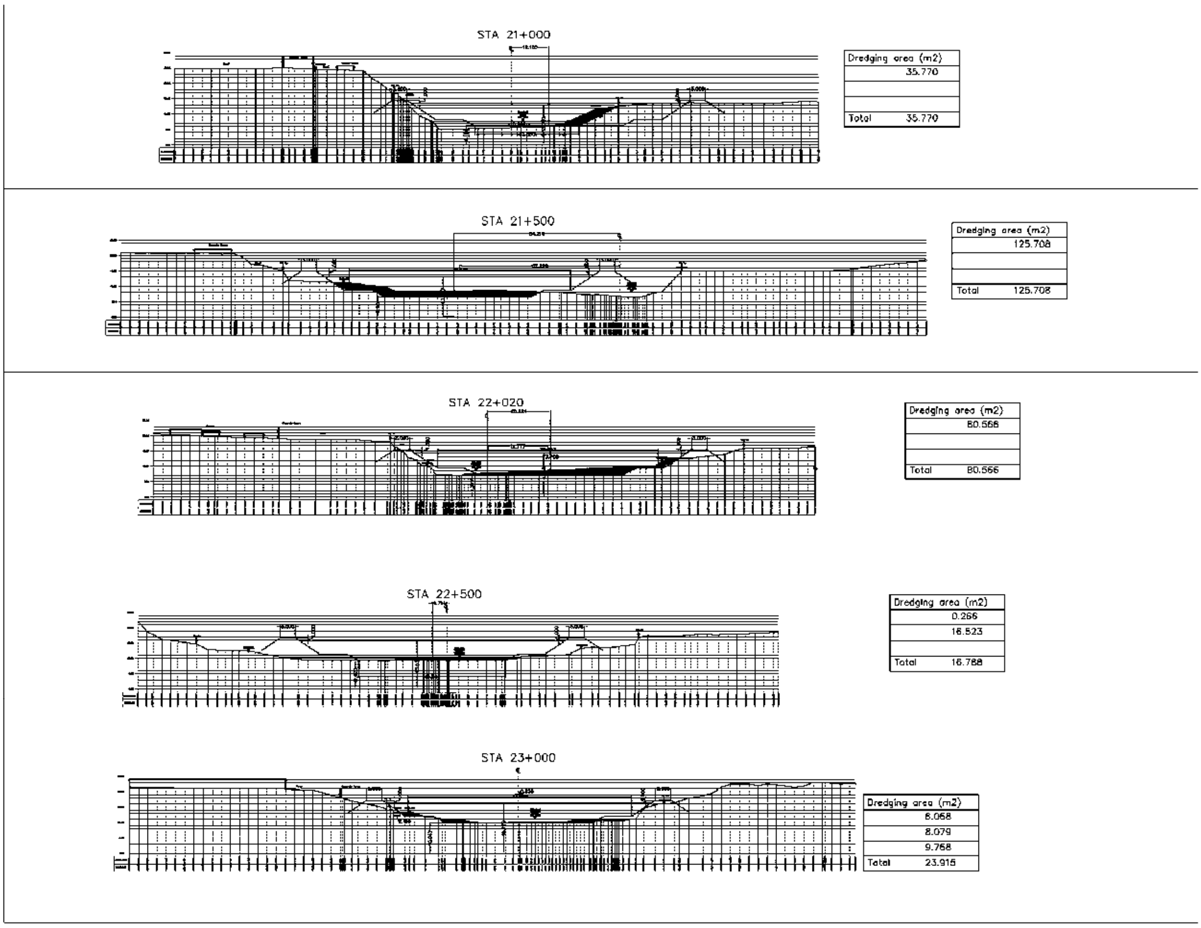
Source: Project Team

Figure 4.1.43(3) Davao River Dredged Channel Cross-section



Source: Project Team

Figure 4.1.43(4) Davao River Dredged Channel Cross-section



Source: Project Team

Figure 4.1.43(5) Davao River Dredged Channel Cross-section

- **Roughness Coefficient**

The roughness coefficient is set as shown in the table below with reference to the roughness coefficient applied to the existing river channel flow capacity calculation. Here, for the cut-off portion, 0.030, which is the roughness coefficient of the planned river channel set in "(1)Design River Shape", is applied.

Table 4.1.13 Applied Roughness Coefficient

River Section	Left bank	Main channel	Right bank
STA 23+000 ~ STA 17+000	0.060	0.032	0.060
STA 16+750 ~ STA 12+000	0.060	0.035	0.060
STA 11+500 ~ STA 10+500	0.060	0.032	0.060
STA 10+040	0.100	0.035	0.060
STA 9+480 ~ STA 8+460, STA 7+000	0.100	0.035	0.100
STA 8+000 ~ STA 7+500, STA 6+500 ~ STA 5+929	0.100	0.036	0.100
STA 5+500 ~ STA 4+500	0.100	0.032	0.100
STA 4+000 ~ STA 0+000	0.100	0.030	0.100

Source: Project Team

- **Downstream End Water Level**

The downstream end water level is the water level given as a boundary condition in the one-dimensional non-uniform flow calculation, and it greatly affects the flow capacity especially in the case of a gentle slope river channel. Since the downstream ends of the calculation section of the target river in this study is estuary, the estuary tide level is given as the downstream end water level. Here, the average high tide level (MHHW) is applied to the water level given in the flow capacity study because high tides and floods are generally handled as independent events. The average high tide level (MHHW) is MSL+0.881m (excluding +0.10m sea level rise expected due to climate change) based on the analysis regarding coastal disasters.

- **Effect to Water Level by Bridges**

The energy loss caused by contraction/expansion of bridge section and obstacles such as bridge piers is calculated by modelling bridges for properly taking into the water level rise due to bridges.

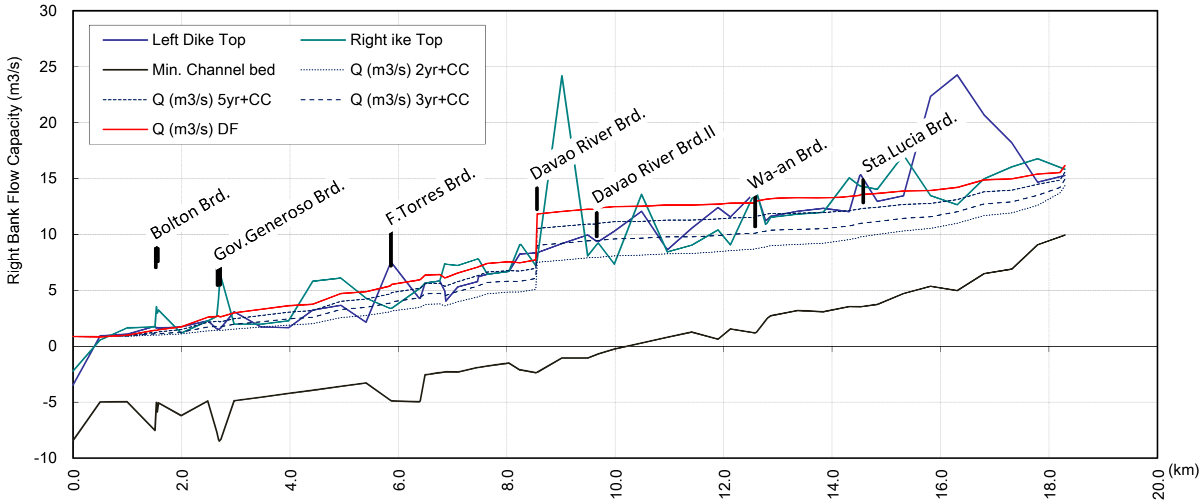
Table 4.1.14　List of Bridges to be Considered

River	Staiton	Bridge Name	Pier		
			number	width (m)	length (m)
Davao	STA 1+550	Bolton Bridge	5	1.8	7.3
	STA 2+576	Gov.Generoso Bridge	6	1.5	9.8
	STA 6+000	F.Torres Bridge	1	1.85	5.6
	STA 13+000	Davao River Bridge	4	1.9	11.75
	STA 14+130	Davao River Bridge II	2	1.8	7.32
	STA 17+207	Davao Bridge	3	1.9	3.04
	STA 19+172	Sta.Lucia Brdige	3	2.2	4.35

Source: Project Team

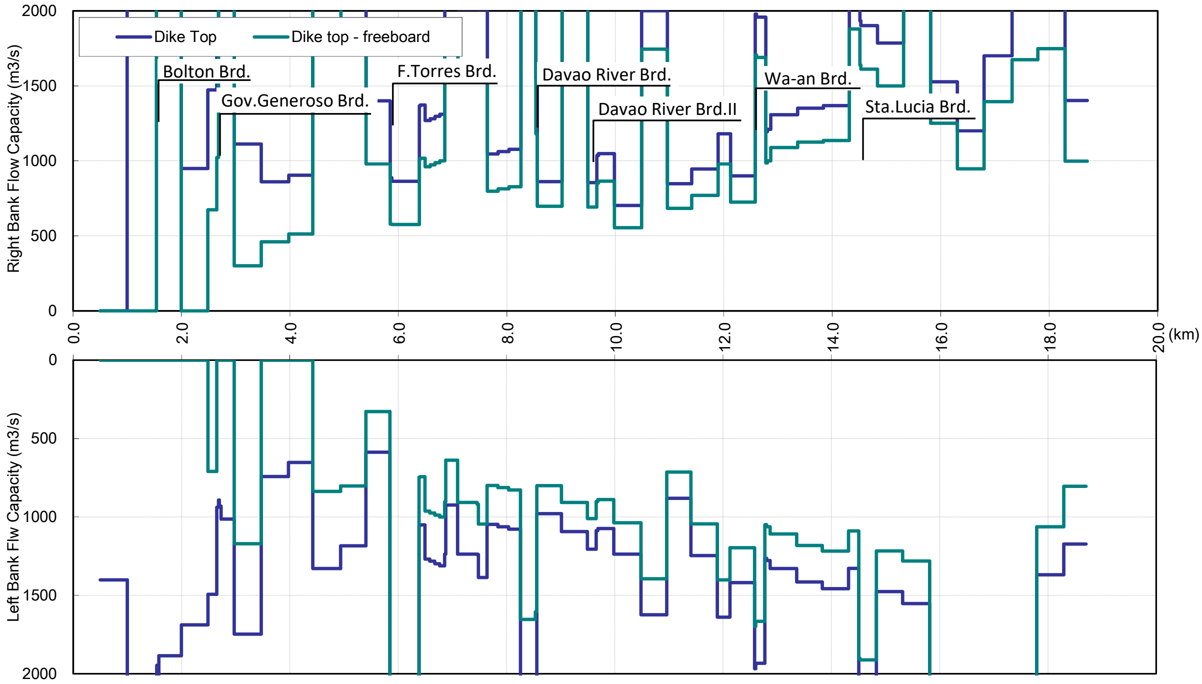
- **Flow Capacity after Dredging Work**

Under the conditions up to the previous section, H-Q relational formulas for each cross section were created by one-dimensional non-uniform flow calculation, and the flow capacity was calculated corresponding to the left and right riverbank height and the height of adding clearance to the riverbank height. The minimum flow capacity after dredging the river channel is 587 m^3/s on the left bank of STA5+500, and the average is approximately 700 to 800 m^3/s. Here, in the vicinity of the estuary, there is a cross section whose evaluation height is lower than the downstream end water level, however, a high tide embankment (MSL+3.0 m) is planned in M/P up to 2 km from the estuary.



Source: Project Team

Figure 4.1.44 Longitudinal Profile of Water Level for Dredged Channel of Davao River



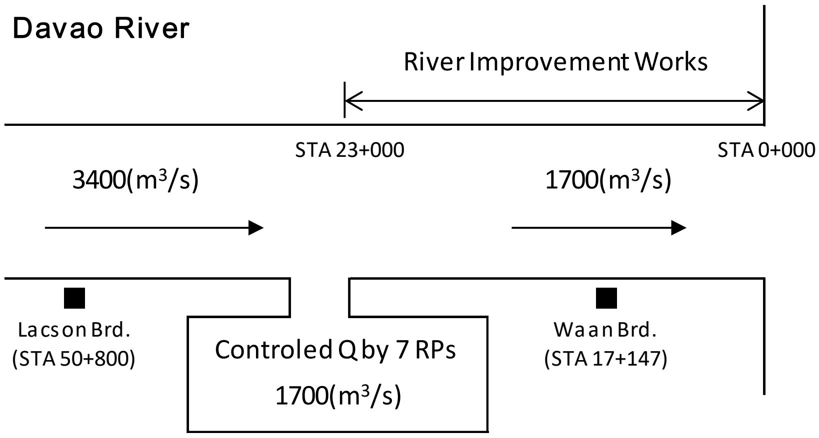
Source: Project Team

Figure 4.1.45 Flow Capacity of Dredged Channel of Davao River

(3) Retarding Ponds

Similar to the study of the design river channel, the inlet facility of the retarding ponds will be examined for the 100-year scale flood, which is the design scale of M/P.

As shown in Figure 4.1.46, the riverine flood measures in the Davao River M/P is the plan that the design flood discharge of the design river is 1,700m^3/s out of the basic design flood discharge of 3,400 m^3/s for the target section, STA 0+000 - STA 23+000, and the remaining 1,700 m^3/s is to be stored by the retarding ponds. At the candidate sites of retarding ponds set in the M/P, the inlet facility will be examined so that the design flood discharge can be stored. Table 4.1.15 shows the retarding ponds planned in M/P.



Source: Project Team

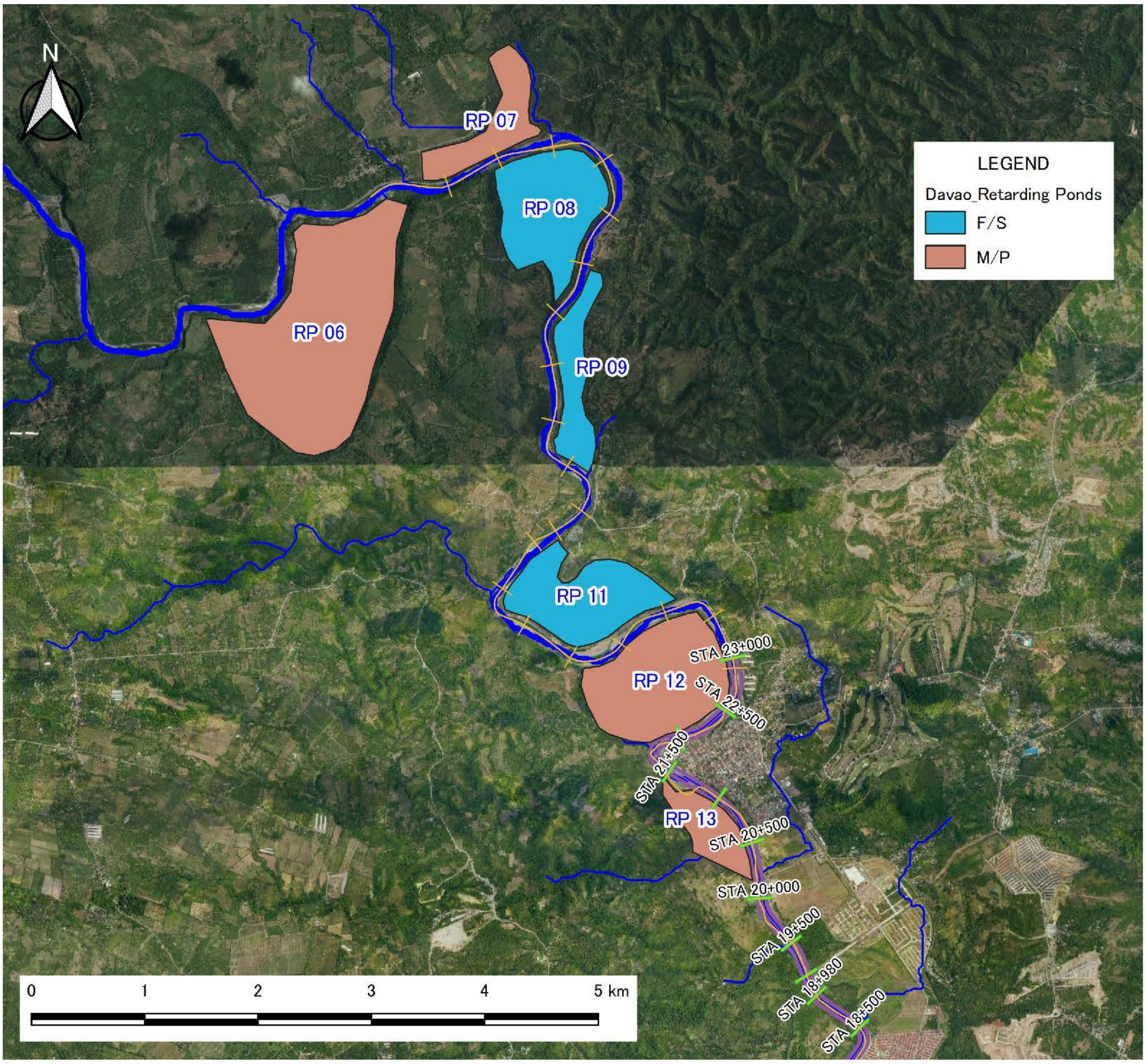
Figure 4.1.46 Design Flood Discharge Distribution of Davao River (100-yr scale flood)

Table 4.1.15 Retarding Ponds in M/P of Davao River

ID	Location*	Planning Area (km^2)	Planning Capacity (MCM)	Planning Water Depth (m)	Note
RP 06	STA 32+200 (Right bank)	2.19	10.95	5.00	
RP 07	STA 31+000 (Left bank)	0.44	2.20	5.00	
RP 08	STA 29+000 (Right bank)	0.85	4.25	5.00	Target of F/S
RP 09	STA 27+200 (Left bank)	0.39	1.95	5.00	Target of F/S
RP 11	STA 23+800 (Left bank)	0.76	3.80	5.00	Target of F/S
RP 12	STA 21+800 (Right bank)	1.03	5.15	5.00	
RP 13	STA 20+200 (Right bank)	0.31	1.55	5.00	
Total		5.97	29.85		

* Distance from the river mouth in current Davao River Alignment

Source: Project Team



Source: Project Team

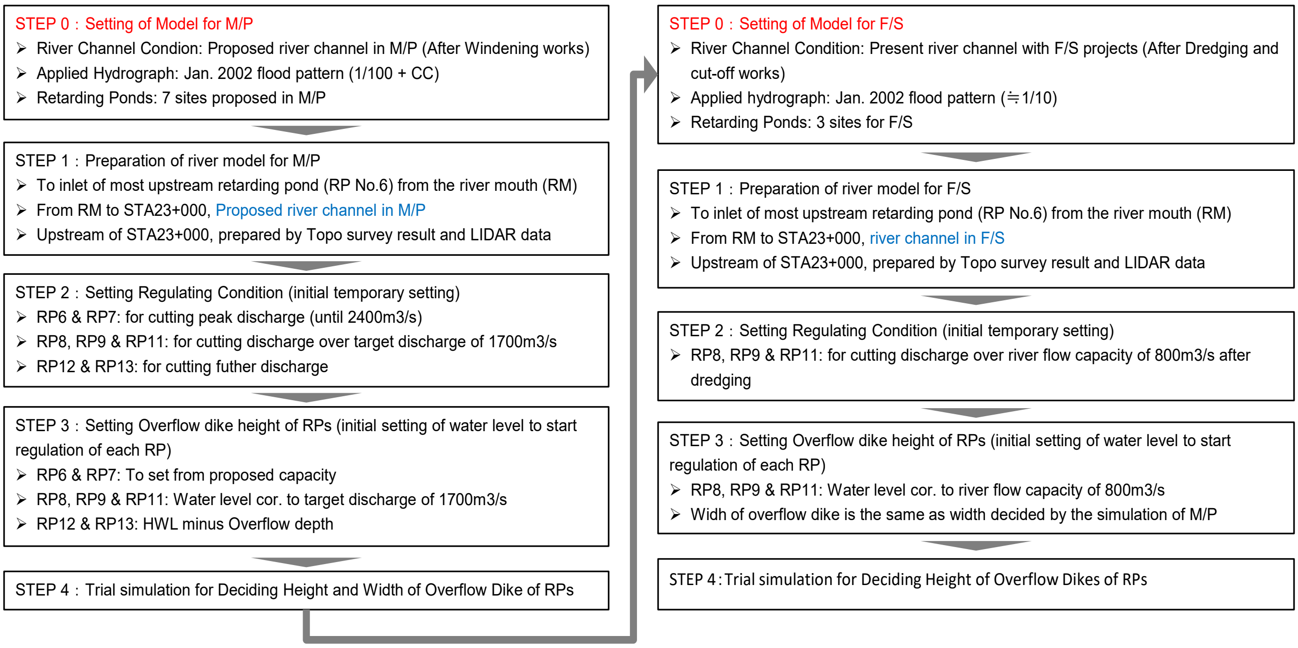
Figure 4.1.47 Location of Design Retarding Ponds in Davao River Basin

1) Tentatively Setting of Overflow Dike Specification

In order to bring out the flood control function of the retarding ponds as planned, the height and width of the overflow dike of each retarding pond is set by hydraulic analysis. For hydraulic analysis, HEC-RAS is used to build a model that combines a one-dimensional unsteady flow model of river channels and retarding ponds. The overflow dike would be the boundary condition for the transfer of discharge between the river channel model and the retarding pond model. Here, the river channel model is the design river channel of M/P, and the inflow hydrograph is the January 2002 type flood, which is the decisive flood of the basic design flood discharge (100-yr scale + 10% increase due to climate change).

Since the purpose of the study of the overflow dike is to adjust the discharge that exceeds the flow capacity of the downstream river channel, the height of overflow dike is set guided by the water level that the river channel discharge at each retarding pond inlet is to be the downstream channel design flood discharge of 1,700 m^3/s. Here, for RP12 and RP13 whose inlet is located within the design river channel section, the overflow water level shall not exceed HWL even at the peak inflow to the retarding pond. When the overflow dike height is tentatively set in this way, the overflow width would be set so that the inflow volume against the inflow hydrograph corresponding to the design control volume is expected.

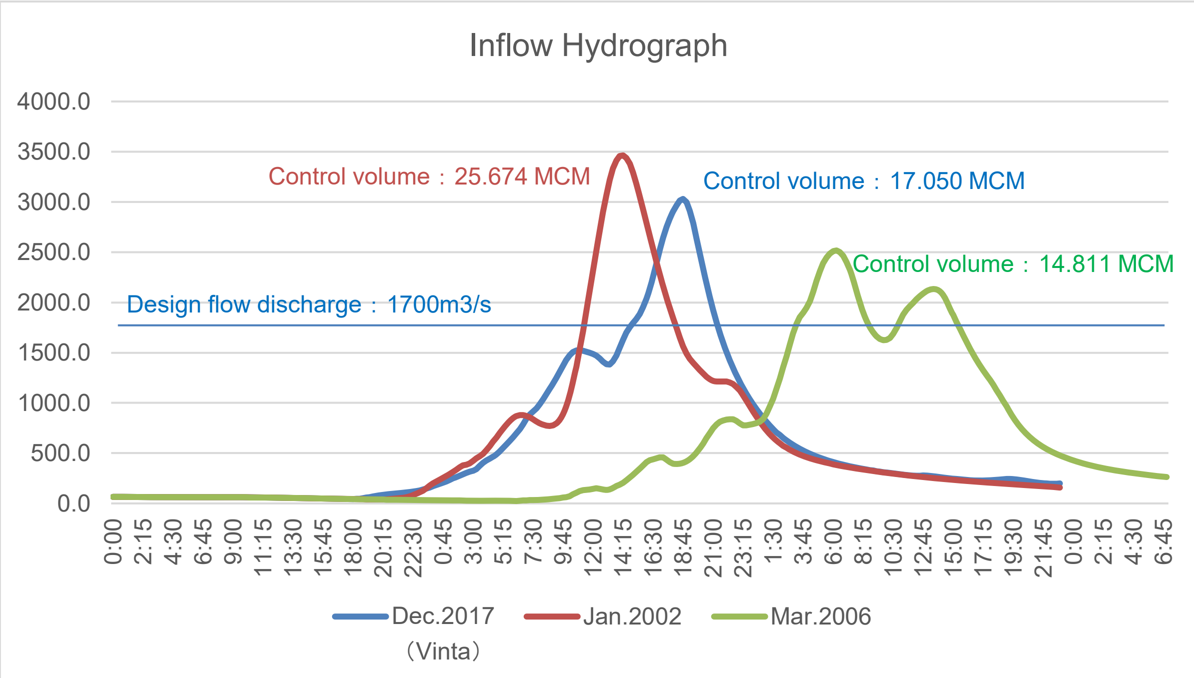
Here, it is difficult to completely reproduce a complicated flow in the simulation using the hydraulic analysis model. Therefore, it is strongly recommended that a hydraulic model experiment shall be conducted to finalize the specifications of the overflow dike in the detailed design stage.



Source: Project Team

Figure 4.1.48 Flowchart for Overflow Dike Specification Setting

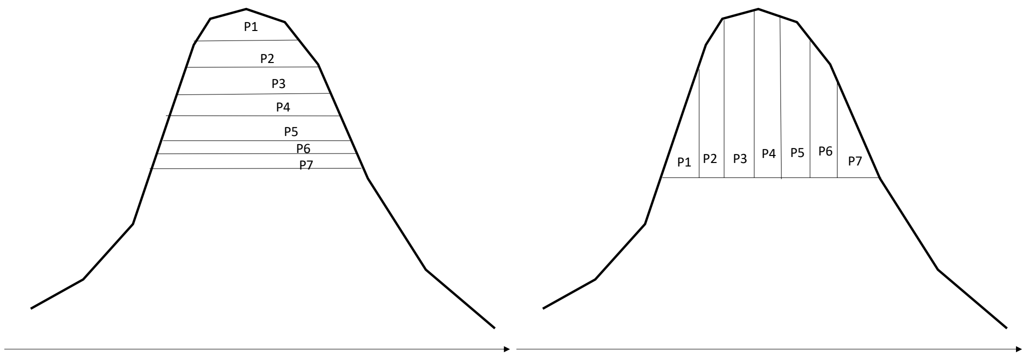
For setting the specification of retarding ponds, the target inflow hydrograph shall be determined. The inflow hydrograph that flows into the retarding ponds is created by the result of runoff analysis of the floods that the past large scale floods in the Davao River basin, January 2002 flood, March 2006 flood, and December 2017 flood (typhoon Vinta), are extended to 100-yr scale. Then, the exceeded volume of the design flood discharge of downstream river channel (1,700m3/s) is calculated (see Figure 4.1.49). As a result, since January 2002 type flood requires the largest control volume, that flood is determined as the design hydrograph. In addition, whether the retarding ponds whose specifications are determined by January 2002 type flood have sufficient flood controlling effect also against March 2006 type flood and December 2017 type flood is to be confirmed.



Source: Project Team

Figure 4.1.49 Required Flood Control Volume of each Type of Hydrograph

In case of flood controlling by multiple retarding ponds, each retarding pond can take the flood controlling way of peak-cut or stripe-cut (see Figure 4.1.50).

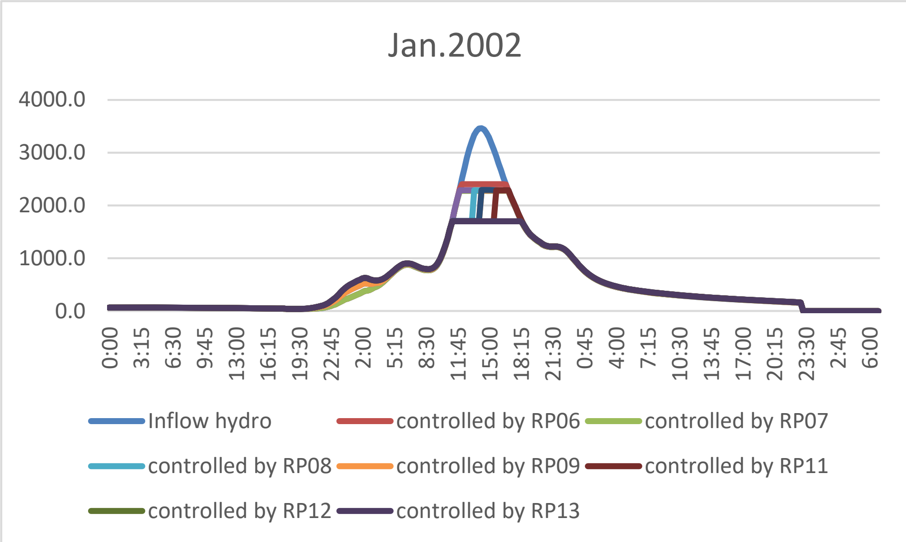


Source: Project Team

Figure 4.1.50 Flood Controlling Way of Retarding Pond (left: peak-cut, right: stripe-cut)

Peak-cut is flood controlling way to reduce the peak discharge of the hydrograph by setting the inlet level corresponding the design volume of each retarding pond. While, stripe-cut is flood controlling way to sequentially stored the volume exceeded the design flood discharge of downstream river.

The characteristic of the peak-cut is that although control volume is according to the capacity of each retarding pond, the height of the overflow levee is set according to the design hydrograph, therefore, the flood controlling effect of the retarding pond could not be fully exhibited against floods below the design scale. In addition, since the stripe-cut is corresponding to the design flood discharge of the downstream river channel, it is planned that the discharge exceeding the capacity of the retarding pond will flow in. Based on the characteristics of these flood controlling methods, RP06 and RP07 are set as peak-cut, and RP 08, RP09, and RP11, which are the target structures for F/S, are applied with stripe-cut that stores exceeded discharge of the design flood discharge. For the purpose of simplicity, the calculation is performed on the condition that all the discharge exceeding the overflow dike height flows into the retarding ponds, and then guideline value for the overflow dike height is set. As a result of this calculation, it is assumed that the peak flow rate was reduced to 2,400 m^3/s by adjusting with RP06, and the peak flow rate was reduced to 2,275 m^3/s by adjusting with RP07, then the discharge, which exceed the design flood discharge of the river channel of 1,700 m^3/s will be sequentially adjusted by the other retarding ponds (RP08 to RP13). The overflow dike height of each retarding pond is tentatively set from the H-Q relation obtained by the non-uniform flow calculation of the river channel cross-section near the assumed inlet location, and finally set by unsteady flow calculation considering with the overflow calculation.



Source: Project Team

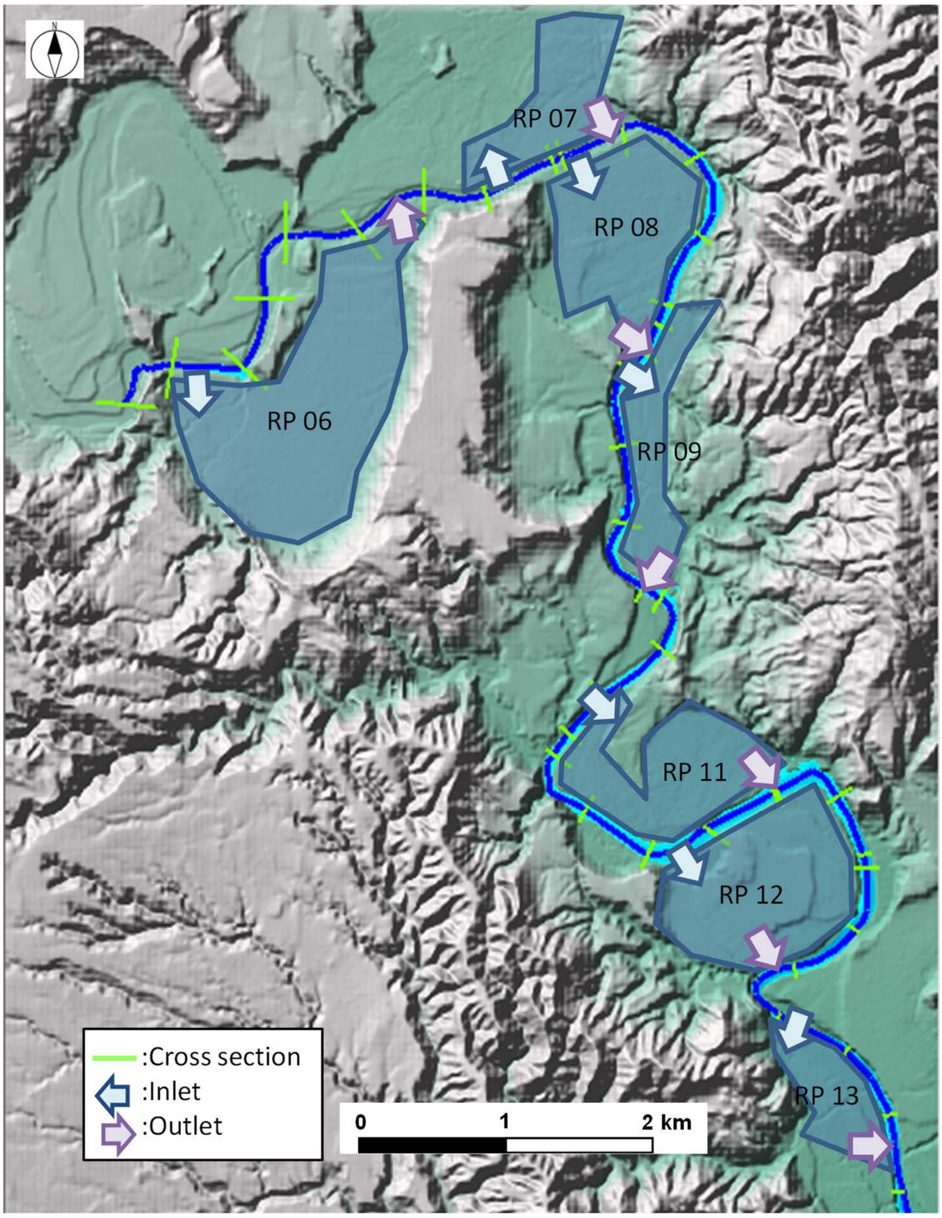
Figure 4.1.51 Hydrograph Controlled by Tentative Overflow Dike Height

The invert level of the retarding pond is tentatively set by referring to the river water level at the normal flow discharge calculated by the river channel H-Q relationship near the outlet, in order to plan to drain stored water by the gravity after floods. Here, the normal flow discharge is 73.49 m^3/s shown in Table 4.1.11 of (2) Riverbed Dredging. In addition, since flood control will be carried out by multiple retarding ponds in this project, as a result of examining comparative study with the construction cost and the stability of structure depending on the presence or absence of spillway (see Section 4.1.5 for details), spillway will be installed to each retarding basin. The height of the spillway set the height of 5m above from the invert level of the retarding pond as the same as design water depth of retarding ponds.

Table 4.1.16 Tentative Specification of Retarding Ponds

Retaring Pond ID	Control-start Flow disch. (m3/s)	Tentative Inlet-Wier top elev. (MSL+m)	Normal Flow disch. (m3/s)	Tentative RP invert elev. (MSL+m)	Tentative Spillway elev. (MSL+m)
RP 06	2400	41.79	128.98	22.95	27.95
RP 07	2275	29.88	128.98	21.12	26.12
RP 08	1700	28.08	128.98	20.43	25.43
RP 09	1700	26.72	128.98	19.22	24.22
RP 11	1700	22.13	128.98	13.65	18.65
RP 12	1700	20.67	128.98	8.96	13.96
RP 13	1700	13.73	128.98	7.41	12.41

Source: Project Team



Source: Project Team

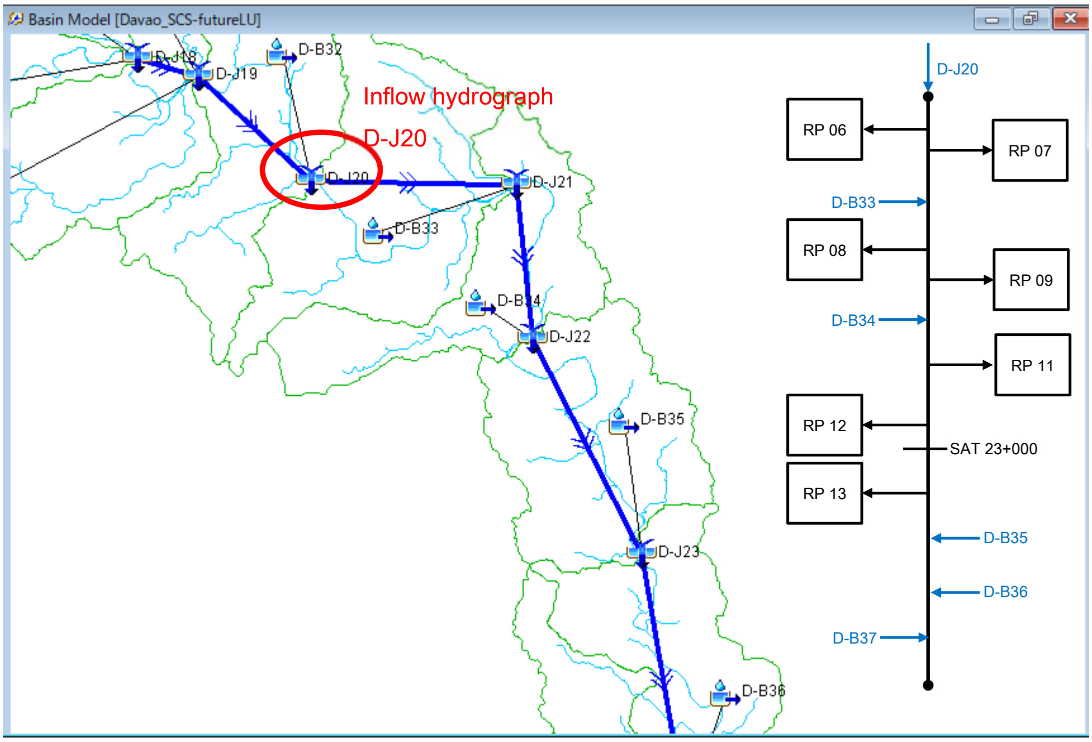
Figure 4.1.52 Location of Inlet and Outlet of Retarding Ponds

2) Unsteady Flow Analysis

The initial values of the parameters tentatively set in the previous section are used in the unsteady flow calculations, and the retarding ponds specifications are adjusted to obtain the desired flood controlling effect. The following shows the calculation conditions for the unsteady flow calculations and the policy for adjusting the retarding ponds specifications based on the analysis results.

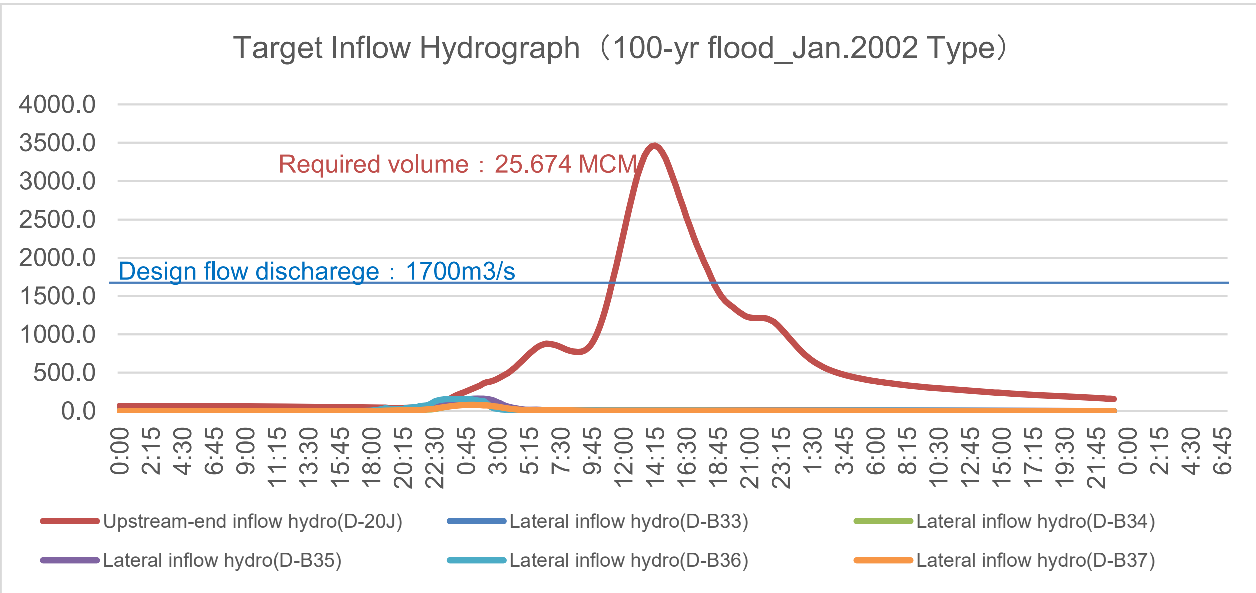
① Inflow Hydrograph and Water Level Hydrograph

For the upstream inflow hydrograph and lateral inflow hydrograph from the river basin, the results of the runoff analysis described in "Chapter 2.7 Riverine Flood Analysis" are applied. The target flood waveform is the January 2002 flood, which, as mentioned earlier, has a high flow volume exceeding the design flood discharge (1,700 m^3/s) of the downstream river channel. The inflow hydrograph and inflow points in the analytical model are shown below. The downstream end hydrograph, which is the boundary condition in the unsteady flow analysis, is given as the mean high tide level (MHHW) (MSL+0.981m), which takes climate change into account, and is constant throughout the analysis time.



Source: Project Team

Figure 4.1.53 Location of Inflow Hydrograph for Retarding Ponds Study



Source: Project Team

Figure 4.1.54 Inflow Hydrograph for Retarding Ponds Study

② **Retarding Ponds Inflow Volume Calculation**

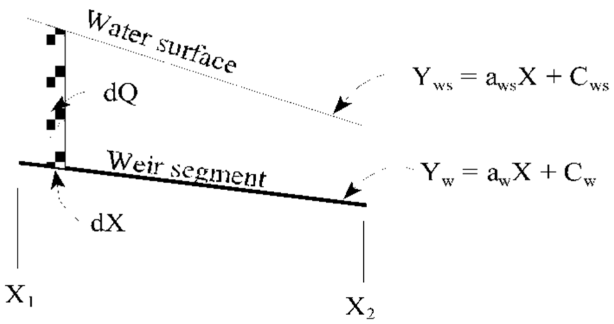
The inflow volume through the overflow dike to retarding ponds is calculated by the overflow volume formula at the weir shown below.

$$Q = CLH^{3/2}$$

Were,

C: Flow discharge coefficient
L: overflow dike top length
H: Water head exceeding overflow dike top

Since the inflow to the retarding ponds is assumed to be from the overflow dike installed in the longitudinal direction of the river, the above formula is calculated by integrating the length of the top of the overflow dike in the longitudinal direction of the river.



$$dQ = C(y_{ws} - y_w)^{3/2}\,dx$$

$$dQ = C(a_{ws}x + C_{ws} - a_w x - C_w)^{3/2}\,dx$$

$$dQ = C((a_{ws} - a_w)x + C_{ws} - C_w)^{3/2}\,dx$$

Assuming: $a_1 = a_{ws} - a_w$ and $C_1 = C_{ws} - C_w$

$$\int_{x_1}^{x_2} dQ = C\int_{x_1}^{x_2}(a_1x + C_1)^{3/2}\,dx = \frac{2C}{5a_1}(a_1x + C_1)^{5/2}\Big]_{x_1}^{x_2}$$

$$Q_{x_1-x_2} = \frac{2C}{5a_1}((a_1x_2 + C_1)^{5/2} - (a_1x_1 + C_1)^{5/2})$$

Source: "HEC RAS5.0 Reference Manual"

The values shown in Table 4.1.17 are general values for the flow discharge coefficient (C) for overflow dikes installed in the longitudinal direction of the river channel. In this study, a flow discharge coefficient (C) of 1.1 is applied because the design water depth of the retarding ponds is set at about 5 m.

Table 4.1.17　Flow Discharge Coefficient for Overflow Dike

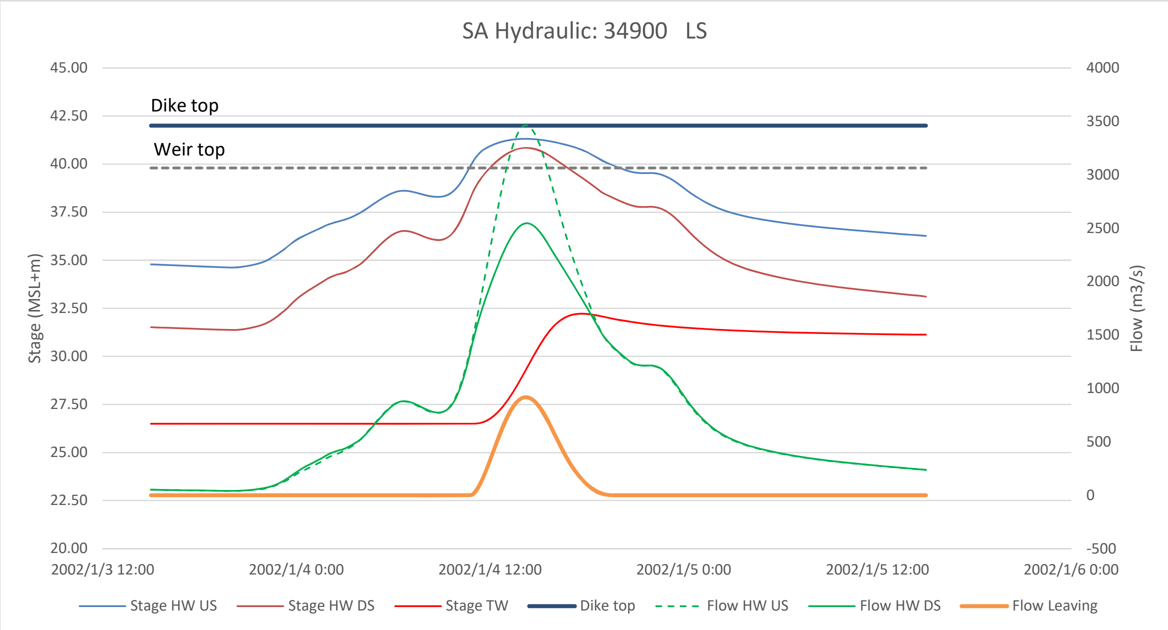
Hydraulic Structure Being Modeled	Lateral Weir Coefficient (SI units)
Levee/Roadway – 1.0m or higher above natural ground	0.83 to 1.2 (1.1 default)
Levee/Roadway – 0.3m to 1.0m higher above natural ground	0.55 to 1.1
Natural high ground barrier – 0.3m to 1.0m high	0.28 to 0.55
Non-elevated overbank terrain. Overland flow escaping the main river	0.06 to 0.28

Source: "Combine 1D and 2D Modelling with HEC-RAS」Hydrologic Engineering Centre", August 2013

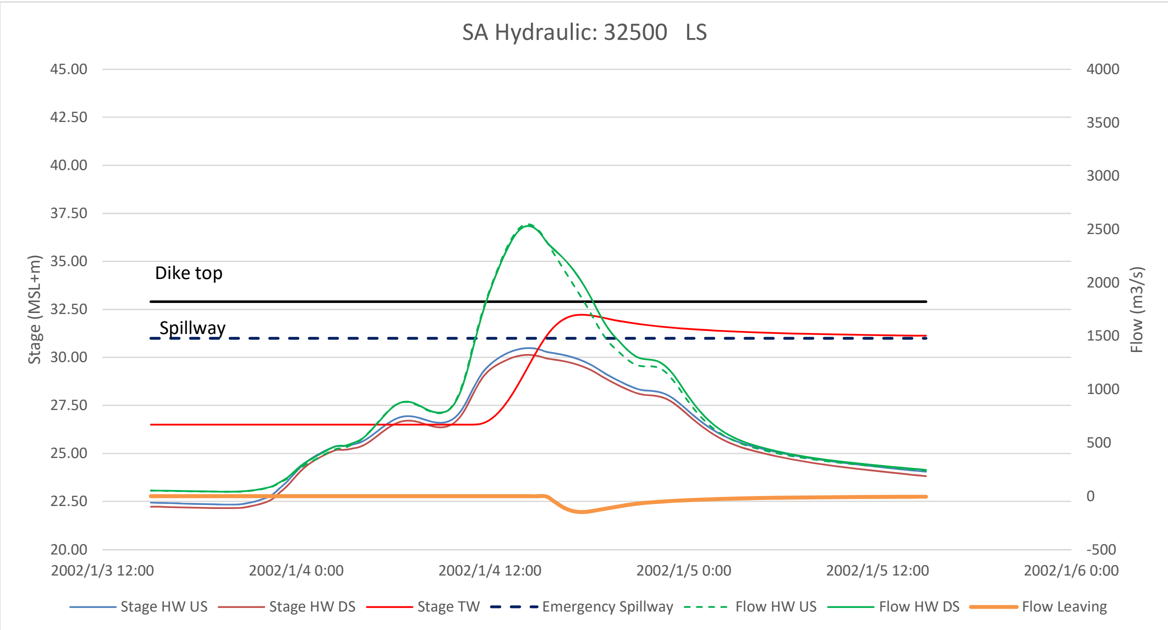
③ **Adjustment of Retarding Pond Specifications**

It is described regarding the adjustment of specifications of retarding pond corresponding to the river water level by the unsteady flow analysis. The purpose of RP 06 and RP 07 is to reduce the peak flow discharge of the target hydrograph by flood controlling. Therefore specifications (overflow dike height and width) of these retarding ponds are adjusted to the existing topographically feasible so that the peak flow discharge after adjustment is close to the tentatively set value. Here, since inflow from other than the inlet is not assumed in the planning, the height of the spillway is set to be higher than the peak channel water level near the outlet (during the target flood). The results of the analysis are shown in Figure 4.1.55 (1)-(7).

RP 06 Inlet



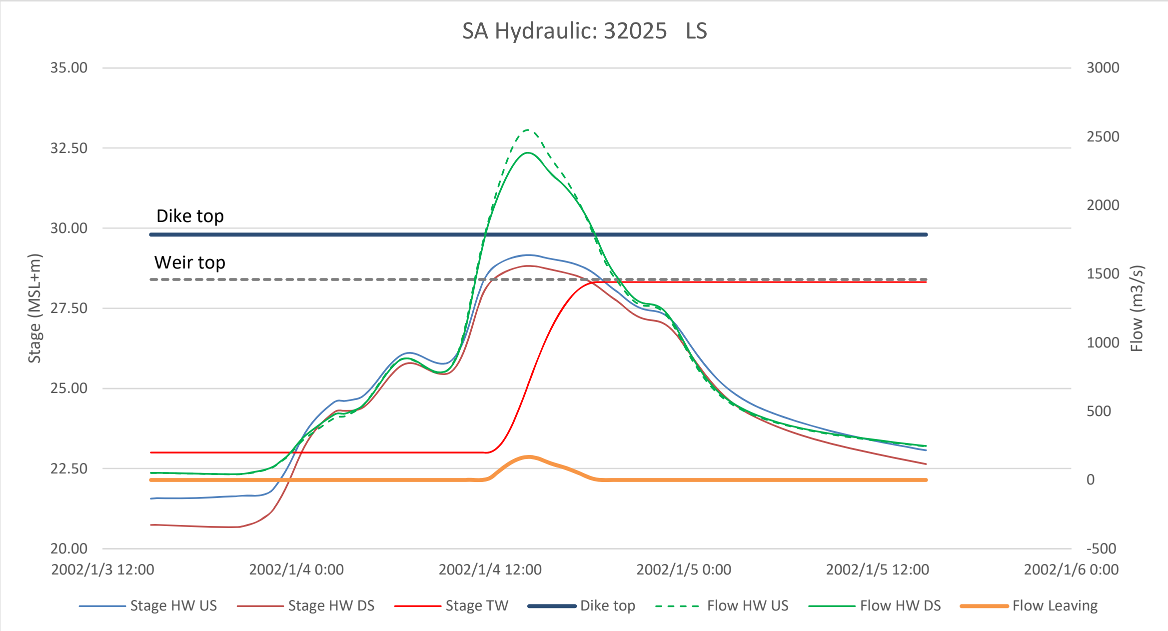
RP 06 Outlet



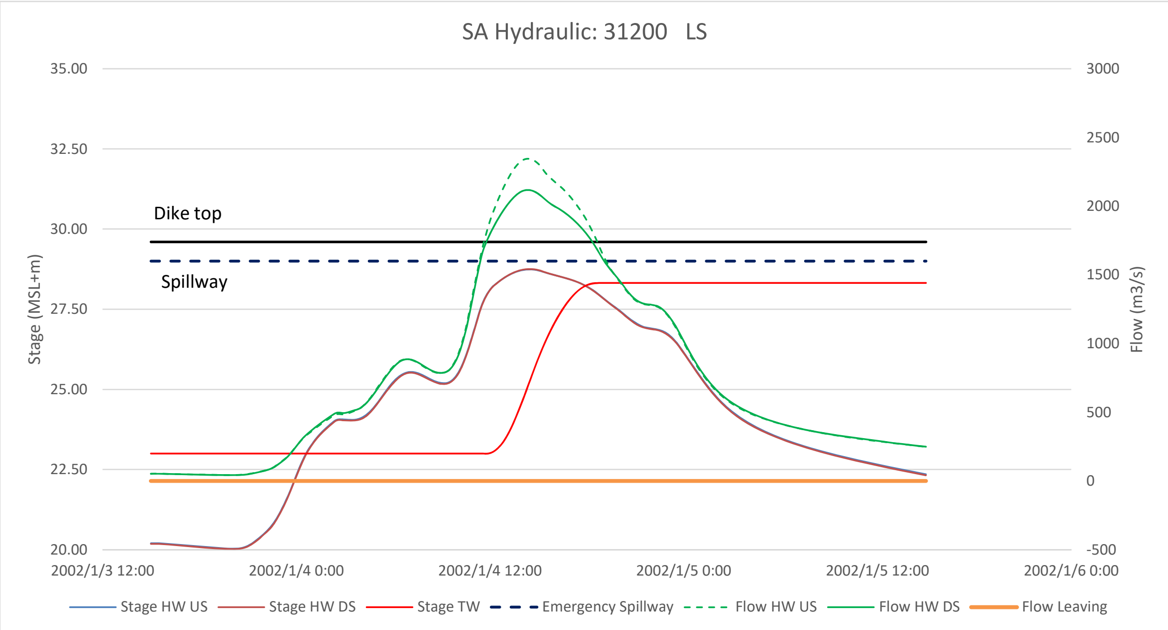
Source: Project Team

Figure 4.1.55(1) Result of Unsteady Flow Analysis of Retarding Pond (RP 06)

RP 07 Inlet



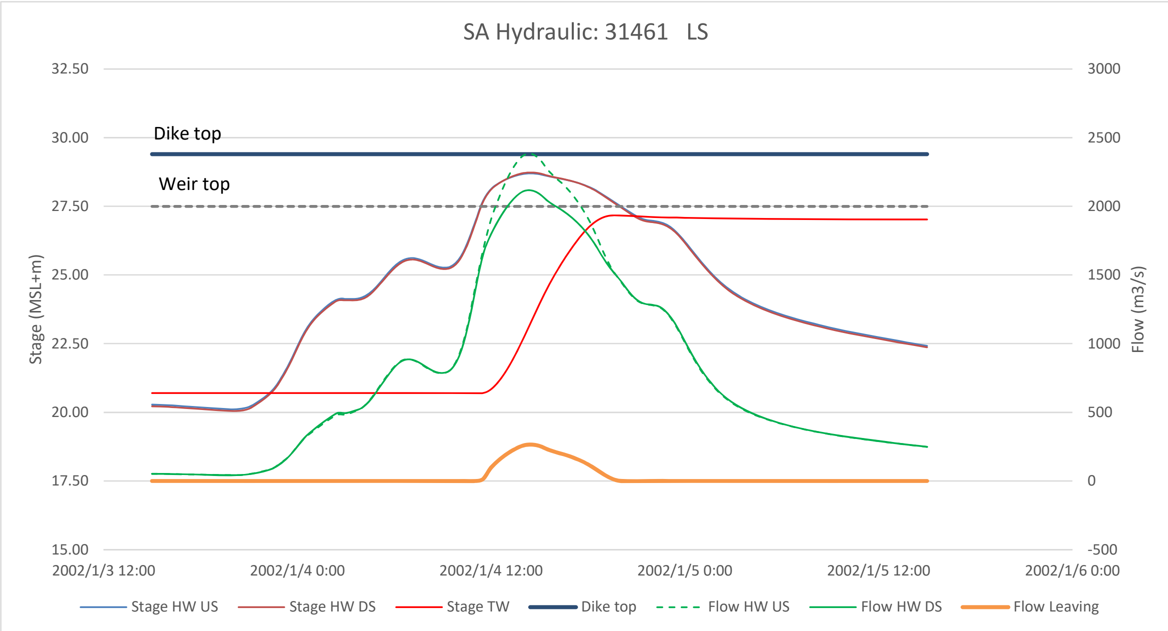
RP 07 Outlet



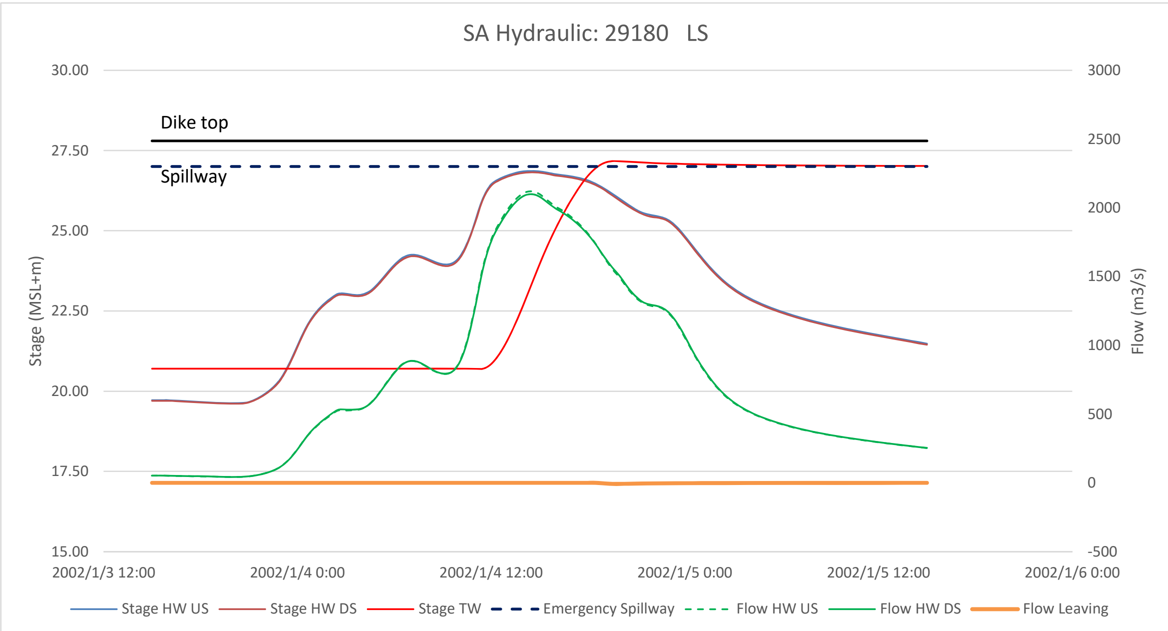
Source: Project Team

Figure 4.1.55(2) Result of Unsteady Flow Analysis of Retarding Pond (RP 07)

RP 08 Inlet



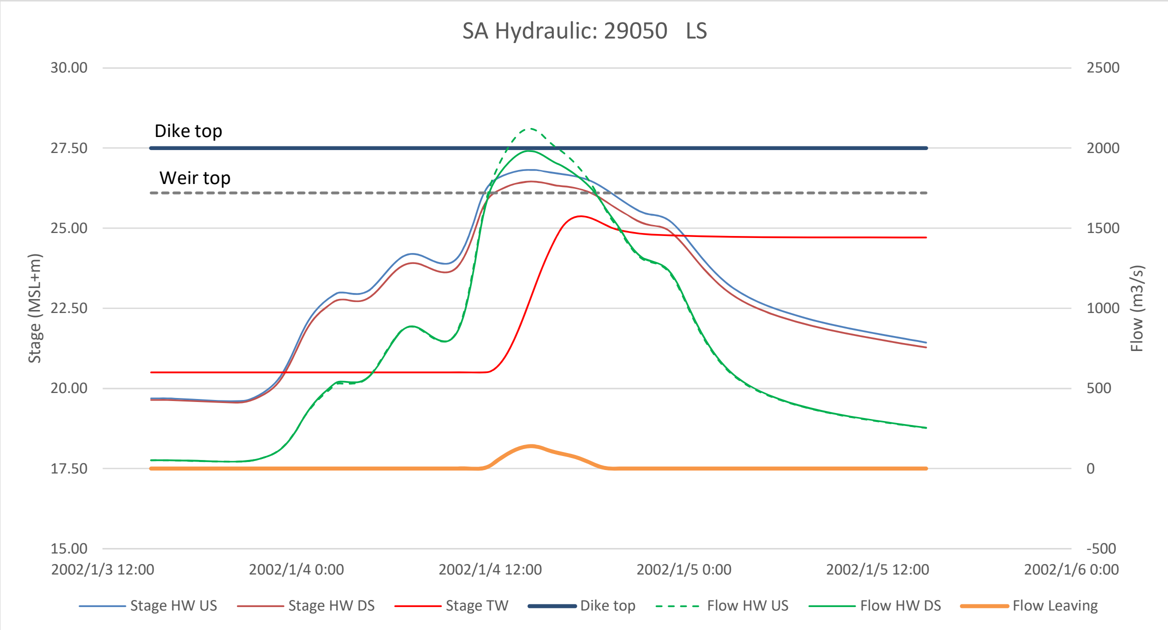
RP 08 Outlet



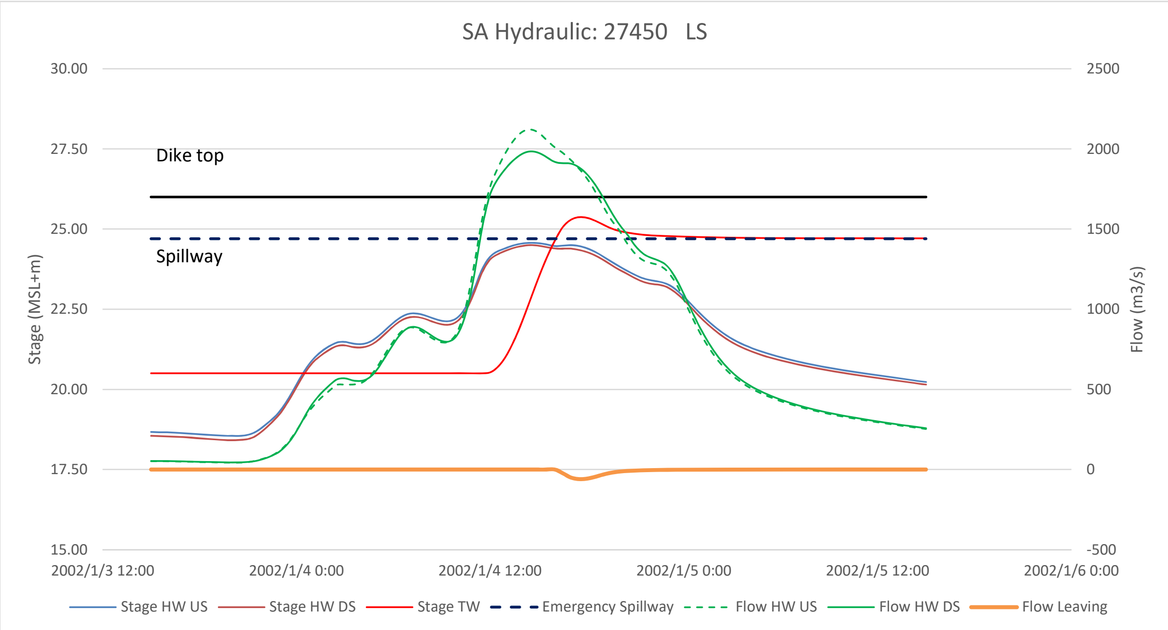
Source: Project Team

Figure 4.1.55(3) Result of Unsteady Flow Analysis of Retarding Pond (RP 08)

RP 09 Inlet



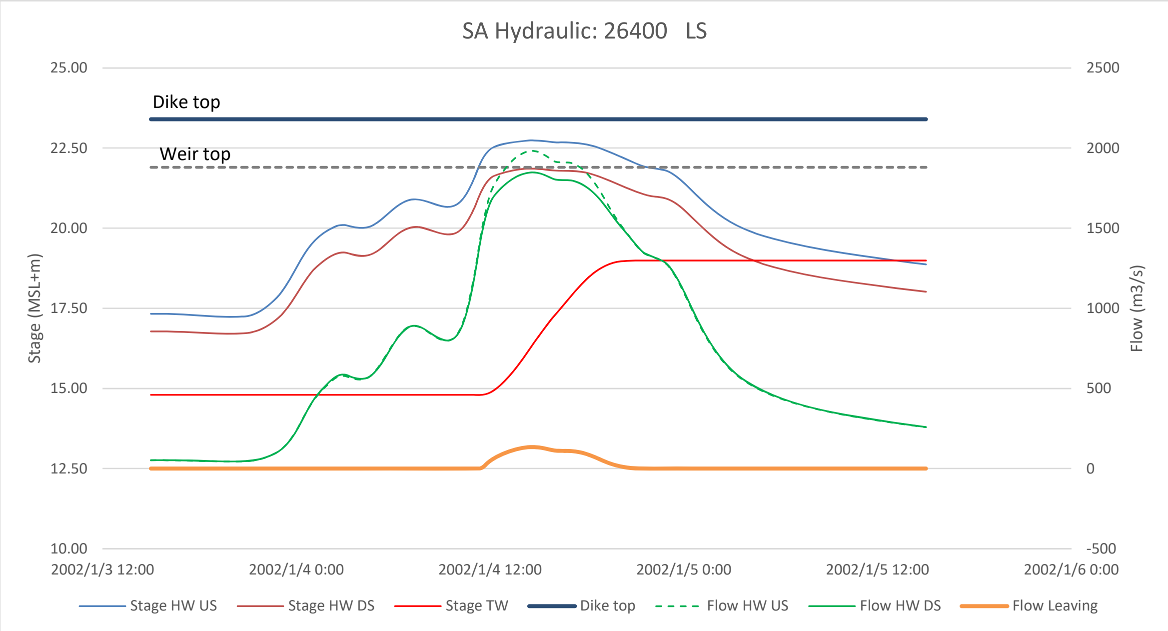
RP 09 Outlet



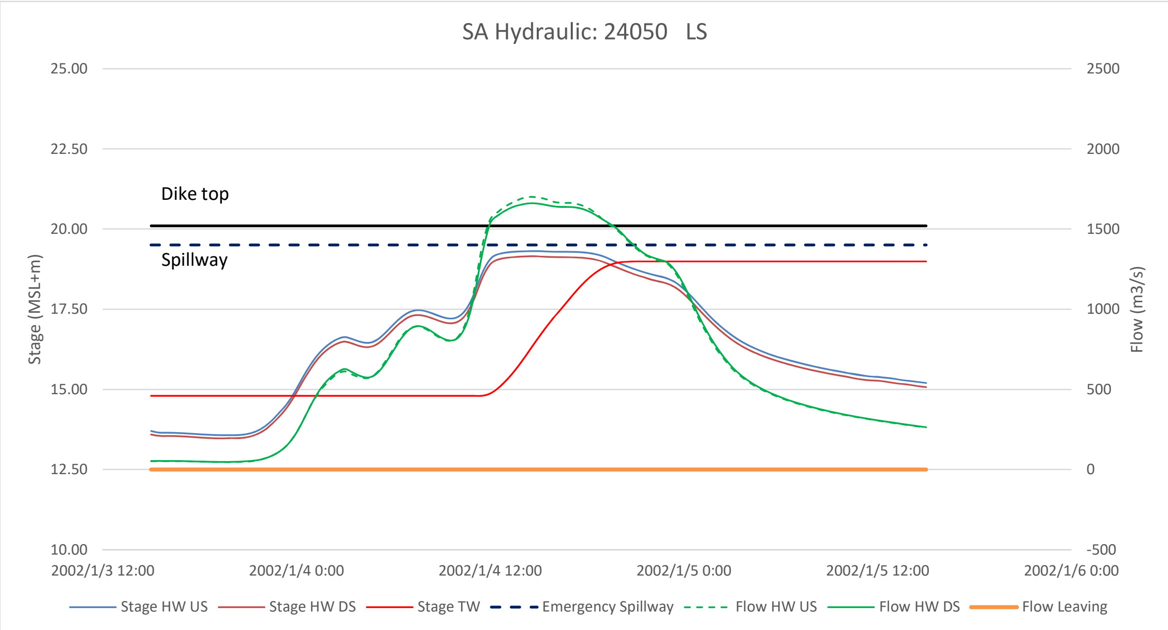
Source: Project Team

Figure 4.1.55(4) Result of Unsteady Flow Analysis of Retarding Pond (RP 09)

RP 11 Inlet



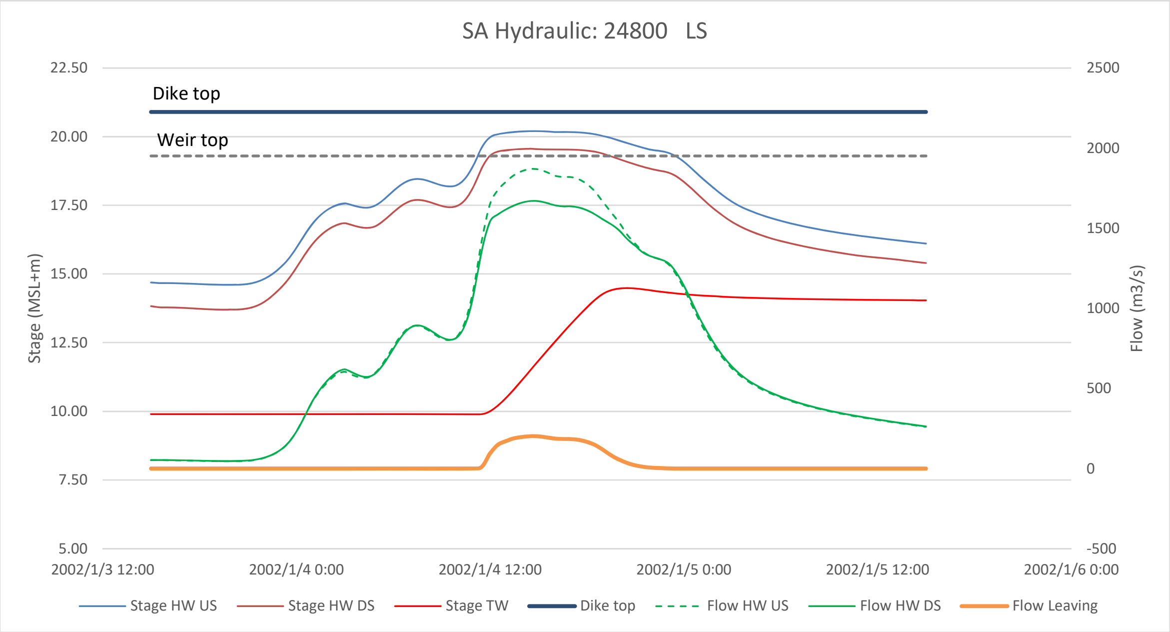
RP 11 Outlet



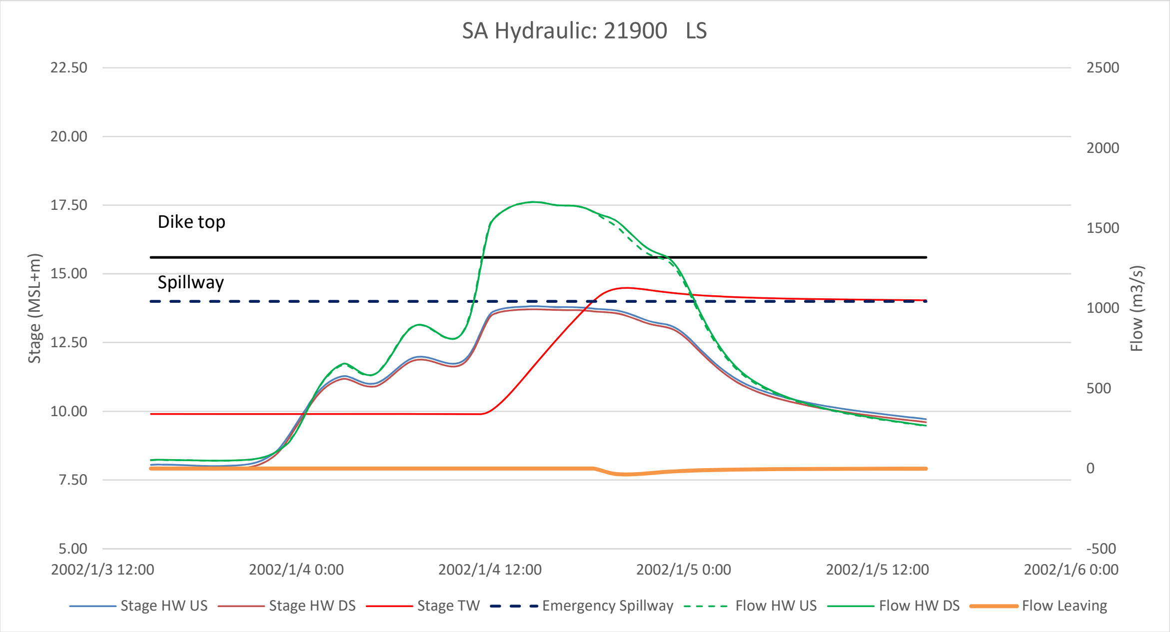
Source: Project Team

Figure 4.1.55(5) Result of Unsteady Flow Analysis of Retarding Pond (RP 11)

RP 12 Inlet



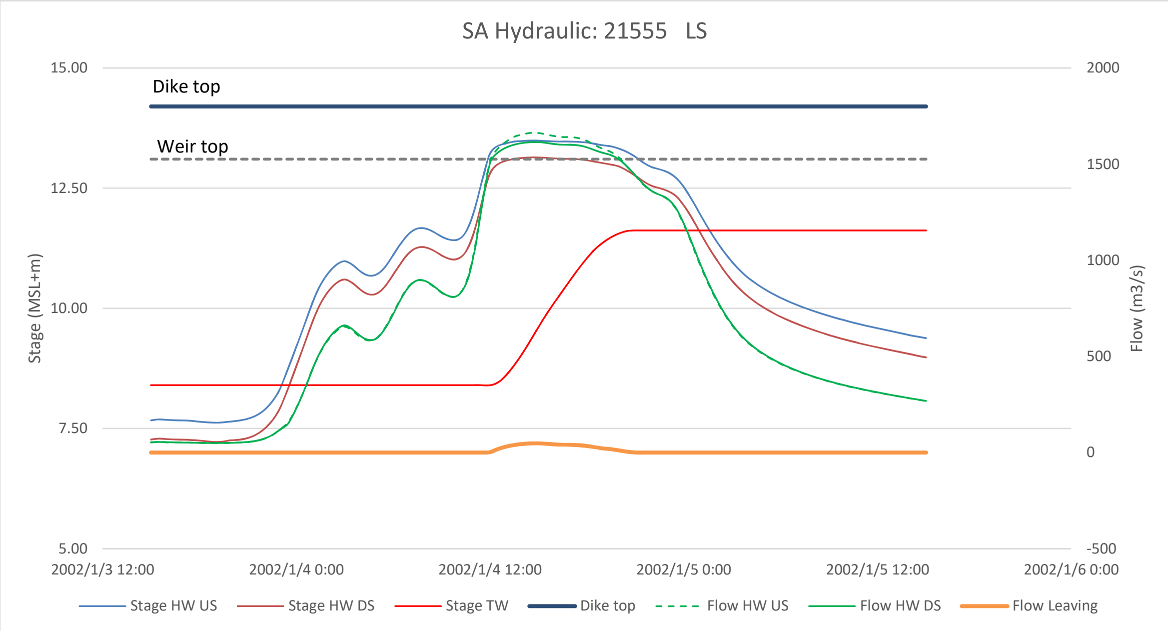
RP 12 Outlet



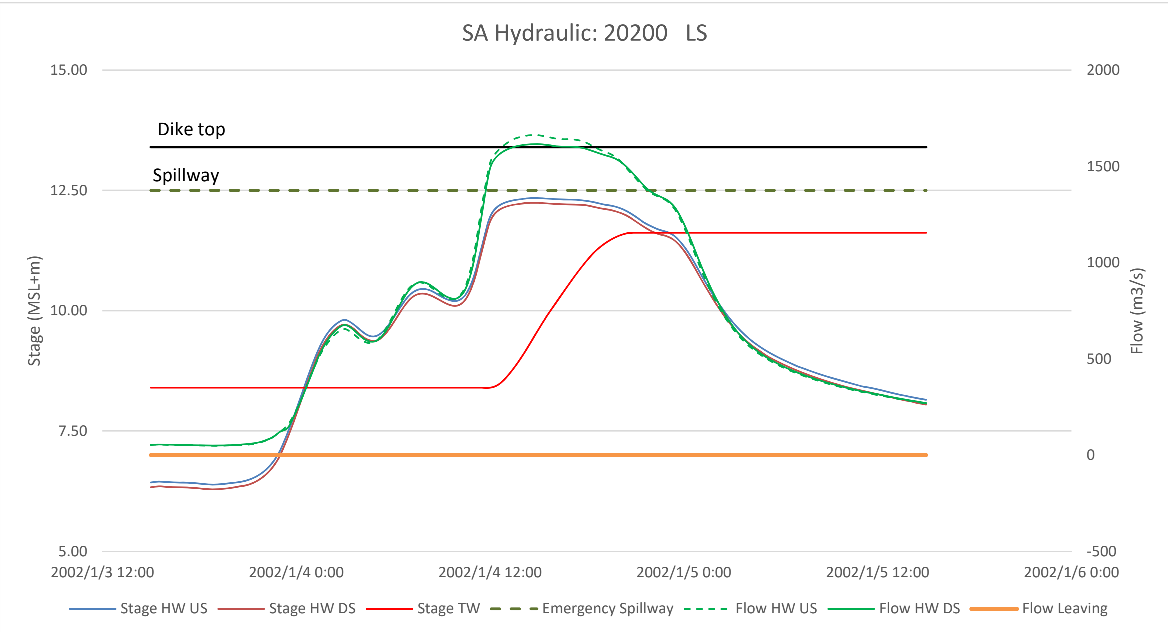
Source: Project Team

Figure 4.1.55(6) Result of Unsteady Flow Analysis of Retarding Pond (RP 12)

RP 13 Inlet



RP 13 Outlet



Source: Project Team

Figure 4.1.55(7) Result of Unsteady Flow Analysis of Retarding Pond (RP 13)

Table 4.1.18 shows the specification of the retarding ponds corresponding to the M/P. As shown in Figure 4.1.55, the maximum storage levels in RP 06, RP 09, and RP 12 are planned to exceed the spillway height. This is due to the fact that it is inefficient to control the inflow to the retarding ponds only at the inlet side because of the topographical difference in elevation between the location of the inlet and the outlet. In order to prevent unforeseen breakage of the surrounding dikes and separation dikes of the retarding ponds, the spillways are designed in all retarding ponds in consideration of cases where the waveform differs from the target flood hydrograph, even in the three retarding ponds mentioned above, even if there is an excess flood or the probability of a similar scale. This will reduce the peak of the target hydrograph and make better use of the improvement effect of the downstream river channel.

Table 4.1.18 List of Retarding Ponds Specifications

Retarding Pond ID	Control-start Flow discharge (m3/s)	Design Inlet-wier top (MSL+m)	Design Inlet-wier width (m)	Design RP invert (MSL+m)	Design Spilway (MSL+m)	Maximum RP water level (MSL+m)	Maximum RP storage volume (MCM)
RP 06	1517.99	39.80	500	26.50	31.00	32.22	12.54
RP 07	1929.92	28.40	350	23.00	29.00	28.31	2.36
RP 08	1682.00	27.50	180	20.70	27.00	27.17	4.88
RP 09	1761.51	26.10	300	20.50	24.70	25.39	1.80
RP 11	1488.02	21.90	400	14.80	19.50	19.18	2.94
RP 12	1429.74	19.30	450	9.90	14.00	14.68	4.91
RP 13	1530.25	13.10	400	8.40	12.50	12.35	1.22

Source: Project Team

By applying the above specifications, as a result of the flood control calculations for the March 2006 type flood and the December 2017 type flood, which are large-scale floods other than the January 2002 flood, it is confirmed that the discharge for both flood hydrographs controlled by retarding ponds would be below 1,700 m^3/s, which is the design flood discharge of the downstream river channel. Figure 4.1.56(1)-(7) and Figure 4.1.57(1)-(7) show the analysis results.

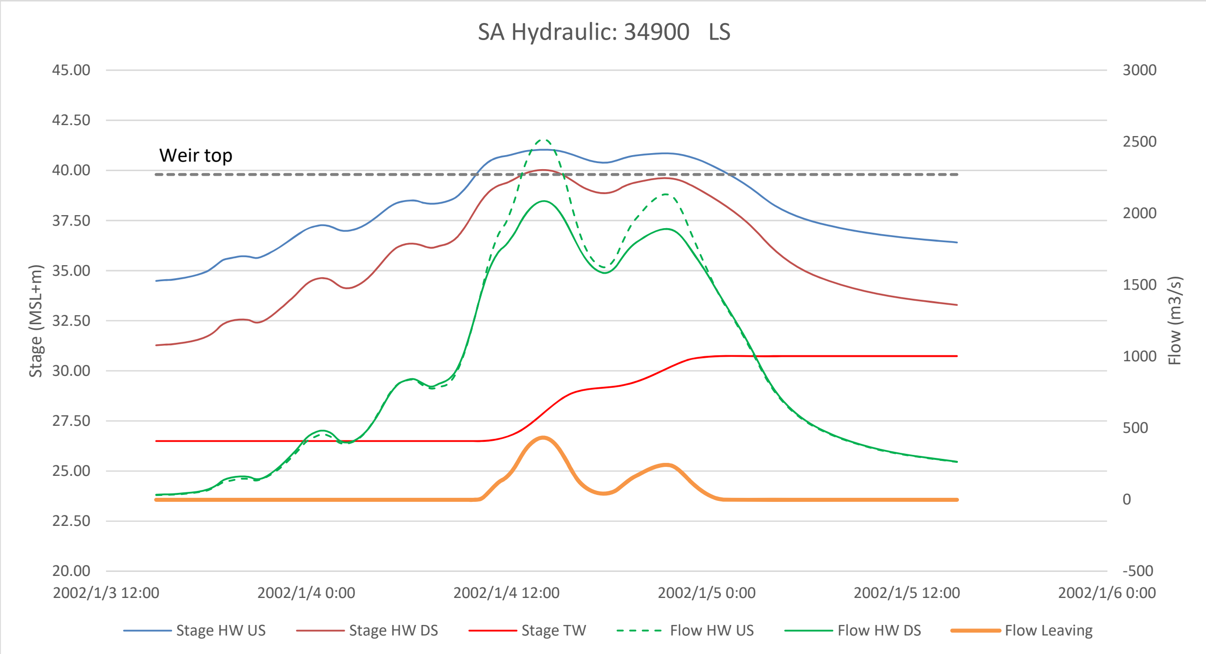
Based on the results of the flood control calculations for the three hydrographs, the height of the separation dike should be set to satisfy the height obtained by adding 0.6 m as a clearance to the maximum water level at the inlet and outlet.

Table 4.1.19 Separation Dike Height of Retarding Ponds

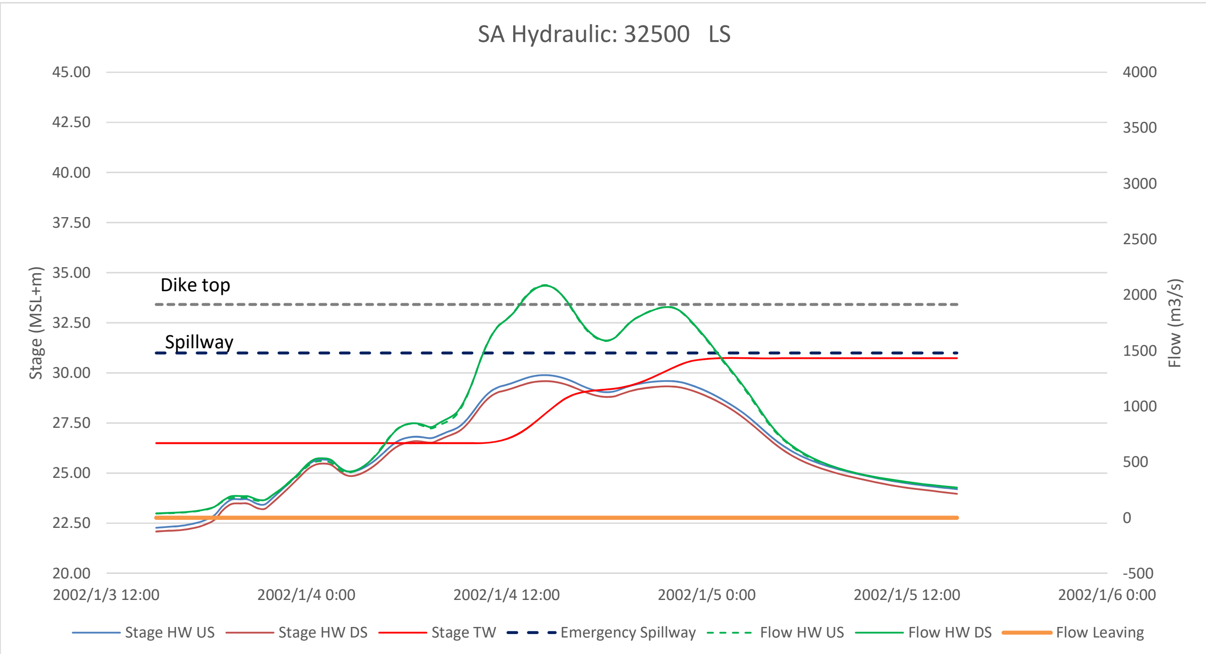
		RP 06		RP 07		RP 08		RP 09		RP 11		RP 12		RP 13	
		Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
type-2002	Dike top	41.93	32.82	29.76	29.60	29.33	27.77	27.42	25.99	23.35	20.10	20.84	15.28	14.12	13.10
	Max WS	41.33	32.22	29.16	28.75	28.73	27.17	26.82	25.39	22.75	19.36	20.24	14.68	13.52	12.38
	Weir/Spillway	39.80	31.00	28.40	29.00	27.50	27.00	26.10	24.70	21.90	19.50	19.30	14.00	13.10	12.50
type-2006	Dike top	41.63	31.60	29.46	29.60	28.95	27.60	27.19	25.30	23.22	20.10	20.75	15.56	14.10	13.36
	Max WS	41.03	30.74	28.86	28.35	28.35	26.64	26.59	24.35	22.62	19.28	20.15	14.96	13.50	12.76
	Weir/Spillway	39.80	31.00	28.40	29.00	27.50	27.00	26.10	24.70	21.90	19.50	19.30	14.00	13.10	12.50
type-2017	Dike top	41.80	31.60	29.63	29.60	29.16	27.60	27.32	25.30	23.28	20.10	20.78	15.02	14.08	13.10
	Max WS	41.20	30.93	29.03	28.57	28.56	26.77	26.72	24.47	22.68	19.30	20.18	14.42	13.48	12.31
	Weir/Spillway	39.80	31.00	28.40	29.00	27.50	27.00	26.10	24.70	21.90	19.50	19.30	14.00	13.10	12.50
	Design Dike top	42.00	32.90	29.80	29.60	29.40	27.80	27.50	26.00	23.40	20.10	20.90	15.60	14.20	13.40
	Dike top - Weir/Spillway	2.20	1.90	1.40	0.60	1.90	0.80	1.40	1.30	1.50	0.60	1.60	1.60	1.10	0.90

Source: Project Team

RP 06 Inlet



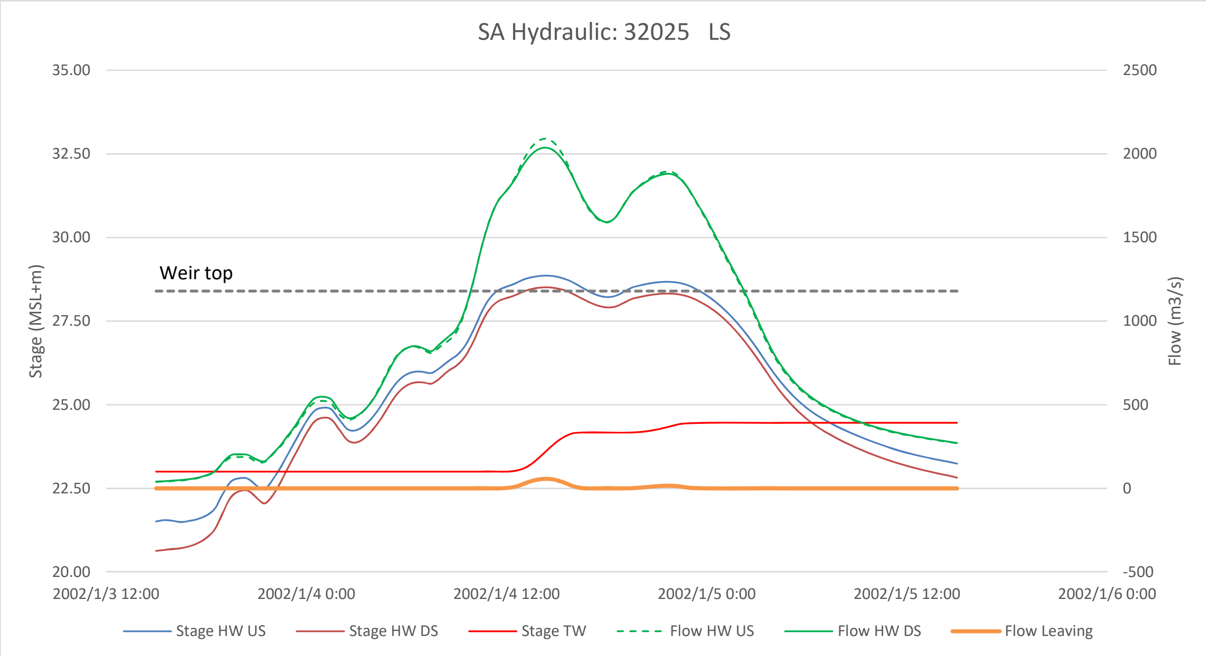
RP 06 Outlet



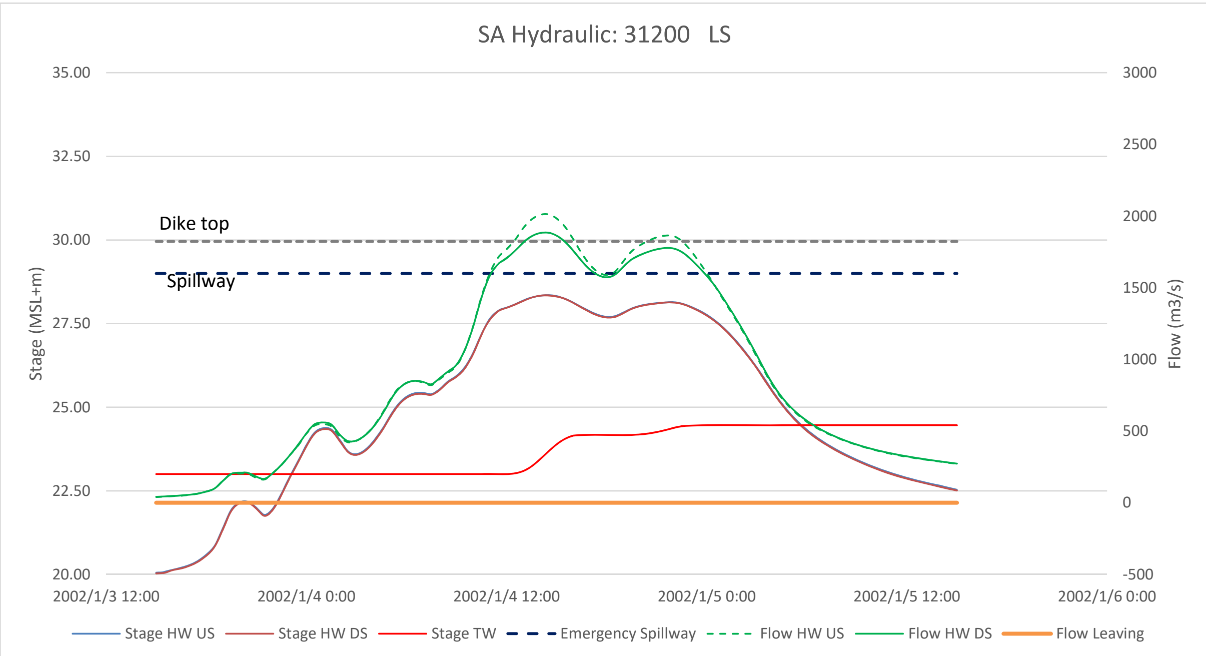
Source: Project Team

Figure 4.1.56(1) Result of Unsteady Flow Analysis of Retarding Pond (RP 06): March 2006 Type Flood

RP 07 Inlet



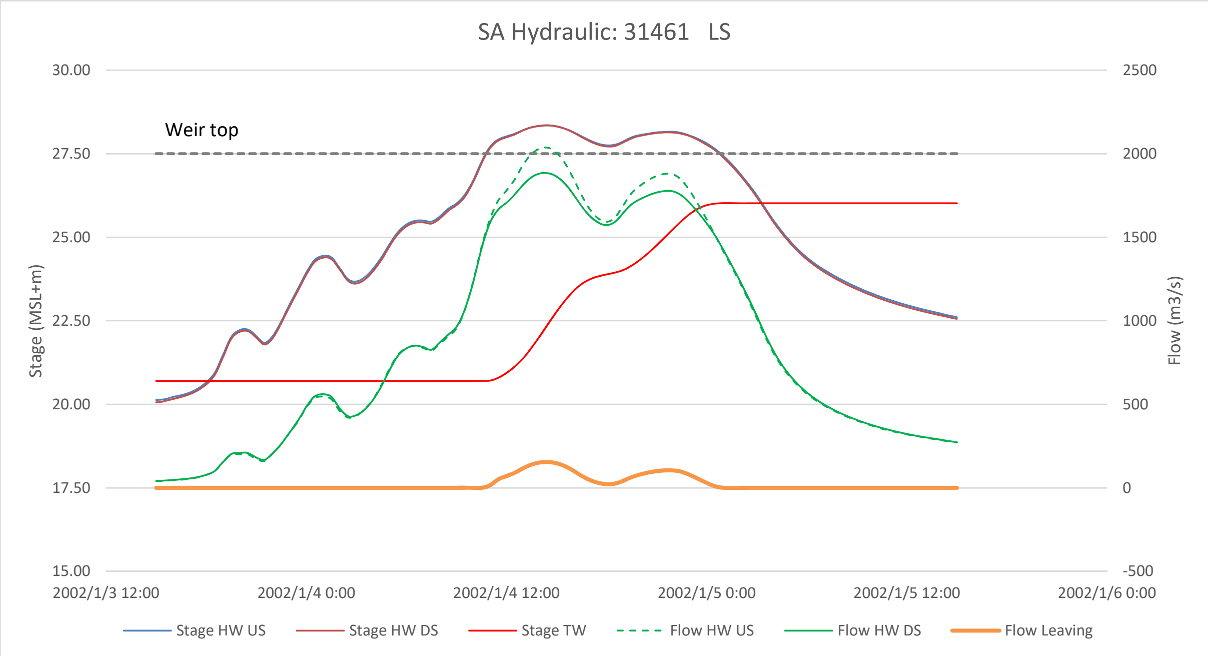
RP 07 Outlet



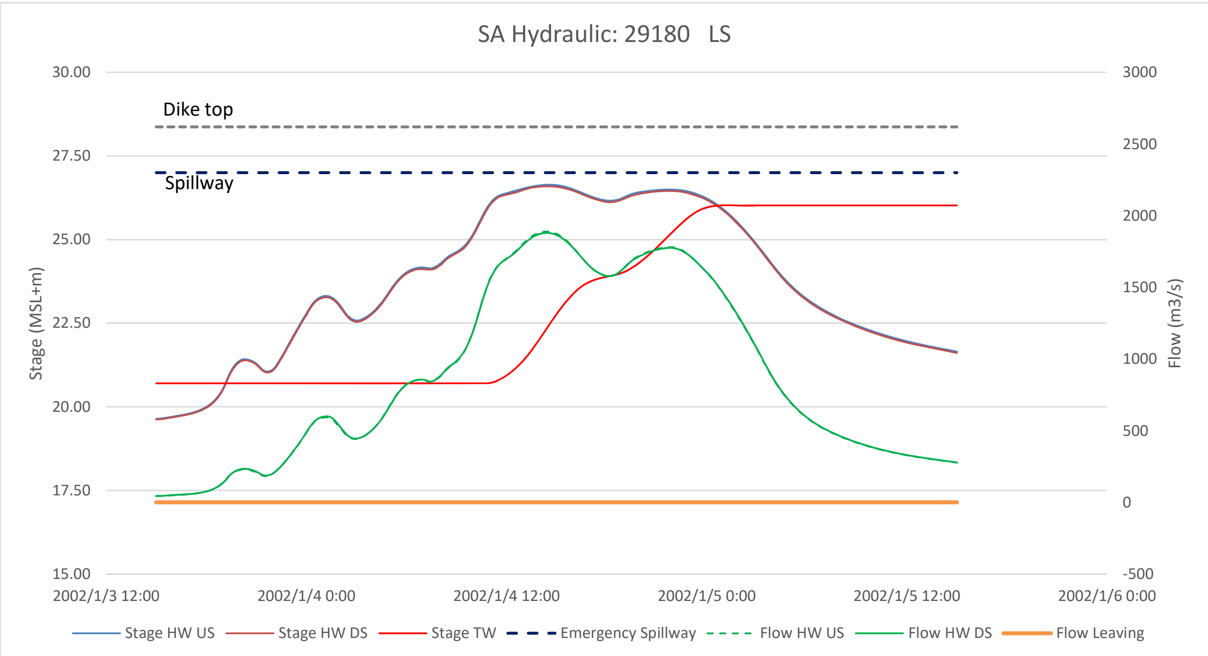
Source: Project Team

Figure 4.1.56(2) Result of Unsteady Flow Analysis of Retarding Pond (RP 07): March 2006 Type Flood

RP 08 Inlet



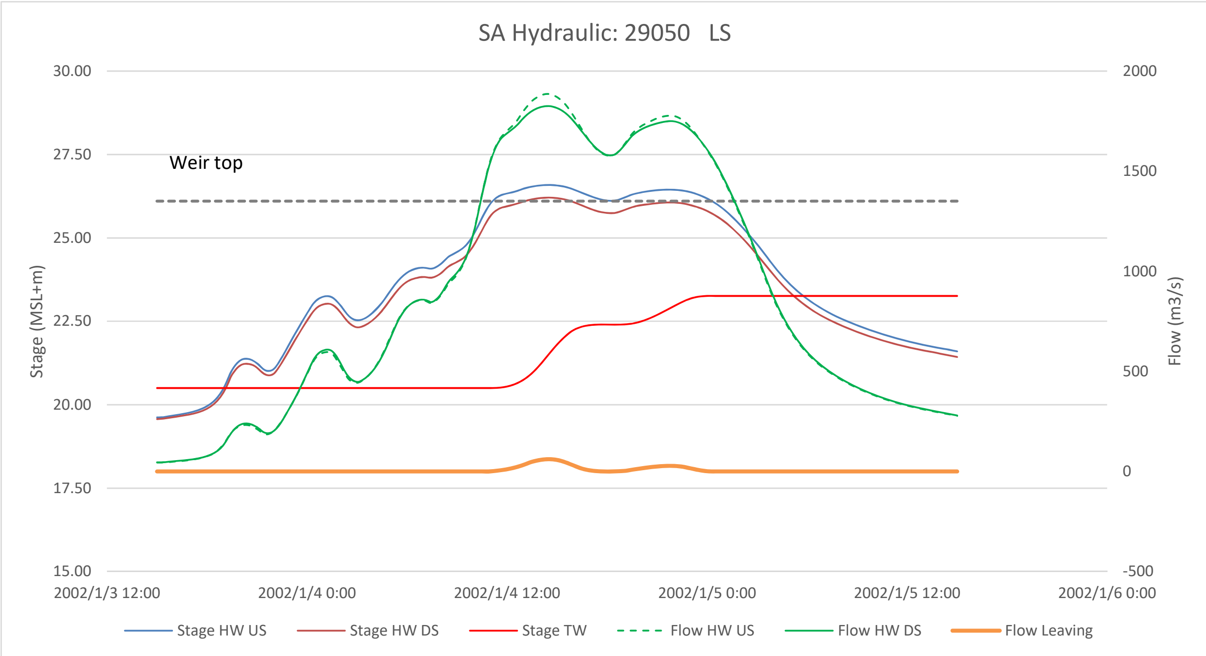
RP 08 Outlet



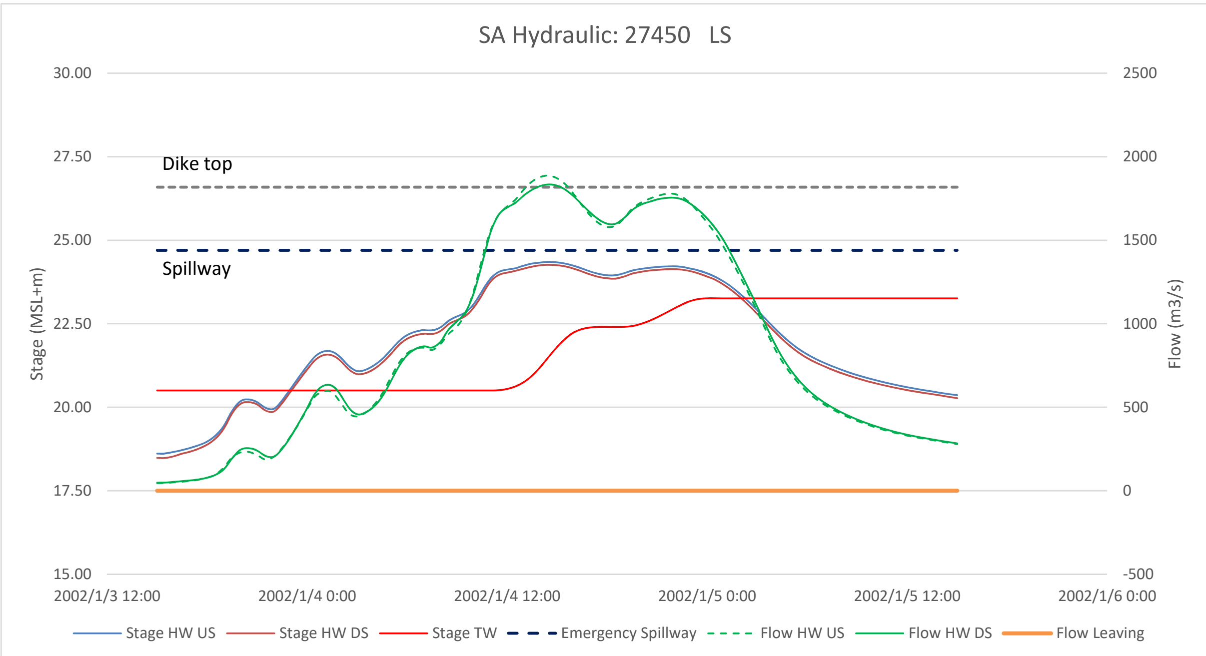
Source: Project Team

Figure 4.1.56(3) Result of Unsteady Flow Analysis of Retarding Pond (RP 08): March 2006 Type Flood

RP 09 Inlet



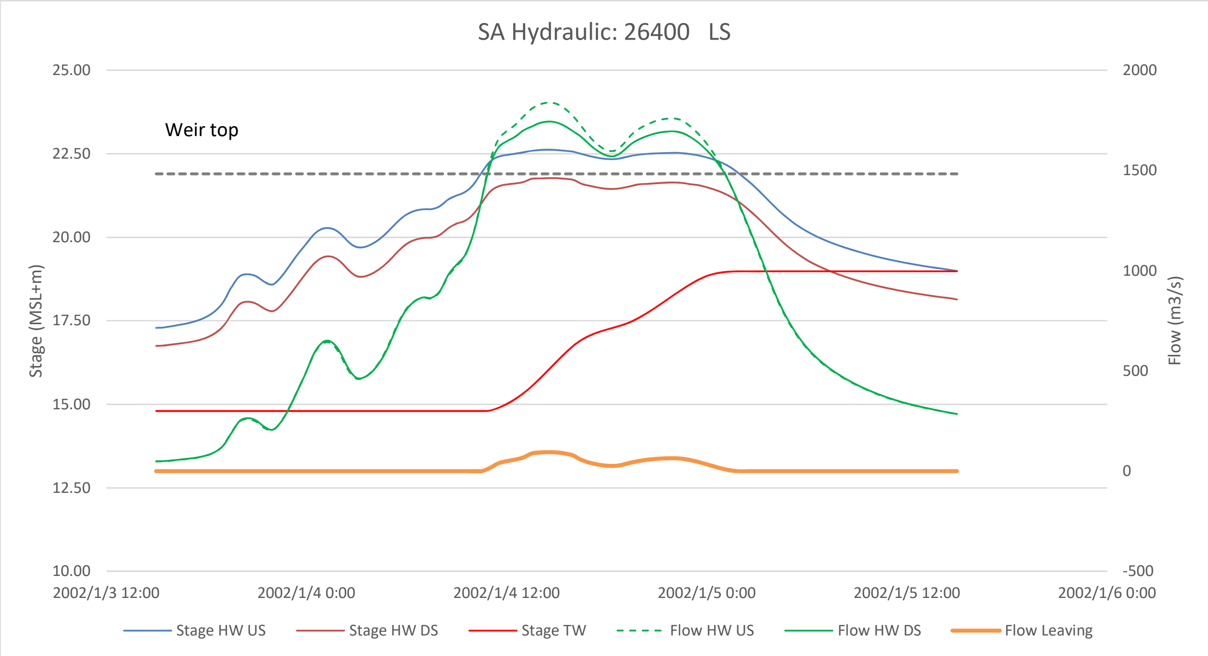
RP 09 Outlet



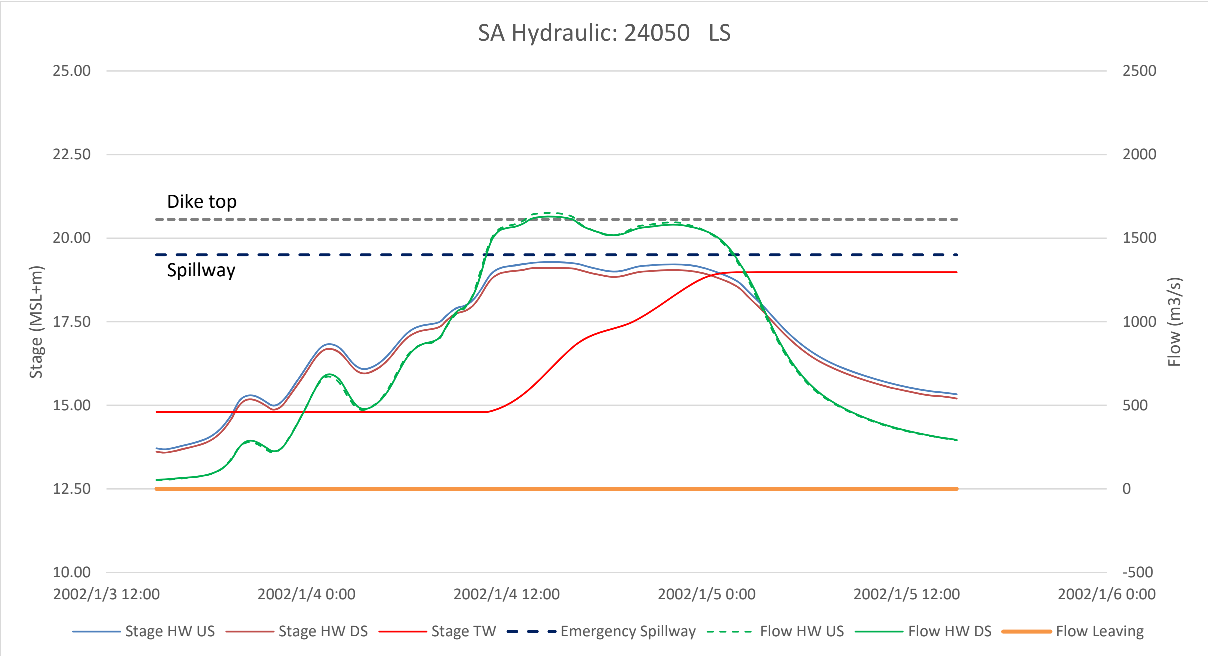
Source: Project Team

Figure 4.1.56(4) Result of Unsteady Flow Analysis of Retarding Pond (RP 09): March 2006 Type Flood

RP 11 Inlet



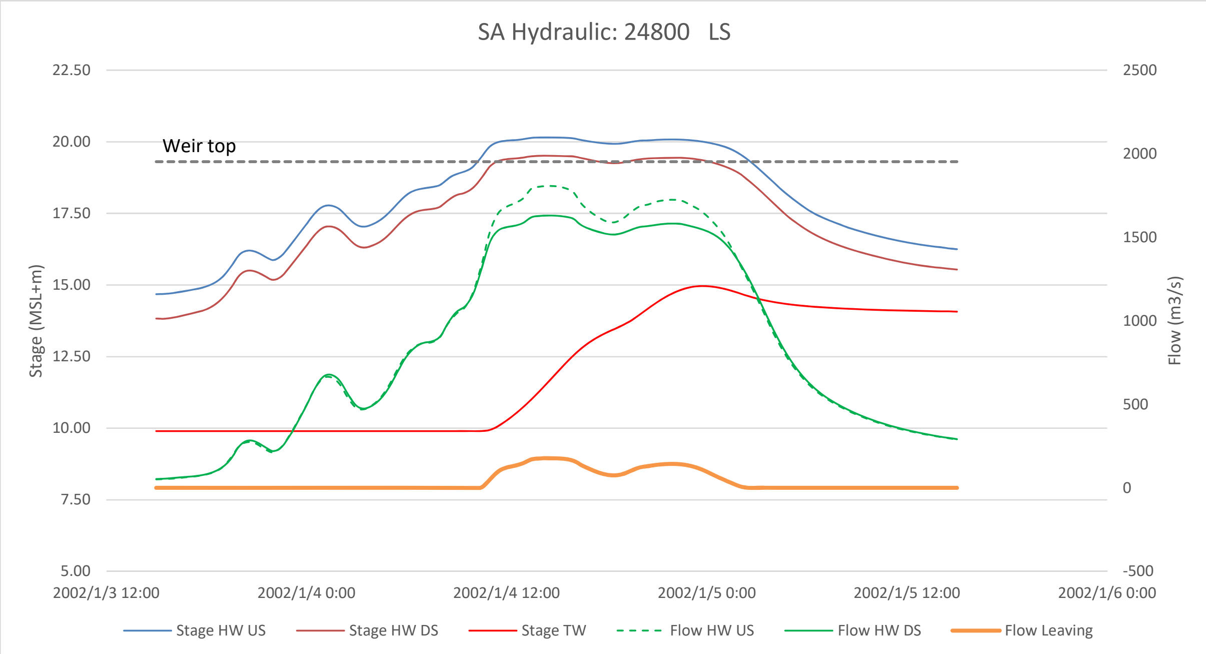
RP 11 Outlet



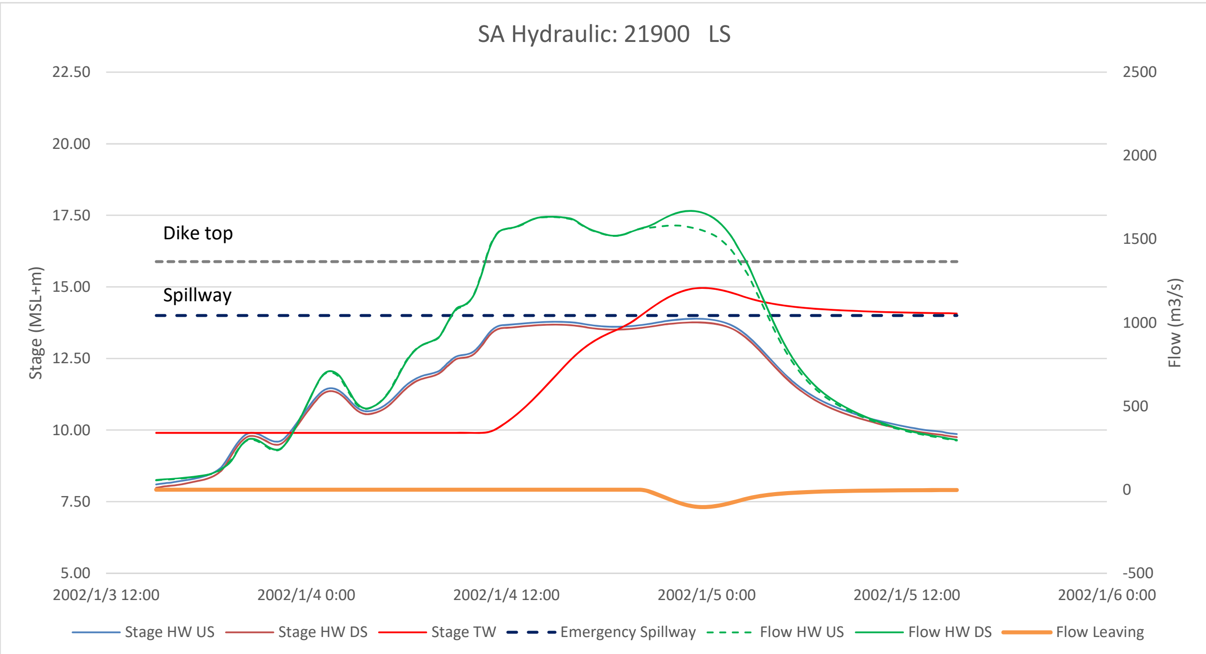
Source: Project Team

Figure 4.1.56(5) Result of Unsteady Flow Analysis of Retarding Pond (RP 11): March 2006 Type Flood

RP 12 Inlet



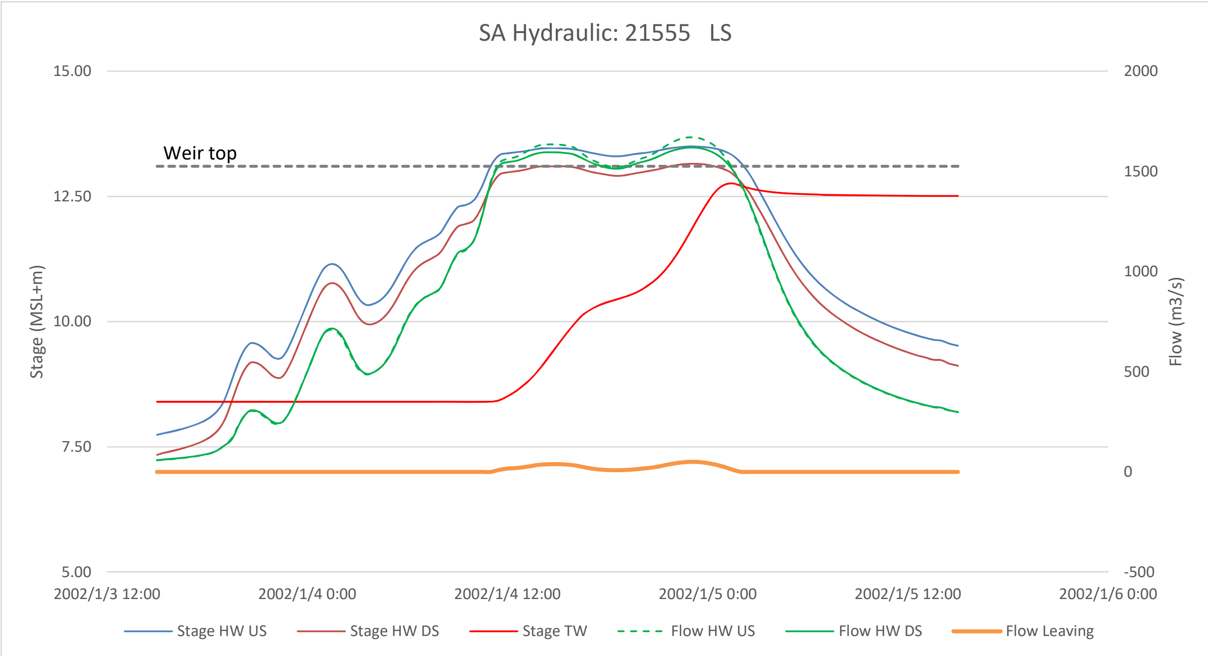
RP 12 Outlet



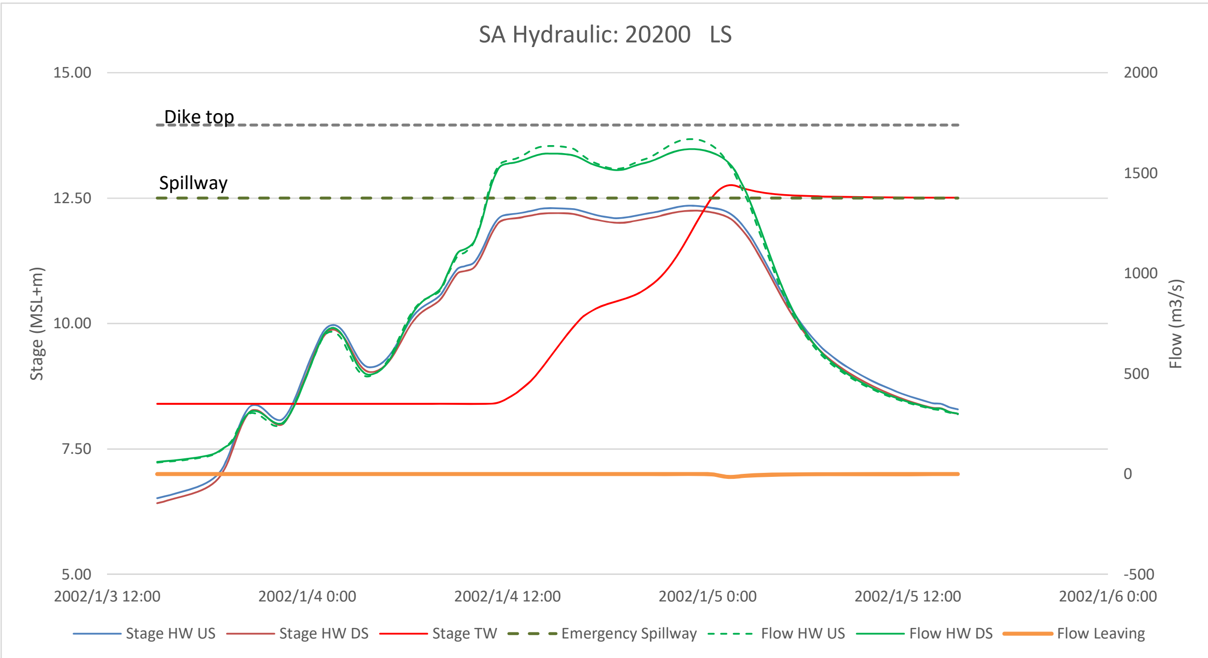
Source: Project Team

Figure 4.1.56(6) Result of Unsteady Flow Analysis of Retarding Pond (RP 12): March 2006 Type Flood

RP 13 Inlet



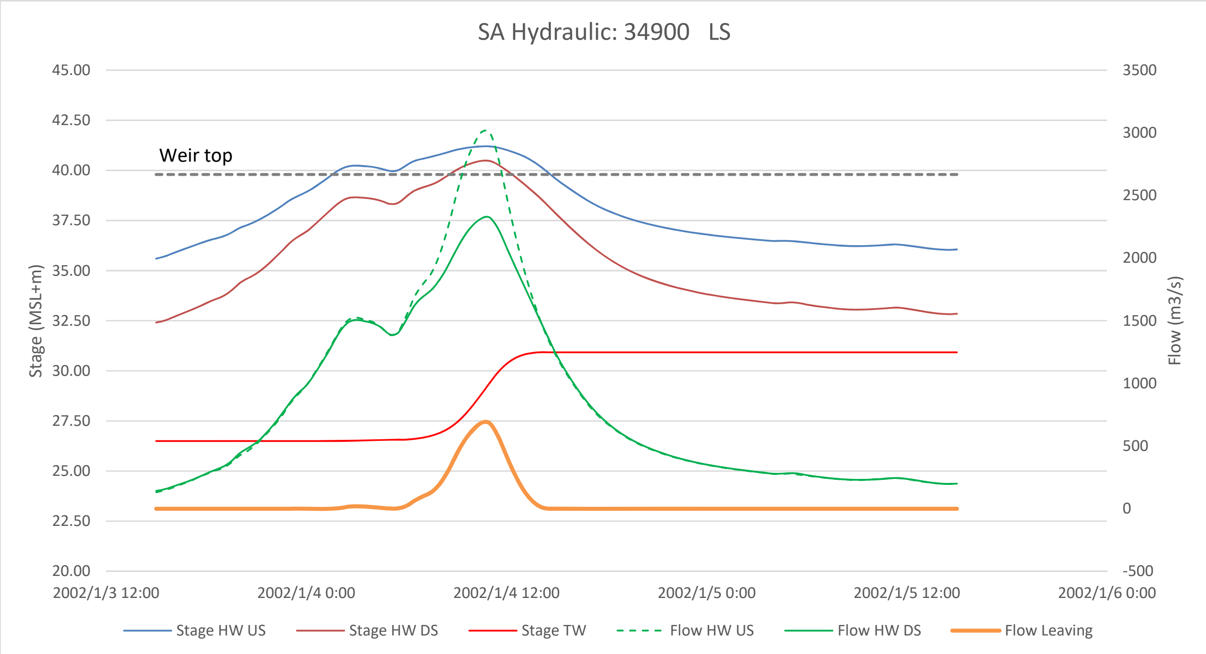
RP 13 Outlet



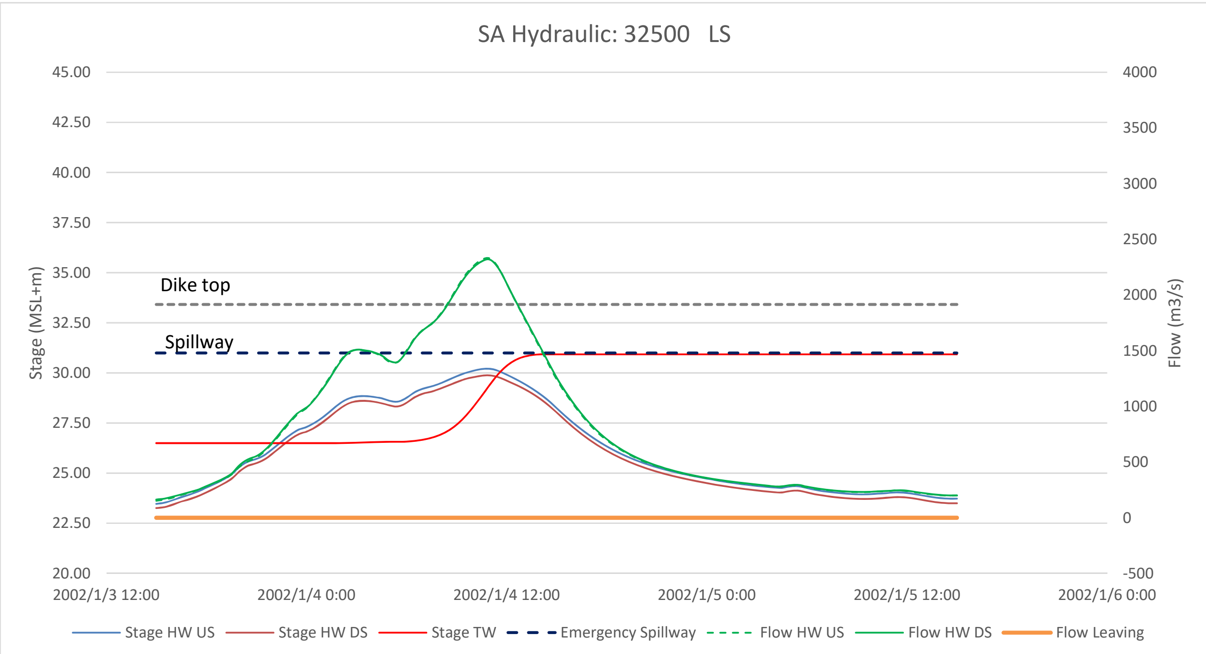
Source: Project Team

Figure 4.1.56(7) Result of Unsteady Flow Analysis of Retarding Pond (RP 13): March 2006 Type Flood

RP 06 Inlet



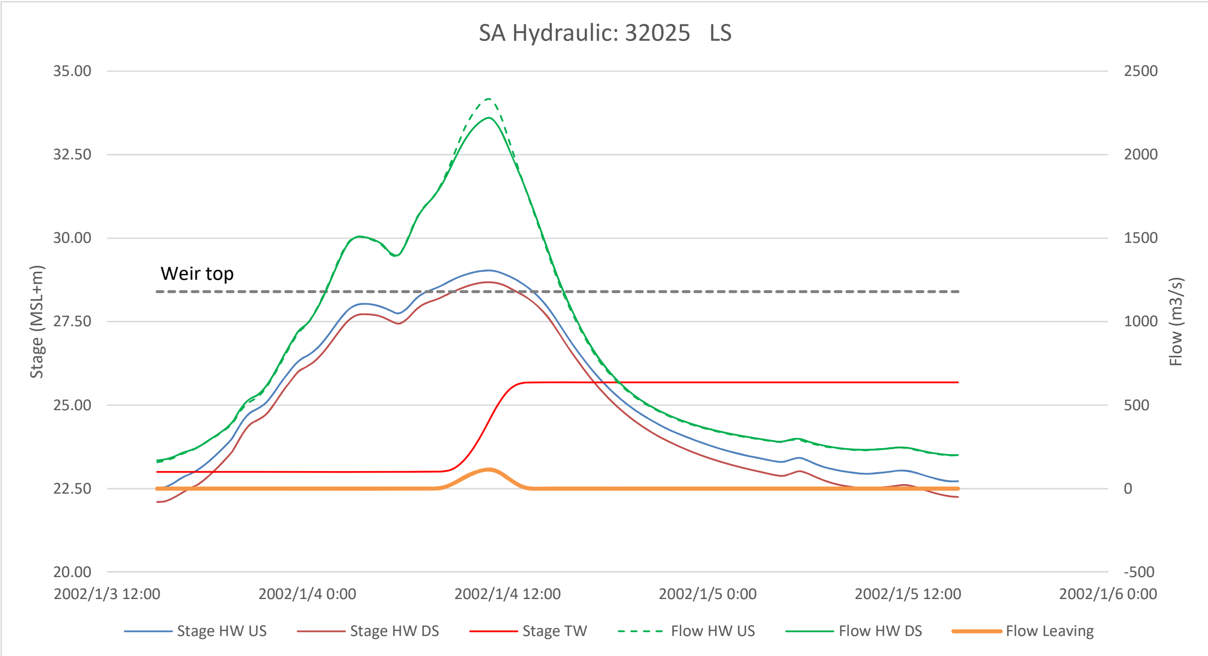
RP 06 Outlet



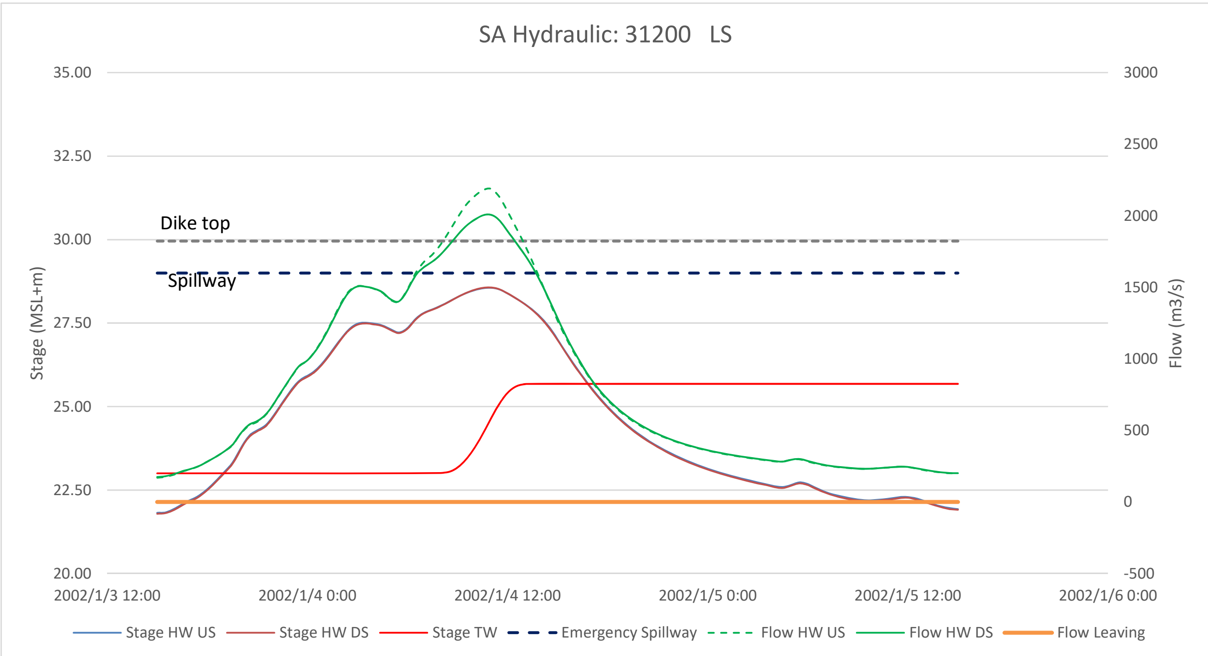
Source: Project Team

Figure 4.1.57(1) Result of Unsteady Flow Analysis of Retarding Pond (RP 06): December 2017 Type Flood

RP 07 Inlet



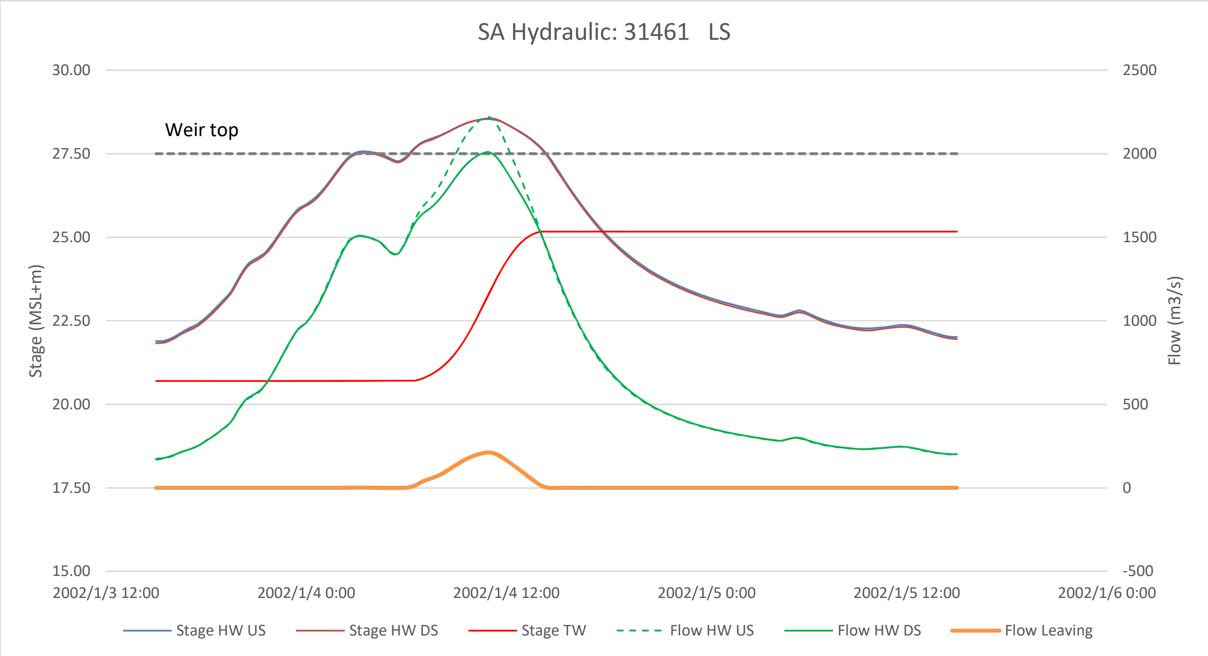
RP 07 Outlet



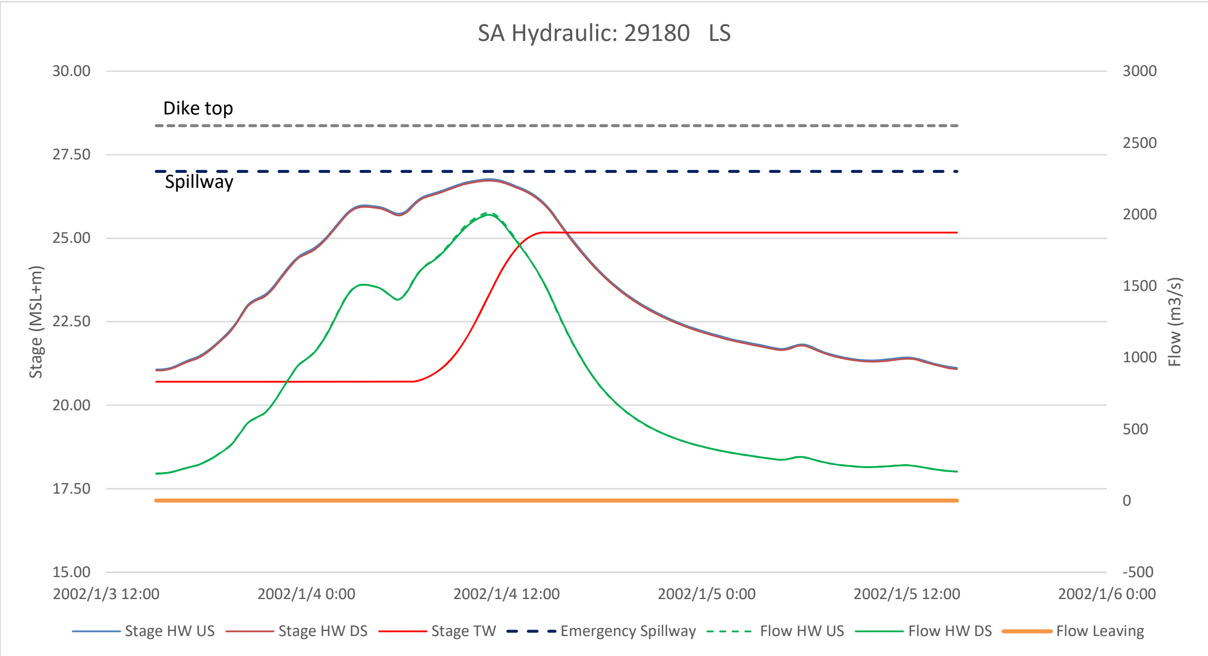
Source: Project Team

Figure 4.1.57(2) Result of Unsteady Flow Analysis of Retarding Pond (RP 07): December 2017 Type Flood

RP 08 Inlet



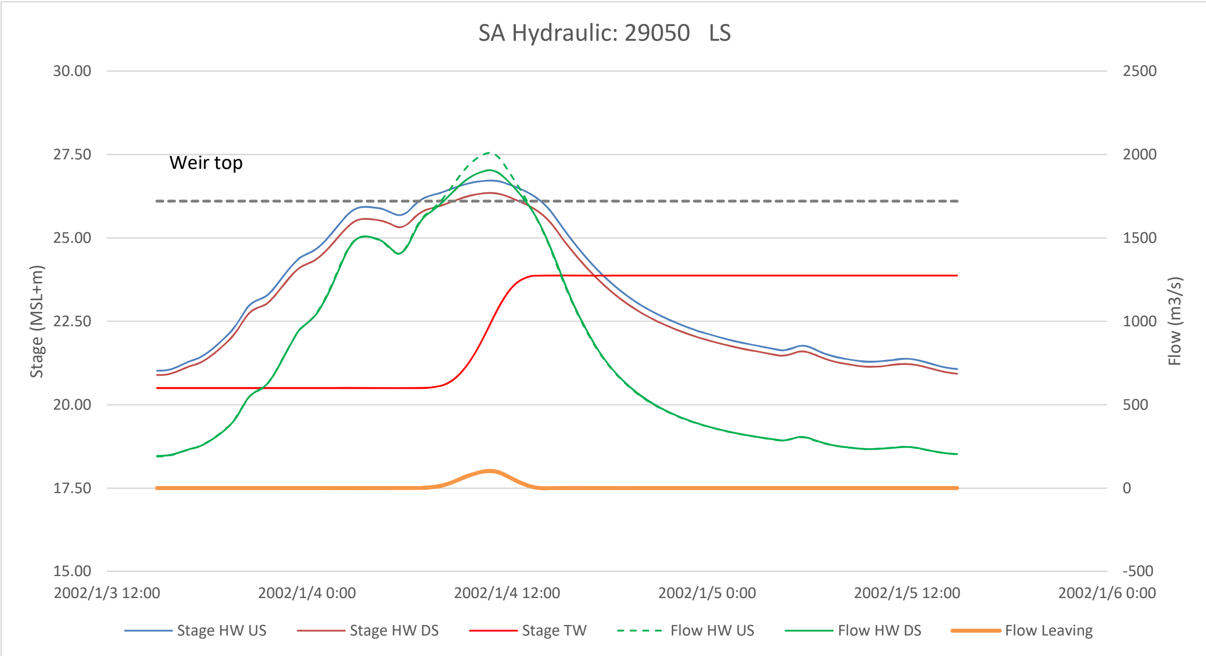
RP 08 Outlet



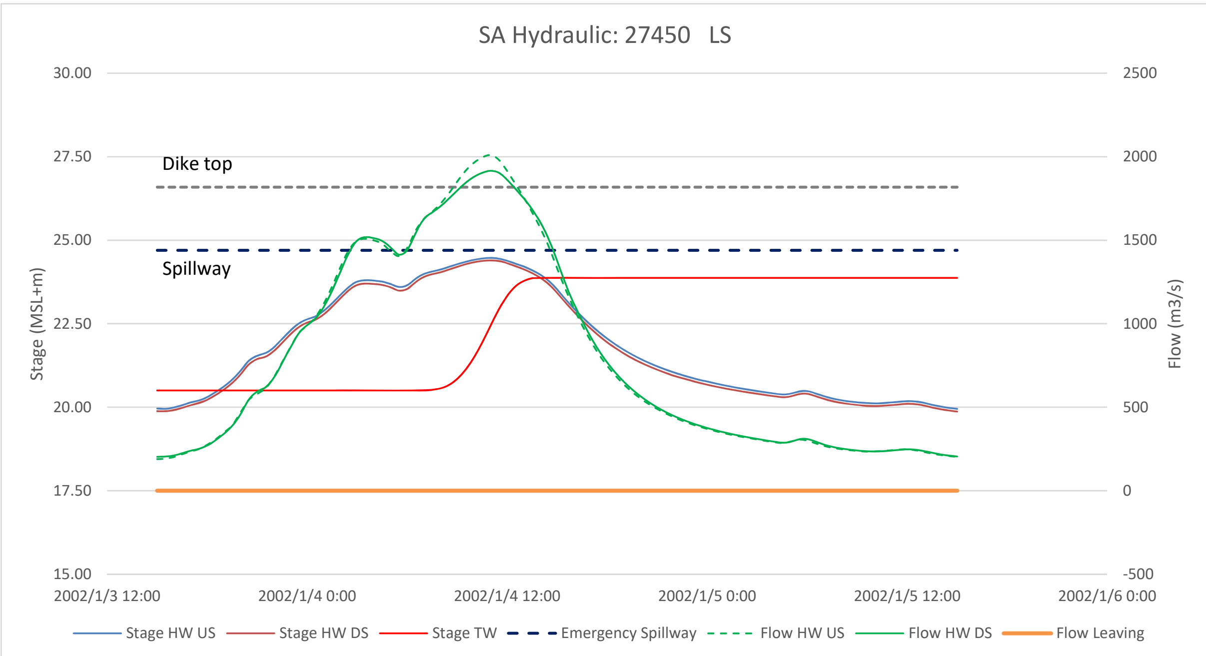
Source: Project Team

Figure 4.1.57(3) Result of Unsteady Flow Analysis of Retarding Pond (RP 08): December 2017 Type Flood

RP 09 Inlet



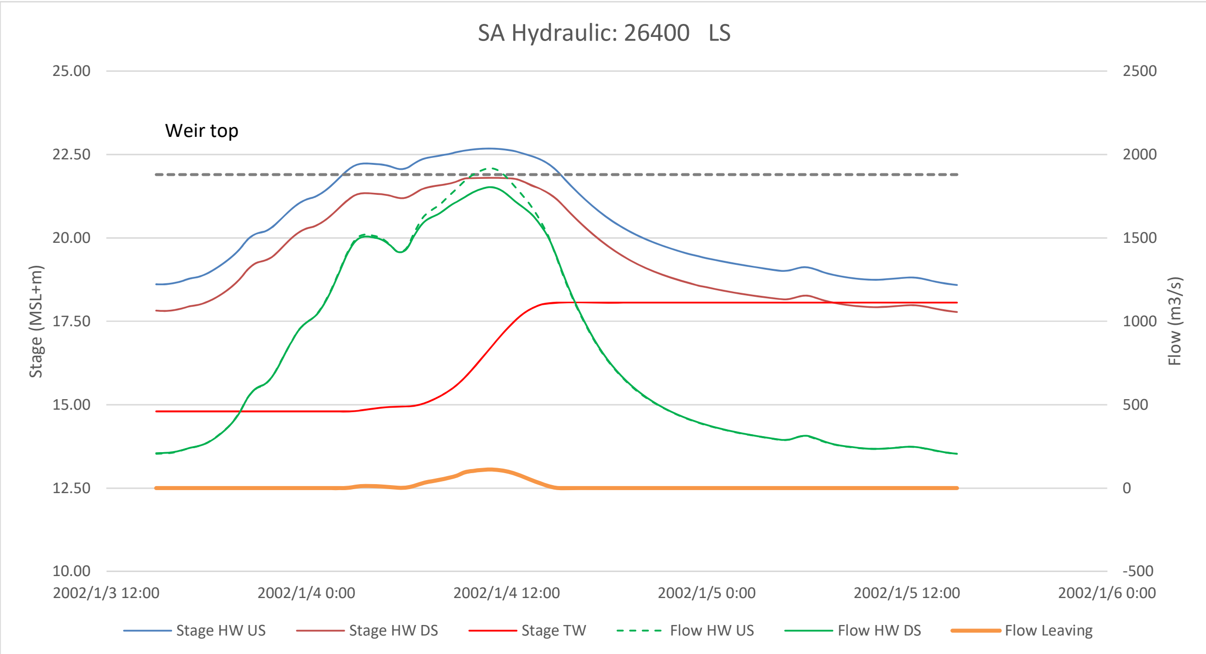
RP 09 Outlet



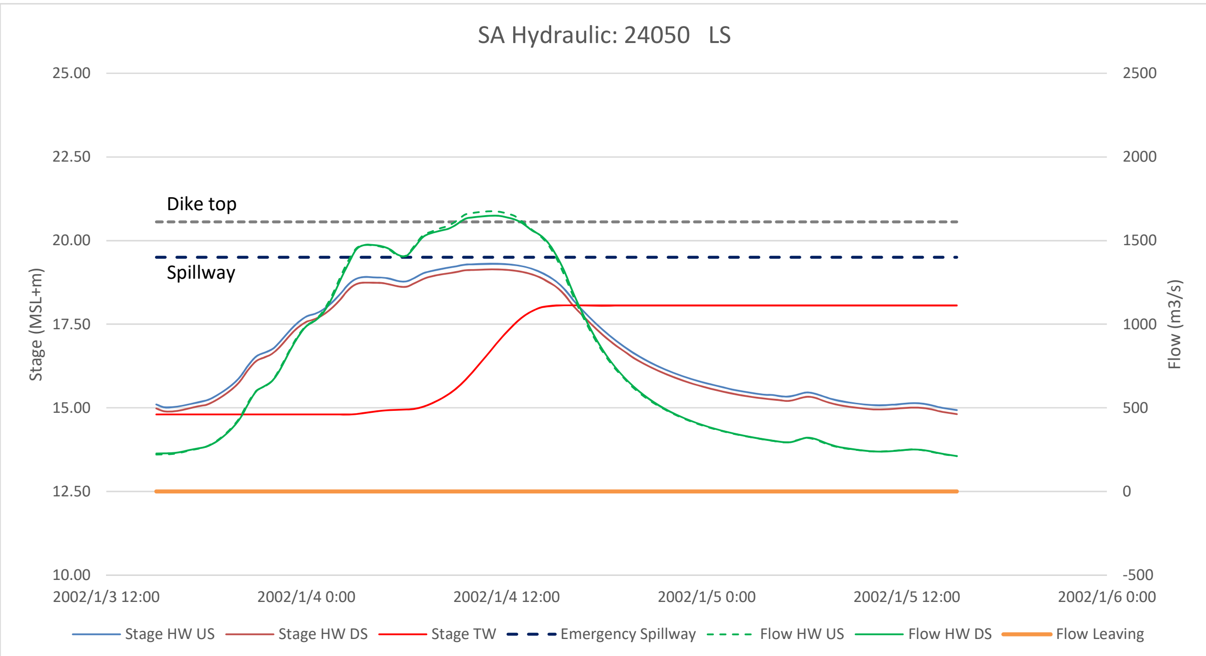
Source: Project Team

Figure 4.1.57(4) Result of Unsteady Flow Analysis of Retarding Pond (RP 09): December 2017 Type Flood

RP 11 Inlet



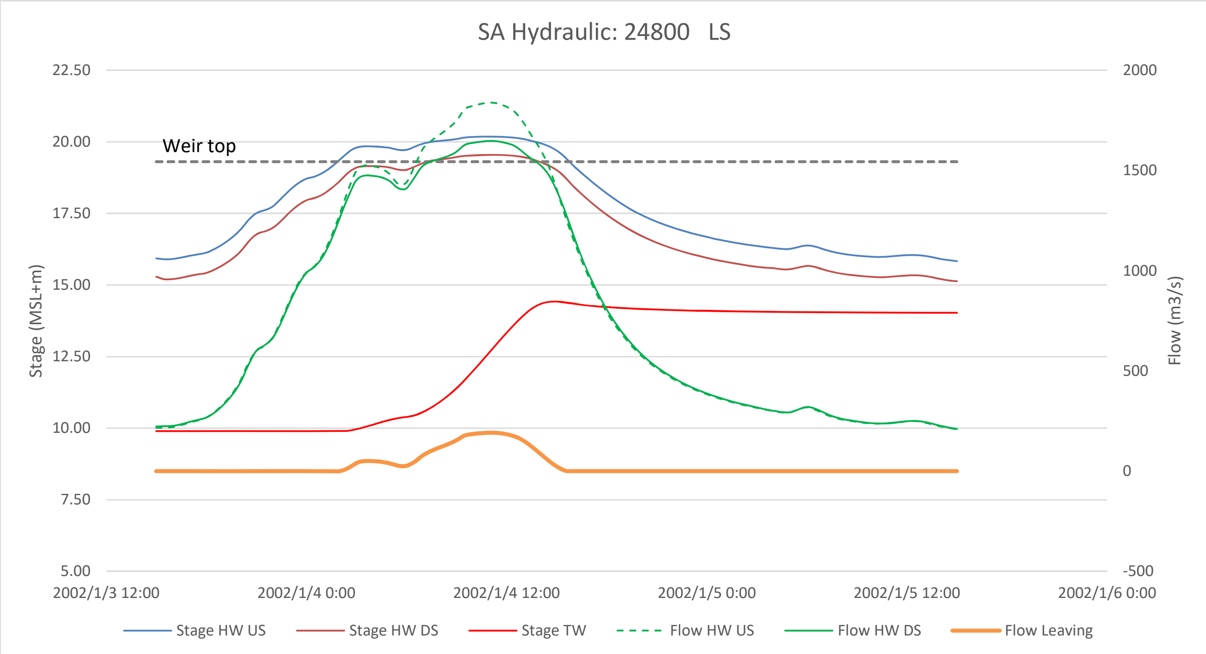
RP 11 Outlet



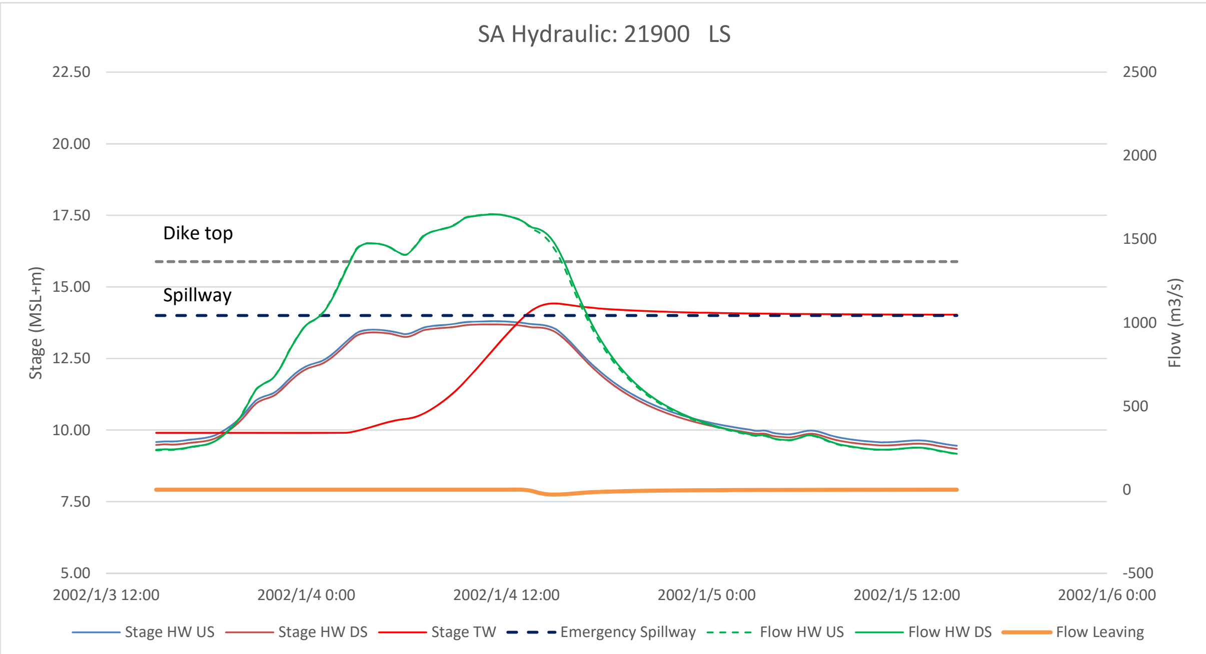
Source: Project Team

Figure 4.1.57(5) Result of Unsteady Flow Analysis of Retarding Pond (RP 11): December 2017 Type Flood

RP 12 Inlet



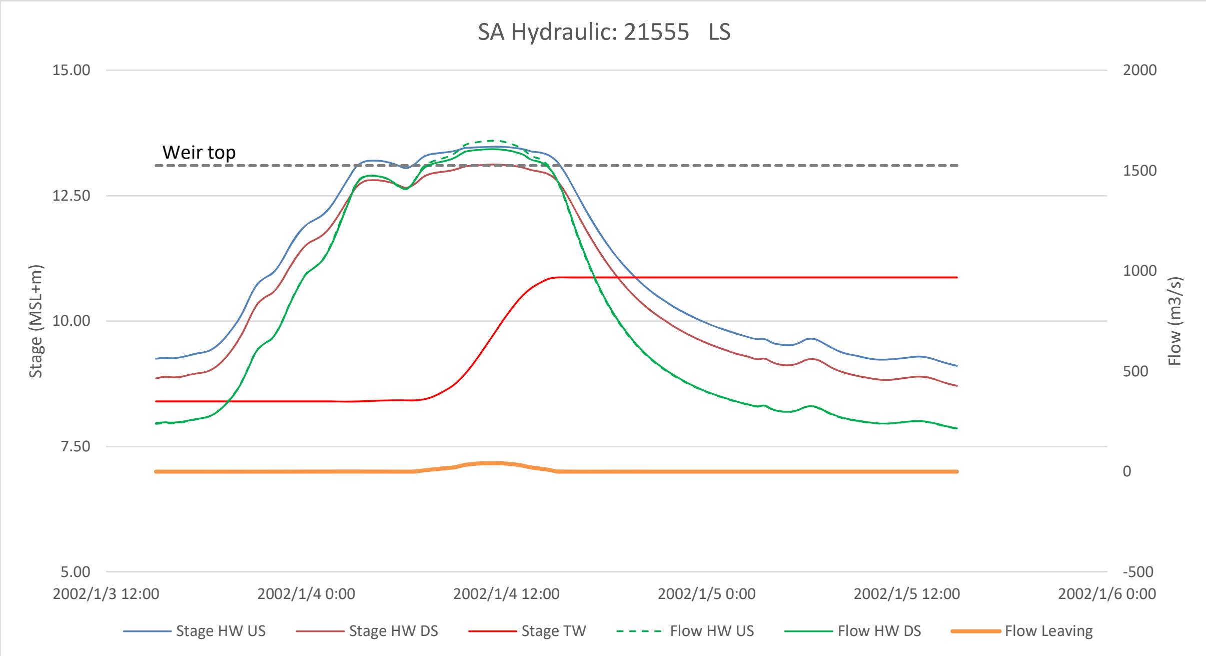
RP 12 Outlet



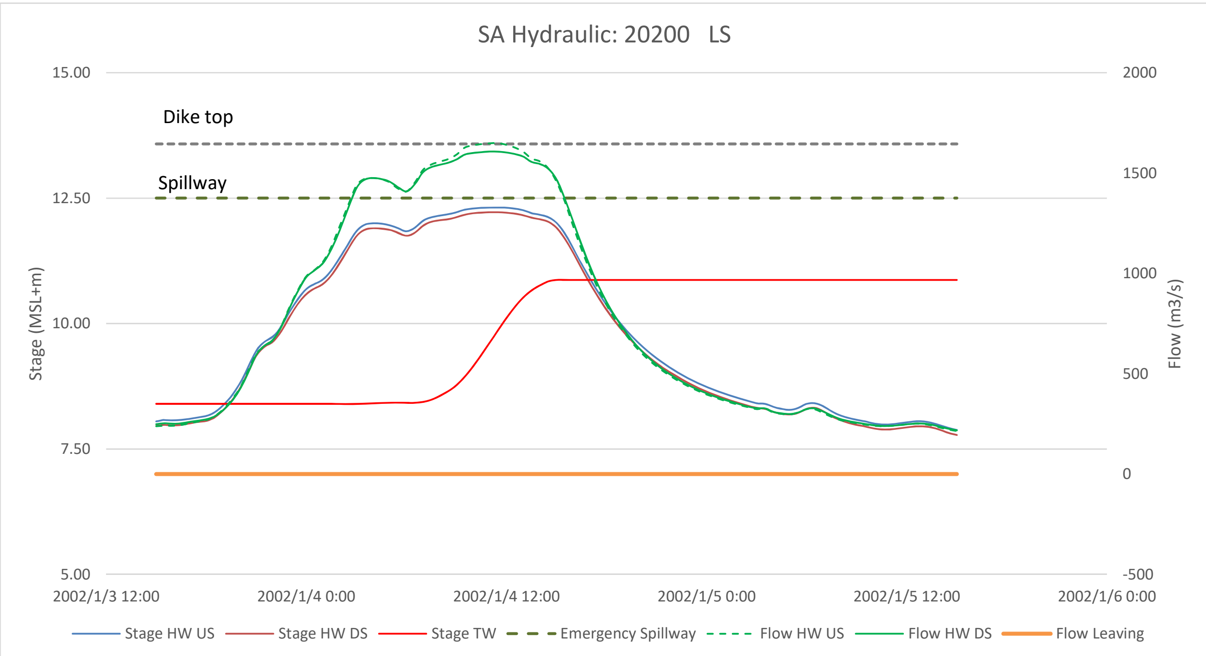
Source: Project Team

Figure 4.1.57(6) Result of Unsteady Flow Analysis of Retarding Pond (RP 12): December 2017 Type Flood

RP 13 Inlet



RP 13 Outlet



Source: Project Team

Figure 4.1.57(7) Result of Unsteady Flow Analysis of Retarding Pond (RP 13): December 2017 Type Flood

3) Retarding Ponds Specification for Short-term Project

As mentioned above, the short-term project plans to dredge the river channel in addition to the installation of retarding ponds (RP 08, RP 09, and RP 11). The target of the short-term project is set at a level equivalent to the 10-year probability scale, and it is desirable to control the 10-year scale flood to a level equivalent to the channel flow capacity after river channel dredging works in order to achieve the control effect of the retarding ponds to be developed in this project. The flow capacity after dredging the river channel is evaluated to be approximately 700-800m^3/s as a result of the study described in "(2)Riverbed Dredging".

Based on the above-mentioned policy, the heights of the overflow dike of the retarding ponds, which are the target of the short-term project, are set as shown in Table 4.1.20.

Table 4.1.20 Overflow Dike Height of Target Retarding Ponds for Short-term Project

Retarding Pond ID	Design Inlet dike top for M/P (MSL+m)	Design Inlet wier top for M/P (MSL+m)	Design Inlet wier top for S/T (MSL+m)*	Design RP invert (MSL+m)	Design Spilway top (MSL+m)
RP 08	29.40	27.50	25.40 (2.10)	20.70	27.00
RP 09	27.50	26.10	24.00 (2.10)	20.50	24.70
RP 11	23.40	21.90	20.50 (1.40)	14.80	19.50

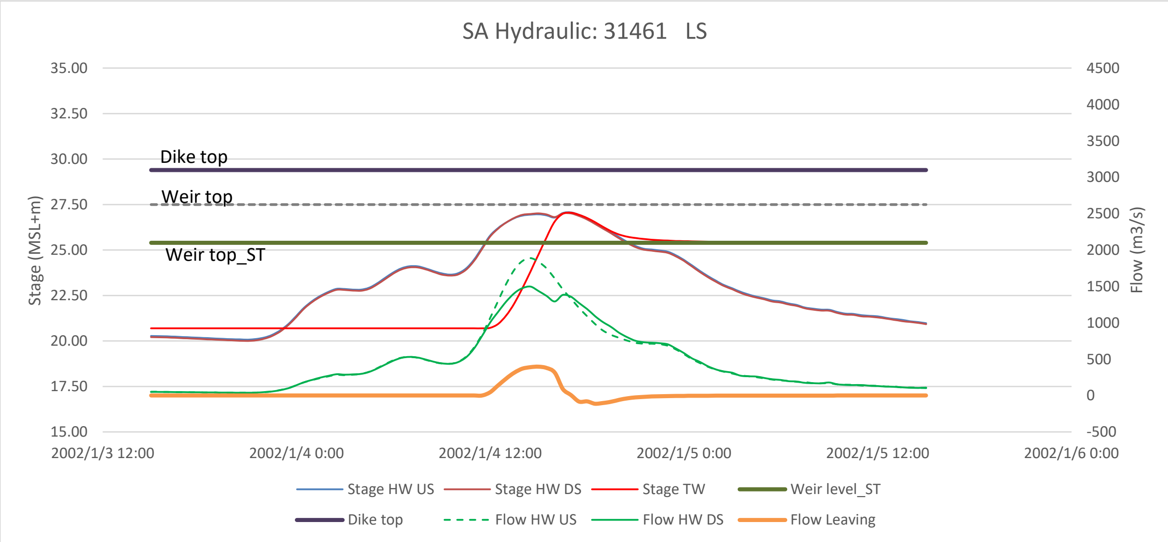
note*: Brackets numbers are difference between the wier top of M/P and S/T

Source: Project Team

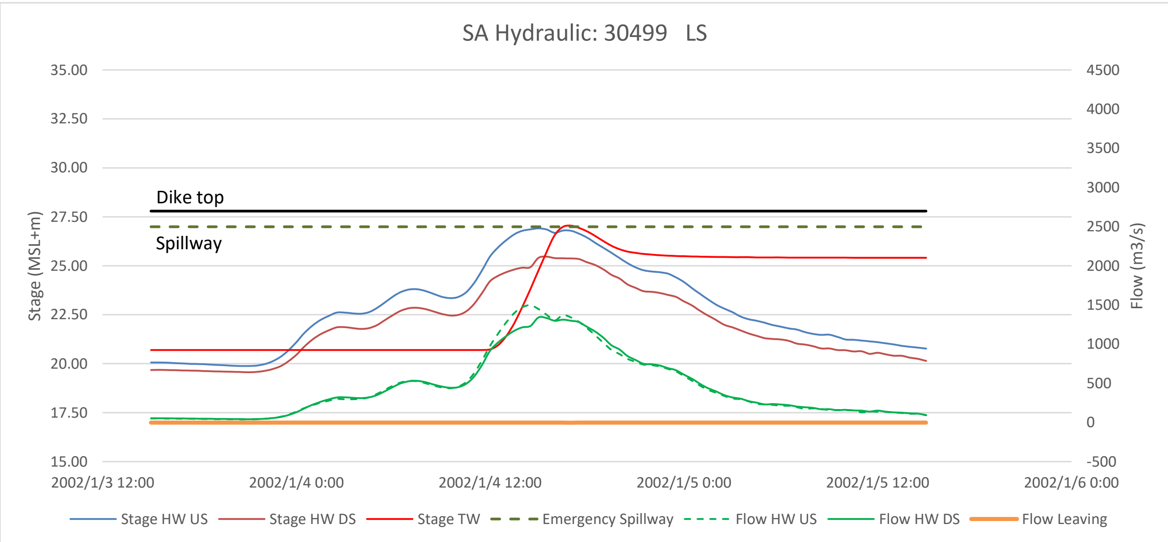
Figure 4.1.58 shows the results of the analysis for the 10-year scale flood under the set overflow dike heights, and Figure 4.1.59 shows the results of the inundation analysis by probability scale. It was confirmed that a flood control safety level of approximately 10-year scale can be obtained after the implementation of the short-term project.

Here, in case of that, the riverbed of the channel facing the overflow dike would be aggradation / degradation or the overflow dike by gabion would be sinking, the planned flood control effect might not be achieved. As a point of consideration during the detailed design phase, the stability of the river channel shall be studied and measures shall be taken if necessary.

Inlet RP08



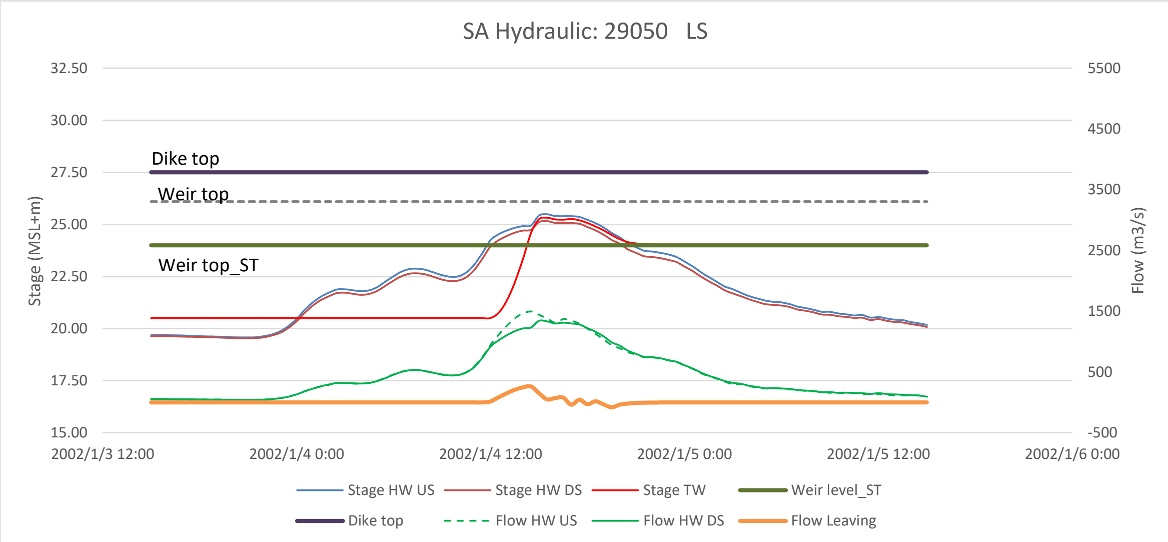
Outlet RP08



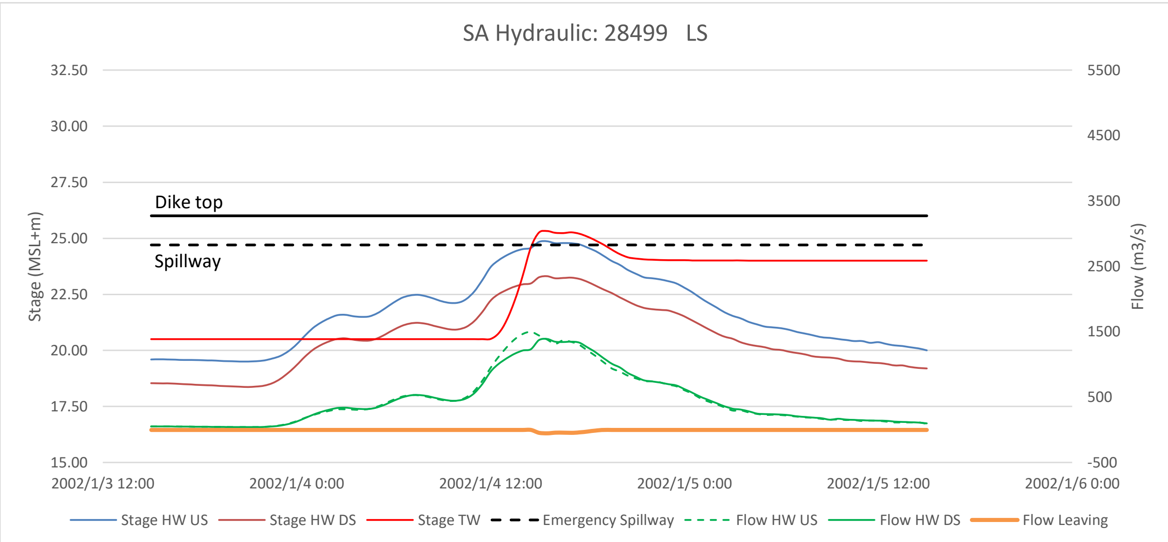
Source: Project Team

Figure 4.1.58(1) Result of Unsteady Flow Analysis of Retarding Pond (RP 08): January 2002 Type Flood

Inlet RP09



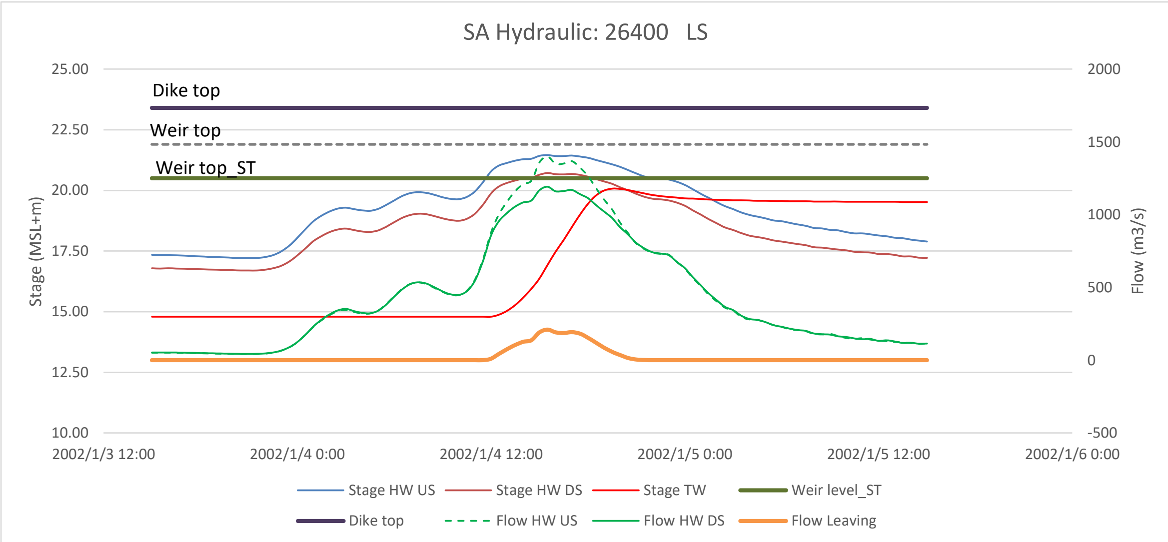
Outlet RP09



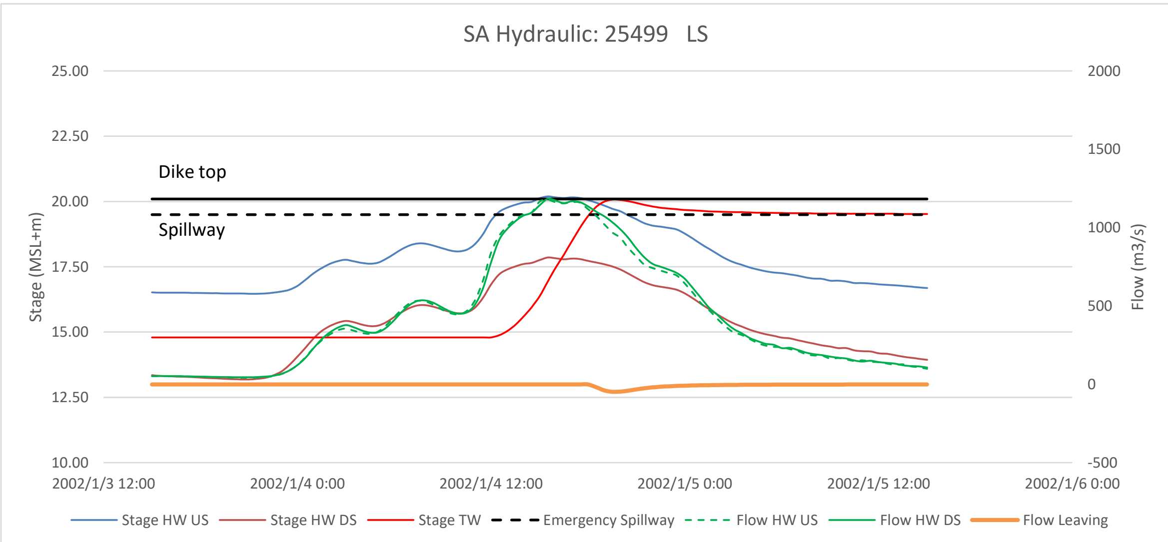
Source: Project Team

Figure 4.1.58(2) Result of Unsteady Flow Analysis of Retarding Pond (RP 09): January 2002 Type Flood

Inlet RP11

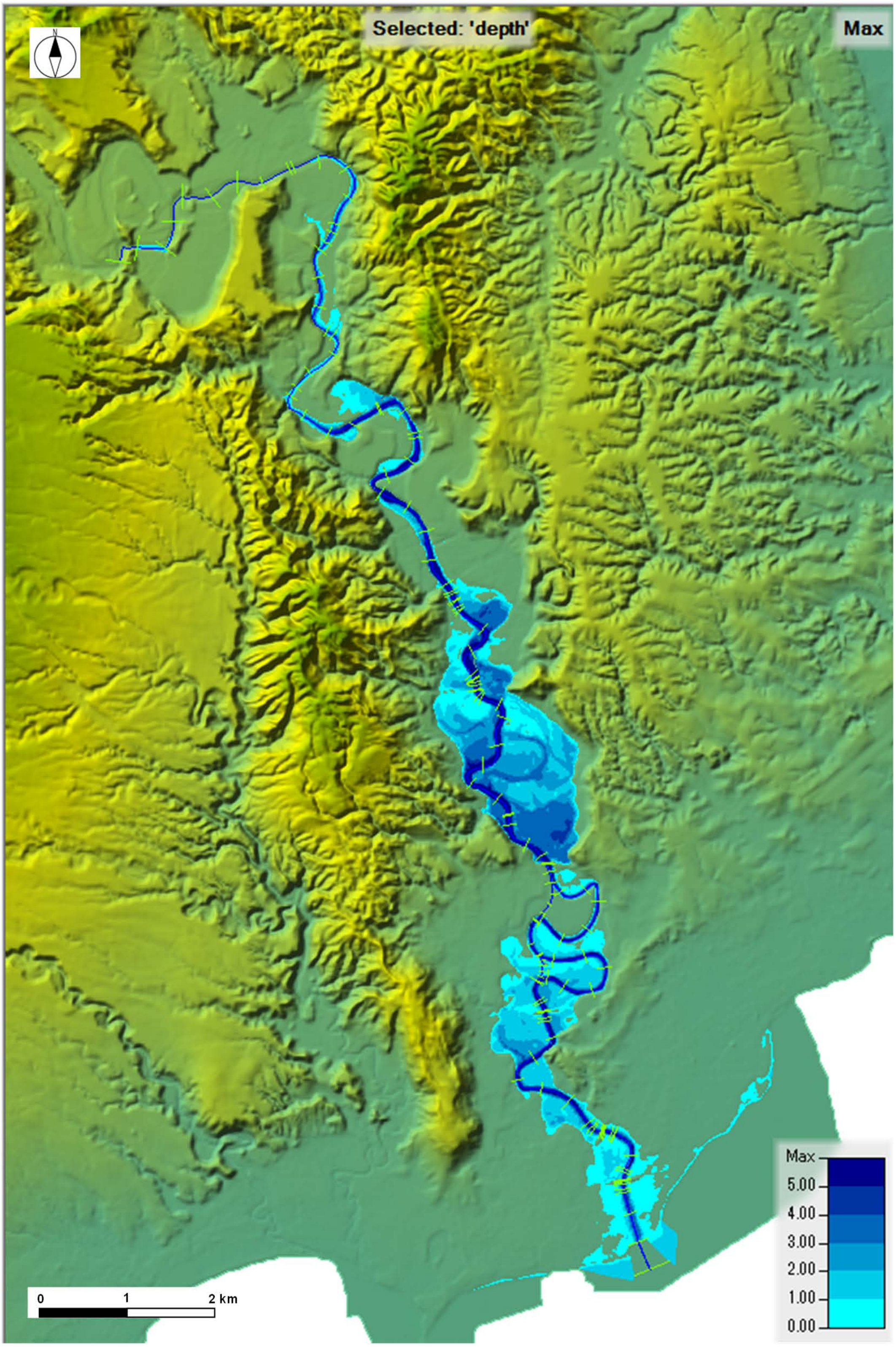


Outlet RP11



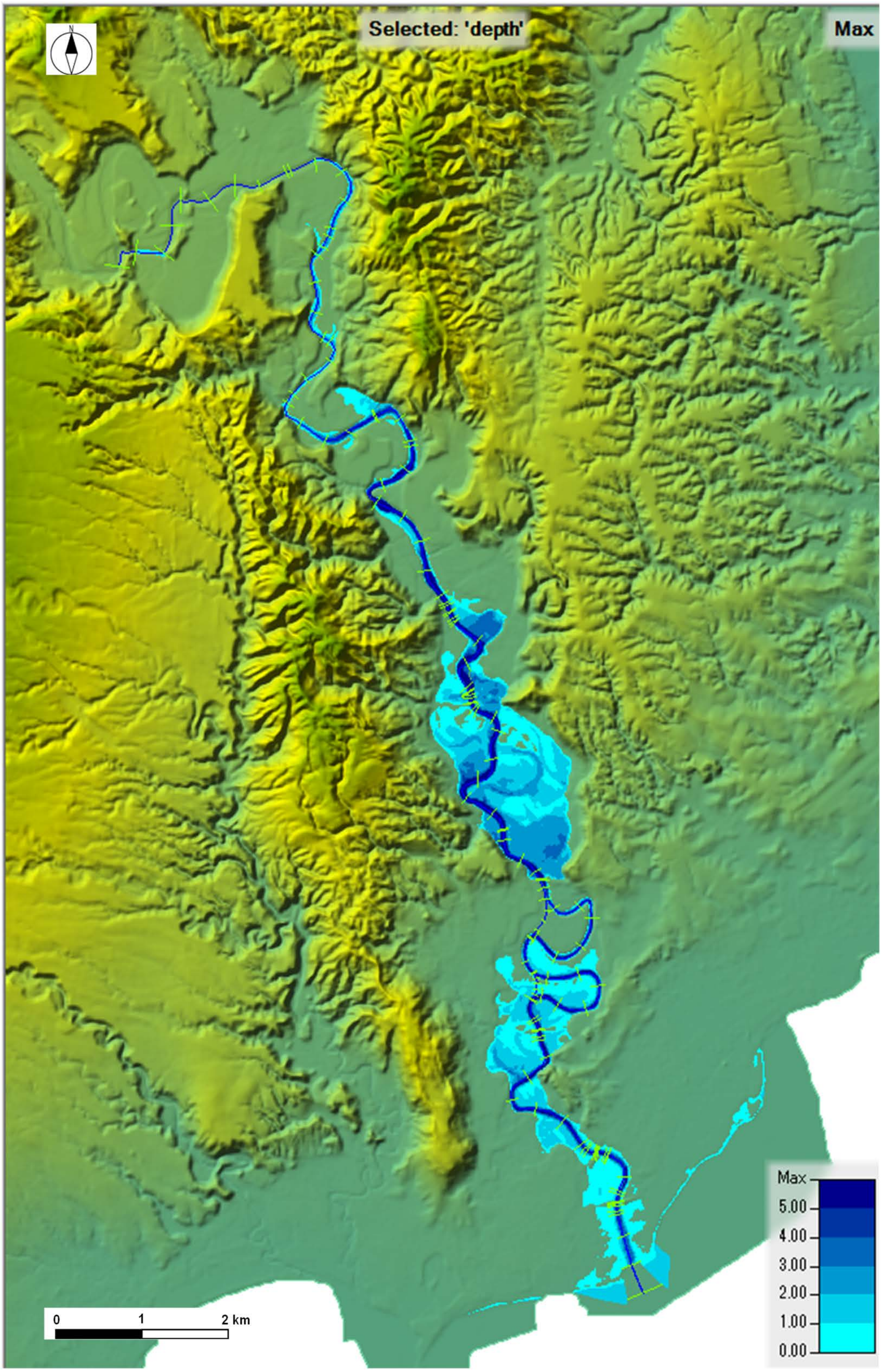
Source: Project Team

Figure 4.1.58(3) Result of Unsteady Flow Analysis of Retarding Pond (RP 11): January 2002 Type Flood



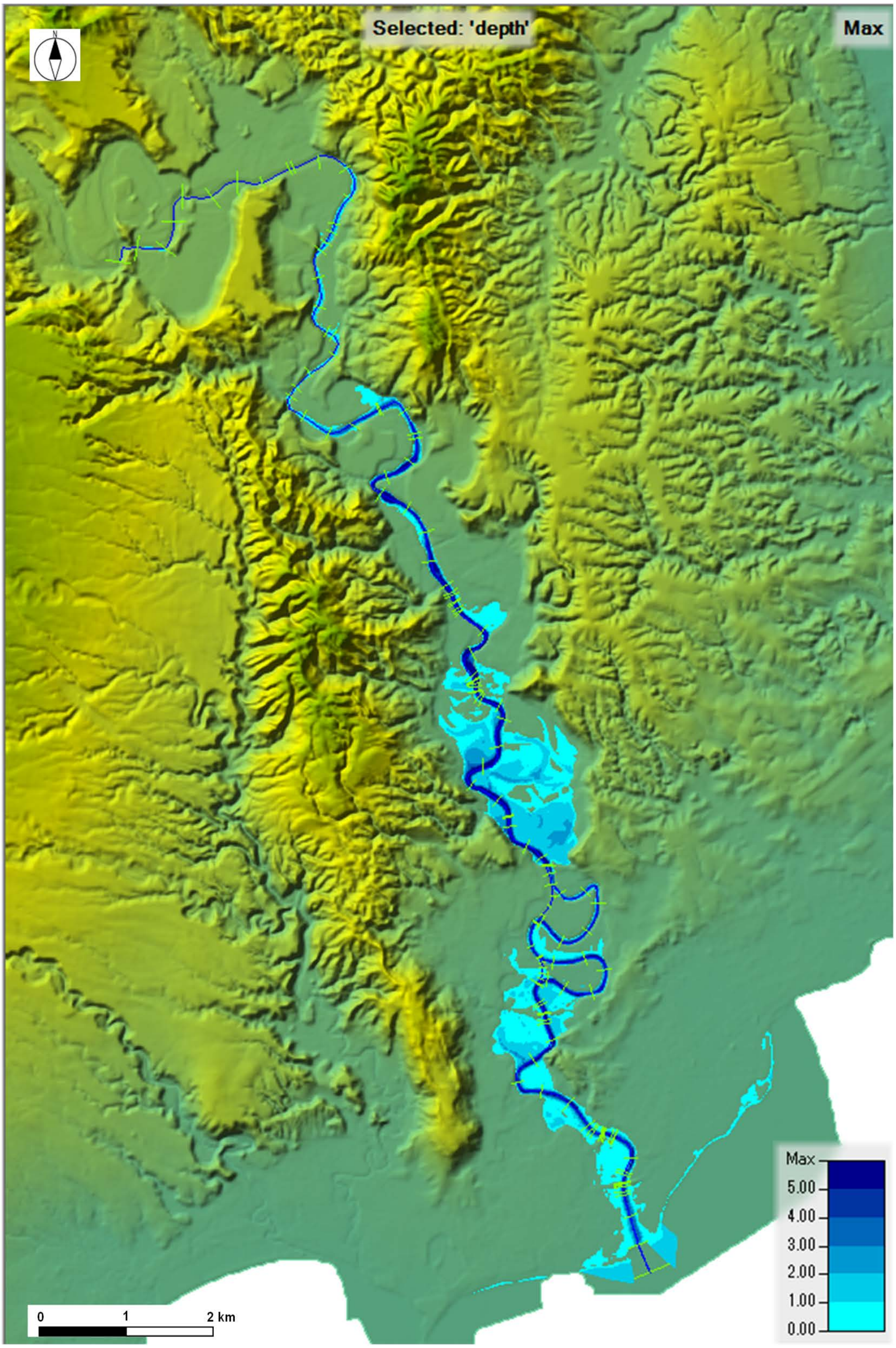
Source: Project Team

Figure 4.1.59(1) Result of Inundation Analysis of After Short-term Project (100-yr scale): January 2002 Type Flood



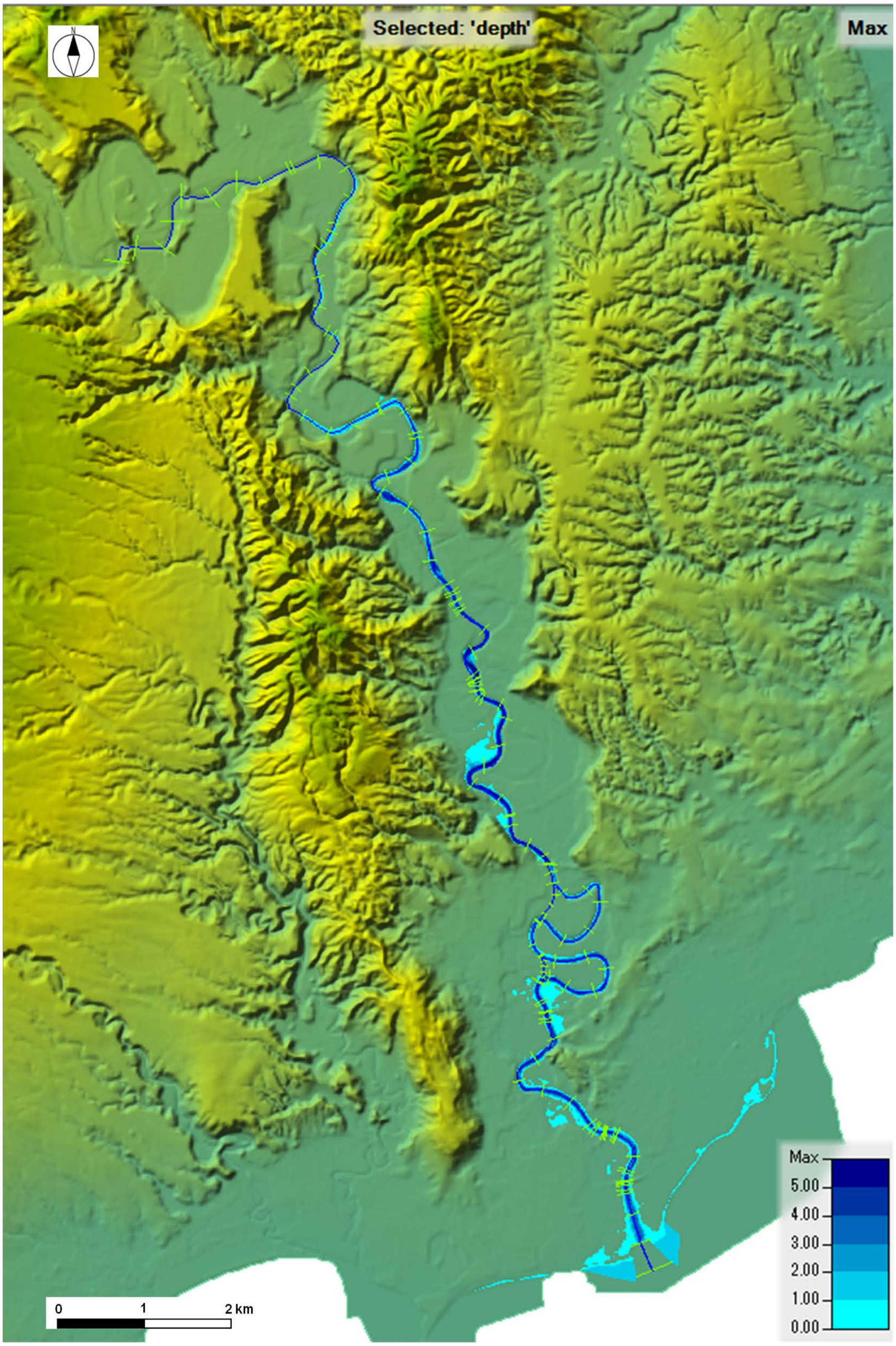
Source: Project Team

Figure 4.1.59(2) Result of Inundation Analysis of After Short-term Project (50-yr scale): January 2002 Type Flood



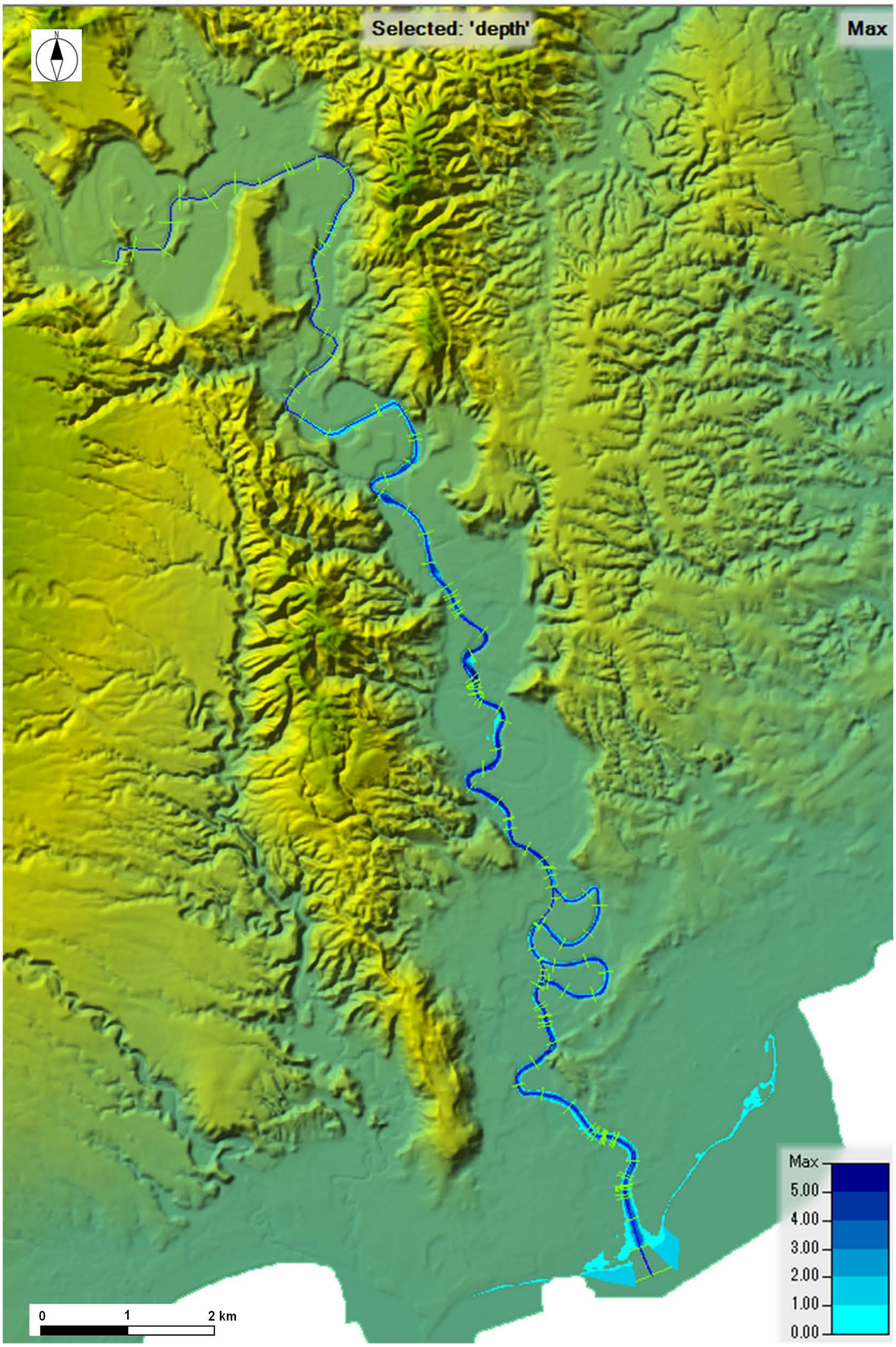
Source: Project Team

Figure 4.1.59(3) Result of Inundation Analysis of After Short-term Project (25-yr scale): January 2002 Type Flood



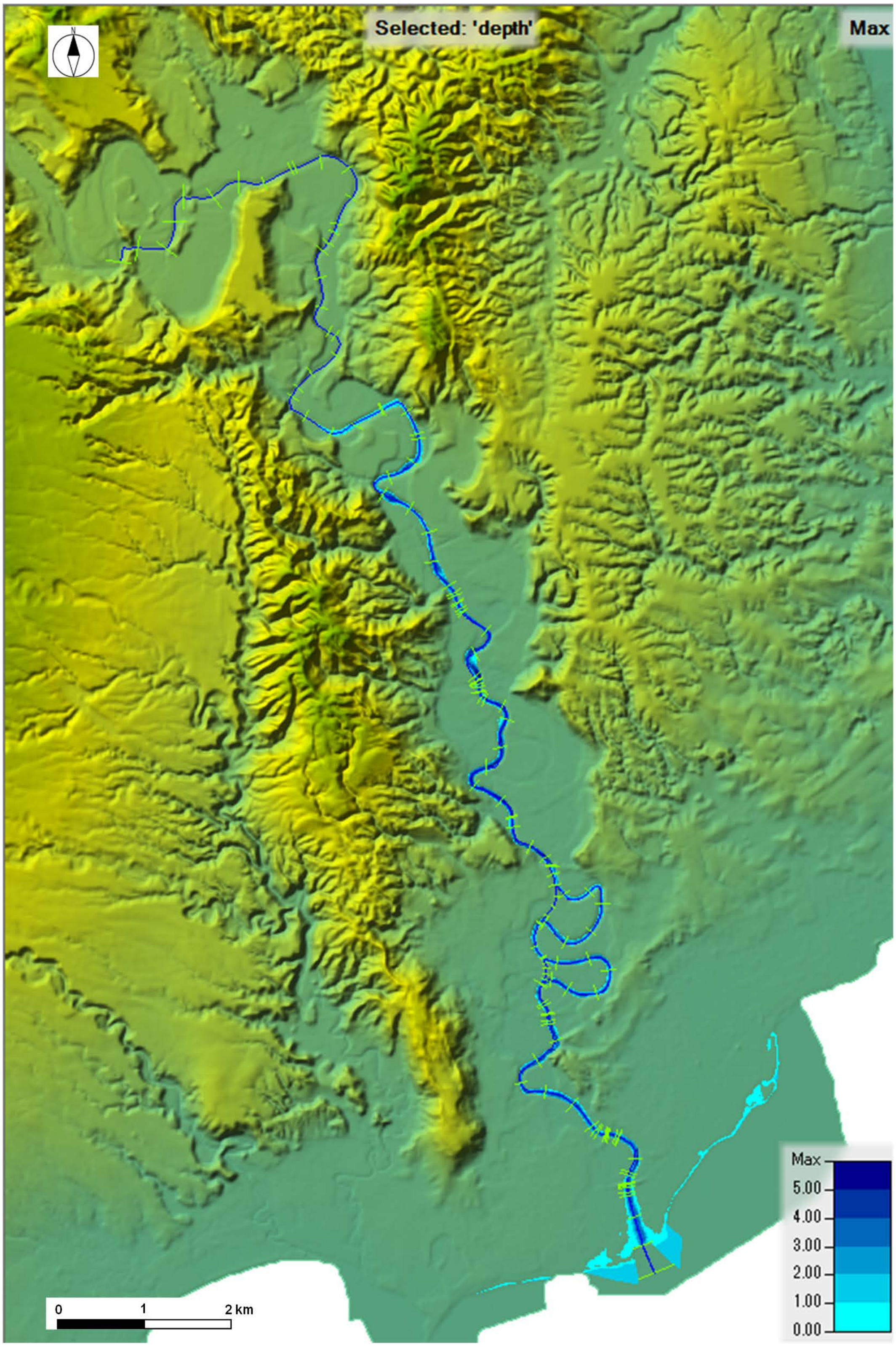
Source: Project Team

Figure 4.1.59(4) Result of Inundation Analysis of After Short-term Project (10-yr scale): January 2002 Type Flood



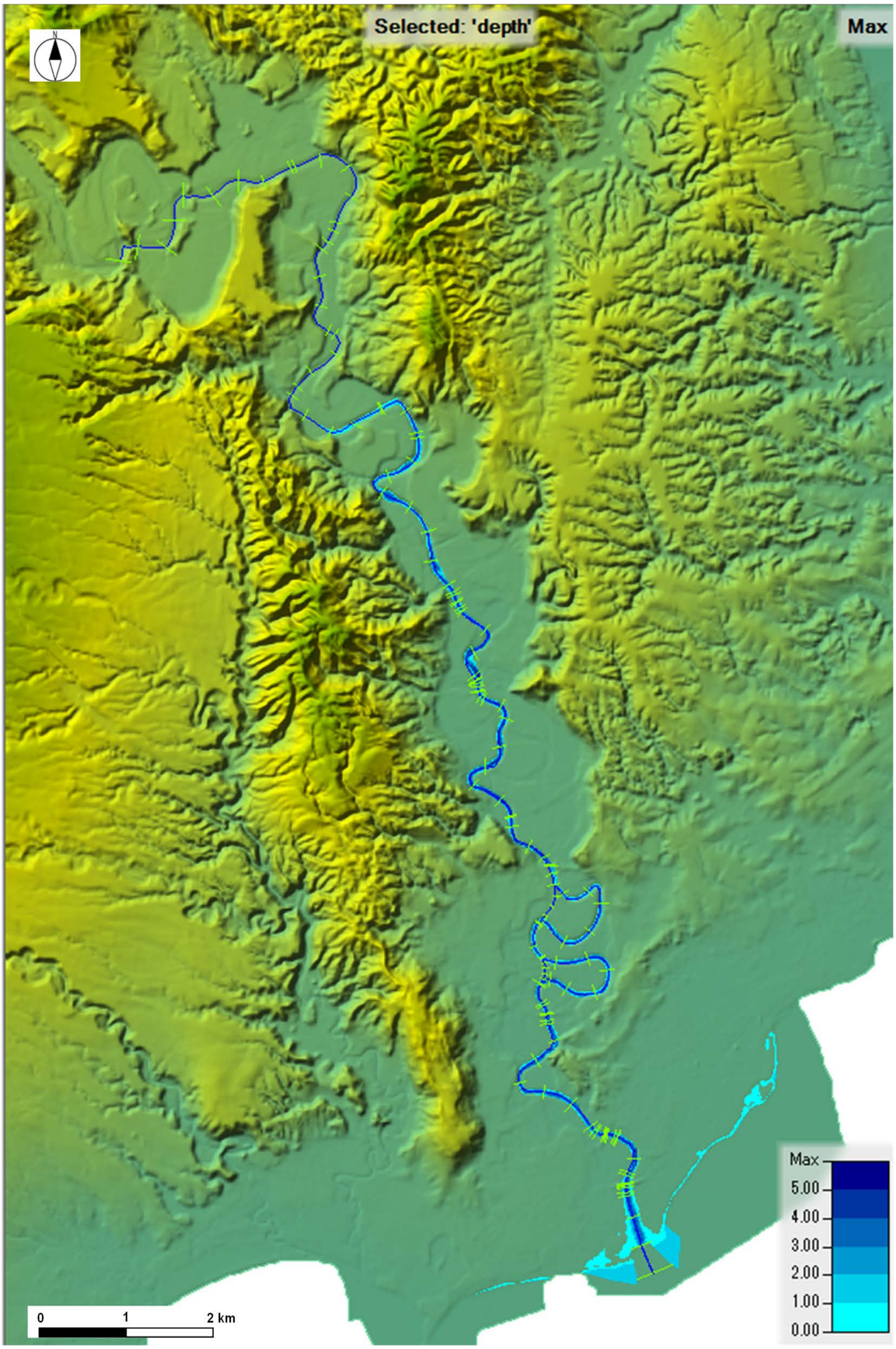
Source: Project Team

Figure 4.1.59(5) Result of Inundation Analysis of After Short-term Project (5-yr scale): January 2002 Type Flood



Source: Project Team

Figure 4.1.59(6) Result of Inundation Analysis of After Short-term Project (3-yr scale): January 2002 Type Flood



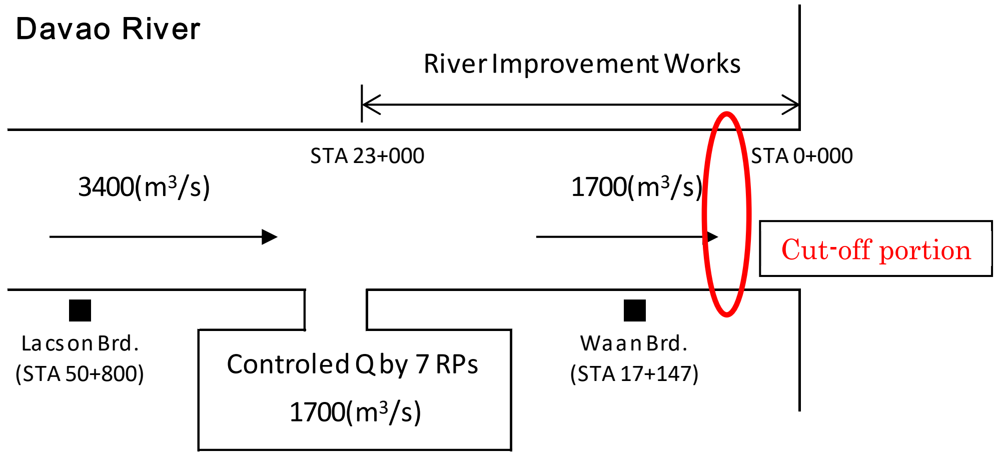
Source: Project Team

Figure 4.1.59(7) Result of Inundation Analysis of After Short-term Project (2-yr scale): January 2002 Type Flood

(4) Cut-off Works

In the short-term project, cut-off works will be implemented for the portion of continuous river channel bends from STA 6+500 to STA 12+700. In the M/P stage, it was proposed that the existing river channel that is the subject reach for cut-off would be reclaimed for utilizing as a relocation site for settlers who would be affected by the river widening works. In the F/S stage, a detailed survey of the site and a comparative study including width of cut-off works and utilization of existing river was conducted (detailed in Section 4.1.5), for a result of that, it was decided that design flood discharge would be run off only by cut-off channel and the existing river could be reclaimed for utilization.

The study of the cut-off portion was conducted for the 100-year scale flood, which is the target scale of the M/P, and the design flood discharge is 1,700 m^3/s, which is the discharge after regulation by the retarding ponds.



Source: Project Team

Figure 4.1.60 Design Flood Discharge of Davao River (100-yr scale flood)

1) Plan View Design

As described in "(1)Design River Shape", the design channel alignment of the cut-off portion is set so that it connects smoothly with the existing channel (see Figure 4.1.61).

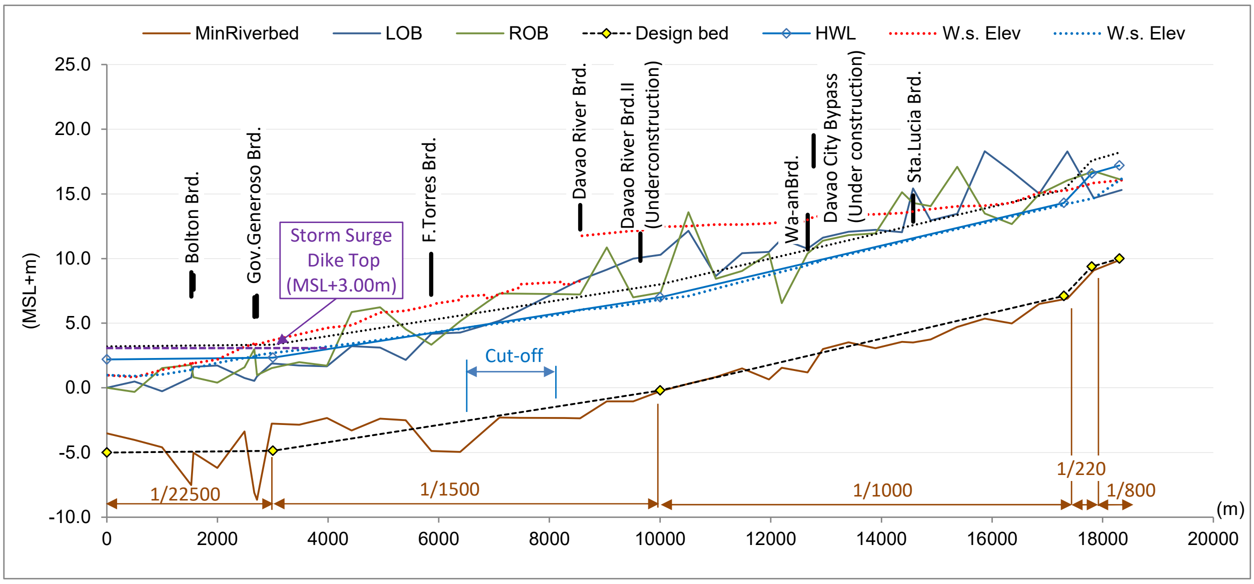
Cut-off works would be undertaken on the north side (approximately STA 10+040 - STA 12+500) and on the south side (approximately STA 6+500 - STA 9+000). The northern cut-off is located on private land, and the river channel was set so that it would not affect the development of residential areas. In the vicinity of the southern cut-off, the river channel was set to avoid fragmentation of the area inhabited by the Kagan community, which is classified as a Muslim minority, and to minimize relocations.

Source: Project Team

Figure 4.1.61 Design River Channel Alignment of Cut-off Portion

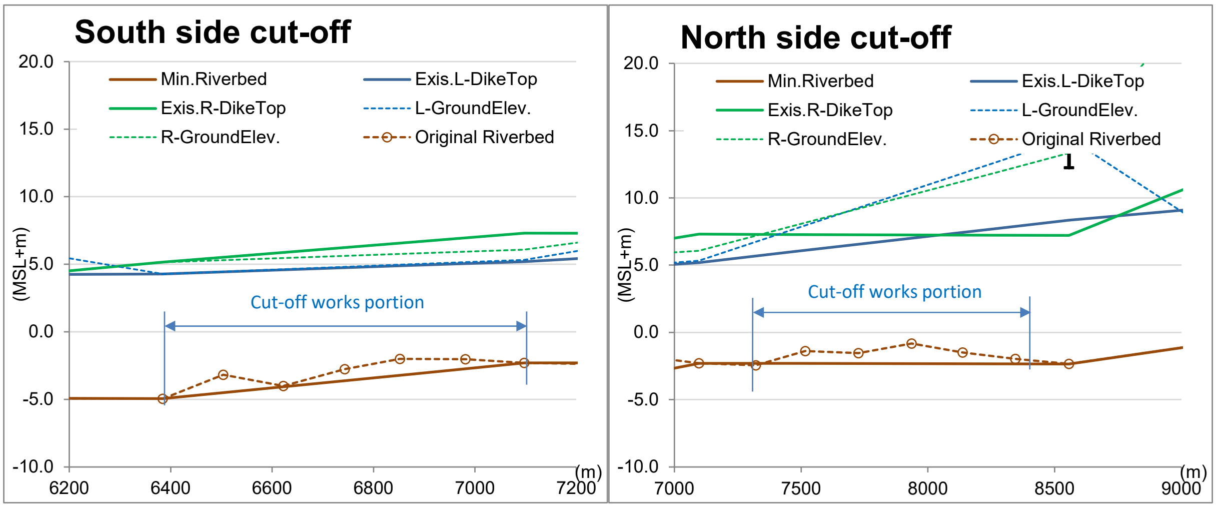
2) Longitudinal Profile Designing

As described in "(1)Design River Shape", the design longitudinal profile was set in consideration of the change in the design channel length due to the cut-off (see Figure 4.1.62). The relationship between the elevation of the riverbed near the connection point between the cut-off and the existing channel is shown in Figure 4.1.63. Although the elevation of the riverbed at the connection point is almost the same, it is desirable to maintain the elevation of the riverbed at the design riverbed elevation because the slope of the riverbed becomes steeper due to the cut-off works than the existing channel.



Source: Project Team

Figure 4.1.62 Design Longitudinal Profile of Davao River



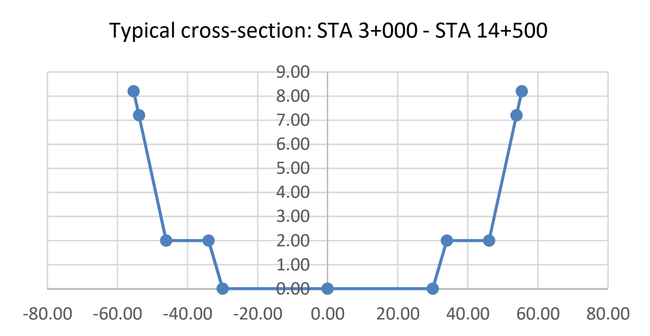
Source: Project Team

Figure 4.1.63 Connection between Cut-off and Existing Channel Bed

3) Typical Design Cross-section

The design cross-sectional of the cut-off portion is set referring to the typical design cross-sectional for the reach from STA3+000 to SAT14+500 in "(1)Design River Shape".

Table 4.1.21 Calculation Sheet for Typical Design Cross-section (STA 3+000 - STA 14+500)



Chanle width:	110.8
Channle water depth:	7.2
low-water channel bed width:	60.0
low-water channel bank slope:	1:2.0
high-water channel bank slope:	1:1.5
Wetted primeter:	111.89
Channel flow area:	648.0
Manning's n:	0.030
Chanle bed gradient:	1/1500
Flow velocity:	2.78
Flow capacity:	1798.55

Source: Project Team

4.1.5 Comparison of Alternatives for Priority Project (Structural Measure) Target for Feasibility Study

In this section, alternatives for key structural issues for each of F/S targets, which are riverbed dredging, retarding ponds, and cut-off works are compared and examined.

(1) Riverbed Dredging

Regarding riverbed dredging, the extension of the conservation stretches upstream and downstream of the bridge (the stretch where river dredging will not be performed) is considered as an alternative comparison item.

In the DPWH order related to river dredging, in addition to ensuring a buffer zone of 10m from the existing structure, the conservation stretch is basically 1km upstream and downstream of the existing bridge, where no river dredging is to be conducted. However, if this criterion is applied to the Davao River, the reach of river dredging is limited, and improvement of flood safety level cannot be expected. On the other hand, the standard mentioned above states, "This limitation shall not apply if appropriate analysis shows that dredging will not affect the stability of the bridge, and if permission is obtained from the relevant agencies. Therefore, a hydraulic analysis was conducted to determine the variation in channel hydraulics (water level and flow velocity) and the impact on the existing bridge was examined (see 4.1.4(2)). The results of the study showed that when the conservation stretch is 400 m or more, the maximum increase in flow velocity is less than 10%, which is almost the same as the case when the conservation stretch is 1 km following the ordinance. Even when the conservation stretch is reduced to 100 m, the increase in flow velocity is less than 20%.

Here, the Davao River bridge significantly obstructs flow area of the river, and the analysis shows a rise in the water level of the river channel, therefore, it was considered the case of that no conservation stretch for the Davao River Bridge with riverbed protection works for securing the stability of the bridge, in order to further express the flood control effect of river dredging. Based on these considerations, a comparative study of the following alternatives was conducted.

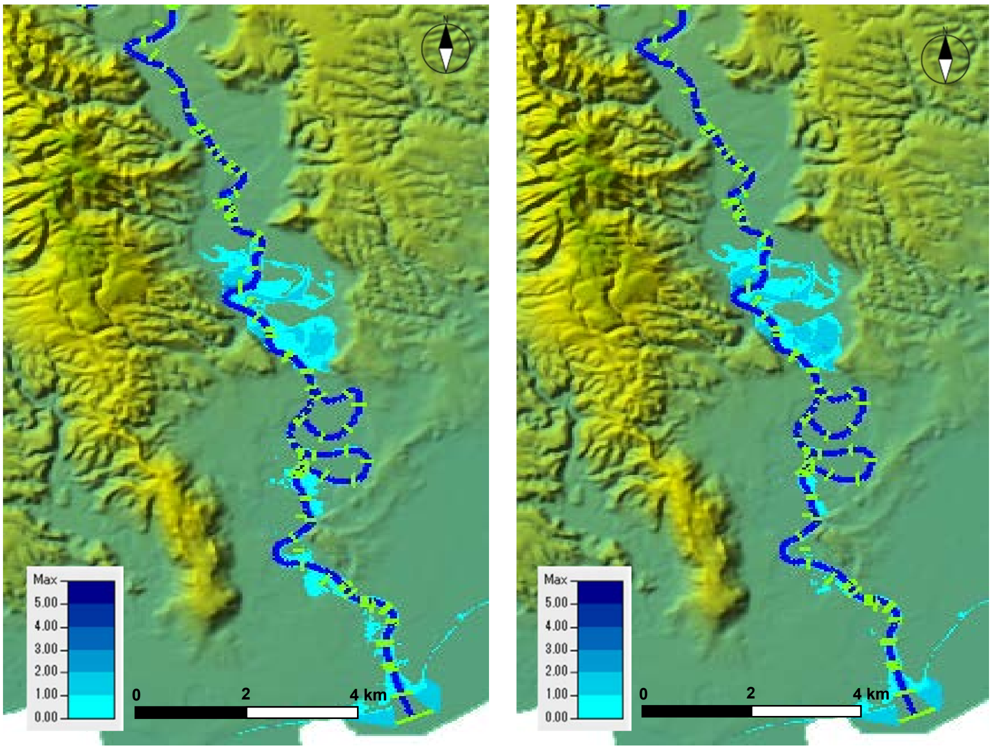
Table 4.1.22 Alternatives of Riverbed Dredging

Alternatives	Alt.1	Alt.1-2	Alt.2	Alt.3
Contents	- conserve 400m upstream and downstream	- conserve 100m upstream and downstream	- conserve 400m upstream and downstream - except Davao River Brd. (w/ riverbed protection)	- conserve 100m upstream and downstream - except Davao River Brd. (w/ riverbed protection)

Source: Project Team

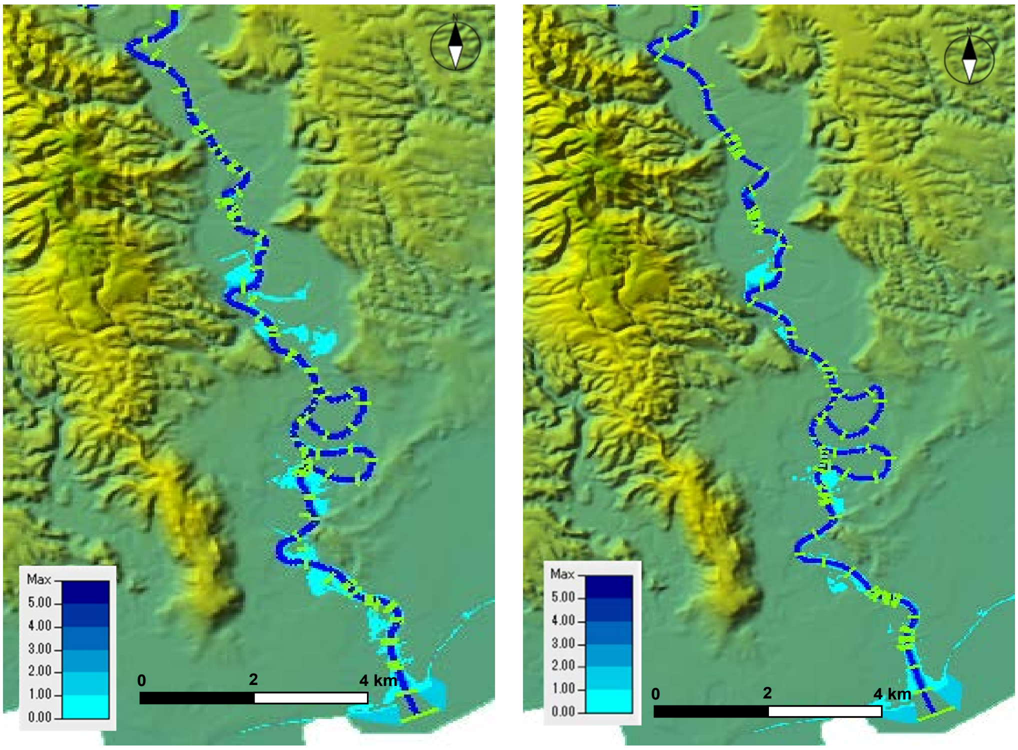
In order to quantitatively evaluate the flood control effects of each alternative, an inundation analysis was conducted. Here, the inundation analysis was conducted after the completion of the priority projects for F/S (retarding ponds and cut-off works), except for the riverbed dredging. By doing so, the effect of each alternative on the degree of flood safety level after the completion of the priority projects for F/S was ascertained. The results of the inundation analysis for the 10-yr scale flood, the target flood safety level for the short-term project, are shown in Figure 4.1.64.

Comparing Alt.1 with Alt.1-2, it was confirmed that Alt.1-2 reduced the inundation area downstream from the meandering portion, and that extending the dredging stretch would reduce flood damage. However, upstream of the Davao River Bridge, inundation has not been eliminated due to the bottleneck at the Davao River Bridge. Alt.2 and Alt.3 will significantly reduce the inundation area upstream of the Davao River Bridge by widening the river flow area while ensuring the stability of the Davao River Bridge through riverbed protection works.



Source: Project Team

Figure 4.1.64(1) Inundation Map by 10-yr Scale Flood after Shot-term Works (left: Alt.1, right: Alt.1-2)



Source: Project Team

Figure 4.1.64(2) Inundation Map by 10-yr Scale Flood after Shot-term Works (left: Alt.2, right: Alt.3)

The results of the comparison of alternatives for riverbed dredging are shown in Table 4.1.23. As a result of the comparison, Alt.3: 100m conserving upstream and downstream of the bridge and no conservation stretch for the Davao Bridge (installation of riverbed protection works) is recommended as the optimal alternative because it can achieve the target of flood safety level of the short-term project, although it is less economical than the other alternatives due to the increased dredging area and installation of riverbed protection works at the Davao River Bridge.

Table 4.1.23 Comparison of Alternatives for Riverbed Dredging

Alternatives / Evaluation axis	Alt.1: Conserve 400m upstream and downstream	Alt.1-2: Conserve 100m upstream and downstream	Alt.2: Conserve 400m upstream and downstream, except Davao River Brd. (w/ riverbed protection)	Alt.3: Conserve 100m upstream and downstream, except Davao River Brd. (w/ riverbed protection)
A. Flood protection level (expected damage reduction)	Inundation area reduction rate against 10-yr flood: 65%※ Flow velocity increase rate at/around bridges: 110%	Inundation area reduction rate against 10-yr flood: 76%※ Flow velocity increase rate at/around bridges: 116%	Inundation area reduction rate against 10-yr flood: 88%※ Flow velocity increase rate at/around bridges: 110%	Inundation area reduction rate against 10-yr flood: 97%※ Flow velocity increase rate at/around bridges: 116%
B. Economic effectiveness	Direct cost for works: 0.27Billion PhP	Direct cost for works: 0.35Billion PhP	Direct cost for works: 0.29Billion PhP	Direct cost for works: 0.36Billion PhP
C. Feasibility from in regards with social restriction	No house compensation	No house compensation	No house compensation	No house compensation
D. Feasibility from the technical viewpoint to construct countermeasures	Phased construction is available.	Phased construction is available.	Phased construction is available.	Phased construction is available.
E. Sustainability	Sustainable	Sustainable	Sustainable	Sustainable
F. Flexibility	–	–	–	–
G. Social and natural environment impact	The habitat for aquatic organisms (especially benthos) to be conserved is wider than in Alt.1-2 and Alt.3.	The habitat for aquatic organisms (especially benthos) to be conserved is narrower than in Alt.1-2 and Alt.3.	Basically the same as Alt.1	Basically the same as Alt.1-2
Other	–	–	–	–
Evaluation Result				**Although the construction cost is about 30% larger than the minimum one, the inundation area reduction rate is extremely high and the disaster mitigation effect is high.** **◎(Recommended)**

Source: Project Team

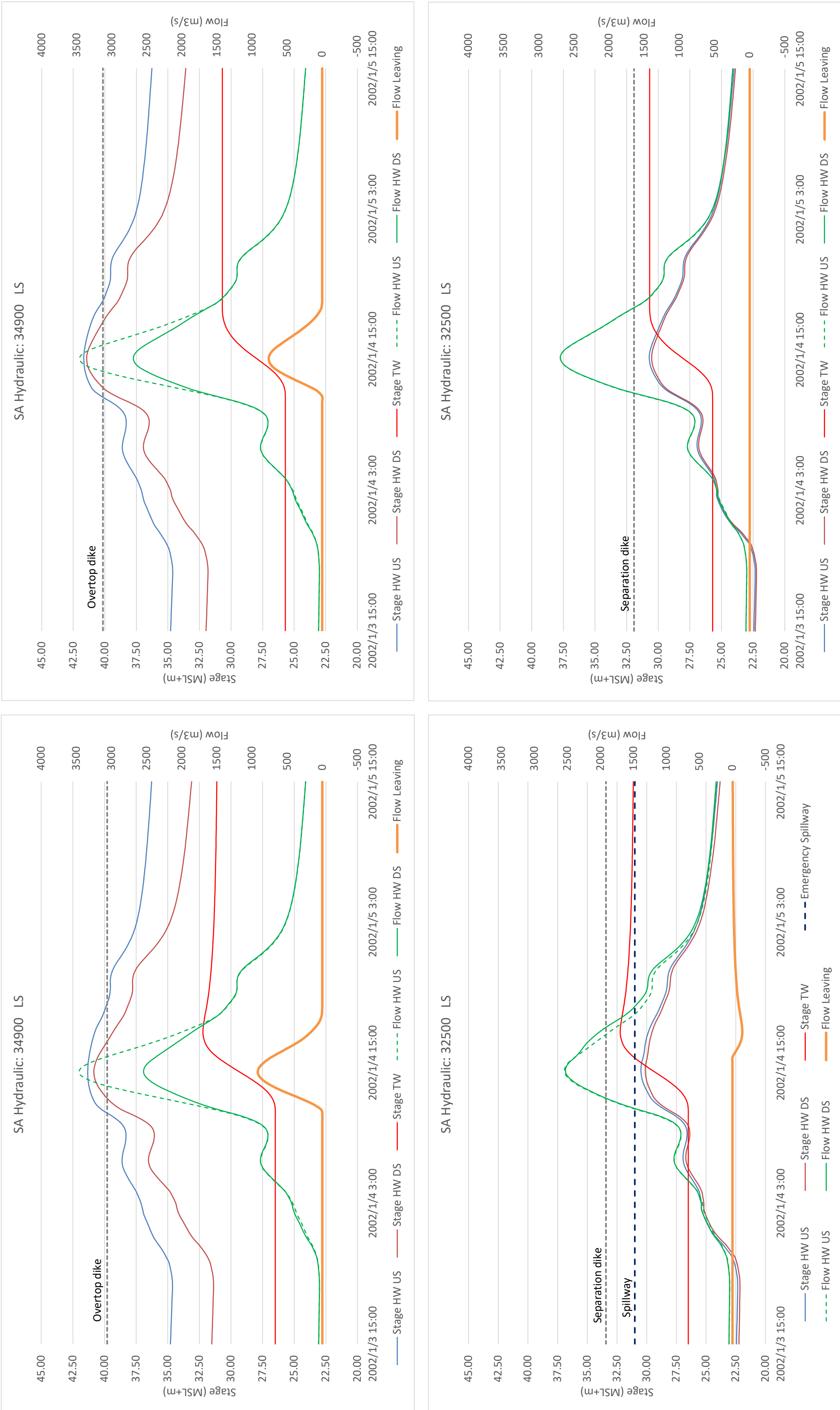
(2) Retarding Ponds

Regarding the retarding ponds, it is expected that the installation of spillways could make more efficient flood control since flood control will be performed by not a single retarding pond but by a group of retarding ponds, in addition there are large elevation gap between inlet and outlet in this Project. Therefore, the presence or absence of a spillway is considered as an alternative comparison item. Here, the facility specifications including spillways are set by the flood control in M/P (against 100-yr scale flood). In F/S, the facility specifications except the overflow dike height are based on the results of M/P study.

Table 4.1.24 Alternatives of Retarding ponds

Alternatives	Alt.1	Alt.2
Contents	- With spillways	- Without spillways

Source: Project Team



Source: Project Team

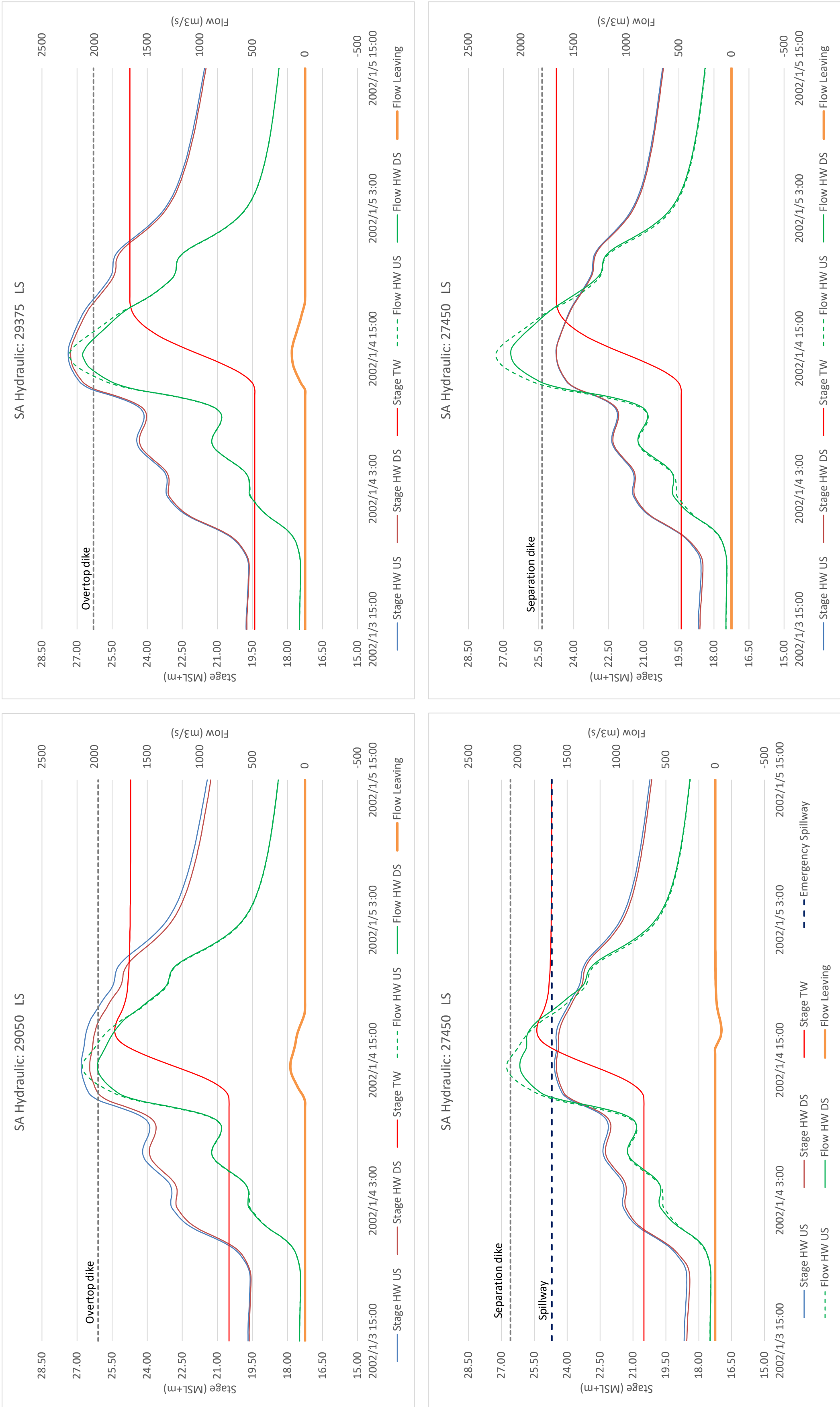
Figure 4.1.65 Unsteady Flow Analysis for Retarding Ponds: RP 06 (left: w/ spillway, right: w/o spillway)

Source: Project Team

Figure 4.1.66 Unsteady Flow Analysis for Retarding Ponds: RP 07 (left: w/ spillway, right: w/o spillway)

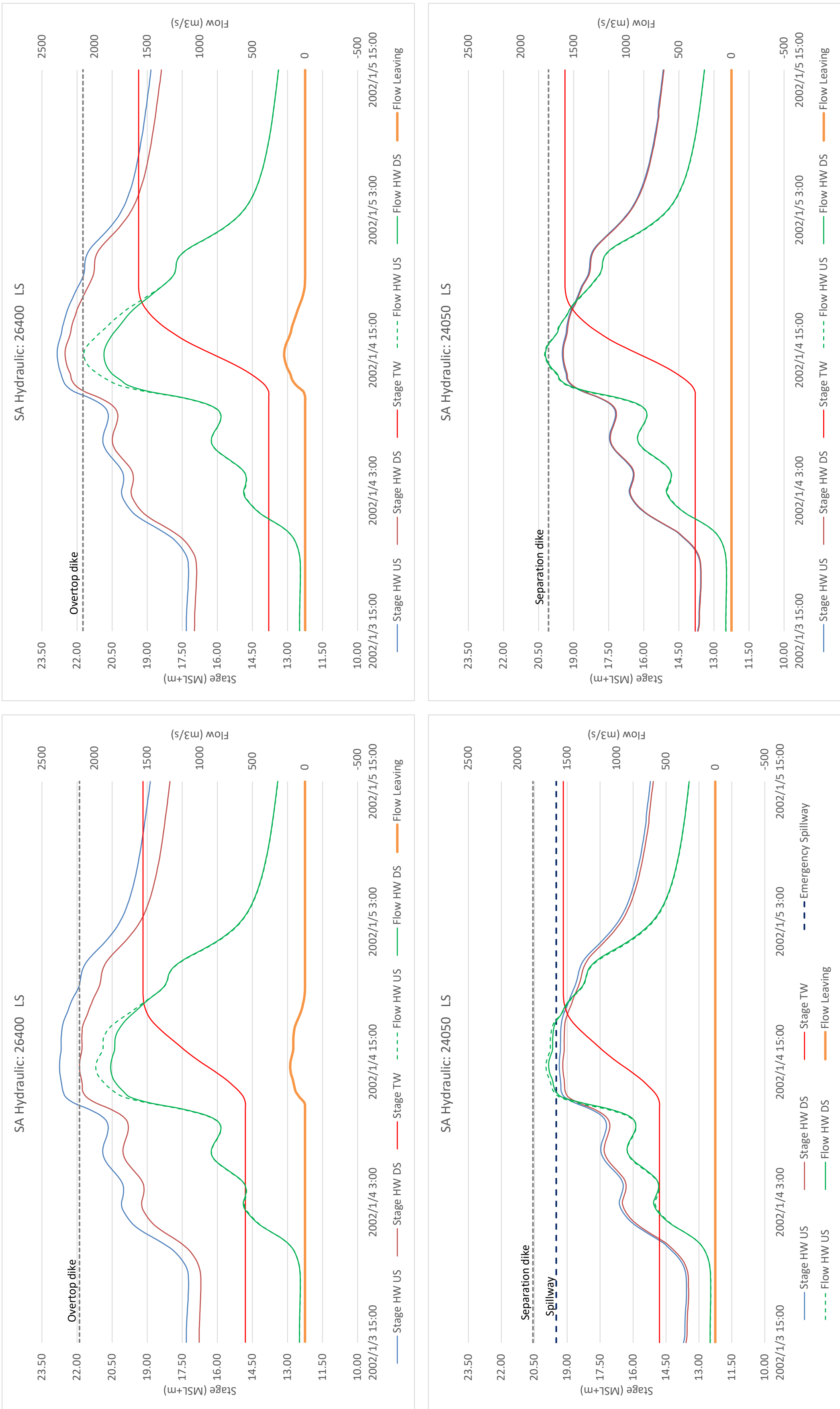
Source: Project Team

Figure 4.1.67 Unsteady Flow Analysis for Retarding Ponds: RP 08 (left: w/ spillway, right: w/o spillway)



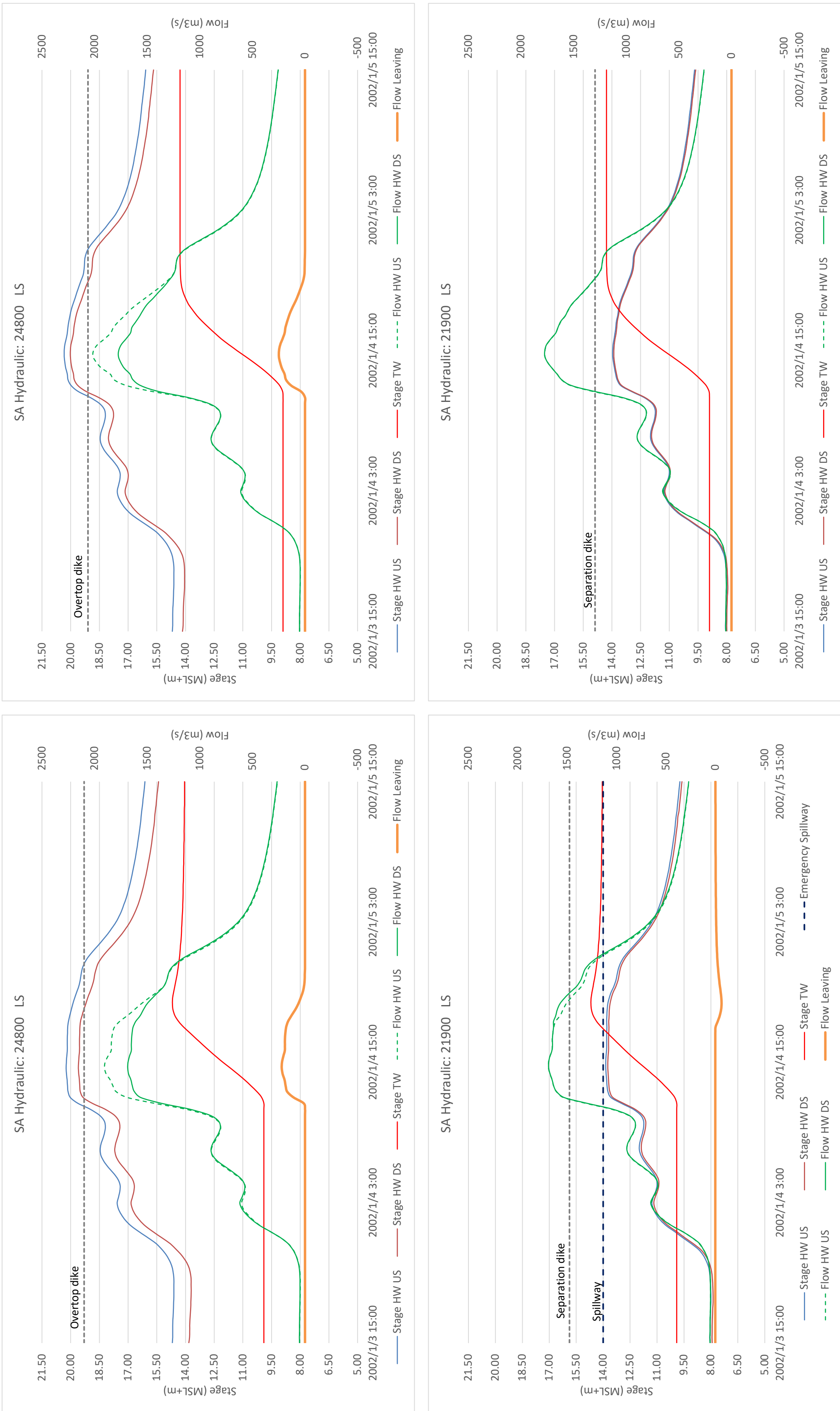
Source: Project Team

Figure 4.1.68 Unsteady Flow Analysis for Retarding Ponds: RP 09 (left: w/ spillway, right: w/o spillway)



Source: Project Team

Figure 4.1.69 Unsteady Flow Analysis for Retarding Ponds: RP 11 (left: w/ spillway, right: w/o spillway)



Source: Project Team

Figure 4.1.70 Unsteady Flow Analysis for Retarding Ponds: RP 12 (left: w/ spillway, right: w/o spillway)

Source: Project Team

Figure 4.1.71 Unsteady Flow Analysis for Retarding Ponds: RP 13 (left: w/ spillway, right: w/o spillway)

Table 4.1.25 shows a list of the facility specifications obtained from the aforementioned analysis, depending on whether or not a spillway is installed. The results showed that the invert level of RP08 is the same as the case without spillway (Alt.2), in other hands, the invert level of RP09 and RP11 could be increased by 1.1 m and 1.0 m respectively, and the amount of soil excavation could be reduced.

Table 4.1.25 Facility Specifications with/without Spillways

		RP 06		RP 07		RP 08		RP 09		RP 11		RP 12		RP 13	
		Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
Alt.1 (w/ spillway)	Max WS	41.33	30.48	29.16	28.74	28.69	26.87	26.82	24.58	22.75	19.36	20.24	13.85	13.52	12.38
	Overtop dike/Spillway	39.80	31.00	28.40	29.00	27.50	27.00	26.10	24.70	21.90	19.50	19.30	14.00	13.10	12.50
	Dike top	42.53	33.42	30.36	29.94	29.89	28.37	28.02	26.59	23.95	20.56	21.44	15.88	14.72	13.58
	RP MAX Stage	32.22		28.31		27.17		25.39		19.18		14.68		12.35	
	RP MAX Storage (MCM)	12.54		2.36		4.88		1.80		2.94		4.91		1.22	
	RP invert	26.50	(−)	23.00	(−)	20.70	(−)	20.50	(−)	14.80	(−)	9.90	(−)	8.40	(−)
	Dike top − invert	16.03	6.92	7.36	6.94	9.19	7.67	7.52	6.09	9.15	5.76	11.54	5.98	6.32	5.18
	River Flow (m^3/s)		2528.66		2119.64		2101.52		1980.30		1687.29		1688.23		1633.58
Alt.2 (w/o spillway)	Max WS	41.66	30.72	29.33	28.95	28.89	27.20	27.38	24.75	22.85	19.48	20.34	13.96	13.61	12.50
	Overtop dike/Spillway	40.15	−	28.50	−	27.50	−	26.30	−	21.75	−	19.10	−	13.10	−
	Dike top	42.86	31.92	30.53	30.16	30.09	28.40	28.58	25.95	24.05	20.68	21.54	15.48	14.81	13.70
	RP MAX Stage	30.69		28.30		26.98		24.74		19.37		14.28		12.37	
	RP MAX Storage (MCM)	10.91		2.31		4.69		1.99		3.73		5.54		1.30	
	RP invert	25.70	(0.80)	23.00	(0.00)	20.70	(0.00)	19.40	(1.10)	13.80	(1.00)	8.90	(1.00)	8.20	(0.20)
	Dike top − invert	17.16	6.22	7.53	7.16	9.39	7.70	9.18	6.55	10.25	6.88	12.64	6.58	6.61	5.50
	River Flow (m^3/s)		2690.91		2229.70		2104.73		2096.97		1767.93		1774.88		1687.07

Source: Project Team

The result of the comparison of alternatives for the retarding ponds is shown in Table 4.1.26. Even considering the construction costs associated with the installation of spillways, it is recommended that Alt.1: with spillways as the optimal alternative because the reduction in construction costs due to the reduced excavation volume is significant, and the overall economic efficiency is superior to the other alternatives.

Table 4.1.26 Comparison of Alternatives for Retarding Ponds

Alternatives / Evaluation axis	Alt.1 With spillways	Alt.2 Without spillways
A. Flood protection level (expected damage reduction)	2032 (F/S) : W=1/5~10 ; 2045 (M/P) : W=1/100	
B. Economic effectiveness	Direct cost for works: 7.09 Billion PhP	Direct cost for works: 7.54 Billion PhP
C. Feasibility from in regards with social restriction	Affected houses: 1	Affected houses: 1
D. Feasibility from the technical viewpoint to construct countermeasures	Phased construction is available.	Phased construction is available.
E. Sustainability	Sustainable	Sustainable
F. Flexibility	After the construction of F/S scale structures, overflow on the separation dike can be avoided due to the effect of the spillways for a certain degree of excess flooding over the corresponding scale.	After the construction of F/S scale structures, overflow on the separation dike can be happened for a certain degree of excess flooding over the corresponding scale.
G. Social and natural environment impact	Amount of soil excavation can be reduced.	Amount of soil excavation can be increase comparing with Alt.1.
Other	—	—
Evaluation Result	**It is highly economical and is expected to reduce the risk of dike breach in the event of excess floods.** ◎ **(Recommended)**	

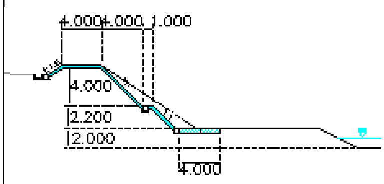
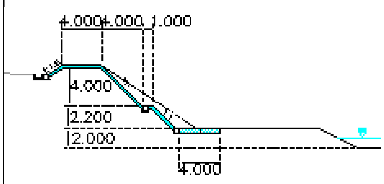
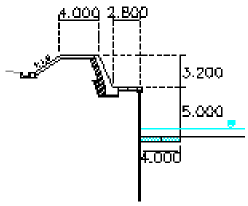
Source: Project Team

(3) Cut-off Works

Regarding the cut-off works, several issues were identified through F/S, including the typical cross-section of the new channel reach (including the revetment structure) and dealing with the existing channel subject to the cut-off works.

Therefore, three alternatives for dealing with the existing channel subject to the cut-off works and the revetment structure of the new river channel were designed and compared as shown in Table 4.1.27.

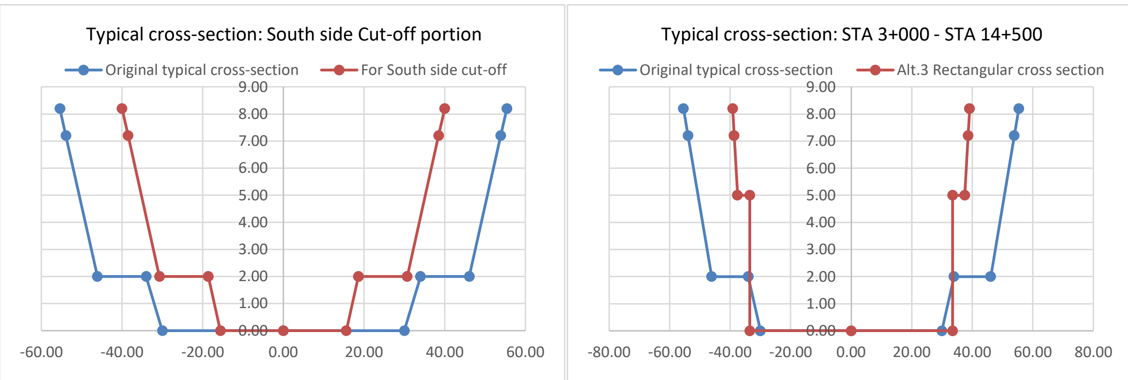
Table 4.1.27 Alternatives of Cut-off Works

Alterna-tives	Alt.1	Alt.2	Alt.3
Contents	- Inverted trapezoidal double cross-section - Channel width: 111 m + ROW - No expectation of flow capacity of existing river channel (dealing with existing channel after cut-off works as appropriate)	- Inverted trapezoidal double cross-section - Channel width: 80 m + ROW - Expectation of flow capacity of existing river channel (requiring to maintain existing channel after cut-off works)	- Rectangular cross-section with straight wall - Channel width: 80 m + ROW - No expectation of flow capacity of existing river channel (dealing with existing channel after cut-off works as appropriate)
Revetment structure			

Source: Project Team

Regarding the typical cross-section of each alternative, Alt.1 applies the typical cross-section studied in M/P. In order to make the design channel as narrow as possible, Alt.3 applies a sheet pile revetment (maximum height 5m) for the low-channel and a concrete retaining wall is used for the portion exceeding the maximum height of the sheet pile revetment. Following this policy, the typical cross-section of Alt.3 was set by non-uniform flow calculation.

For Alt.2, since the flow distribution to the existing channel varies depending on the flow capacity of the cut-off channel, an inverted trapezoidal cross-section with the same design channel width of approx. 80 m as Alt.3 was set, and an unsteady flow analysis was conducted and confirmed that the design flood discharge (1,700 m3/s) could be safely flow down both the cut-off channel and existing channel.



Source: Project Team

Figure 4.1.72 Typical Cross-section of Cut-off Channel (left: Alt.2, right: Alt.3)

Figure 4.1.73 shows the design alignments of each alternative. Number of affected houses would be counted utilizing these alignments.

Source: Project Team

Figure 4.1.73 Design Alignments of Cut-off Portion

The result of the comparison of alternatives for cut-off works is shown in Table 4.1.28. For the north side, Alt.1: Inverted trapezoidal double-section (111m wide + ROW) without expecting the current channel's flow capacity, which is superior to the other alternatives overall in terms of economical effectiveness, sustainability, flexibility, and environmental impact, is recommended as the optimal alternative.

For the south side, although the number of affected houses is larger than the other proposals, based on an overall assessment of economic effectiveness, sustainability, flexibility, and environmental impact, Alt.1: Inverted trapezoidal double-section (111m wide + ROW) without expecting the current channel's flow capacity is recommended as the optimal proposal.

Table 4.1.28 Comparison of Alternatives for Cut-off Works (North side)

Alternatives / Evaluation axis	**Alt.1 : Inverted trapezoidal double cross-section, width: 111 m + ROW No expectation of flow capacity of existing river**	**Alt.2 : Inverted trapezoidal double cross-section, width: 80 m + ROW Expectation of flow capacity of existing river**	**Alt.3 : Rectangular cross-section with straight wall, width: 80 m + ROW No expectation of flow capacity of existing river**
A. Flood protection level (expected damage reduction)	Flow capacity 1700m^3/s (Design flood discharge in M/P (100-yr scale floods)		
B. Economic effectiveness	Direct cost for works: 0.49 Billion PhP (incl. 111m bridge construction cost) Land acquisition/compensation cost: 0.45 Billion PhP Total: 0.94 Billion PhP	Direct cost for works: 0.39 Billion PhP (incl. 81m bridge construction cost) Land acquisition/compensation cost: 0.38 Billion PhP Total: 0.77 Billion PhP	Direct cost for works: 0.66 Billion PhP (incl. 81m bridge construction cost) Land acquisition/compensation cost: 0.38 Billion PhP Total: 1.04 Billion PhP
C. Feasibility from in regards with social restriction	Affected houses: seldom	Affected houses: seldom	Affected houses: seldom
D. Feasibility from the technical viewpoint to construct countermeasures	Phased construction is available.	Phased construction is available.	Phased construction is available.
E. Sustainability	- Maintenance dredging volume is minimum	- Maintenance dredging volume increase 25% comparing with Alt.1	- Maintenance dredging volume increase 25% comparing with Alt.1 - Difficulty and cost for rehabilitation/repairing would be higher than the others since structure of straight wall portion will be sheet pile
F. Flexibility	- Dealing with the existing river channel (reclaiming or maintaining) will be determined on an as-needed basis. If the existing river channel is to be reclaimed, facilities (drainage channels, etc.) to treat rainwater drainage (normal and flood) from the watershed (up to approximately 1.4 km^2) around the meandering portion will be required. - It is relatively easy to deal with the need to revise the	- Maintenance work to the existing river channel is essential. - It is relatively easy to deal with the need to revise the	- Dealing with the existing river channel (reclaiming or maintaining) will be determined on an as-needed basis. If the existing river channel is to be reclaimed, facilities (drainage channels, etc.) to treat rainwater drainage (normal and flood) from the watershed (up to approximately 1.4 km2) around the meandering portion will be required. - The straight wall portion will be a sheet pile structure, and it

Alternatives / Evaluation axis	Alt.1 : Inverted trapezoidal double cross-section, width: 111 m + ROW No expectation of flow capacity of existing river	Alt.2 : Inverted trapezoidal double cross-section, width: 80 m + ROW Expectation of flow capacity of existing river	Alt.3 : Rectangular cross-section with straight wall, width: 80 m + ROW No expectation of flow capacity of existing river
	cross-section (increase the flow area) in the future.	cross-section (increase the flow area) in the future.	is difficult to respond to the need to revise the cross-section (increase the flow area) in the future.
G. Social and natural environment impact	- Compared to the others, the land acquisition area would be larger, but maintenance of the existing river channel is not required. - Compared to Alt.3, access to the river is easier and more hydrophilic	- Compared to the others, the land acquisition area would be smaller, but maintenance to control environmental degradation (water quality deterioration, mosquito infestation, etc.) in the existing river channel. - Compared to Alt.3, access to the river is easier and more hydrophilic	- The land acquisition area would be small as the same as Alt.2, but maintenance of the existing river channel is not required. - Compromising access to the river and the landscape due to the high straight wall.
Other	—		
Evaluation Result	**Although the direct construction cost is about 20% higher than the cheapest one, the M/P design flood discharge can be flow without expecting the flow capacity of the existing channel. The amount of maintenance dredging can be minimized, and rehabilitation, repair, and future cross-sectional revisions are relatively easy. In addition, it has relatively high hydrophilicity.** ◎ **(Recommended)**		

Note: Alt. 3 assumes U-shaped steel sheet piles. If hat-shaped steel sheet piles are used, it is roughly estimated that the construction cost will increase by about 10%, on the other hand, it is expected as advantages that since they are wider than U-shaped steel sheet piles, the number of the sheet piles can be reduced (the construction period can be shortened), and there is no need to consider reduction in cross-sectional performance due to joints (the risk of strength reduction of the steel sheet pile wall due to poor joint construction is low).

Source: Project Team

Table 4.1.29 Comparison of Alternatives for Cut-off Works (South side)

Alternatives / Evaluation axis	Alt.1 : Inverted trapezoidal double cross-section, width: 111 m + ROW No expectation of flow capacity of existing river	Alt.2 : Inverted trapezoidal double cross-section, width: 80 m + ROW Expectation of flow capacity of existing river	Alt.3 : Rectangular cross-section with straight wall, width: 80 m + ROW No expectation of flow capacity of existing river
A. Flood protection level (expected damage reduction)	Flow capacity 1700m^3/s (Design flood discharge in M/P (100-yr scale floods)		
B. Economic effectiveness	Direct cost for works: 0.34 Billion PhP (incl. 111m bridge construction cost) Land acquisition/compensation cost: 0.11 Billion PhP Total: 0.45 Billion PhP	Direct cost for works: 0.25 Billion PhP (incl. 81m bridge construction cost) Land acquisition/compensation cost: 0.10 Billion PhP Total: 0.35 Billion PhP	Direct cost for works: 0.41 Billion PhP (incl. 81m bridge construction cost) Land acquisition/compensation cost: 0.10 Billion PhP Total: 0.51 Billion PhP
C. Feasibility from in regards with social restriction	Affected houses: approx.90	Affected houses: approx.50	Affected houses: approx.50
D. Feasibility from the technical viewpoint to construct countermeasures	Phased construction is available.	Phased construction is available.	Phased construction is available.
E. Sustainability	- Maintenance dredging volume is minimum	- Maintenance dredging volume increase 25% comparing with Alt.1	- Maintenance dredging volume increase 25% comparing with Alt.1 - Difficulty and cost for rehabilitation/repairing would be higher than the others since structure of straight wall portion will be sheet pile
F. Flexibility	- Dealing with the existing river channel (reclaiming or maintaining) will be determined on an as-needed basis. If the existing river channel is to be reclaimed, facilities (drainage channels, etc.) to treat rainwater drainage (normal and flood) from the watershed east area of the meandering portion (2.6 km^2) will be required. - It is relatively easy to deal with the need to revise the cross-section (increase the flow area) in the future.	- Maintenance work to the existing river channel is essential. - It is relatively easy to deal with the need to revise the cross-section (increase the flow area) in the future.	- Dealing with the existing river channel (reclaiming or maintaining) will be determined on an as-needed basis. If the existing river channel is to be reclaimed, facilities (drainage channels, etc.) to treat rainwater drainage (normal and flood) from the watershed east area of the meandering portion (2.6 km^2) will be required. - The straight wall portion will be a sheet pile structure, and it is difficult to respond to the need to revise the cross-section (increase the flow area) in the future.
G. Social and natural environment impact	- Compared to the others, the land acquisition area would be larger, but maintenance of the existing river channel is not required. - Compared to Alt.3, access to the river is easier and more hydrophilic	- Compared to the others, the land acquisition area would be smaller, but maintenance to control environmental degradation in the existing river channel. - Compared to Alt.3, access to the river is easier and more hydrophilic	- The land acquisition area would be small as the same as Alt.2, but maintenance of the existing river channel is not required. - Compromising access to the river and the landscape due to the high straight wall.

Alternatives / Evaluation axis	Alt.1 : Inverted trapezoidal double cross-section, width: 111 m + ROW No expectation of flow capacity of existing river	Alt.2 : Inverted trapezoidal double cross-section, width: 80 m + ROW Expectation of flow capacity of existing river	Alt.3 : Rectangular cross-section with straight wall, width: 80 m + ROW No expectation of flow capacity of existing river
Other	If the existing river channel is to be reclaimed, the bridge under construction by DPWH RO XI will be rendered useless.	Maintaining the existing river channel is essential, and the bridge under construction by DPWH RO XI will be rendered useful.	If the existing river channel is to be reclaimed, the bridge under construction by DPWH RO XI will be rendered useless.
Evaluation Result	**Although the direct construction cost is about 30% higher than the cheapest one and the number of affected houses a large, compensation cost would be similar to the others. M/P design flood discharge can be flow without expecting the flow capacity of the existing channel. The amount of maintenance dredging can be minimized, and rehabilitation, repair, and future cross-sectional revisions are relatively easy. In addition, it has relatively high hydrophilicity. ◎ (Recommended)**		

Note: Alt. 3 on the south side also assumes U-shaped steel sheet piles, like the north side. The conditions (increase in construction costs and advantages) when using the hat-shaped steel sheet piles are the same as for the north side.

Source: Project Team

4.1.6 Preliminary Design of Structure Measures of the Priority Project Targeted for Feasibility Study for Riverine Flood in Davao River

(1) Preliminary Design of Structural Measures (Dredging)

River channel dredging work will be implemented according to the dredging extent and work sequences provided in the previous section, and no structures will be installed in the standard section of dredging. However, the dredging of the bridge section will require the reinforcement of the existing pier foundations by means of additional piles or continuous wall. As the design drawings of the bridge foundations were not available and the pile lengths could not be confirmed, a pile length survey using P-wave logging, magnetic logging, etc. is required for the design of the reinforcement of the bridge foundation. In addition, large-size concrete blocks are to be installed within a width of 5 m from the piers as river-bed protection work.

(2) Preliminary Design of Structural Measures (Retarding Pond)

1) Structural type of overflow dikes

For the structure of overflow dike, concrete-facing type structure is adopted for the F/S study, taking into account the results of geological survey result conducted for the study as well as site constructability, durability and ease of maintenance of the structure based on local conditions, and the construction track record of the project in the Philippines.

Other common structural types of overbank dikes include asphalt-facing, concrete block and gabion types. Selection should be made at the time of detailed design, including consideration of material availability and price. A reference comparison of the concrete fencing type and the gabion type is given below.

Table 4.1.30 Structure Type of Overflow Dike

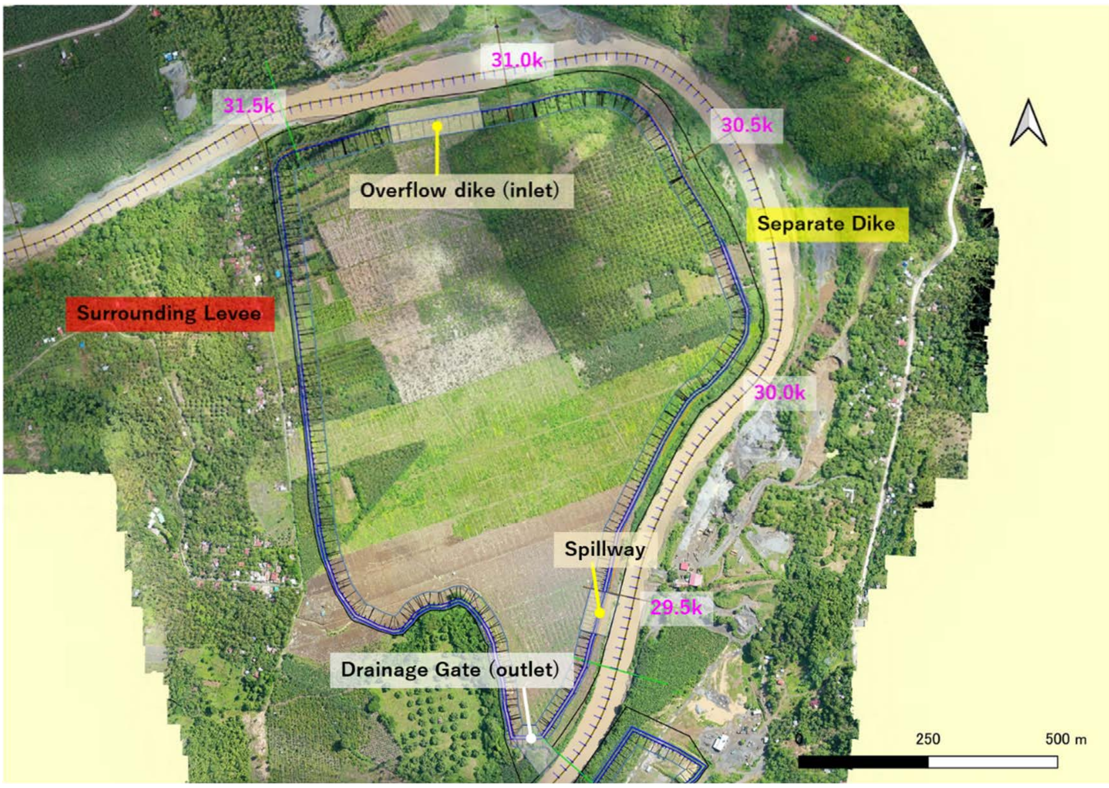
	Concrete-facing Protection	Gabion Protection
Type	 (example: Arakawa No.1 Retarding Pond)	 (example: Ichinoseki Retarding Pond)
Applicable Site	No constraints for site conditions	Not applicable where boulders of more than 20cm exists.
Constructability	Not major difficulties in construction	Not major difficulties in construction
Material availability	Available, but need to check at the time of D/D	Available, but need to check at the time of D/D
Maintenance	Easy maintenance due to due to high durability of concrete-facing	Maintenance required in case of wire damages / corrosion. Need to cut vegetation if any.
Cost	Less economical compared to Gabion type	Economical compared to Concrete type
Applied cases in the Philippines	Already exist (ex. Imus, Bacoor)	Not yet
Application to Davao River	✓ **(Applied)**	

Source: Images are from MLIT homepage, other than images from Project Team

2) Outline of structure layout

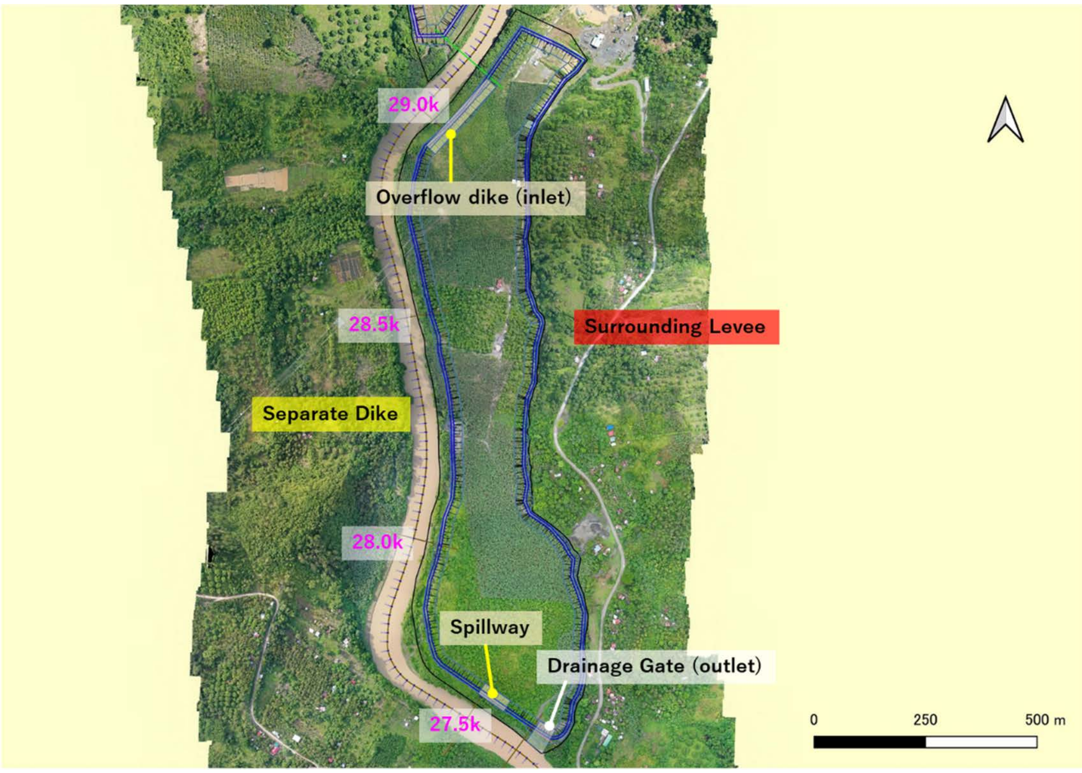
An overview of the structure layout of retarding ponds RP08, RP09 and RP11 is shown below. Each retarding pond consist of overflow dike, separate dike, surrounding levee, spillway and drainage gate. The wide area of the retarding ponds are mainly constructed by excavation due to the elevation of exiting grounds. The results of the structural studies for each facility for respective retarding pond are presented, but the structures shown here need to be examined closely in the detailed design, taking into account the results of additional geological and topographical survey as well as the availability and price of materials at that time.

In addition, environmental aspects and usability for residents were also considered in the layout of the structures. The environment and habitat of aquatic organisms were maintained by installing the embankment of the surrounding levee as close to the retarding pond as possible and maintaining the waterfront area in front of the retarding pond. Also, the usability as a place for residents' recreation was considered by setting the slope of the embankment of the surrounding levee at 1:3.



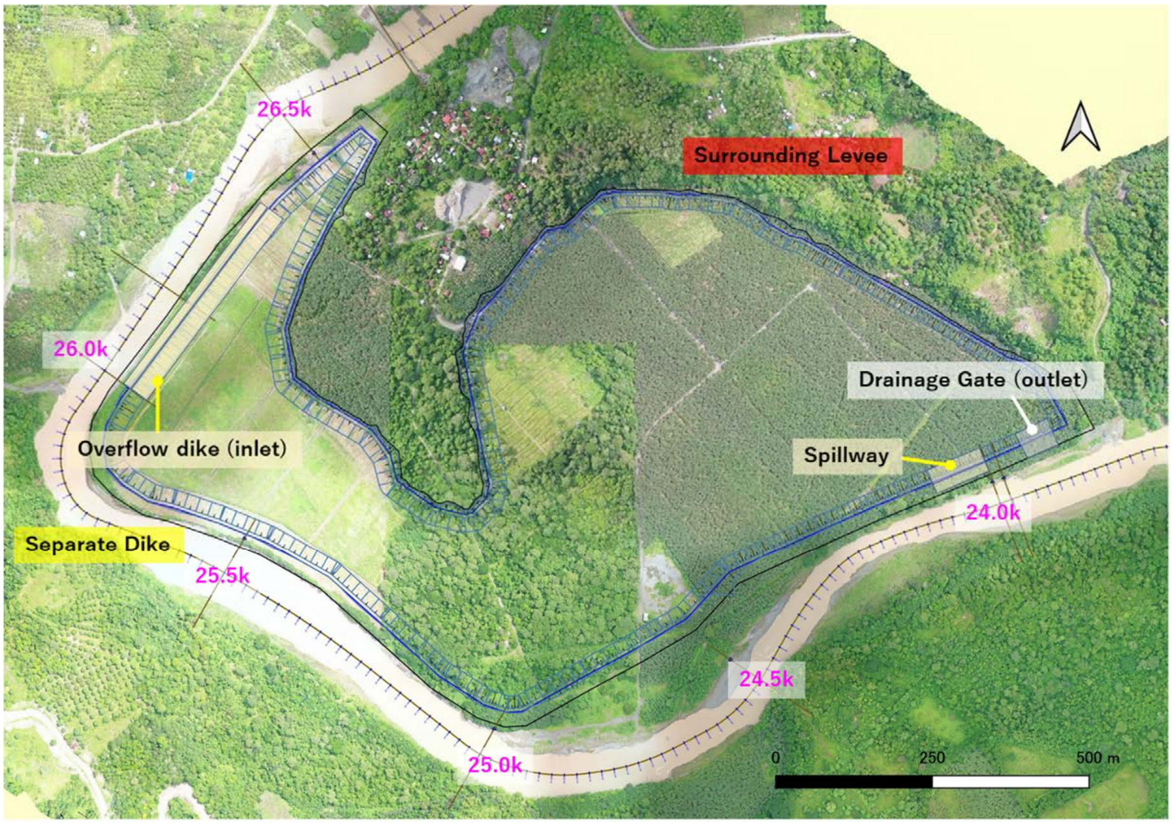
Source: Project Team

Figure 4.1.74 Retarding Pond RP08: Structure Layout



Source: Project Team

Figure 4.1.75 Retarding Pond RP09: Structure Layout

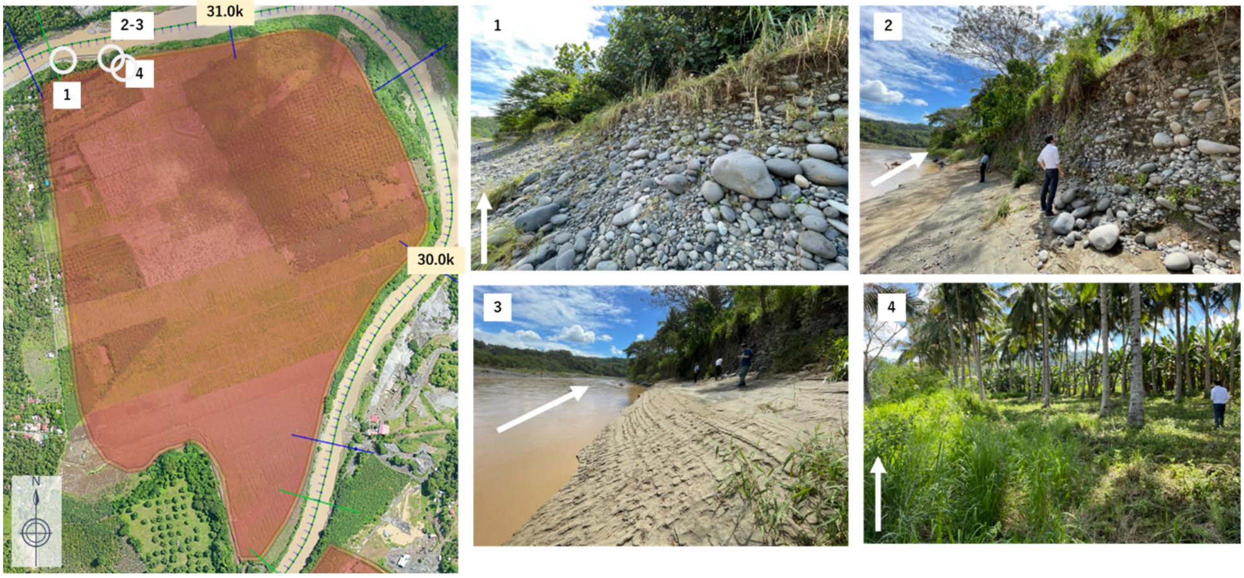


Source: Project Team

Figure 4.1.76 Retarding Pond RP11: Structure Layout

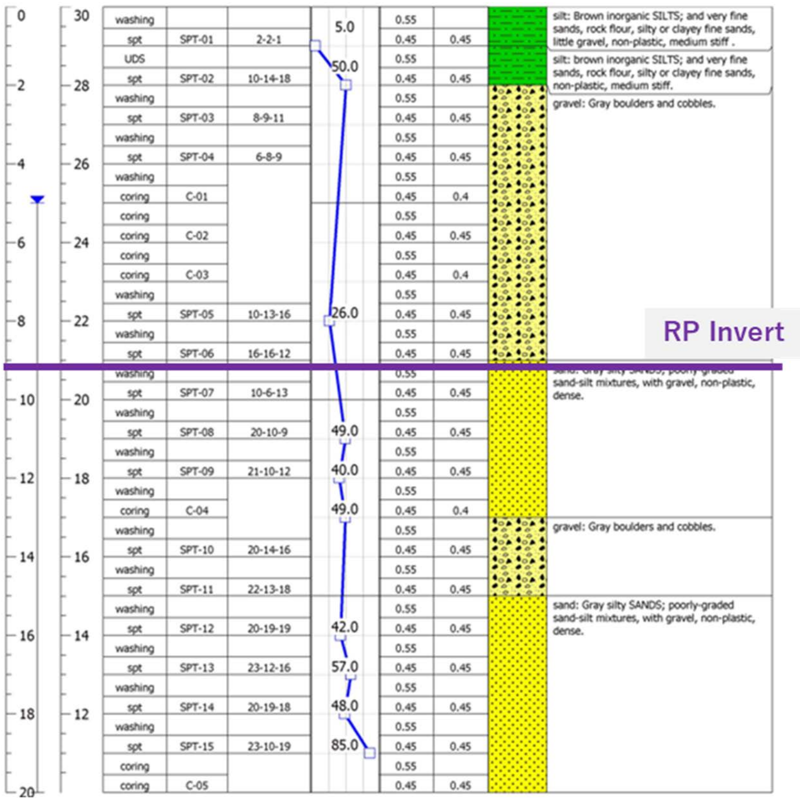
3) Preliminary design of retarding pond: RP08

Near the inlet (overflow dike) location of the retarding pond: RP08, boulders with a diameter of more than 20 cm are observed in the riverbed as well as at along the bank. The results of the geotechnical survey conducted along the riverbank at an elevation of +30.0m indicate the presence of a clayey layer of about 2m at the surface, but below this depth, the layer is mostly dominated by gravels to a depth equivalent to the planned retarding pond bed level (+20.7m), which is consistent with field observations.



Source: Project Team

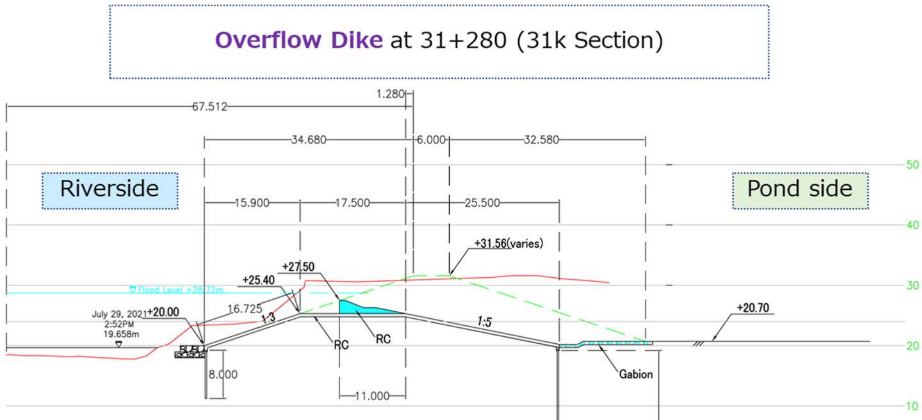
Figure 4.1.77 Site Photos near the Inlet of Retarding Pond RP08



Source: Project Team

Figure 4.1.78 Geotechnical Survey Results and Retarding Pond RP08 Invert Level

A cross-sectional structure of the overflow dike is shown below, considering ground conditions / site situations. The overflow dike will be covered with RC-facing protection with foot protection on riverside using locally procured boulders having the largest diameter. The planned crest level of the overflow dike is +25.40 m in the F/S phase and +27.50 m in the MP phase, and the raising in the MP phase will be carried out by installing a 2.1 m high drop work (RC retaining wall) at crest of F/S-phase overflow dike. Impermeable sheet piles should be installed at toe of the slope on the pond side of the overflow dike / separate dike, embedded into the impermeable soil layer. In addition, if the impervious sheet piles are installed on the river side, these sheet piles will also serve as erosion protection sheet piles, and the size of the sheet pile type is likely to increase. In the detailed design, the location of the impervious sheet piles should be further examined taking into account the location of the normal of bank alignment (in particular, the location of the toe of river side slope and the riverbank line) and the elevation of foot protection work.

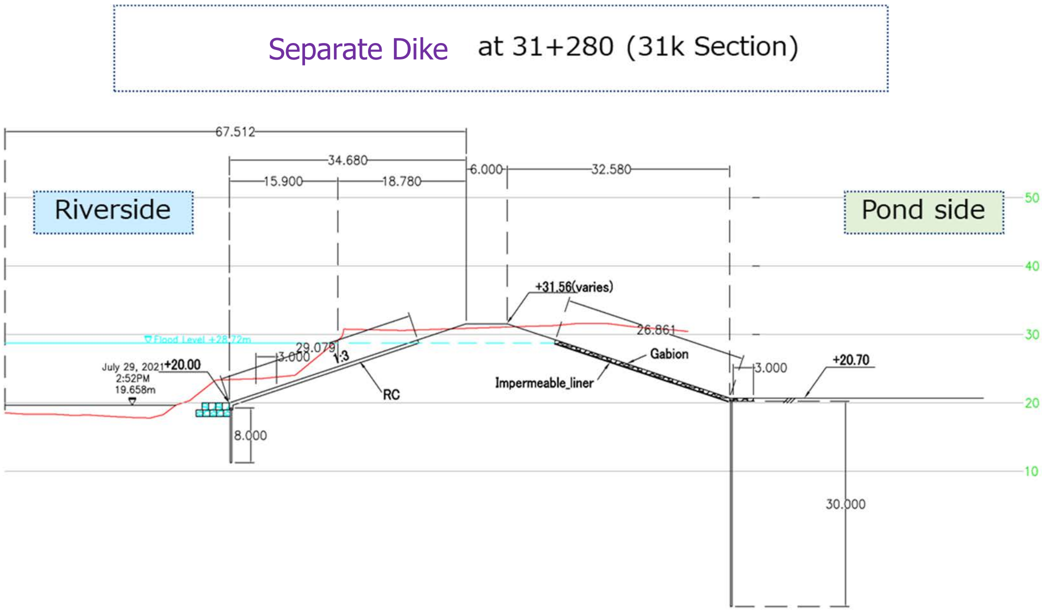


RP 08		MP	FS
RP invre level (MSL+m)		20.70	20.70
inlet overflow dike	Height(MSL+m)	27.50	25.40
	Width(m)	180	180
outlet spilway	Height(MSL+m)	27.00	27.00
	Width(m)	100	100

Source: Project Team

Figure 4.1.79 Standard Cross Section of Overflow Dike at Retarding Pond: RP08

For the separate dike of the retarding pond: RP08, RC revetment will be installed on the river side up to the M/P phase flood level (100-year return period) while gabion revetment with impermeable sheets will be installed on the pond side up to maximum storage level, as shown below.



Source: Project Team

Figure 4.1.80 Standard Cross Section of Separate Dike at Retarding Pond: RP08

The gabions and impermeable sheets function together to 1) prevent water from entering the embankment during impoundment and 2) prevent leakage of water that has entered the embankment from the river side. For the former case, as the sheet piles on river side are shallow and not embedded into the impermeable layer, it is assumed that the water level in the embankment will rise in accordance with the rise in river level, which will be resisted by the 'gabion + impermeable sheet' on the pond side slope. The gabion on the pond-side slope only functions as a weight, and was adopted because it was widely used for the revetment of the Davao River revetment at the time of the study. These countermeasures are necessary because the dike material of the separate dike is gravelly. It is to be noted that a more detailed understanding of the dike material as well as that of its longitudinal profile of the separate dike is required in the detailed design.

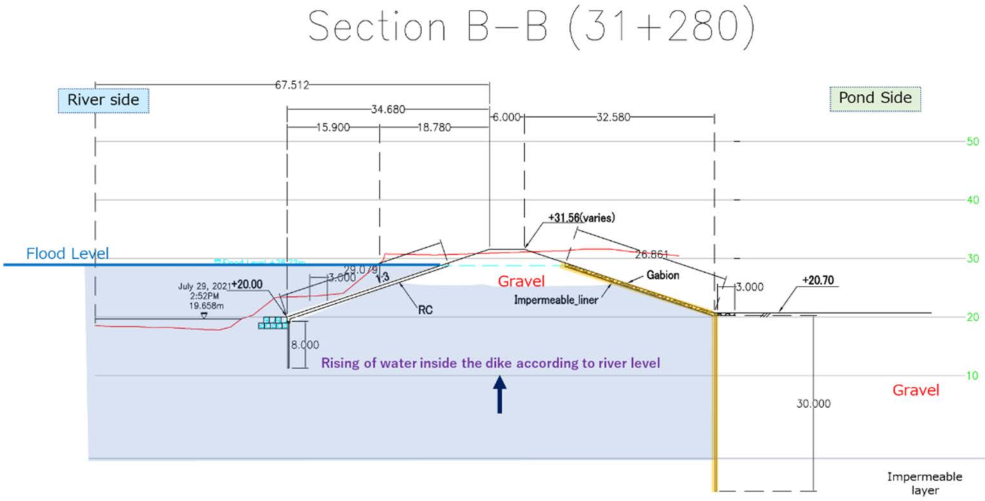
Concrete revetments on the river side are installed to prevent erosion of the slope (erosion by running water and collision of gravels) and to prevent washout of dike material (especially soil between gravels). Drainage of residual water inside the dike is expected to be done through the permeable base ground towards the river side, but depending on the soil conditions, and for faster drainage, the installation of a water drainage pipe with a check valve and retaining sheet on the RC revetment should be considered in the detailed design. In this case, these can also be considered as a measure to prevent the revetment from being uplifted by the residual water level inside the dike after the river water level has fallen.

If the crest is not covered, the lifting pressure due to residual air inside the dike at the time of water level rise is considered to be limited, but detailed design should be carried out taking into account the need to install a drainage layer, depending on the dike material and structure of the revetment.

Steel sheet piles and foot protection are installed as well to prevent scouring on the river side, and impermeable sheet piles are to be installed on the pond side down to the impermeable layer to prevent water leakage of the foundation ground from the river side to the pond side. The depth of the impermeable layer and its longitudinal variation should be determined by geological investigation in the detailed design. In particular, ensuring the quality of construction is a major issue in order for the facility to function as expected in the design. With regard to the difficulty of sheet pile driving, it is desirable that a detailed geological survey is carried out and a description of the specifications, taking into account the possibility of adopting any necessary auxiliary construction methods, is reflected in the bidding documents.

Furthermore, with regard to the impact of the measures on the groundwater flow, the impact on groundwater use is considered to be limited, as water supply is being developed in the surrounding settlements, the partially used wells are deep wells, and groundwater is not used for agriculture. For the considerations in the detailed design, a detailed study of groundwater use in the surrounding area should be included in the study of environmental and social considerations.

The top of foot protection on the river side is set to be uniformly +20.0 m (equivalent to the level of normal water) for the entire section of the separate dike.

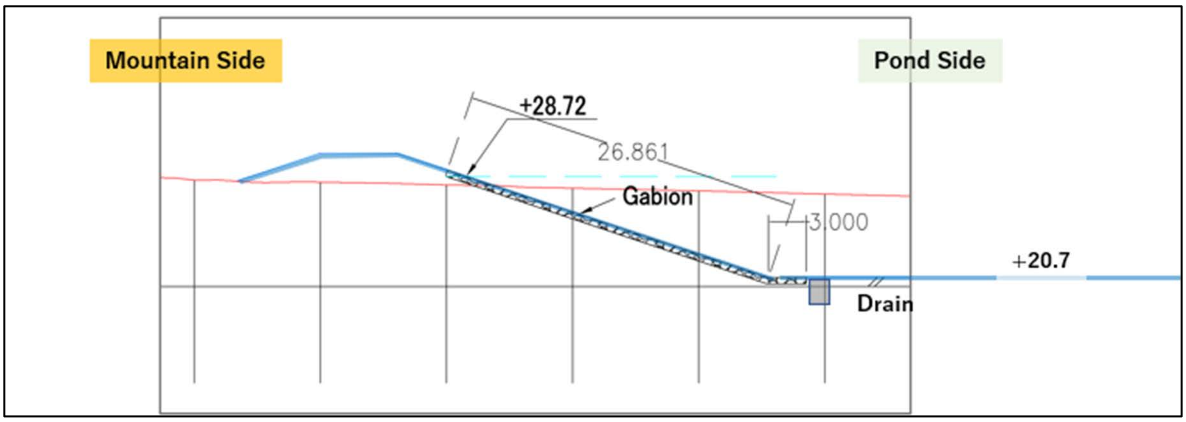


Source: Project Team

Figure 4.1.81 Concept of Separate Dike Pond-side Structure at Retarding Pond: RP08

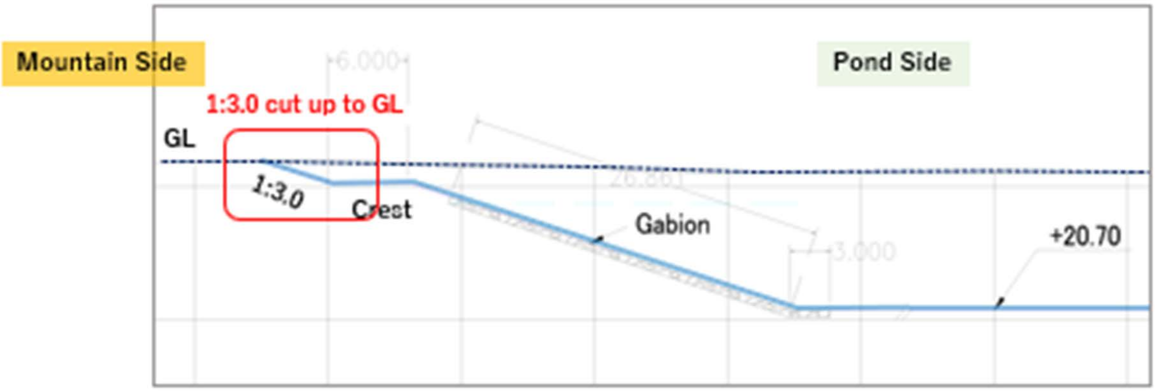
As for the structure of the surrounding levee, as with the separate dike, gabion revetment is installed up to maximum storage level along the pond-side slope. The main purpose of installing gabions on the surrounding levees is to protect and maintain the slope, such as preventing soil run-off from the slope which may fill up the drainage ditch or preventing excessive growth of vegetation on the slope, and to facilitate management of the location and sectional shape of the slope. The gradient of slope is 1:3.0 on both the mountain side and the pond side. Where the crest elevation is lower than existing ground level, 1:3.0 slope will be cut from the crest to reach the existing ground behind.

Although gabions are commonly used for revetments along the Davao River, it is necessary to take into account the availability of materials and price fluctuations during detailed design to determine its application.



Source: Project Team

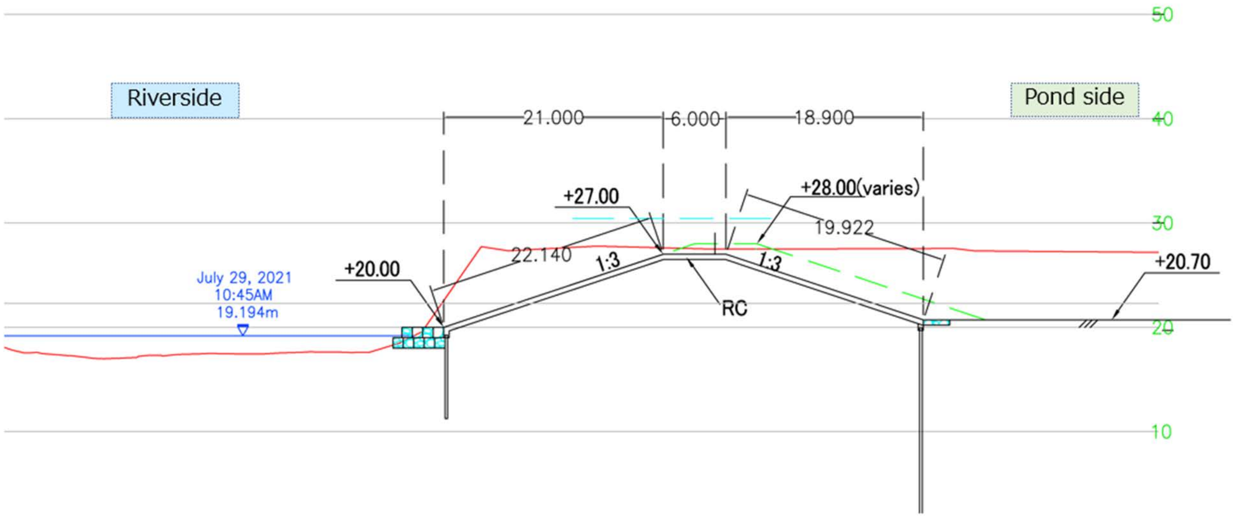
Figure 4.1.82 Standard Cross Section of Surrounding Levee at Retarding Pond: RP08 (Where the crest is higher than existing ground)



Source: Project Team

Figure 4.1.83 Standard Cross Section of Surrounding Levee at Retarding Pond: RP08 (Where the crest is lower than existing ground)

For the spillway to be installed in the downstream part of the retarding pond, the concrete-facing type slope protection is selected, as with the overflow dike.

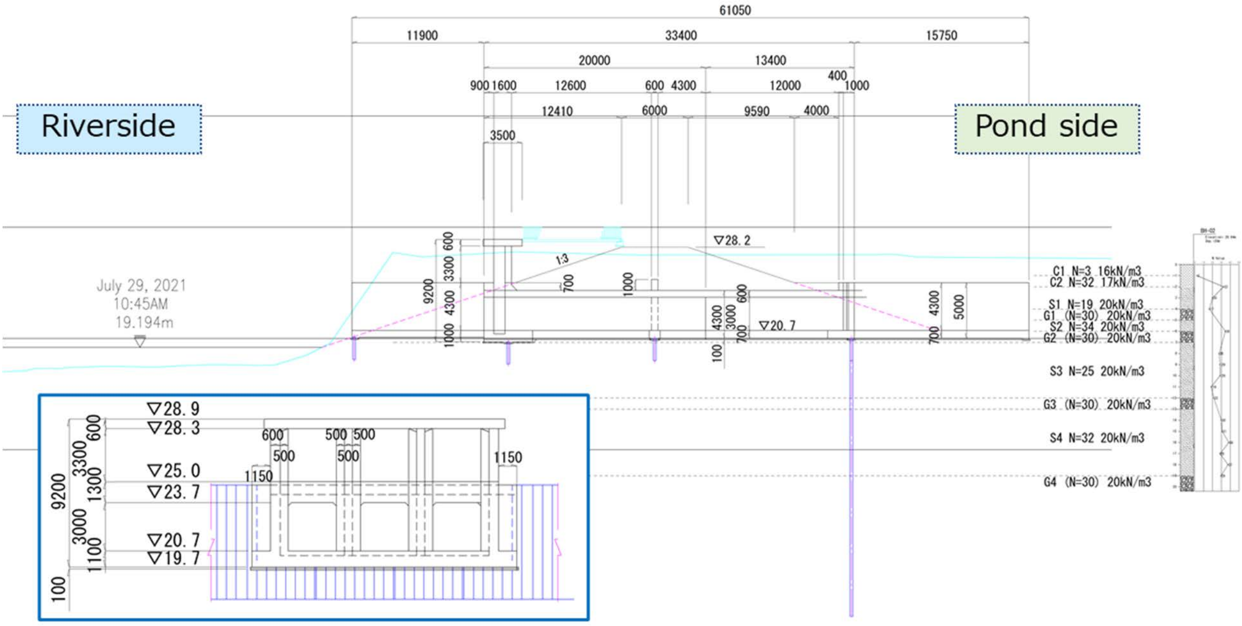


Source: Project Team

Figure 4.1.84 Standard Cross Section of Spillway at Retarding Pond: RP08

In addition to a spillway, a drainage facility (sluice gates) is installed at outlet of the pond. During flood events, the gates are fully closed to allow floodwaters to be stored inside the retarding pond. The gates are only raised when the water level on the river side has fallen sufficiently (the river water level then must be below the invert level of the drainage facility). The gate dimension was calculated to allow natural drainage within approximately two days (48 hours) after the raising of the gates, resulting in a cross-sectional dimension of height = 3 m: width = 9 m.

On this basis, a drainage facility with 3 gates of 3m x 3m is assumed for the retarding basin: RP08. According to the results of geotechnical investigations, the ground below the invert level is rather firm with an N value of over 25-30, so spread foundation is assumed for the foundation type. A dust screen shall be installed on the pond side (intake) of the drainage facility. At least one of the drainage gates should be open at normal time to drain groundwater from the pond side.

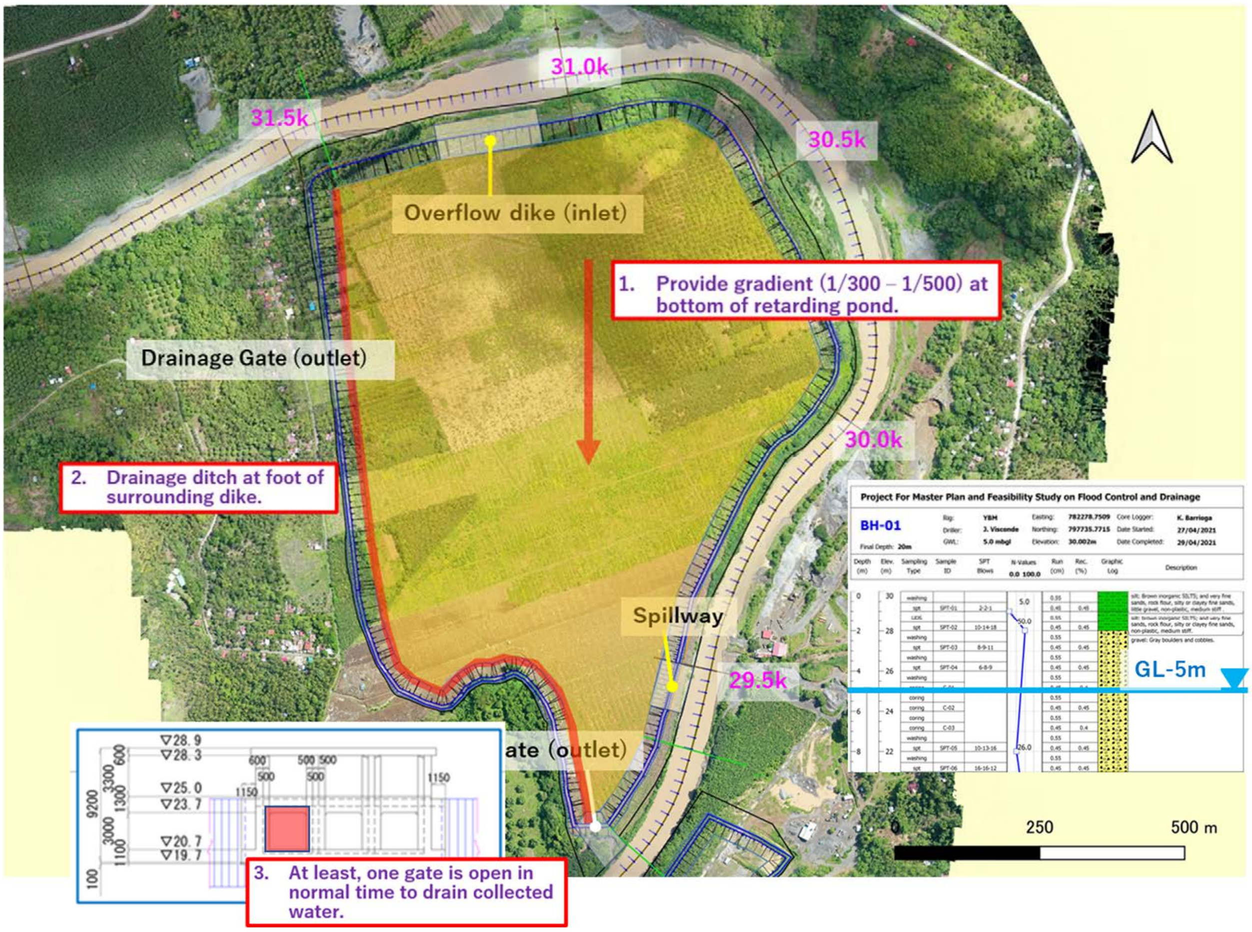


Source: Project Team

Figure 4.1.85 Standard Section of the Drainage Facility at Retarding Pond: RP08

The results of the geotechnical investigations (BH-01 and BH-02) indicate that the groundwater table in the study area is 4m to 5m below the existing ground level. Groundwater is considered to be recharged from the mountainous area to the west as well as by rainwater inside the pond area. Although the groundwater table level is expected to decrease after the creation of the retarding pond by excavation, following measures should be considered to cope with groundwater inside the pond: (i) a drainage gradient of 1/300 to 1/500 at the bottom of the pond, (ii) a drainage ditch at the toe of surrounding levee, and (iii) raising of the gate in normal time. For retarding pond R08, the permeable formation is considered to be distributed widely at the pond bottom level, and the above measures are used to drain and lower the water table.

In addition, it is necessary to understand geological conditions and groundwater table along the surrounding dike by carrying out geological investigations to assess the volume of groundwater.

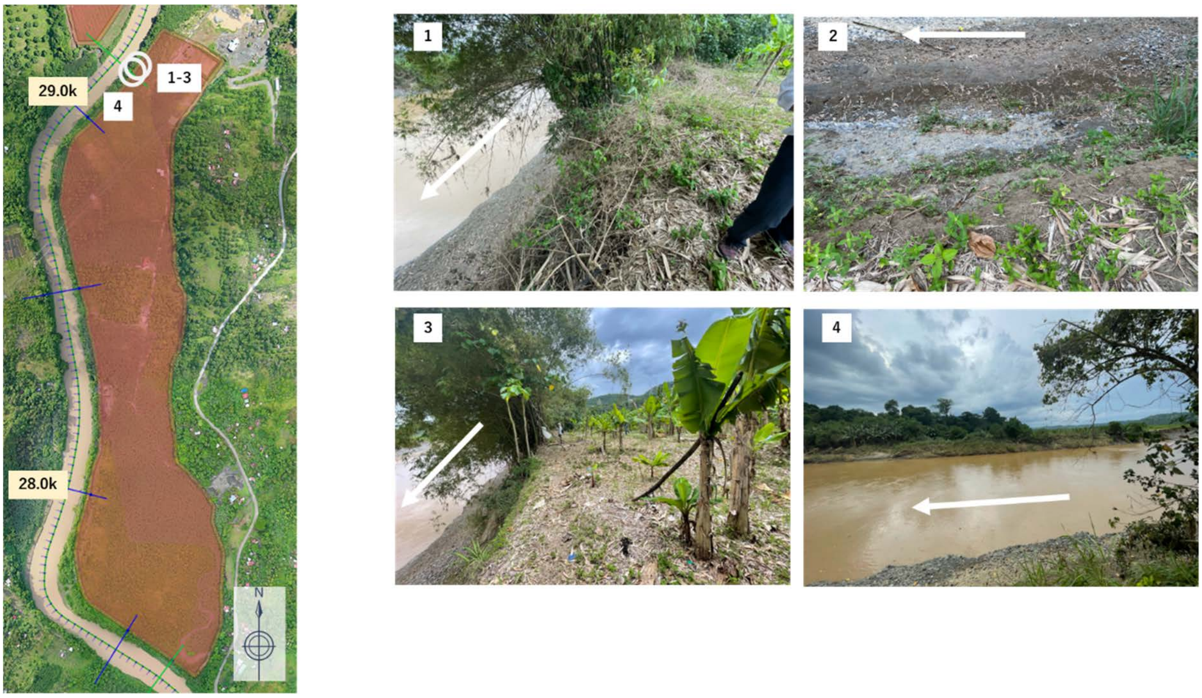


Source: Project Team

Figure 4.1.86 Measures to cope with Groundwater at Retarding Pond: RP08

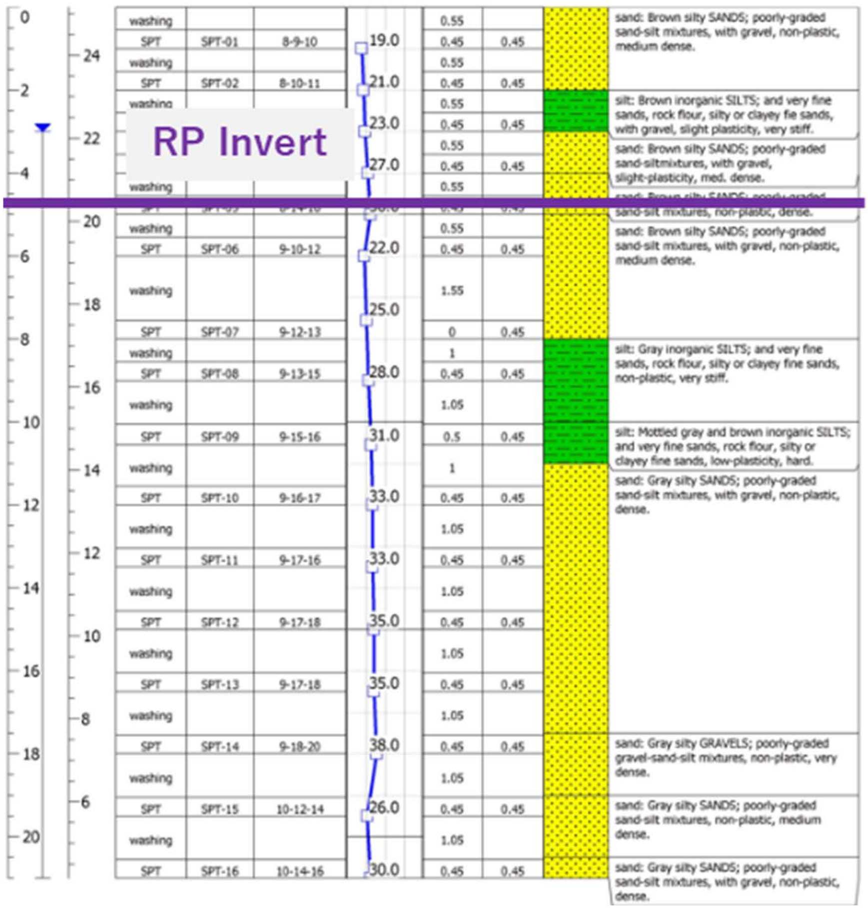
4) Preliminary design of retarding pond: RP09

Near the inlet (overflow dike) location of the retarding pond: RP09, boulders observed at riverbed / bank are smaller than those observed along the retarding pond RP08 in the upstream. The geotechnical survey results also show that sand and silt layers are the main constituent layers, replacing the gravel layers with boulders observed in the RP08 intake area.



Source: Project Team

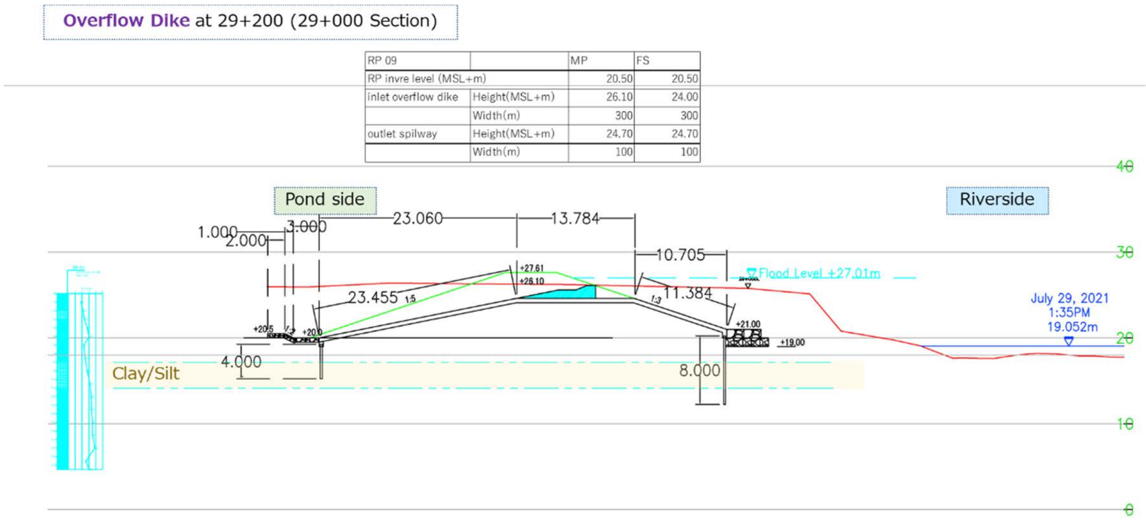
Figure 4.1.87 Site Photos near the Inlet of Retarding Pond RP09



Source: Project Team

Figure 4.1.88 Geotechnical Survey Results and Retarding Pond RP09 Invert Level

A cross-sectional structure of the overflow dike is shown below. The overflow dike will be covered with RC-facing protection with foot protection on riverside. The planned crest level of the overflow dike is +24.00 m in the F/S phase and +26.10 m in the MP phase, and the raising in the MP phase will be carried out by installing a 2.1 m high drop work (RC retaining wall) at crest of F/S-phase overflow dike. In addition, as is also the case for RP08, impermeable sheet piles should be installed at toe of the slope on the pond side of the overflow dike / separate dike, embedded into the impermeable soil layer. Other considerations in the detailed design of impermeable sheet piles are the same as for the RP08.



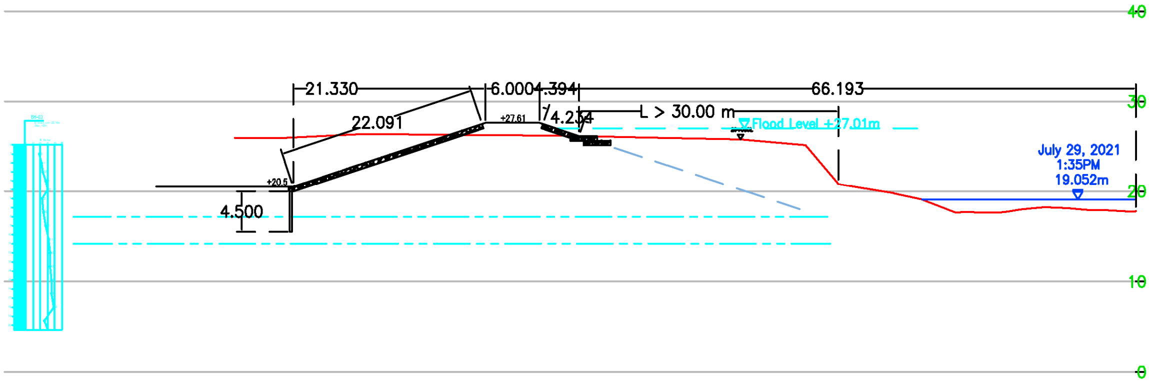
RP 09		MP	FS
RP invre level (MSL+m)		20.50	20.50
inlet overflow dike	Height(MSL+m)	26.10	24.00
	Width(m)	300	300
outlet spilway	Height(MSL+m)	24.70	24.70
	Width(m)	100	100

Source: Project Team

Figure 4.1.89 Standard Cross Section of Overflow Dike at Retarding Pond: RP09

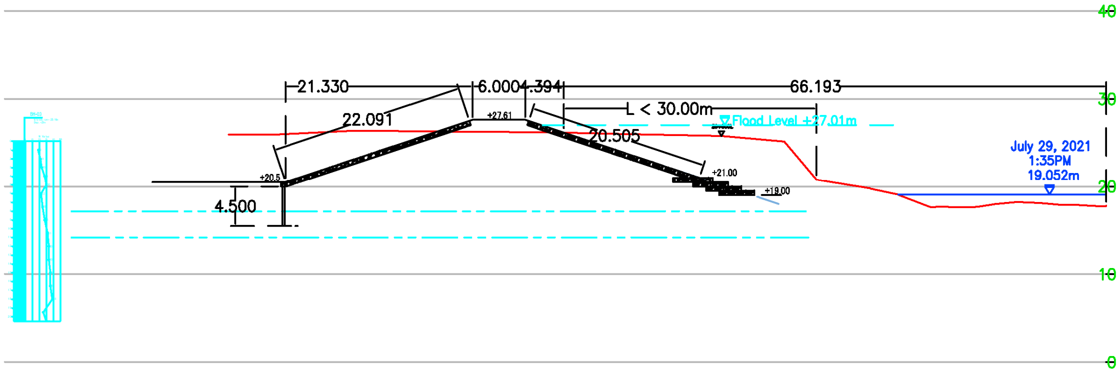
For the separate dike of the retarding pond: RP09, gabion revetment with impermeable sheets will be installed on the river side up to the M/P phase flood level (100-year return period) while the same gabion revetment with impermeable sheets will be installed also on the pond side up to maximum storage level. The gabions and impermeable sheets function together to 1) prevent water from entering the embankment during impoundment and 2) prevent leakage of water that has entered the embankment from the river side, as with RP08.

As shown in the field photos above, riverbank erosion is progressing at some sections of the bank. Therefore, if the distance between the planned cross-section of the separate dike (at intersection with the current ground surface) and the existing bank for low-water channel is narrow (as a reference, less than 30 m), gabion revetment shall be installed on the river-side slope to prevent riverbank erosion (depth of gabion embedment: 17.00m). On the other hand, if the distance between the planned section of the separate dike and the existing bank for low-water channel is sufficiently wide (as a reference, 30 m or more), the existing ground in front of the separate dike shall be left in place and no gabion revetment is to be installed below the existing ground surface. However, it is advisable to monitor the riverbank condition on site over time and implement the necessary measures where riverbank erosion is progressing.



Source: Project Team

Figure 4.1.90 Standard Cross Section of Separate Dike at Retarding Pond: RP09 (Minimum gabion on river side slope)

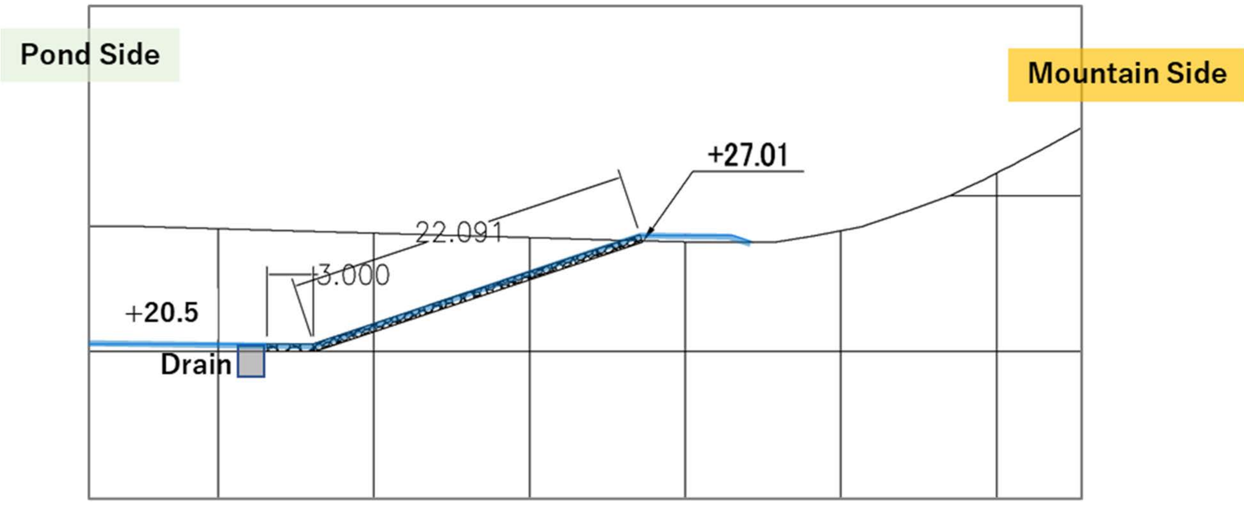


Source: Project Team

Figure 4.1.91 Standard Cross Section of Separate Dike at Retarding Pond: RP09 (With gabion on river side slope)

As for the structure of the surrounding levee, as with the separate dike, gabion revetment is installed up to maximum storage level along the pond-side slope. The main purpose of installing gabions on the surrounding levees is to protect and maintain the slope, such as preventing soil run-off from the slope which may fill up the drainage ditch or preventing excessive growth of vegetation on the slope, and to facilitate management of the location and sectional shape of the slope. The gradient of slope is 1:3.0 on both the mountain side and the pond side. Where the crest elevation is lower than existing ground level, 1:3.0 slope will be cut from the crest to reach the existing ground behind.

Although gabions are commonly used for revetments along the Davao River, it is necessary to take into account the availability of materials and price fluctuations during detailed design to determine its application.



Source: Project Team

Figure 4.1.92 Standard Cross Section of Surrounding Levee at Retarding Pond: RP09

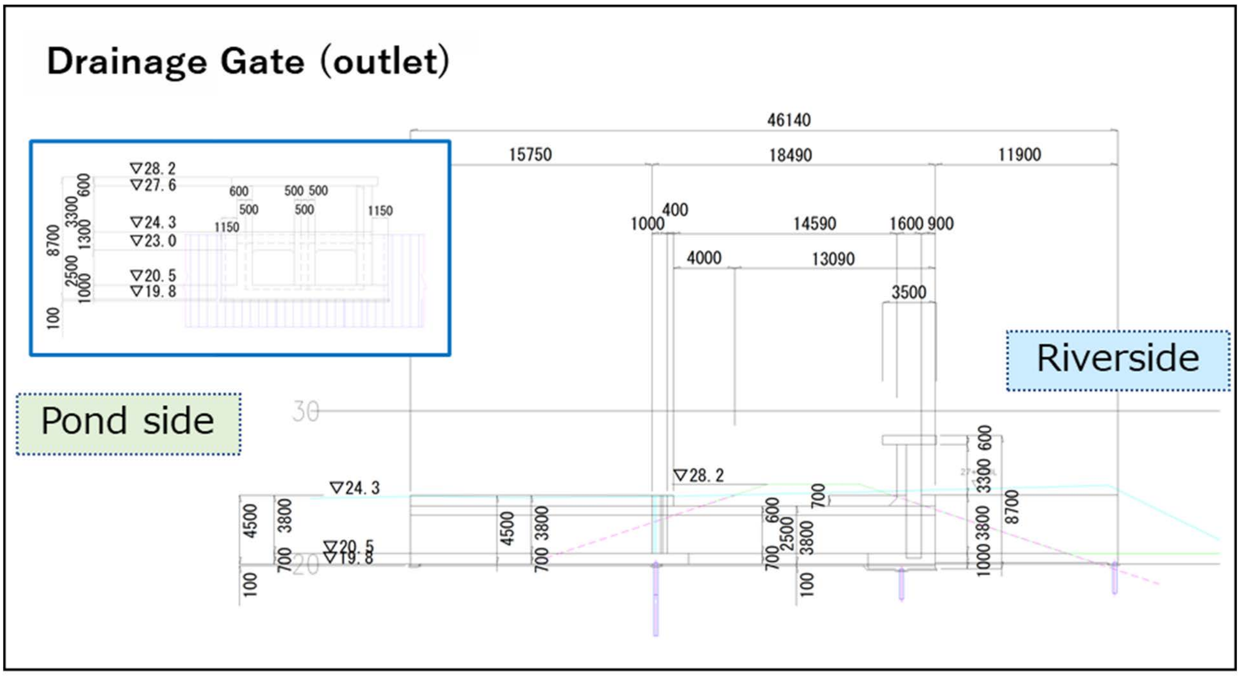
For the spillway to be installed in the downstream part of the retarding pond, the gabion-type slope protection is selected due to its less frequent use, reduced velocity of overflowing water and sediment diameter compared to the overflow dike, and presumably limited degree of wearing of steel wires, etc. The applicable structural type shall be determined at the detailed design stage, taking into account material availability and the results of flow conditions studied by means of detailed hydraulic experiments, etc.

Source: Project Team

Figure 4.1.93 Standard Cross Section of Spillway at Retarding Pond: RP09

In addition to a spillway, a drainage facility (sluice gates) is installed at outlet of the pond. During flood events, the gates are fully closed to allow floodwaters to be stored inside the retarding pond. The gates are only raised when the water level on the river side has fallen sufficiently (the river water level then must be below the invert level of the drainage facility). The gate dimension was calculated to allow natural drainage within approximately two days (48 hours) after the raising of the gates, resulting in a cross-sectional dimension of height = 2.5 m: width = 5 m.

On this basis, a drainage facility with 2 gates of 2.5m x 2.5m is assumed for the retarding basin: RP09. According to the results of geotechnical investigations, the ground below the invert level is rather firm with an N value of over 25-30, so spread foundation is assumed for the foundation type. A dust screen shall be installed on the pond side (intake) of the drainage facility. At least one of the drainage gates should be open at normal time to drain groundwater from the pond side.



Source: Project Team

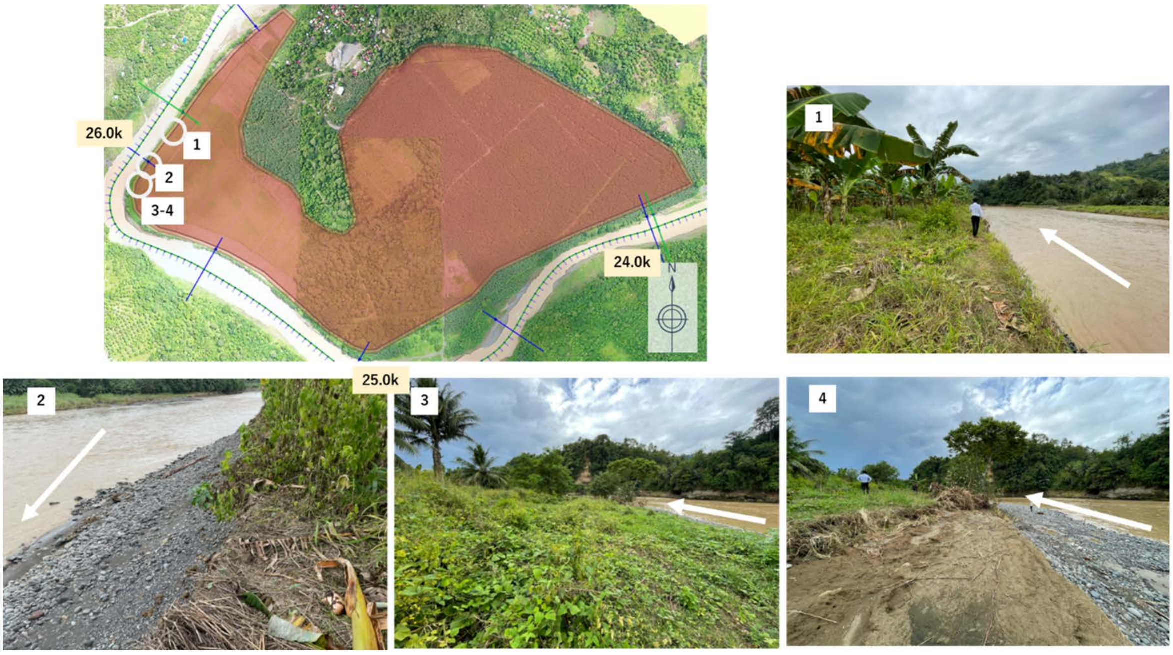
Figure 4.1.94 Standard Section of the Drainage Facility at Retarding Pond: RP09

As for measures against groundwater, as in RP08, (i) a drainage gradient of 1/300 to 1/500 at the bottom of the pond, (ii) a drainage ditch at the toe of surrounding levee, and (iii) raising of the gate in normal time are to be considered.

In addition, it is necessary to understand geological conditions and groundwater table along the surrounding dike by carrying out geological investigations to assess the volume of groundwater.

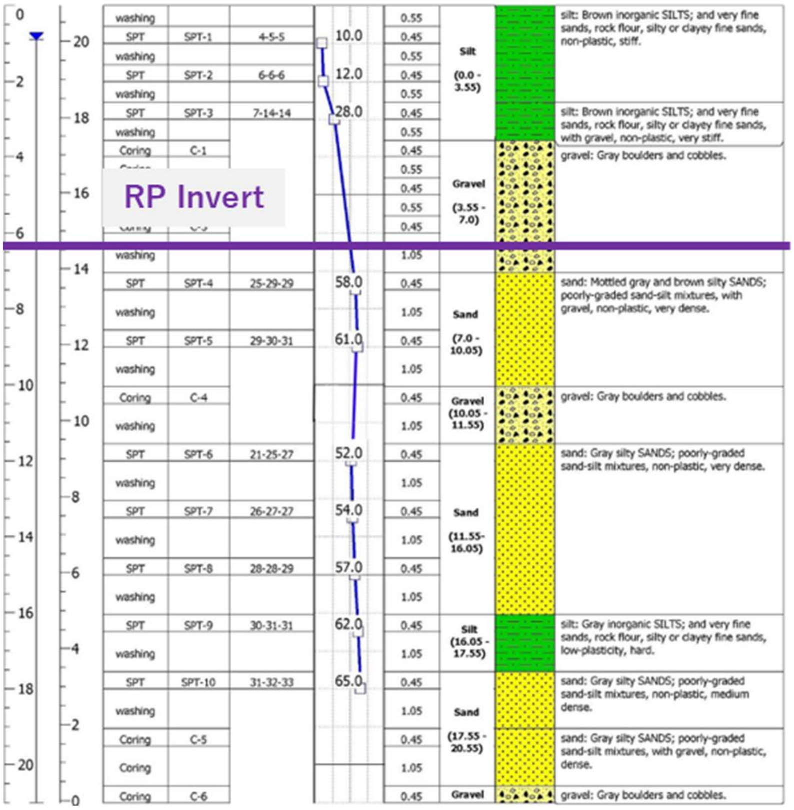
5) Preliminary design of retarding pond: RP11

The riverbed and riverbank conditions near the inlet of the retarding pond: RP11 (overflow dike) are similar to those in RP09, and in RP11, riverbank erosion is particularly pronounced from the inlet location to around 25.0km location. The results of the geotechnical survey (elevation of the top of borehole: 20.9 m) show that there is a clayey layer with an N value of more than 10 with a thickness of about 3 m in the surface, and that the layers deeper than that are composed of alternating layers of compacted gravel, sand and clay.



Source: Project Team

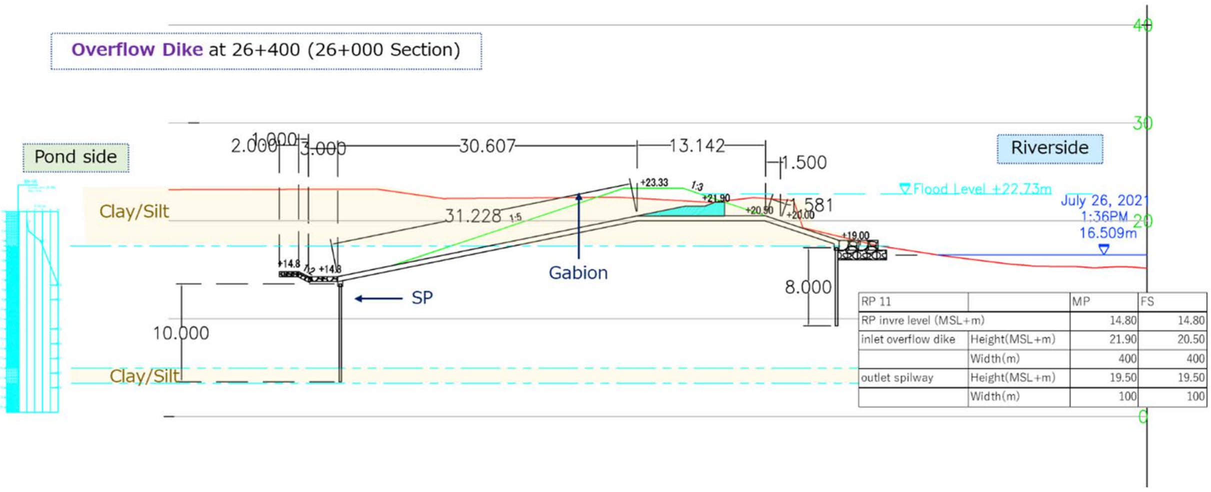
Figure 4.1.95 Site Photos near the Inlet of Retarding Pond RP11



Source: Project Team

Figure 4.1.96 Geotechnical Survey Results and Retarding Pond RP11 Invert Level

A cross-sectional structure of the overflow dike is shown below. The overflow dike will be covered with RC-facing protection with foot protection on riverside. The planned crest level of the overflow dike is +20.50 m in the F/S phase and +21.90 m in the MP phase, and the raising in the MP phase will be carried out by installing a 1.4 m high drop work (RC retaining wall) at crest of F/S-phase overflow dike. In addition, as is also the case for RP08, impermeable sheet piles should be installed at toe of the slope on the pond side of the overflow dike / separate dike, embedded into the impermeable soil layer. Other considerations in the detailed design of impermeable sheet piles are the same as for the RP08.

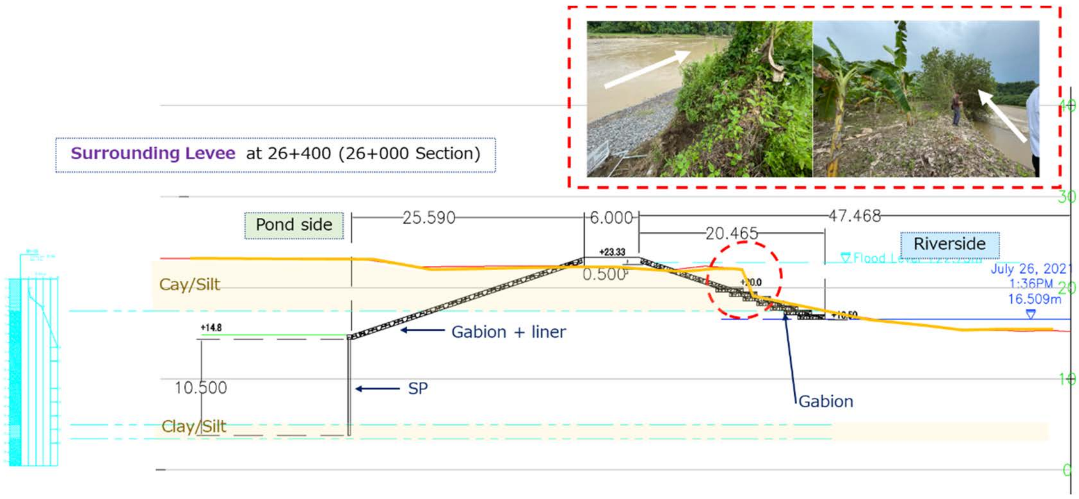


Source: Project Team

Figure 4.1.97 Standard Cross Section of Overflow Dike at Retarding Pond: RP11

For the separate dike of the retarding pond: RP11, gabion revetment with impermeable sheets will be installed on the river side up to the M/P phase flood level (100-year return period) while the same gabion revetment with impermeable sheets will be installed also on the pond side up to maximum storage level. The gabions and impermeable sheets function together to 1) prevent water from entering the embankment during impoundment and 2) prevent leakage of water that has entered the embankment from the river side as with RP08.

The concept of installing a gabion revetment on river side is the same as in RP09. If the distance between the planned cross-section of the separate dike (at intersection with the current ground surface) and the existing bank for low-water channel is narrow (as a reference, less than 30 m), gabion revetment shall be installed on the river-side slope to prevent riverbank erosion. For the RP11, the water surface gradient and topographic gradient in the longitudinal direction changes, with mean water level of about +17.5 m near the inlet and about +12.0 m near the outlet. For this reason, the embedment depth of gabion revetment should also be varied longitudinally.

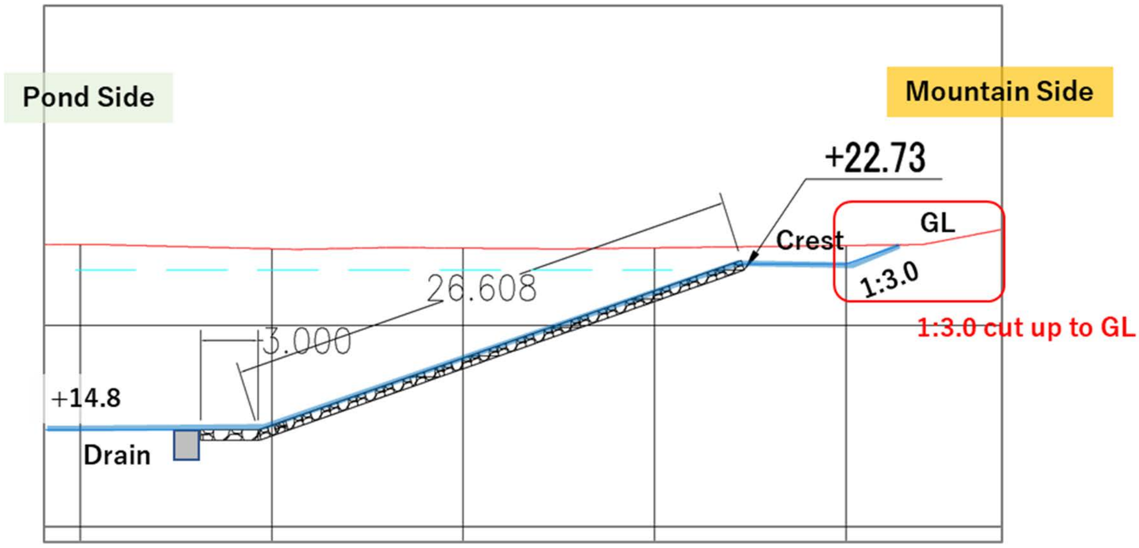


Source: Project Team

Figure 4.1.98 Standard Cross Section of Separate Dike at Retarding Pond: RP11

As for the structure of the surrounding levee, as with the separate dike, gabion revetment is installed up to maximum storage level along the pond-side slope. The main purpose of installing gabions on the surrounding levees is to protect and maintain the slope, such as preventing soil run-off from the slope which may fill up the drainage ditch or preventing excessive growth of vegetation on the slope, and to facilitate management of the location and sectional shape of the slope. The gradient of slope is 1:3.0 on both the mountain side and the pond side. Where the crest elevation is lower than existing ground level, 1:3.0 slope will be cut from the crest to reach the existing ground behind.

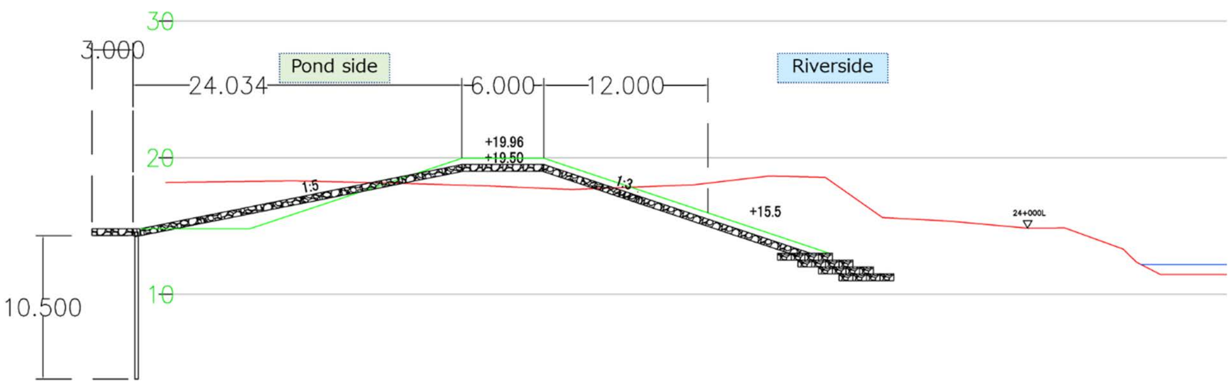
Although gabions are commonly used for revetments along the Davao River, it is necessary to take into account the availability of materials and price fluctuations during detailed design to determine its application.



Source: Project Team

Figure 4.1.99 Standard Cross Section of Surrounding Levee at Retarding Pond: RP11

For the spillway to be installed in the downstream part of the retarding pond, the gabion-type slope protection is selected due to its less frequent use, reduced velocity of overflowing water and sediment diameter compared to the overflow dike, and presumably limited degree of wearing of steel wires, etc. The applicable structural type shall be determined at the detailed design stage, taking into account material availability and the results of flow conditions studied by means of detailed hydraulic experiments, etc.

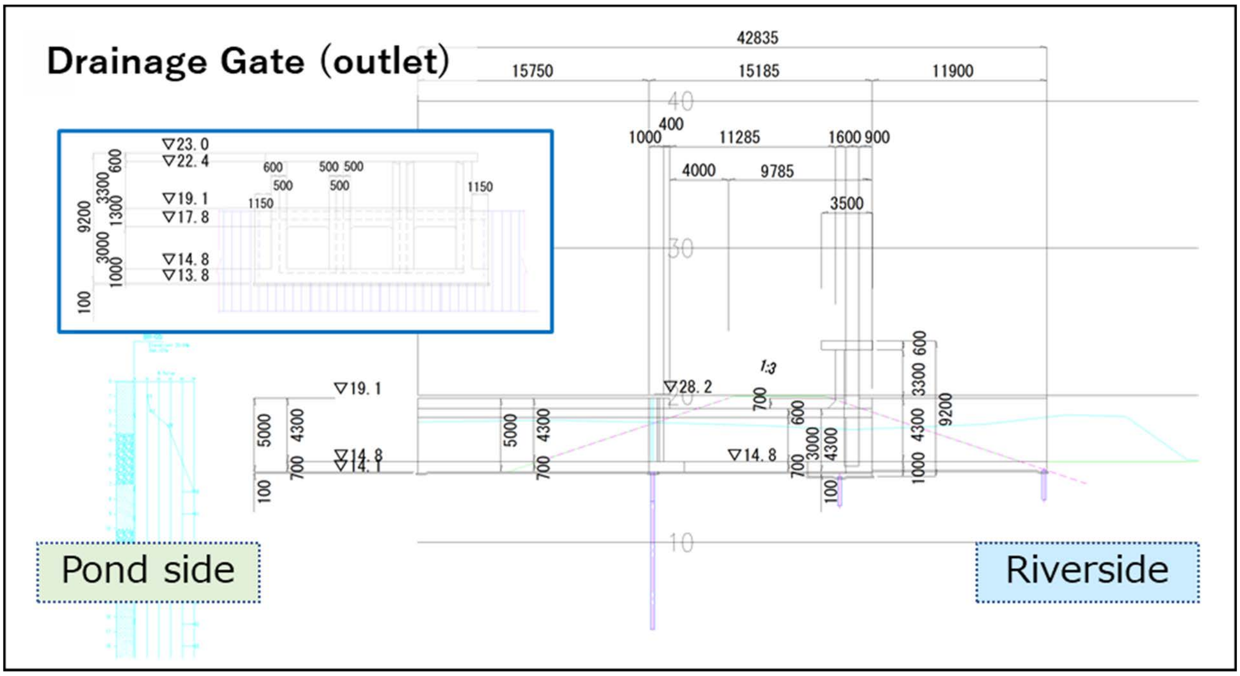


Source: Project Team

Figure 4.1.100 Standard Cross Section of Spillway at Retarding Pond: RP09

In addition to a spillway, a drainage facility (sluice gates) is installed at outlet of the pond. During flood events, the gates are fully closed to allow floodwaters to be stored inside the retarding pond. The gates are only raised when the water level on the river side has fallen sufficiently (the river water level then must be below the invert level of the drainage facility). The gate dimension was calculated to allow natural drainage within approximately two days (48 hours) after the raising of the gates, resulting in a cross-sectional dimension of height = 3 m: width = 9 m.

On this basis, a drainage facility with 3 gates of 3m x 3m is assumed for the retarding basin: RP11. According to the results of geotechnical investigations, the ground below the invert level is rather firm with an N value of over 25-30, so spread foundation is assumed for the foundation type. A dust screen shall be installed on the pond side (intake) of the drainage facility. At least one of the drainage gates should be open at normal time to drain groundwater from the pond side.



Source: Project Team

Figure 4.1.101 Standard Section of the Drainage Facility at Retarding Pond: RP11

As for measures against groundwater, as in RP08, (i) a drainage gradient of 1/300 to 1/500 at the bottom of the pond, (ii) a drainage ditch at the toe of surrounding levee, and (iii) raising of the gate in normal time are to be considered.

In addition, it is necessary to understand geological conditions and groundwater table along the surrounding dike by carrying out geological investigations to assess the volume of groundwater.

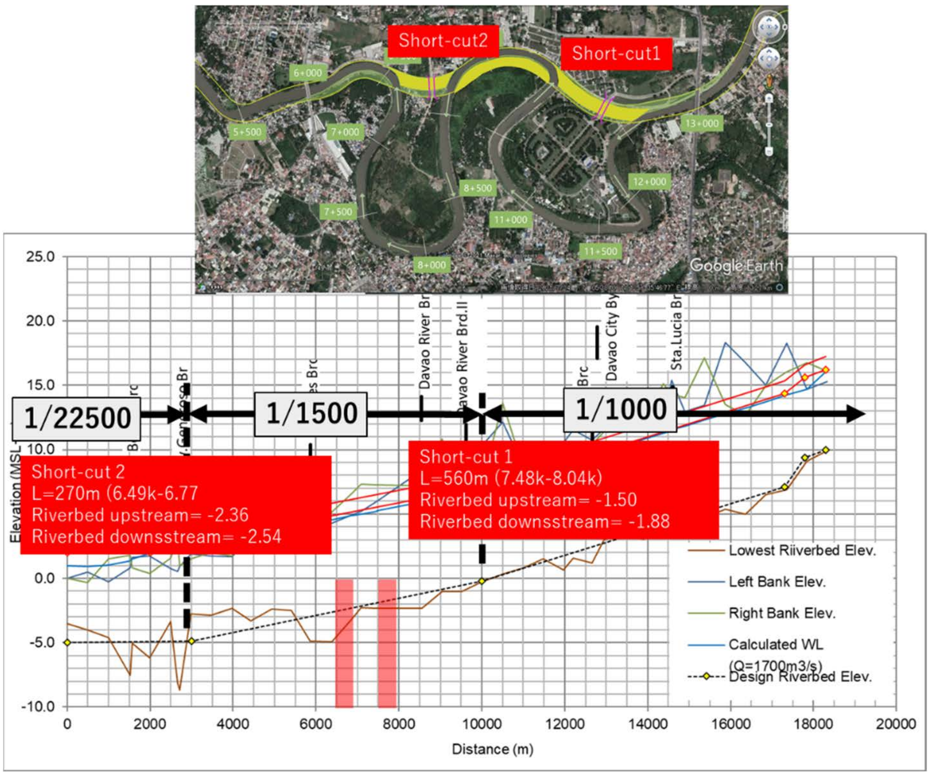
(3) Preliminary Design of Structural Measures (Cut-off Works)

1) Riverbed Measures at Cut-off Locations

As described previously, the planned longitudinal profile after the cut-off works is set for a section of certain lengths, including the area before and after the cut-off, so that the cut-off sections will not create a local transition point for the riverbed gradient. The riverbed elevation at diversion/confluence points are set to match the current riverbed heights, and the planned riverbed gradient for the 7 km-long section including the cut-off section is 1/1500. The difference in riverbed height between the upstream and downstream of the cut-off section (at the diversion and confluence points) is 38 cm for a distance of approximately 560 m in the upstream section and 18 cm for a distance of approximately 270 m in the downstream section.

As the riverbed gradient does not change before and after the cut-off section, the difference in riverbed drop between the upstream and downstream sections is small, and the riverbed height at the diversion and confluence points is set to match the current riverbed height, no drop works will be installed at the diversion/confluence points.

Here, in case of that, the riverbed of the cut-off section, including upstream and downstream of that, would not be stable after the short-term works, there is concern that structures such as revetments might become unstable and the planned flood control effect might not be achieved. Therefore, the simple riverbed stability check method with the rate of variation of shear velocity (u*) was examined. The rate of variation of u* corresponding to the average annual maximum flow discharge between the existing channel and the channel after the short-term works was calculated for the cut-off section including upstream and downstream. Result of this simple method, the average rate of variation of u* was about 1.10, satisfying the criteria (0.85 - 1.15 times the existing u*)[1] for determining the stability of the riverbed. However, as a point of consideration during the detailed design phase, a study on the long-term stability of the riverbed should be conducted and countermeasures should be taken if necessary.



Source: Project Team

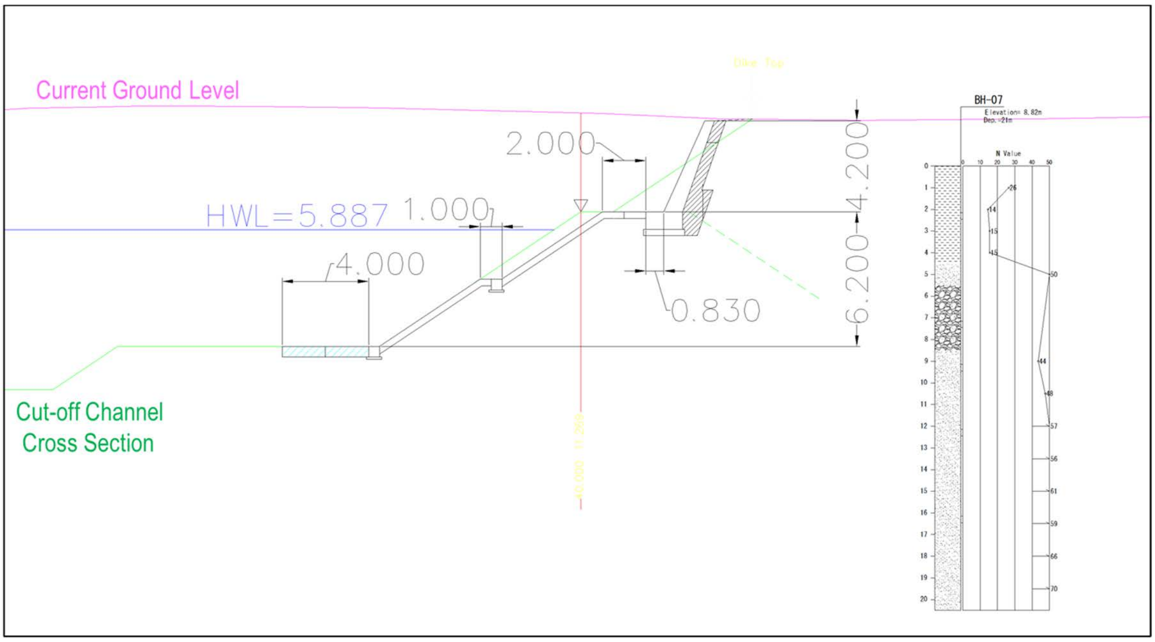
Figure 4.1.102 Longitudinal profile and riverbed height at cut-off sections.

2) Structure of revetment at Cut-off Locations

The cross-sectional geometry of the cut-off section was examined in terms of the revetment structure. Both the upstream and downstream sections are excavated channels where HWL is below the ground level. For the slope of 1.50% at bank below HWL, a concrete revetment (rubble concrete), which is the method used in the Davao River revetment work by DPWH, is used. However, as the height of the revetment exceeds 5 m, a berm shall be provided in the middle of the revetment in accordance with

[1] "Guideline for River Channel Planning Study", Japan Institute of Country-ology and Engineering

DGCS stipulation. The maximum height of the slope between the HWL and the existing ground level is 4.2 m for the case where diversion to the current river channel is considered, for which a retaining wall shall be installed to minimize the encroachment on the surrounding land. In case the diversion to current river channel is not considered, due to site restrictions, a retaining wall of up to 7.5 m will be needed. The standard cross section of the revetment in the cut-off section is shown below.



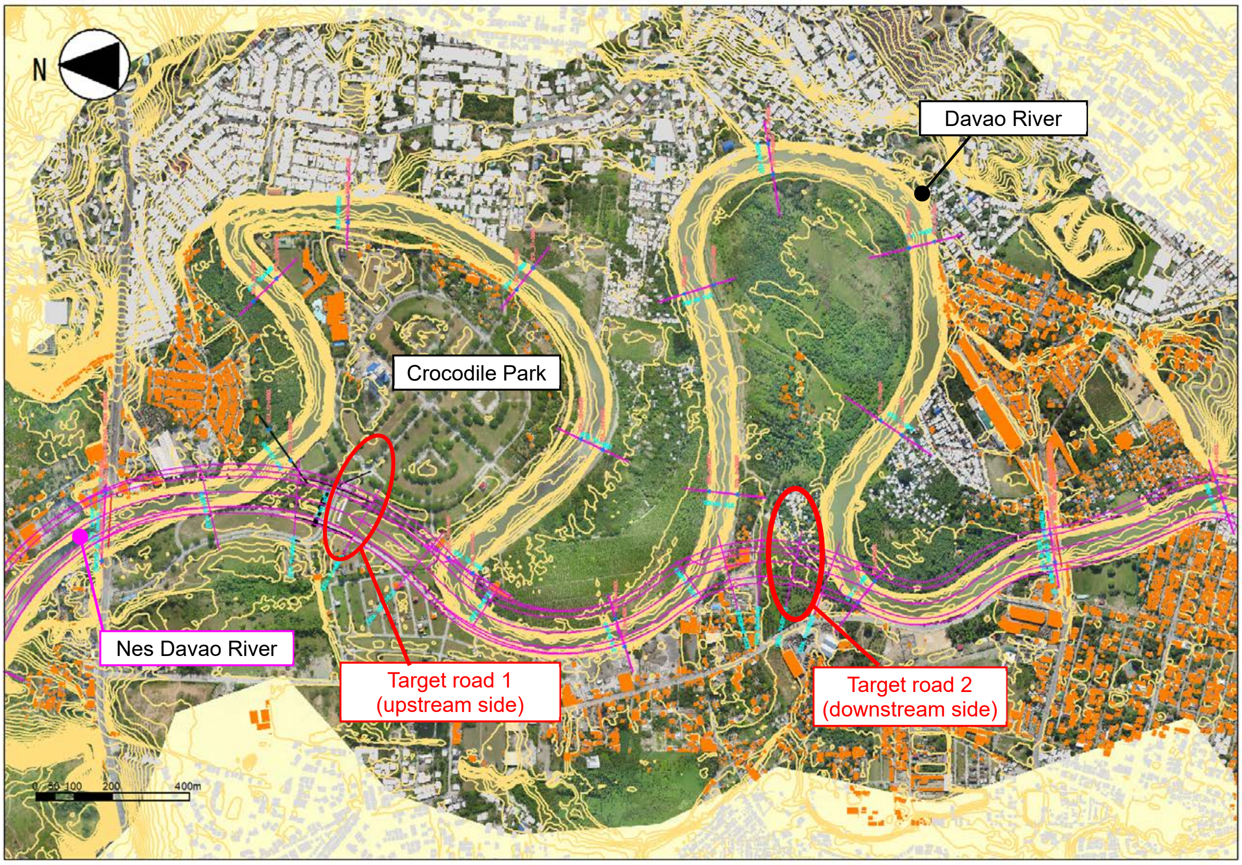
Source: Project Team

Figure 4.1.103 Standard Cross Section at Cut-off Section (Revetment)

(4) Facility design of structural measures (bridges (shortcut section))

1) Overview

In this section, the two roads (bridge section) that will be divided at the cut-off section is designed for. Figure 4.1.104 shows the locations of the two roads.



Source: Project Team

Figure 4.1.104 Location map of Target Roads

The following design standards are applicable for road geometric design and bridge design under the Project. The primary design standard should be DPWH's "Design Guidelines, Criteria and Standards", which is the Philippine national standard. The Japanese and U.S. standards should be referred for the design components, which is not indicated in the DPWH Standards.

[Primary Standard]

・"Design Guidelines, Criteria and Standards: Volume 4 HIGHWAY DESIGN, 2015 ,DPWH"
・"Design Guidelines, Criteria and Standards: Volume 5 BRIDGE DESIGN, 2015 ,DPWH"

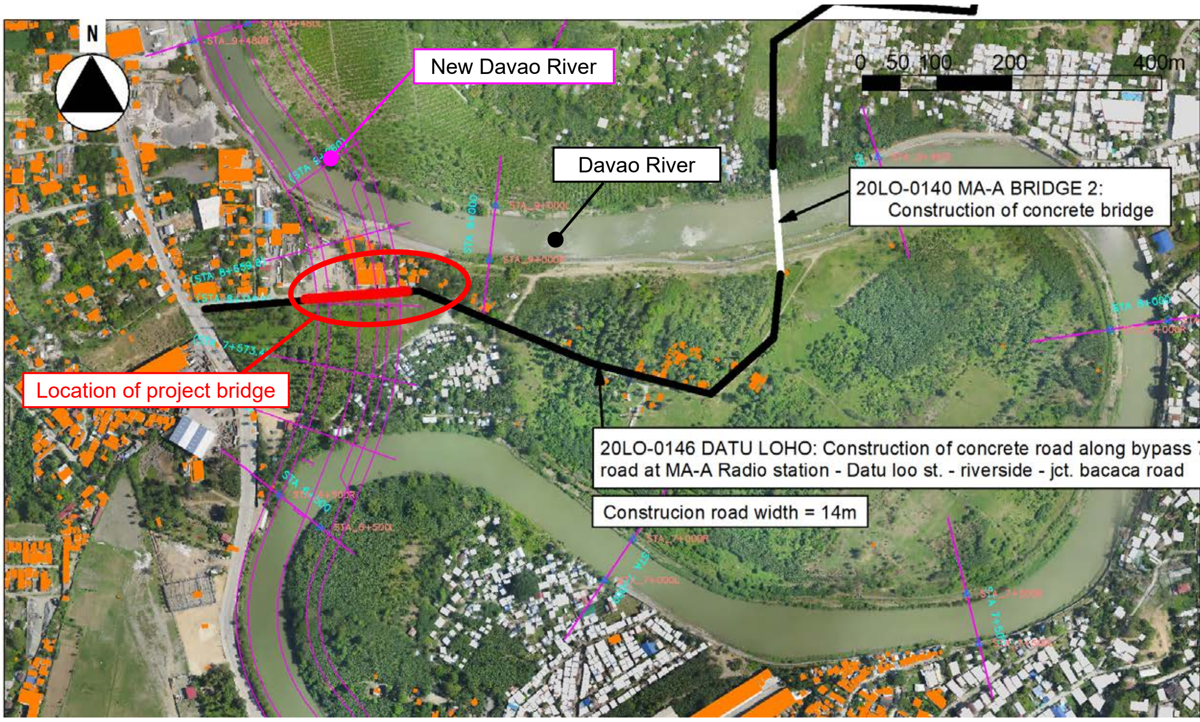
[References]

・"A Policy on Geometric Design of Highways and Streets,2018 ,AASHTO"
・" Road Structure Ordinance, 2021, Japan Road Association"
・"AASHTO LRFD Bridge Design Specifications, 9th Edition, 2020 ,AASHTO"
・"Specifications for Highway Bridges, 2017, Japan Road Association"

2) Outline of the target roads and road design criteria

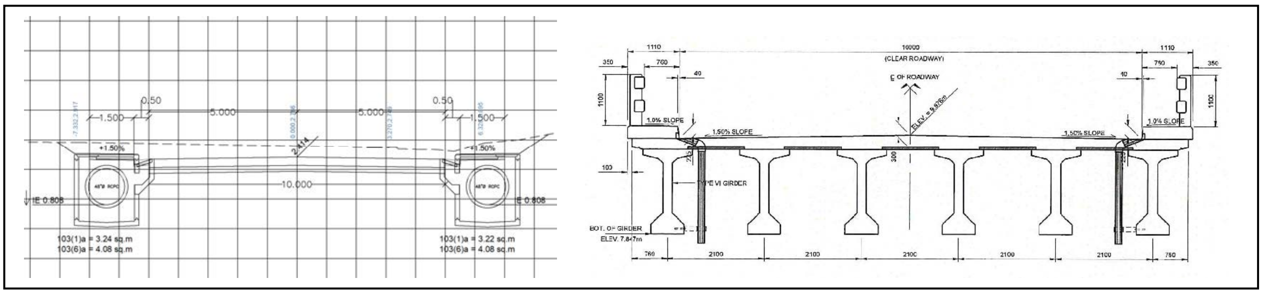
<Outline of the target roads>

The target road on the downstream is undergoing construction on the current road. This work has the widening construction of an existing road ("Project No. 20LO-0146 DATU LOHO") and the construction of a new bridge ("Project No. 20LO-0140"). As shown in Figure 4.1.105, the New Davao River (cut-off works) planned for this Project is part of the widening section of existing road. The typical cross-section of the construction is shown in Figure 4.1.106 and the construction status is shown in Figure 4.1.107



Source: Project Team

Figure 4.1.105 Location of the undergoing Construction on the Target Road on Downstream



Source: Project Team

Figure 4.1.106 Cross-section of the Roadworks on the Downstream Side (left: earthwork section, right: bridge section)

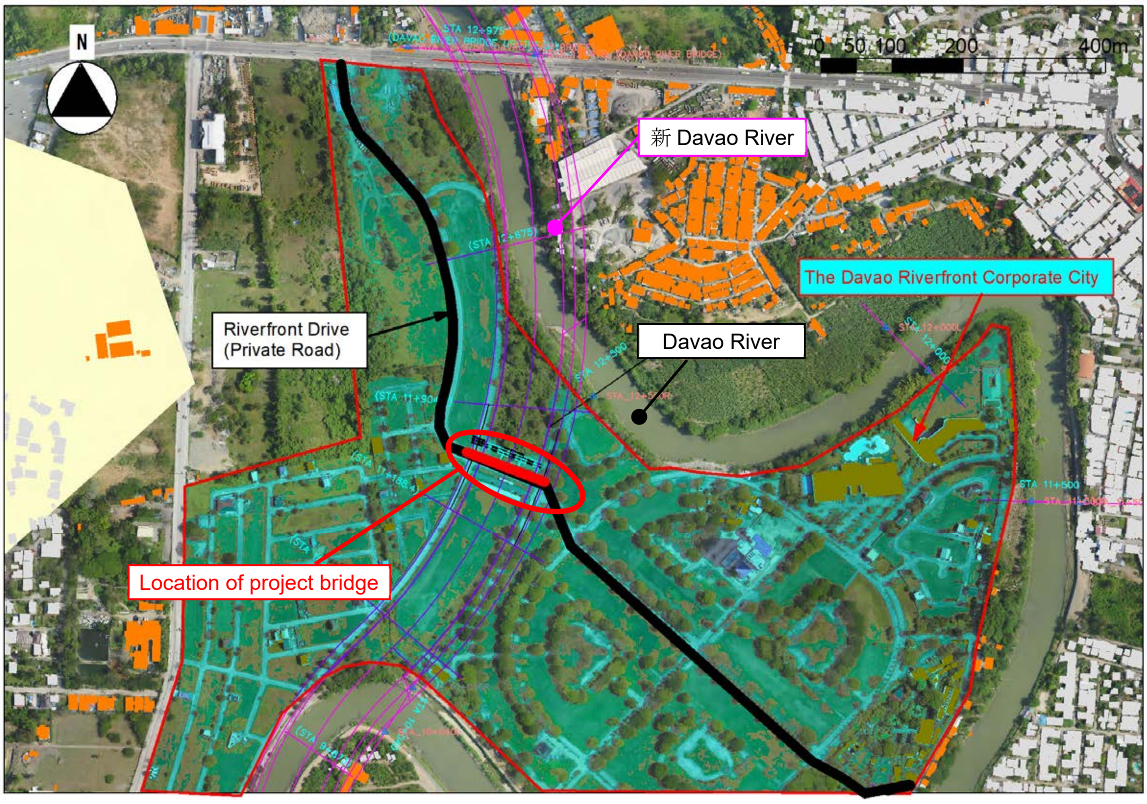
Widening construction section

New construction section

Source: Project Team

Figure 4.1.107 Construction Status of the Target Road on Downstream Side

The target road on the upstream side is Riverfront Drive (private road), which exists within "The Davao Riverfront Corporate City" (Figure 4.1.108). "The Davao Riverfront Corporate City" is the joint venture project of premiere developer, ”Sta. Lucia Realty & Development, Inc. (SLRDI)" and land owner, "F. S. Dizon & Sons, Inc." and a mixed-use development consisting of a 10 ha residential area, a 55 ha business park, and a 5 ha tourist center.



Source: Project Team

Figure 4.1.108 Location Map of the Target Road on Upstream Side

Riverfront Drive, the target road on upstream side, has two lanes in each direction, as shown in Figure 4.1.109, but very few vehicles pass through the around area.

Source: Project Team

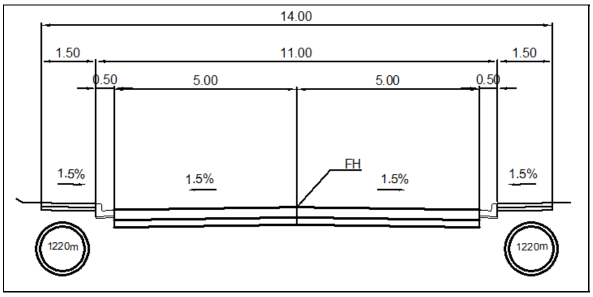
Figure 4.1.109 Status of the Riverfront Drive

<Design criteria for the road>

- **Cross section**

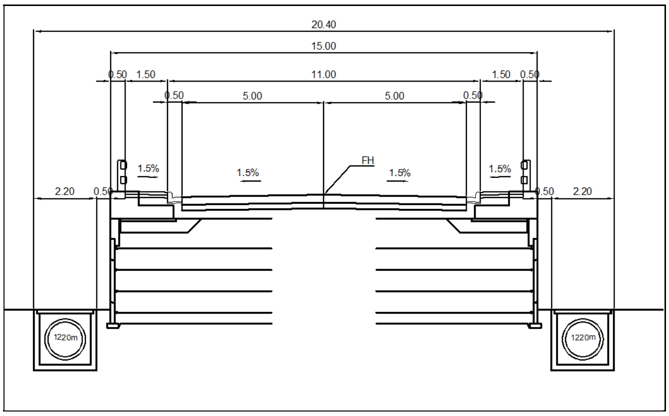
The road width shall be the same as the width configuration planned for the road widening project that is currently under construction. The road width configuration differs between the road widening section and the newly constructed bridge section, so these widths shall be also set each in this project. In addition, drainage pipe, diameter 1220mm, is buried under the sidewalk in the widening project. Therefore, the drainage pipe needs to be relocations outside of the retaining wall in the planned approach area.

The typical cross-section for the earthwork, approach section, and bridge are shown in from Figure 4.1.110 to Figure 4.1.112.



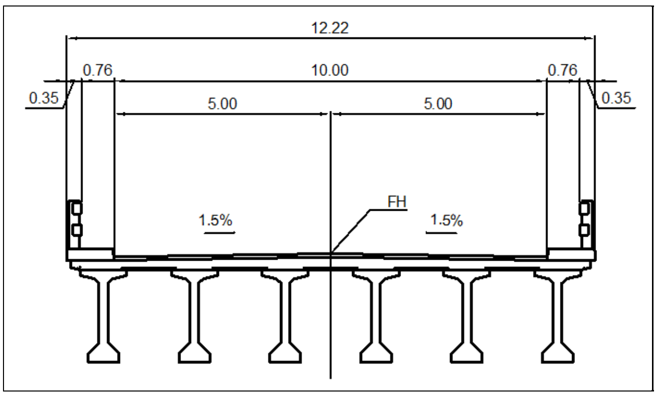
Source: Project Team

Figure 4.1.110 Typical Cross-Section for the Earthwork



Source: Project Team

Figure 4.1.111 Typical Cross-Section for the Approach Section



Source: Project Team

Figure 4.1.112 Typical Cross-Section for the Bridge

- **Geometric Design Condition**

In the design, the geometric design condition shall be set as shown in Table 4.1.31 based on "Design Guidelines, Criteria and Standards: Volume 4 HIGHWAY DESIGN, 2015 (DPWH)". The design speed shall be set to V=30km/h based on the existing geometric conditions.

Table 4.1.31 Geometric Design Conditions for the Planning Road

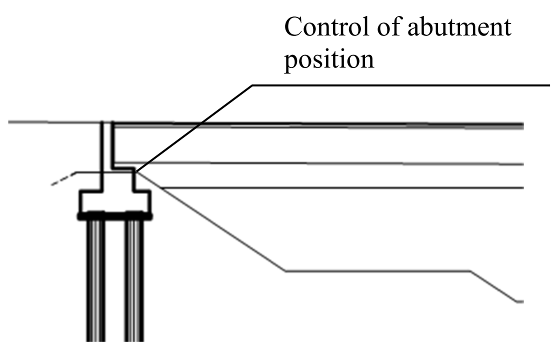
		Unit	Applied	Note
Classification of Roads	On the upstream side	-	Local Road	
	On the downstream side	-	Private Road	
General Design Considerations				
Design speed		Km/h	30	
Minimum Stopping Sight Distance		m	35	
Horizontal Alignment				
Minimum Radius		m	30	
Maximum Radius for use of a Transition Curve		m	54	
Radius for Normal Crown		m	421	
Radius for Reversed Crown		m	299	
Minimum Transition Curve Length		m	17	
Super-elevation Runoff		-	1/133	
Vertical Alignment				
Maximum Grade		%	10	
Minimum Grade		%	0.3	
Minimum Rate of Crest Vertical Curvature (K)		K	2	
Minimum Rate of Sag Vertical Curvature (K)		K	6	

Source: Project team based on "Design Guidelines, Criteria & Standards Volume 4 HIGHWAY DESIGN"

3) Design criteria for the bridge

- **Bridge Length**

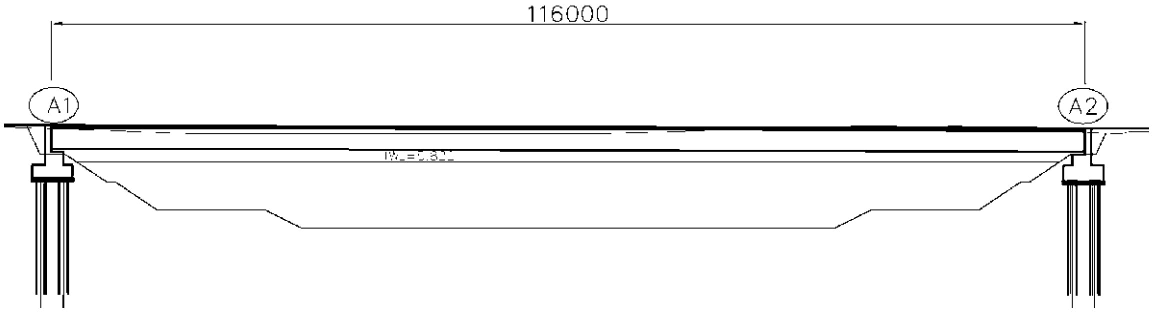
The abutment positions shall be set based on the planned river cross section. The abutment location shall be such that the front of the abutment's vertical wall does not extend forward of the river cross section (slope shoulder).



Source: Project Team

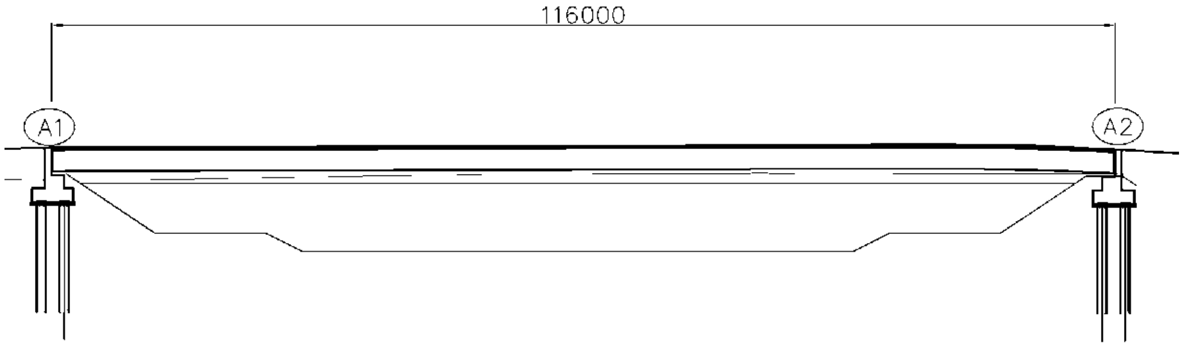
Figure 4.1.113 Abutment Position

The bridge lengths to be set based on the abutment locations were as follows.



Source: Project Team

Figure 4.1.114 Bridge Length for STA 11+188.4



Source: Project Team

Figure 4.1.115 Bridge Length for STA 8+116.6

- **Pier location**

The pier location conditions were set in accordance with Chapter 4.2 of DGCS Volume 5, considering the following equation, which is the desired minimum standard span length. The minimum standard span length is the distance between the center of the pier and the center of the pier, or the distance from the center of the pier to the front of the vertical wall abutment.

L = 20 + 0.005Q、
L: desired minimum standard radius length (m), Q: design flow rate (m^3 /sec)

The river conditions near the bridge crossing are as follows, and the minimum standard span length is 28.5 m (←20+0.005x1625.12), which allows for a four-span span.

◆Upstream side:	◆downstream side:
Station: STA 11＋188.4 H.W.L: 5.822 (MSL+m) Planned river bed height: -1.57 (MSL+m) Flow rate: 1623.87 (m^3/s) Flow velocity: 2.62 (m/s)	Station: STA 11＋188.4 H.W.L: 5.822 (MSL+m) Planned river bed height: -1.57 (MSL+m) Flow rate: 1623.87 (m^3/s) Flow velocity: 2.62 (m/s

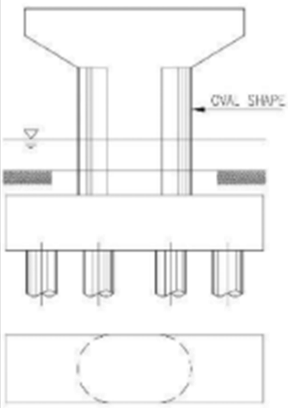
- **Construction sequence**

Regarding the construction sequence of bridges and river improvement, bridges should be constructed first because temporary construction costs such as temporary abutments and in-river tightening will increase if bridge construction is done in the river.

- **Type of Pier**

The type of pier was selected with reference to Chapter 3.3.8 of DGCS Volume 5. Since bridges will be constructed prior to river construction and in-river tightening is not required, wall piers that are more rigid and economical shall be selected. Since the piers are located in a river, the piers with column type were adopted to reduce the influence of the river's running water.

Selection of Pier type

Type of Pier	Hydrologic Consideration	Advantage/Disadvantage
1. Oval Column Type Pier 	- Most applicable type, in case pier is properly aligned with the principal direction of flow. - In meandering river, this type can be a large obstruction against flow. - Local scour might be substantially decreased by pilecap or footing. - Highly recommend for all types of river crossing except meandering of river crossing.	- Very strong lateral resistance against earthquake/seismic loads - Footing (pile cap) suppress vortex below the river bed level and reduce local scouring - Rigid column results in expensive foundation design, thus resulting in higher construction cost - Not flexible for changing river flow

Location	Applicable
Upper Reach	○
Middle Reach	○
Lower Reach	○

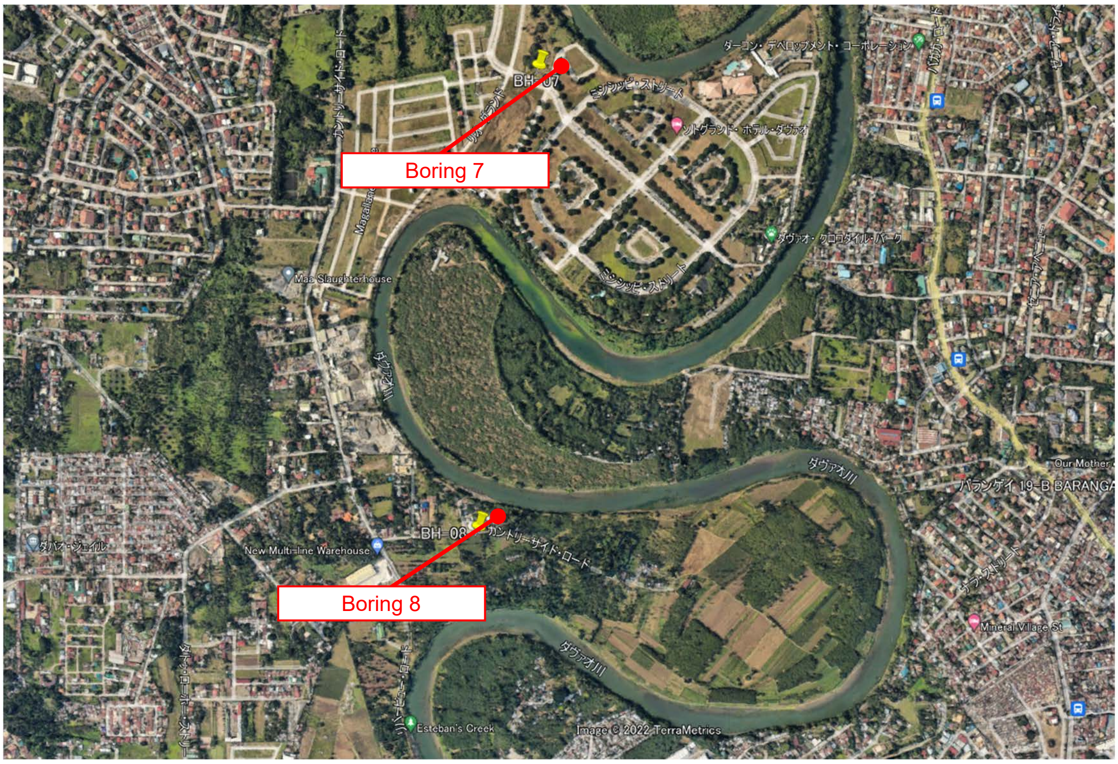
Remark: ○ - good

Source: DGCS Volume5 BRIDGE DESIGN

Figure 4.1.116 Recommended Pier Type

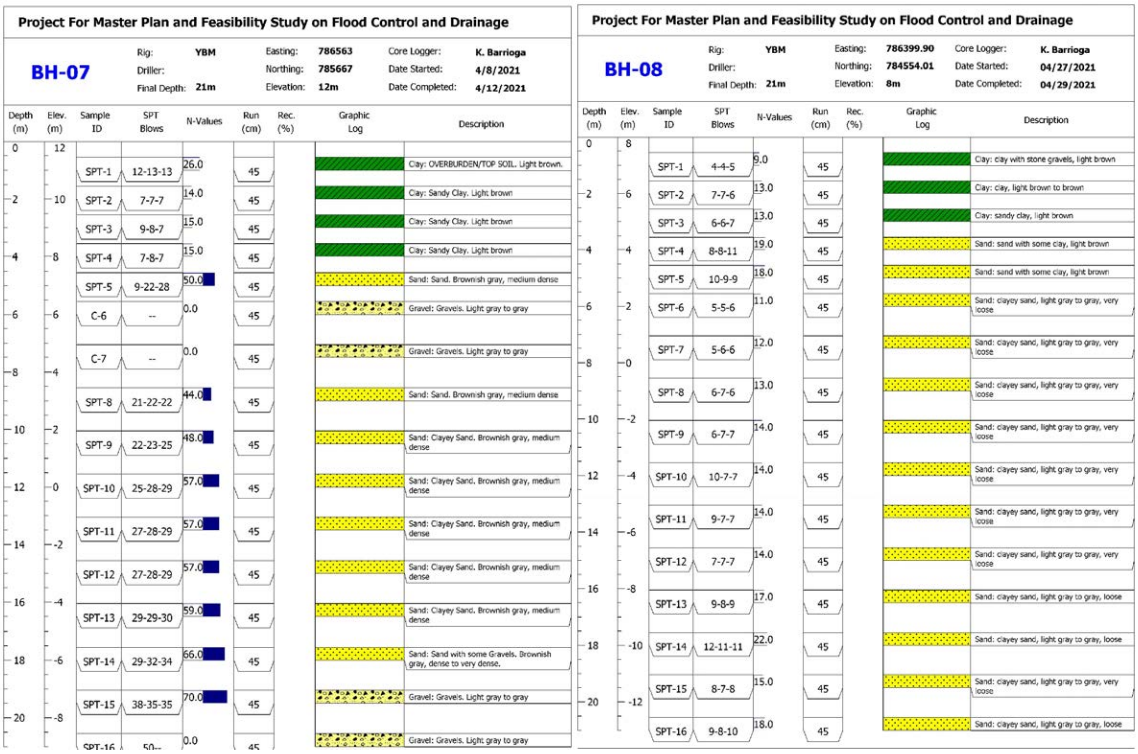
- **Foundation Pile**

The results of borings conducted in the vicinity of the project site were used as a reference in studying the foundation piles. However, since the downstream geological survey did not identify any ground that could be confirmed as a support layer, the foundation piles length shown in the aforementioned new bridge construction project ("Project No. 20LO-0140") were used as a reference.



Source: Project Team

Figure 4.1.117 Location Map of Boring Survey



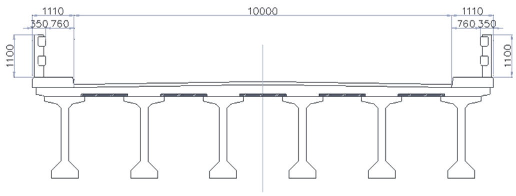
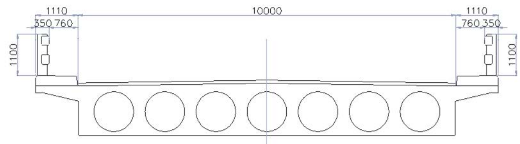
Source: Project Team

Figure 4.1.118 Geologic Columnar Section

4) Bridge type

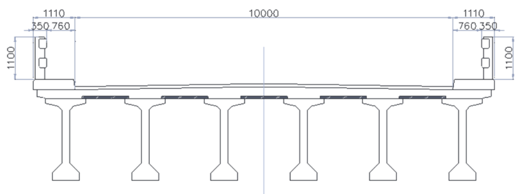
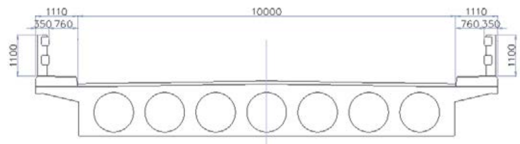
The bridge length and span length of STA 11+188.4 is 116 m (4@29 m) and STA 8+116.6 is 116m (4@29m) since the set reference span length is considered for each bridge. Since the span length is about 30 m, PC hollows and PC-I girders were used for comparison due to economic considerations. Comparison tables are shown below.

Table 4.1.32 STA11+188.4 Comparison Table of Bridge Type

	Alternative 1: PC- I girder	Alternative 2: PC hollow slab girder
Cross-section		
Structural property	PC-I girder bridges are precast girders, which are fabricated in a factory and are of higher quality than cast-in-place girders.	PC hollow girders are slender girders with low girder heights, which are cast-in-place girders.
Constructability	Because the bridge can be constructed in advance, temporary abutments are not required when erecting the girders.	Bridge can be constructed in advance, so support can be constructed with a minimum of shoring.
Construction cost ratio	1.00	1.03
Evaluation	○	

Source: Project Team

Table 4.1.33 STA 8+116.6 Comparison Table of Bridge Type

	Alternative 1: PC- I girder	Alternative 2: PC hollow slab girder
Cross-section		
Structural property	PC-I girder bridges are precast girders, which are fabricated in a factory and are of higher quality than cast-in-place girders.	PC hollow girders are slender girders with low girder heights, which are cast-in-place girders.
Constructability	Because the bridge can be constructed in advance, temporary abutments are not required when erecting the girders.	Bridge can be constructed in advance, so support can be constructed with a minimum of shoring.
Construction cost ratio	1.00	1.01
Evaluation	○	

Source: Project Team

5) Road and bridge design

The general drawings created are shown in Figure 4.1.119 (upstream target road) and Figure 4.1.120 (downstream target road) .

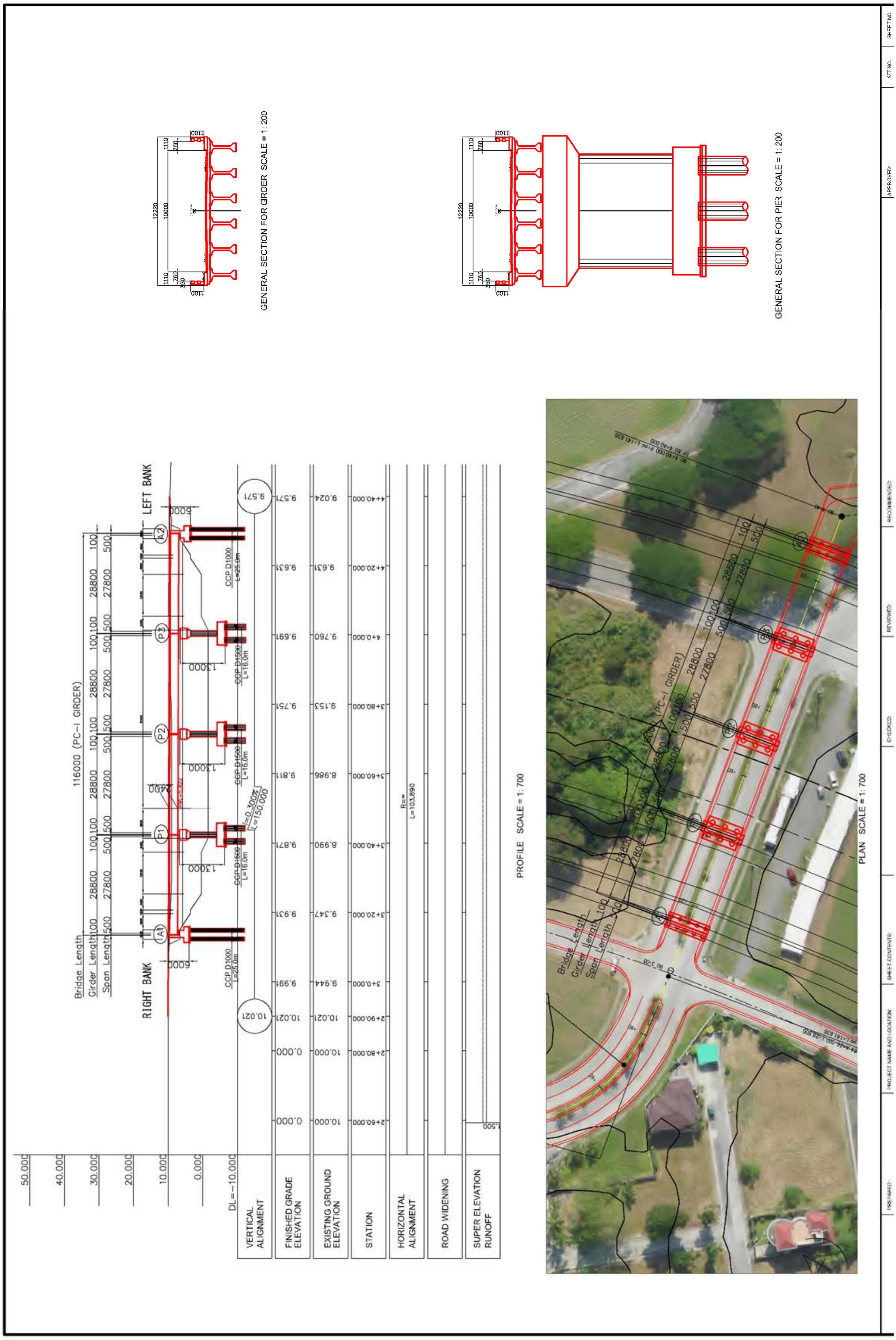


Figure 4.1.119 General View of STA.11+188.4

Source: Project Team

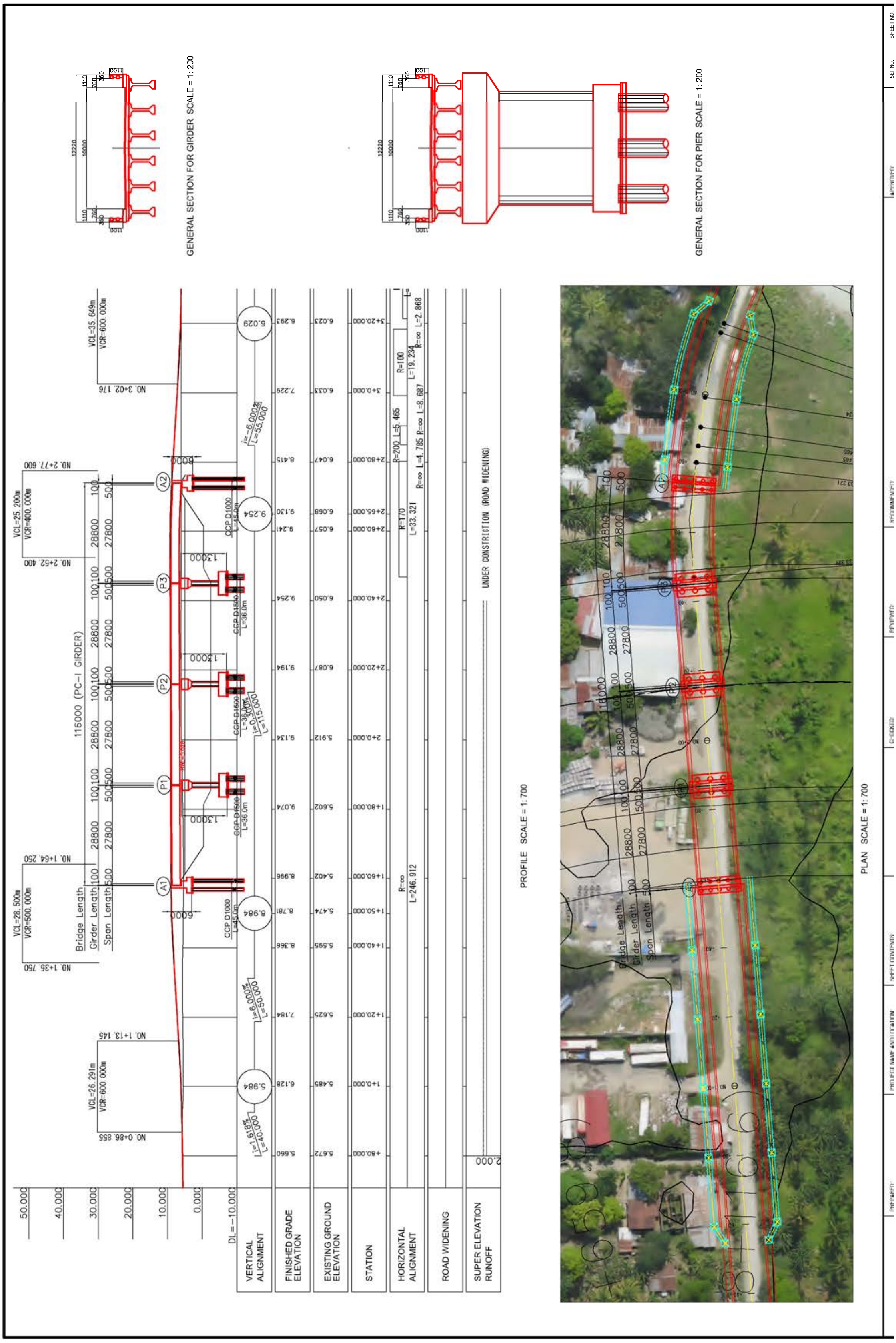


Figure 4.1.120 General View of STA.8+116.6

Source: Project Team

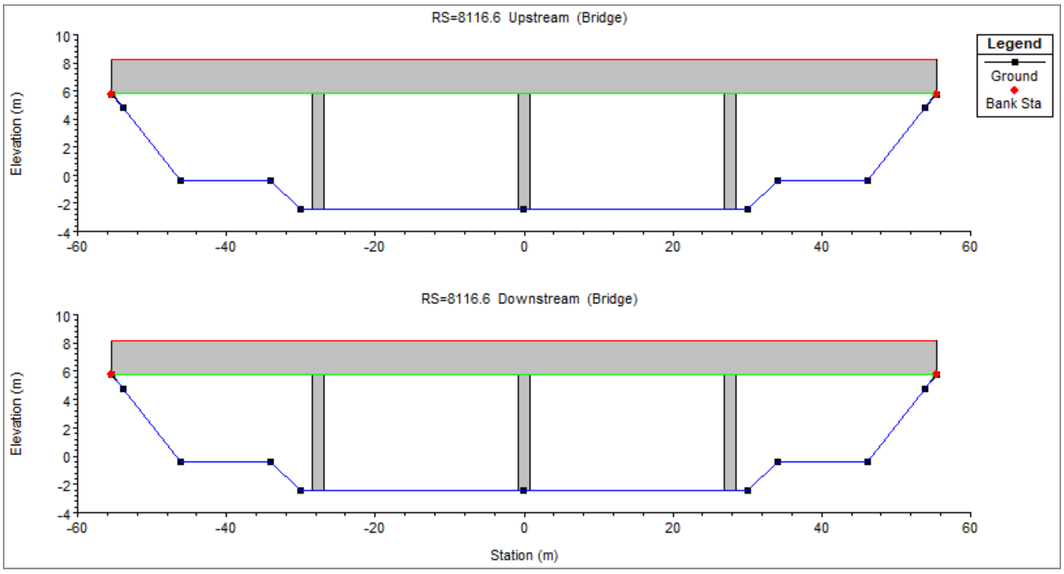
In order to confirm the hydraulic effects of bridges constructed in cut-off sections (water level rise due to piers), river water level calculations were conducted with reflecting the design bridges in the hydraulic analysis model (HEC-RAS) based on the general drawings of the bridges. The conditions for the calculations are shown in Table 4.1.34.

Table 4.1.34 Condition of River Water Level Calculation

River condition	After the improvement Works for M/P (Flood security level: 100-yr)
Subjected flood	100-yr scale flood (2002 January)
Analysis method	To consider the effect of retarding ponds, unsteady flow analysis is applied

Source: Project Team

The bridge cross section was modeled as shown in Figure 4.1.121, with the bridge girder heights and pier dimensions given on the design river cross section at the bridge location. The same cross-sectional shape and pier arrangement are used for STA11+188.4.



Source: Project Team

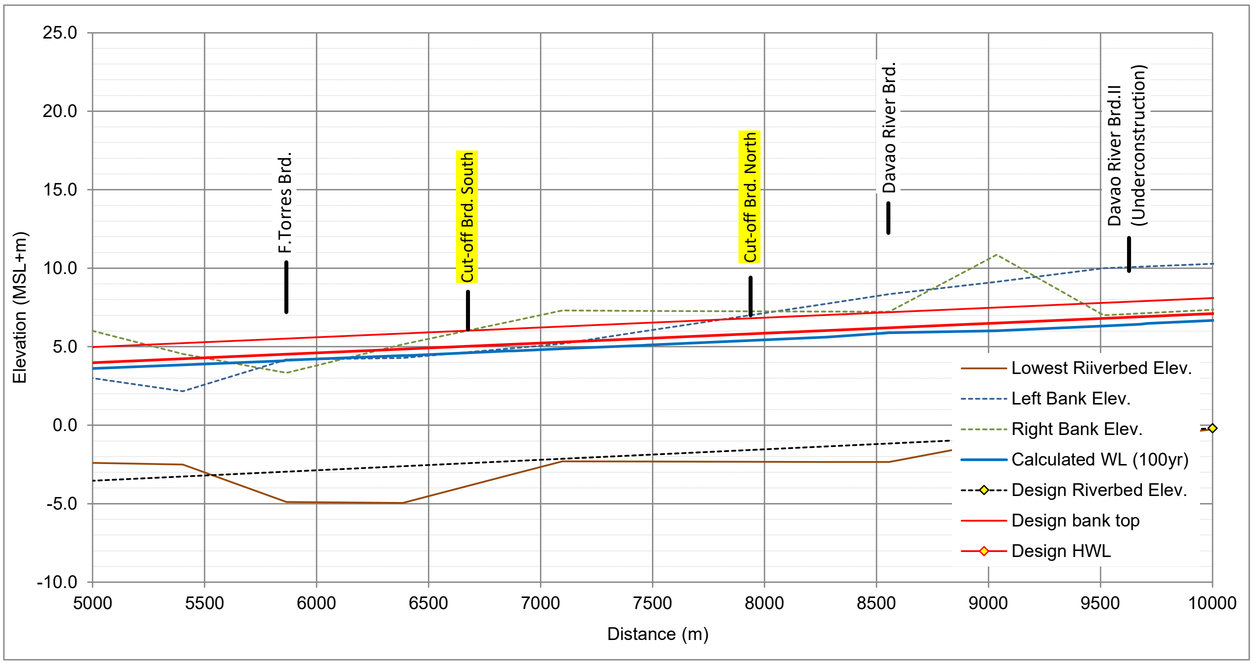
Figure 4.1.121 Modelled Bridge at STA.8+116.6

Table 4.1.35 shows the results of the analysis considering the reduction of the flow area due to the piers and the hydraulic losses (friction loss and rapid widening/shrinking loss). The results compared to the HWL in M/P shows that the calculated water level is below the HWL as shown in Figure 4.1.122.

Table 4.1.35 Hydraulic Analysis Result at Bridge Locations

STA 8+116.6		STA 11+492.4	
W.S. US. (m)	4.63	W.S. US. (m)	5.41
Q Total (m3/s)	1625.15	Q Total (m3/s)	1623.77
Q Bridge (m3/s)	1625.15	Q Bridge (m3/s)	1623.77
Min El Weir Flow (m)	7.20	Min El Weir Flow (m)	9.40
Min El Prs (m)	4.80	Min El Prs (m)	7.00
Delta WS (m)	0.03	Delta WS (m)	0.03
BR Open Area (m2)	617.68	BR Open Area (m2)	759.33
BR Open Vel (m/s)	2.74	BR Open Vel (m/s)	2.77

Source: Project Team



Source: Project Team

Figure 4.1.122 Longitudinal Profile of Water Level in Cut-off Reach

4.2 Non-structural Measures for Riverine Flood in Davao River

4.2.1 Priority Projects on Non-structural Measures for Riverine Flood in Davao River

The following six projects were selected from the non-structural measures proposed in the Master Plan as the priority projects, at the 3rd Steering Committee meeting held on November 24, 2020, and the 4th Steering Committee meeting held on February 10, 2021.

- Additional installation of water level gauges
- Setting warning water level in Davao River corresponding to the latest river and social conditions
- Preparation of IEC materials on the proposed structural measures and non-structural measures
- Formulation and Update of flood hazard map for riverine, inland and coastal with evacuation information
- Land use control along the proposed structural measures
- Capacity enhancement project on riverine flood, rainwater drainage and coastal management in Davao

In the Master Plan survey, the current status, challenges, approaches, implementation organizations, and implementation processes were summarized for each non-structural measure including the above priority projects. Then, the details of priority projects will be examined in the Feasibility Study targeting future implementation. Specifically, an overview of related existing activities, pre-examination through pilot activity, examination of future implementation plan, estimation of necessary budget, and suggestion for future implementation will be conducted in the Feasibility Study.

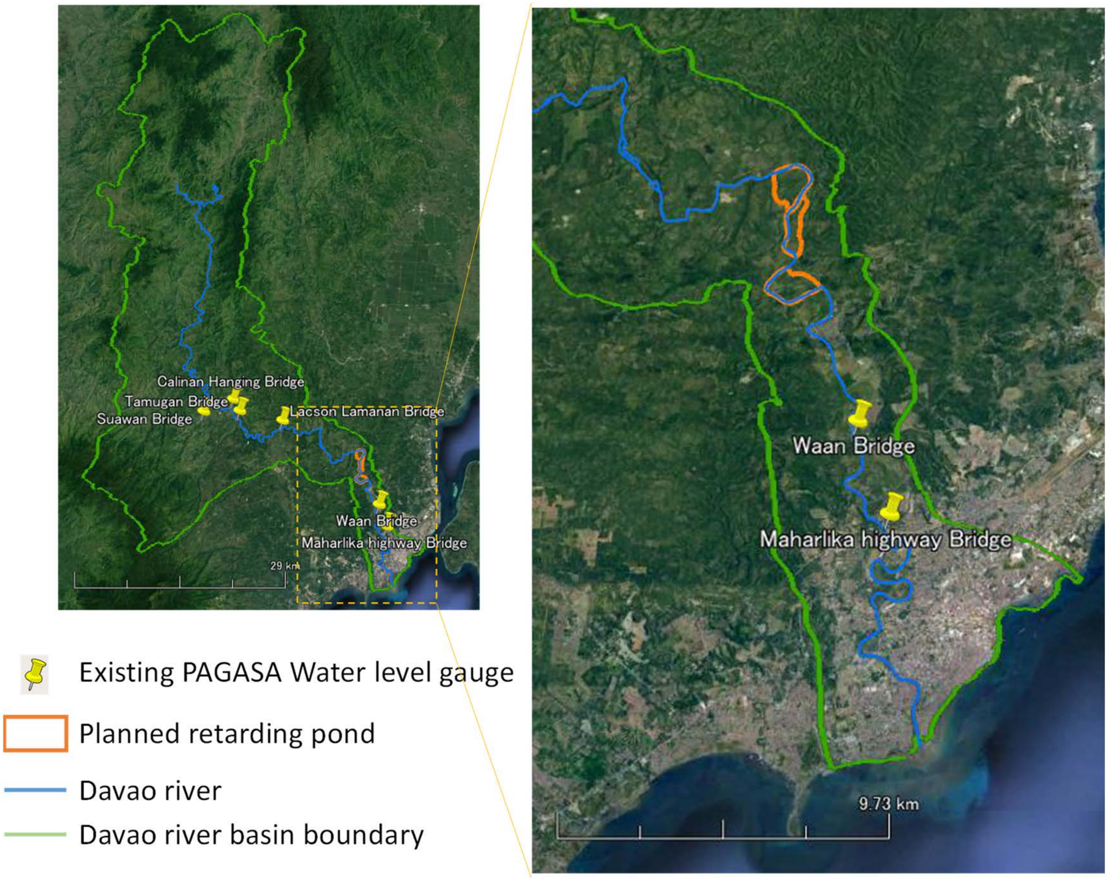
4.2.2 Additional installation of water level gauges

(1) Overview of related existing activities

A sufficient number of water level gauges need to be installed along a river to issue appropriate flood warnings. Since the construction of retarding ponds along Davao River is proposed as one of the structural measures in the Master Plan, installation of new water level gauges in the surrounding area is proposed as the priority project for non-structural measures, considering that water flow around retarding ponds will be complicated when it overflows to them.

Regarding existing hydrological observation, the Davao River Basin Flood Forecasting and Warning Center (DRBFFWC) was established under PAGASA in 2018, and six water level gauges have been installed in the Davao River Basin under support of JICS. Figure 4.2.1 shows the location of the PAGASA water level gauges and the three retarding ponds proposed as priority projects for structural measures. The water level gauge at Lacson Lamanan Bridge is located about 10 km upstream of the retarding ponds, and the one at Waan Bridge is located about 5 km downstream, but there are no water level gauges around the retarding ponds.

In addition, widening of the river channel is planned as one of the mid-long term structural measures in Davao River, and the Davao River Bridge, also known as Maharlika Highway Bridge is planned to be replaced due to the widening work. Therefore, the water level gauge at Waan Bridge needs to be temporarily removed and re-installed when the bridge is replaced in the future.

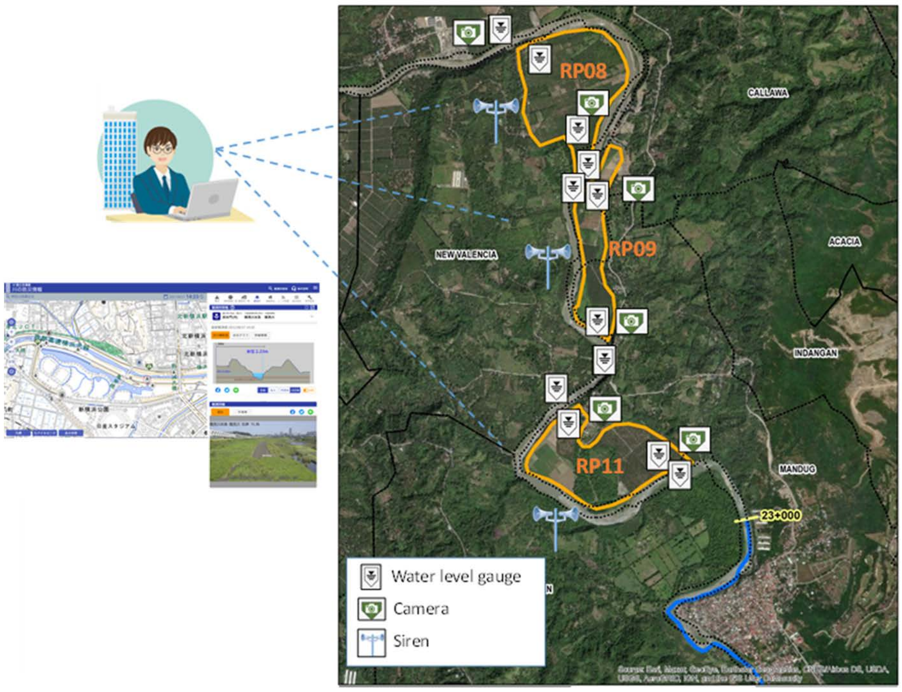


Source: JICA Project Team

Figure 4.2.1 PAGASA's Water Level Gauges and Three Retarding Ponds

(2) Results of pre-examination through pilot activity in F/S

In the feasibility study, discussions were held among the JICA Project team, DPWH RO-XI and Davao CDRRMO to examine the specifications and required project costs for the additional installation of water level gauges. As a result of the discussion, DPWH will procure, install, and manage the necessary equipment, and the data shall be shared with Davao CDRRMO in order to utilize it for disaster preparedness and response activities. In addition to the water level gauges, cameras, sirens, and data server are required to monitor the retarding ponds, and an overview of the system is shown in Figure 4.2.2.



Source: JICA Project Team

Figure 4.2.2 Image for Monitoring System of Retarding Ponds

For each retarding pond, two ultrasonic type water level gauges on the overflow dike and outside of drainage gate, two pressure type water level gauges inside of the retarding pond, two cameras around overflow dike and drainage gate, and one siren are planned to be installed. Regarding the cameras, sirens, and server, the Davao CDRRMO has experience in introducing the same equipment in Davao City. The total cost of the monitoring system for the three retarding ponds targeted by the priority project for structural measures is estimated in approximately 42.92 million Php as shown in Figure 4.2.3, Figure 4.2.4, and Figure 4.2.5.

Item 1. Water level gauge
(install on overflow levee and outside of sluice gate)

	Description	Model	Qty	Unit Price (PHP)	Sub-total (PHP)
1-1	Ultrasonic type water level gauge	TLU16-IVS, Siap+Micros	6		
1-2	Data logger	DA18K	6		
1-3	Polyster IP65 Insulated Patch Box	QE9K-PS	6		
1-4	5m Pole		6	916,855.07	5,501,130.42

* Installation fee is included in the total

Item 2. Water level gauge
(install at two sites inside of retarding pond)

	Description	Model	Qty	Unit Price (PHP)	Sub-total (PHP)
2-1	Piezometric Pressure Type sensor w/ 50m cable	TLDP-50, Siap+Micros	6		
2-2	Data logger	DA18K	6		
2-3	Polyster IP65 Insulated Patch Box	QE9K-PS	6		
2-4	5m Pole		6	930,431.80	5,582,590.8

* Installation fee is included in the total

WATER LEVEL STATIONS

Sample images only

Source: Prepared by JICA Project Team based on cost estimation by BP Integrated Technologies, Inc.

Figure 4.2.3 Cost and Actual Image of the Water Level Gauge Installed for the Retarding Pond

Item 3. Camera
(install at inlet and outlet of retarding pond)

	Description	Model	Qty	Unit Price (PHP)	Sub-total (PHP)
3-1-1	Camera (HD PTZ network)	Panasonic	6	470,000.00	
3-1-2	Single pole mast, 9m		6	145,000.00	
3-1-3	LED flood lights 500W		12	28,000.00	
3-1-4	Single pole mast for flood light, 9m		6	145,000.00	
3-2-1	Data logger Recording system (rack-type server)	Dell	1	350,000.00	
3-2-2	Joystick system controller	Panasonic	1	149,000.00	
3-2-3	Solar panel equipment	Panasonic	6	148,000.00	
3-3-1	IP radio, backhaul link/relay stations Solar panel equipment for relay stations	Panasonic	7	148,000.00	
3-3-2	Solar panel equipment for water level sensors	Panasonic	12	148,000.00	
3-3-3	Single pole mast for relay stations, 60ft.		7	178,000.00	
3-3-4	Single pole mast for water level sensors, 9m		12	145,000.00	
3-3-5	Full duplex point-to-point gigabit radio	Ubiquiti	4	89,000.00	
3-3-6	5 GHz ac radio base station	Ubiquiti	42	18,350.00	
3-3-7	2x2 Point-to-point bridge dish antenna	Ubiquiti	42	28,300.00	
3-3-8	8-port gigabit switch		25	9,800.00	
3-4	Installation, configuration, testing, commissioning and technical training		1	1,392,000.00	
3-5	Maintenance fee (per year)		1	300,000.00	16,333,300.00

* Installation fee is included in the total

Source: Prepared by JICA Project Team based on cost estimation by BP Integrated Technologies, Inc.

Figure 4.2.4 Cost and Actual Image of the Camera Installed for the Retarding Pond

Item 4. Siren

	Description	Model	Qty	Unit Price (PHP)	Sub-total (PHP)
4-1-1	Electronic siren with public address	ATI	3	1,642,000.00	
4-1-2	Solar panel equipment		3	193,500.00	
4-2	Single pole mast, 15m		3	268,000.00	
4-3	Radio communication equipment		3	97,000.00	
4-4-1	Communication control	ATI	1	550,000.00	
4-4-2	Radio communication equipment		1	97,000.00	
4-4-3	Desktop computer		1	100,000.00	
4-4-4	Control station software	ATI	1	515,000.00	
4-5	Installation, configuration, testing, commissioning and technical training			4,194,000.00	
4-4	Maintenance (per year)		1	300,000.00	12,357,500.00

* Installation fee is included in the total

Item 5. Monitoring system

	Description	Model	Qty	Unit Price (PHP)	Sub-total(PHP)
5-1	Industrial PC Server and LCD Display		1		
5-2	Server construction and display content development	Envista ARM for 5 sites + 1 client	1	2,393,412.45	
5-3	Mobile Application	BPIT	1	753,092.77	3,146,505.22

* Installation fee is included in the total

Source: Prepared by JICA Project Team based on cost estimation by BP Integrated Technologies, Inc.

Figure 4.2.5 Cost and Actual Image of the Siren and Server System Installed for the Retarding Pond

Regarding financing for the monitoring system, it will be described later in (5) Suggestions for future implementation.

(3) Examination of future implementation plan

Table 4.2.1 shows an implementation plan for the introduction of monitoring system. The installation of new water level gauges and the re-installation of the existing water level gauge will proceed in line with structural measures for retarding ponds construction and river channel widening.

Table 4.2.1 Implementation Plan for Installing New Water Level Gauges and Monitoring System

Year	Classification of measures	Content of Work
2023-2024	Structural measures	Detailed design of the three retarding ponds proposed as the priority project
2025-2026	Non-Structural measures	Detailed examination of specifications and installation location of the retarding pond monitoring system including water level gauges
2025-2032	Structural measures	Construction of the three retarding ponds
2032-2033	Non-Structural measures	Procurement and installation of the retarding pond monitoring system
2034-2038	Structural measures	Construction of Davao River channel widening and replacement of bridges
2039	Non-Structural measures	Reinstallation of PAGASA's existing water level gauge on the rebuilt bridge

Source: JICA Project Team

(4) Estimation of necessary budget

As mentioned above, the specifications and quantity of equipment required for the monitoring system were examined in this feasibility study. The total cost of the monitoring system for the three retarding ponds targeted as the priority project for structural measures was calculated to be approximately 42.92 million Php. From the viewpoint of system maintenance in the future, the cameras, sirens, and server are selected from those that have been introduced by the Davao CDRRMO before.

Regarding the re-installation of PAGASA's existing water level gauge due to the replacement of the bridge, the project cost is not necessary since new procurement is not required.

(5) Suggestion for future implementation

The procurement of the monitoring system shall basically be carried out by DPWH, who will be the manager of the retarding ponds. As described later in Section 4.6, it is proposed that DPWH RO-XI will acquire the budget and DEO will be in charge of the operation and maintenance of the retarding ponds, so that the similar system on budget acquisition and operation is expected for the monitoring system.

On the other hand, if the detailed design and construction supervision of the priority project for structural measures will be implemented under a Yen loan project with support of the Japanese government in the future, the procurement and installation of this monitoring system might also be integrated with the support of the Japanese government. Regarding financing for the monitoring system, it shall be considered according to the person who will implement the structural measures in the future.

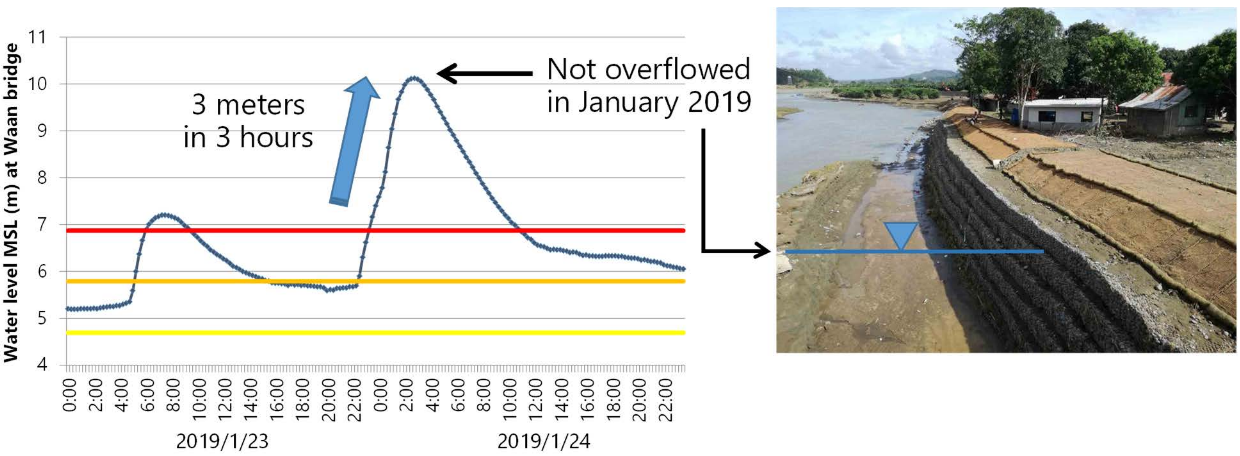
In addition, the introduction of the monitoring system was examined only for the three retarding ponds proposed as priority projects in this feasibility study. On the other hand, four additional retarding ponds are planned as a mid-long term measure in the Master Plan, so that it will be necessary to consider expanding this monitoring system in the future. It is expected that the experience of working with the monitoring system for the three retarding ponds will be utilized to expand to the remaining four retarding ponds.

4.2.3 Setting warning water level in Davao River corresponding to the latest river and social conditions

(1) Overview of related existing activities

As mentioned above in the previous section, six water level gauges were installed by PAGASA along Davao River in 2018. However, there is a concern that the flood warning water level set at these observatories does not match with the latest river channel and social conditions, leading to missed or false warnings. Therefore, re-examination of the flood warning water level and establishment of a regular update system were proposed as the priority project for non-structural measures. Figure 4.2.6 shows the water level data at Waan Bridge in January 2019. The water level had exceeded the red (Critical) flood warning level by more than three meters, however water did not overflow at that time according to interviews with local residents.

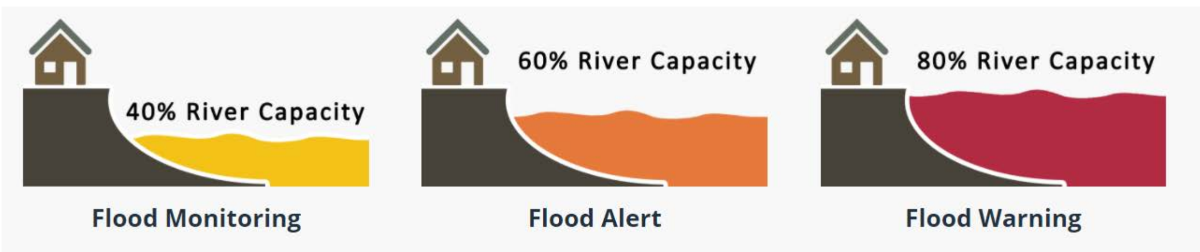
Since the conditions of the Davao River channel are changing due to ongoing construction work by DPWH DEO since 2017, the flood warning water level set by PAGASA needs to reflect the latest river channel conditions.



Source: Prepared by JICA Project Team based on PAGASA water level data

Figure 4.2.6 Water Level Data at Waan Bridge in January 2019

The method of setting the flood warning water level of PAGASA follows the capacity of river channel as shown in Figure 4.2.7. The yellow Flood Monitoring level, the orange Flood Alert level, and the red Flood Warning level are set in accordance with 40, 60 and 80 % of the river channel capacity.



Source: PAGASA

Figure 4.2.7 Flood Warning Water Level Setting by PAGASA

In addition to PAGASA's activities, the Davao CDRRMO has also installed a staff gauge to monitor the water level in Davao River for disaster preparedness and response activities. As of August 2021, staff gauges have been installed at five locations in Davao River, and the water level is visually observed with a real-time camera. For reference, Figure 4.2.8 shows the staff gauge installed at Gov. Generoso Bridge. According to an interview with Davao CDRRMO, these gauges are color-coded at equal intervals of height, but they are not related to the flood warning water level set by PAGASA, and the height of each color is not set in a quantitative basis.

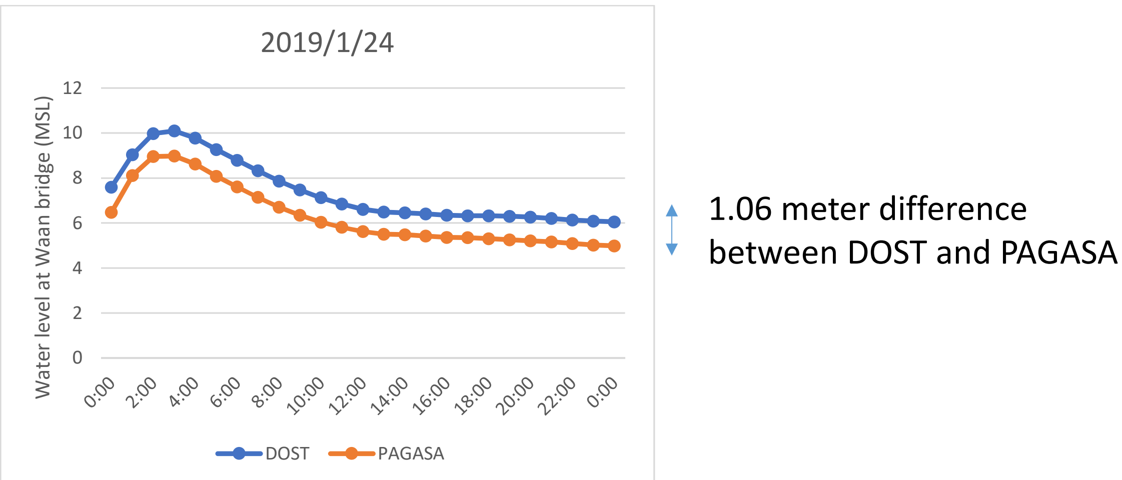
Source: Davao CDRRMO

Figure 4.2.8 Staff Gauge at Gov. Generoso Bridge Installed by Davao CDRRMO

(2) Results of pre-examination through pilot activity in F/S

In the feasibility study, the flood warning water level at Waan Bridge and Davao River Bridge were re-examined using the results of the river cross sectional survey conducted in this project, in line with the PAGASA setting manual (method of setting the flood warning water level of yellow, orange, and red according to 40, 60, and 80% of the river channel capacity).

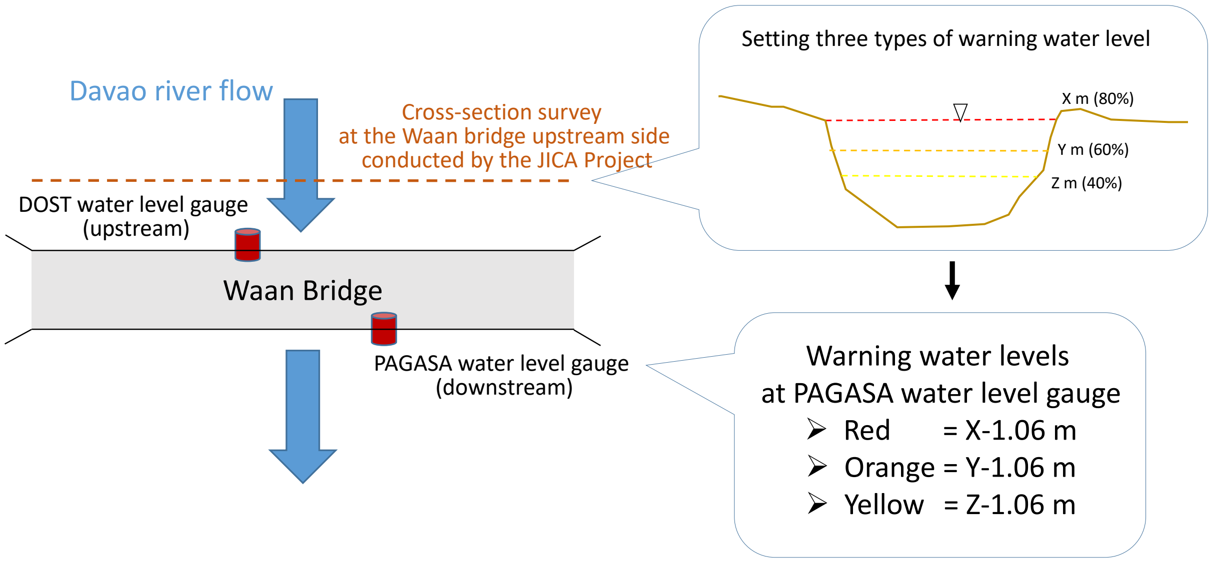
Since it was confirmed that the benchmark used in the river cross sectional survey conducted in this project is different from the one used by PAGASA, it is necessary to make height adjustments between them. In addition, while the river cross sectional survey of this project was carried out on the upstream side of each bridge, the PAGASA water level gauge is installed on the downstream side of each bridge, so height adjustment is also necessary between the upstream and downstream sides. At the Waan Bridge, the DOST water level gauge is installed on the upstream side of the bridge, so it was used for adjusting the reference height and difference between upstream and downstream sides of the bridge. The water level data observed in the cross-sectional survey conducted in this project was 4.583 m (msl) as of 10:47 on April 18, 2019, which is almost the same as the DOST water level data (4.63 m (msl) as of 10:45 on the same day). Therefore, it was confirmed that they were using the same benchmark. In addition, since the DOST and PAGASA water level gauges are installed on the upstream and downstream sides of the Waan Bridge respectively, the height difference is approximately 1.06 m as shown in Figure 4.2.9.



Source: Prepared by JICA Project Team based on DOST and PAGASA water level data

Figure 4.2.9 Comparison of DOST and PAGASA Water Level Data at Waan Bridge

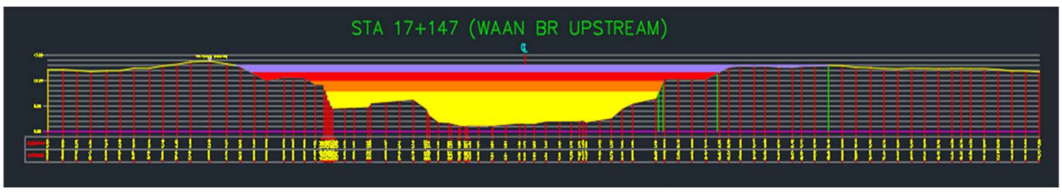
Three types of flood warning water levels, red, orange, and yellow at the PAGASA water level gauges, were calculated by using the river cross sectional survey data carried out in this project. 1.06 m is subtracted from each flood warning water level calculated at the upstream side to adjust the reference height of the PAGASA water level gauges as shown in Figure 4.2.10.



Source: JICA Project Team

Figure 4.2.10 Re-setting PAGASA Flood Warning Water Level Using River Cross Sectional Survey Data

The flood warning water levels set for the Waan Bridge in 2018 were 4.69 m for the yellow Flood Monitoring level, 5.79 m for the orange Flood Alert level, and 6.87 m for the red Flood Warning level. As shown in Figure 4.2.11, the newly calculated flood warning water level at Waan Bridge is 6.68 m for the yellow, 8.78 m for the orange, and 10.48 m for the red. As a reference, the DOST water level gauge installed at the upstream side of the bridge observed 13.9 m during the 2017 typhoon VINTA, which is estimated to be a flood probability of about 40 years.



River capacity (%)	River capacity (m2)	Water level (m) at the bridge upstream (JICA cross section)	Warning Water level (m) at the bridge downstream (PAGASA station)
40	310.1792	7.74 (-1.06 m →)	**6.68**
60	465.2688	9.835 (-1.06 m →)	**8.78**
80	620.3584	11.534 (-1.06 m →)	**10.48**
100	775.448	12.985	

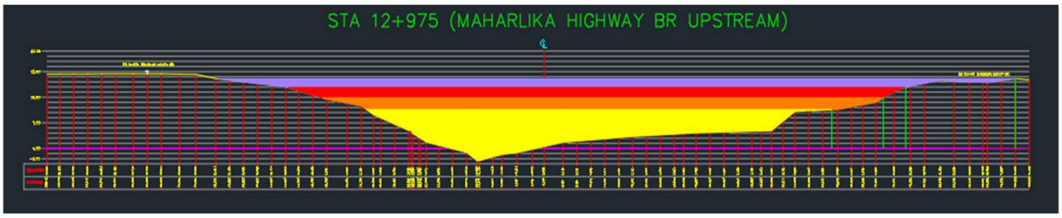
* 100% River capacity was chosen by the highest elevations on both banks

Source: JICA Project Team

Figure 4.2.11 Re-setting of Flood Warning Water Level at Waan Bridge

The flood warning water levels set for Davao River bridge in 2018 were 4.27 m for the yellow Flood Monitoring level, 5.92 m for the orange Flood Alert level, and 7.38 m for the red Flood Warning level.

As shown in Figure 4.2.12, the newly calculated flood warning water levels at Davao River bridge is 6.53 m for the yellow, 8.82 m for the orange, and 10.84 m for the red.



River capacity (%)	River capacity (m2)	Water level (m) at the bridge upstream (JICA cross section)		**Warning Water level (m) at the bridge downstream (PAGASA station)**
40	509.3856	7.582	-1.06 m →	**6.53**
60	764.0784	9.878	-1.06 m →	**8.82**
80	1018.7712	11.892	-1.06 m →	**10.84**
100	1273.464	13.61		

* 100% River capacity was chosen by the highest elevations on both banks

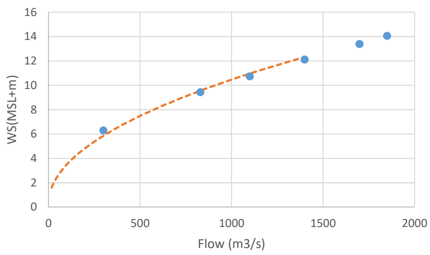
Source: JICA Project Team

Figure 4.2.12 Re-setting of Flood Warning Water Level at Davao River Bridge

The flood warning water level re-examined at the Waan Bridge was officially approved by PAGASA in September 2021. The proposed flood warning water level of the Davao River Bridge was officially approved by PAGASA in March 2022.

Regarding the method of setting the flood warning water level, PAGASA set it according to the river channel capacity. On the other hand, the technical cooperation project with PAGASA carried out by JICA in 2017 proposed to set it based on observed flow rate Q. It is expected that the technology related to flow rate observation and HQ curve creation will be transferred to the PAGASA Davao River Basin Flood Warning Center, and a more precise flood waring water level setting will be carried out.

In the hydraulic model established in this project, the HQ curve at Waan Bridge was created and the flood warning water level was set based on the flow rate as shown in Figure 4.2.13. It was confirmed that it tends to be calculated higher than the flood warning water level set based on the river channel capacity. Therefore, the flood warning water level set based on the river channel capacity tends to be on the safe side to prevent a missed warning, although the frequency of false warnings tends to increase. It is suggested that the flood warning water level will be set based on the river channel capacity for the time being.



(%)	Q (m3/s)	Calculated warning water level (m) by using Q ratio
Yellow 40	623.1406	8.31
Orange 60	934.7109	10.12
Red 80	1246.281	11.64
100	1557.852	12.98

<u>New warning water level at Waan br. calculated by river capacity ratio</u>

Yellow: 6.68 m
Orange: 8.78 m
Red: 10.48 m

Source: JICA Project Team

Figure 4.2.13 Setting of Flood Warning Water Level Using HQ Curve by Hydraulic Model

(3) Examination of future implementation plan

Since the river improvement project of Davao River will be continuously implemented until 2045 based on the Master Plan proposed by this project, the flood warning water level of PAGASA shall also be updated as the river channel capacity changes. The PAGASA water level gauges that are mainly affected by the Master Plan river improvement project are the Waan Bridge observatory and the Davao River Bridge observatory. Table 4.2.2 shows an implementation plan for resetting the flood warning water level. The flood warning water level will be reset regularly in line with the structural measures for dredging and river channel widening work proposed in the Master Plan.

Table 4.2.2 Implementation Plan for Resetting Flood Warning Water Level

Year	Classification of measures	Content of Work
2023	Non-Structural measures	Reset of flood warning water levels at all PAGASA water level gauges (6 locations) in the Davao River Basin
2025-2031	Structural measures	Implementation of dredging in Davao River
2028	Non-Structural measures	Reset of flood warning water levels at Waan Bridge observatory and Davao River Bridge observatory according to the progress of the dredging project (1st)
2030	Non-Structural measures	Reset of flood warning water levels at Waan Bridge observatory and Davao River Bridge observatory according to the progress of the dredging project (2nd)
2032	Non-Structural measures	Reset of flood warning water levels at Waan Bridge observatory and Davao River Bridge observatory according to the progress of the dredging project (3rd)
2034-2038	Structural measures	Implementation of river channel widening in Davao River
2039	Non-Structural measures	Reset of flood warning water levels at Waan Bridge observatory and Davao River Bridge observatory according to the progress of the river channel widening project (4th)

Source: JICA Project Team

(4) Estimation of necessary budget

In order to reset the flood warning water level, it is necessary to carry out a river cross sectional survey at each observatory point. Assuming 18,000 Php per cross section with reference to the survey carried out by the project team, the required project budget is calculated to be 252,000 Php by conducting the survey of 14 cross sections in total. It is expected that this project cost be funded by PAGASA.

(5) Suggestion for future implementation

In order to regularly reset the flood warning water level in the future, it is necessary for DPWH to regularly share with PAGASA the changes in the river channel capacity due to the river improvement projects based on the Master Plan.

In addition, through comparison between the reset flood warning water level and the water level rise event in the recent flood, it was estimated to be about 2 hours to rise from the yellow Flood Monitoring level to the orange Flood Alert level, and another 2 hours from the orange Flood Alert level to the red Flood Warning level. Although lead-time for information dissemination and evacuation action seem to be secured, further discussions and examinations are required in the future among the parties concerned for setting the further precise and effective flood warning water level.

From the perspective of establishing a flood warning system that contributes to proper disaster prevention actions by local residents, it is important not only to technically refine the flood warning water level of PAGASA, but also to carry out awareness activities with the local residents and local governments who receive the warnings and need to take appropriate disaster prevention actions. It is required to update the flood warning system through referring to the viewpoint from the residents side and the past knowledge formed in the local area. As a concrete example, the residents of Tamugan barangay located in the middle part of the Davao River and Waan barangay located in the lower part communicated with each other, and the local residents have empirically recognized that the water level in the Waan barangay will rise 3-4 hours after the water level rises in the Tamugan barangay. In addition to waiting for information from the government, residents need to collect necessary information by themselves. Also, it is expected to carry out public awareness activities and knowledge sharing related to flood warnings and evacuation with the residents.

4.2.4 Preparation of IEC materials on the proposed structural measures and non-structural measures

(1) Overview of related existing activities

In order for the Master Plan proposed in this project to be smoothly implemented, it is important that the residents and related organizations are fully informed and that they understand the plan. Through the preparation of pamphlet and poster as IEC materials that introduce the measures proposed in this Master Plan, it is expected to be an effective tool for disseminating information to residents and related organizations. Therefore, the preparation of IEC materials was proposed as one of the priority projects for non-structural measures.

As an existing activity related to IEC materials, the Davao CDRRMO created a 7 minutes video on flood control in December 2021 and posted it on their Facebook page. The contents of the video summarize the differences in the mechanism of occurrence of riverine flood, inland flood, and coastal disasters, the contents of warnings and information issued by the government before/during disaster, and actions to be taken by residents before/during flood. It is necessary to pay attention to the consistency with this video when preparing IEC materials in this project.

Regarding forest conservation related to flood control measures, promotion of IEC activities was proposed in the existing Davao River basin management and development plan formulated in 2015. There is existing IEC material prepared by DENR-XI related to Executive Order No. 23 in 2011 declaring a moratorium on the cutting and harvesting of timber in the natural and residual forests, and DENR Administrative Regulation No. 2021-11 concerning the issuance of permission for logging and transplanting trees. There is also an IEC material summarizing the role of the private sector in expanding the National Greening Program area under Executive Order 193 of 2015. Since forest conservation is also an effective measures for promoting flood control measures, it is expected to utilize these existing IEC materials together with the one prepared in this Project.

Source: DENR-XI

Figure 4.2.14 Existing IEC Materials on Forest Conservation (left figure: prohibition of tree logging, right figure: greening program)

(2) Results of pre-examination through pilot activity in F/S

In the feasibility study, the first draft of IEC materials were prepared. Two types of IEC materials were prepared, the first is a public awareness material related to flood control measures, and the second is a material introducing the Master Plan formulated in this Project.

Regarding the public awareness IEC material, it was prepared according to the contents shown in Table 4.2.3. Figure 4.2.15 shows the prepared IEC material.

Table 4.2.3 Contents of IEC Material for Public Awareness on Flood Control Measures

Type of IEC material	Public awareness on flood control measures
Target audience	• Flood-prone households along Davao River in 100-year scale inundation area • Community Integrated DRR Training Institute planned to be established by the city government of Davao • Media, etc.
Objective of the material	Awareness and understanding improvement from the following viewpoints • Basic concepts on flooding • Current and projected flooding situation in Davao City • Key and relevant actions before/during/after flooding that they can undertake within their household and/or communities, incorporating LGU's existing initiatives • Emergency services and hotlines that they can access within Davao City prior to and in times of flood emergencies
Contents of the material	• The number of pages: 3 • What is flood/flooding? • What are the types and causes of floods/flooding? • Flood risk/hazard map • Who are the (most) affected population? • Major floods in the past in Davao City • Flood prevention/preparedness categorized in three (3) phases: before, during, and after a disaster for household and barangay levels • Davao City Early Warning System (EWS) • Emergency Hotline Numbers, etc.

Source: JICA Project Team

Source: JICA Project Team

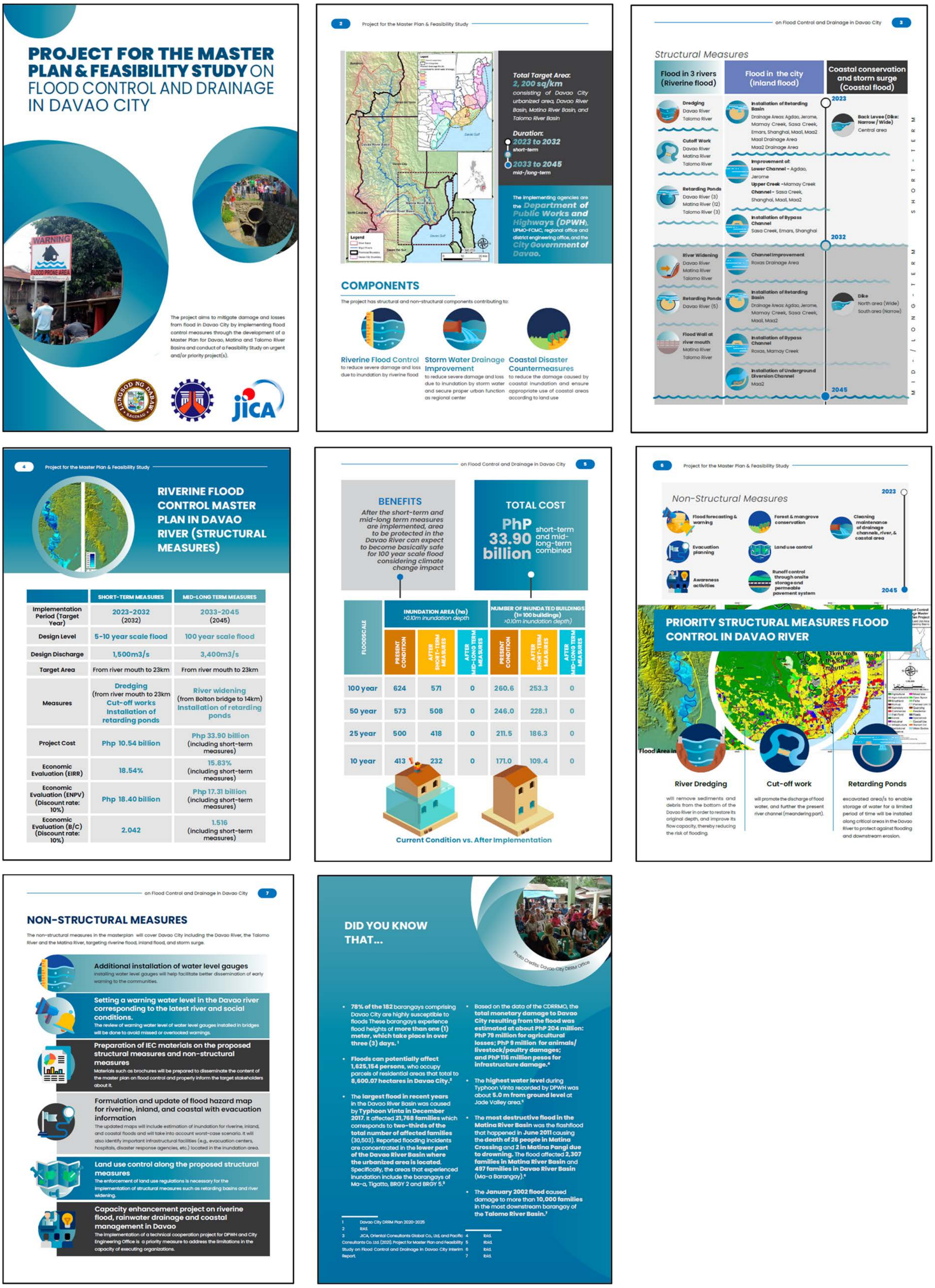
Figure 4.2.15 Public Awareness IEC Material on Flood Control Measures (English Color Version)

Regarding the IEC material introducing the Master Plan formulated in this project, it was prepared according to the contents shown in Table 4.2.4. Figure 4.2.16 shows the prepared IEC material.

Table 4.2.4 Contents of IEC Material for Introducing the Flood Control Master Plan

Type of IEC material	Pamphlet introducing the flood control Master Plan
Target audience	• Davao City Citizens • Community Integrated DRR Training Institute planned to be established by the city government of Davao • Disaster management related organizations • Media, etc.
Objective of the material	Promote understanding of the flood control Master Plan
Contents of the material	• The number of pages: 8 • Purpose of flood control Master Plan, target area, implementing agencies involved • Project schedule/ staged development • Proposed structural measures and its functions/benefits including Riverine Flood in Davao River, Matina River, and Talomo River, Storm Water Drainage Improvement, Structural Measures for Coastal Disaster, and Non-structural measures • Project cost estimation

Source: JICA Project Team



Source: JICA Project Team

Figure 4.2.16 IEC Material for Introduction of the Flood Control Master Plan (English Color Version)

Regarding the language of the IEC materials, the C/P recommended to translate not only in English but also in the local Visaya language, so that the Visaya language version was prepared as well as the English version. In addition, the C/P commented that it is expected to prepare IEC materials that support black-and-white printing, in case color printing is not supported, so that the black-and-white version was also prepared.

(3) Examination of future implementation plan

Based on the Master Plan proposed by this project, it is required to update the contents of the IEC materials as the river improvement project of Davao River will be continuously implemented until 2045. Table 4.2.5 shows an implementation plan for the future updates based on the first draft of the IEC materials prepared in this feasibility study.

Table 4.2.5 Implementation Plan for Update of IEC Materials

Year	Classification of measures	Content of Work
2022	Non-Structural measures (Feasibility Study)	Preparation and distribution of the first draft of IEC materials
2023-2032	Structural measures	Implementation of the short-term structural measures
2033	Non-Structural measures	Update and distribution of IEC materials based on the completion of the short-term structural measures
2033-2045	Structural measures	Implementation of the mid-long term structural measures
2039	Non-Structural measures	Update and distribution of IEC materials based on the progress of the mid-long term structural measures (completion of all planned retarding ponds)
2046	Non-Structural measures	Update and distribution of IEC materials based on the completion of the mid-long term structural measures

Source: JICA Project Team

(4) Estimation of necessary budget

Based on the first draft of IEC materials prepared in the feasibility study, these will be distributed four times by the completion of the Master Plan in 2045. The target audience of the IEC materials will be the residents living in the 100-year scale inundation area along Davao river, and disaster management related organizations in Davao city. The required budget for printing IEC materials is calculated to be 30.40 million Php as it is assumed to be distributed to 10,000 households / organizations four times. Regarding the unit cost for printing IEC materials, the poster for public awareness is 360 Php (Tarpaulin A1 paper, 3 pages printed), and the pamphlet introducing the flood control Master Plan is 400 Php (300GSM Thickness-Semi Gloss A4 paper 8 pages). Since most of the distribution target will be residents of Davao City, the cost is expected to be funded by the Davao CDRRMO.

(5) Suggestion for future implementation

The IEC materials will be effective to utilize at the Community Integrated DRR Training Institute that is planned to be established according to the Davao City Disaster Risk Reduction and Management Plan 2020-2025. As of 2021, the above training institute is still in the planning stage, and construction and detailed examination of the training content have not progressed. It is expected that these IEC materials will be installed in the institute in the future so that the visiting local residents can take them home and learn independently.

In addition, the contents of the IEC materials need to be updated as the river improvement project for Davao River will be implemented until 2045 based on the Master Plan proposed by this project as mentioned above. Based on the first draft of the IEC materials prepared in this feasibility study, it is expected that DPWH and Davao CDRRMO will work together to continuously update.

As mentioned in (1) as overview of related existing activities, DENR-XI has prepared IEC materials for prohibiting tree logging and promoting greening programs. Forest conservation in the upstream area of

Davao River is an effective measure for flood control, so that it is expected to carry out community awareness activities by utilizing these existing IEC materials in addition to the one prepared in this feasibility study.

4.2.5 Formulation and Update of flood hazard map for riverine, inland and coastal with evacuation information

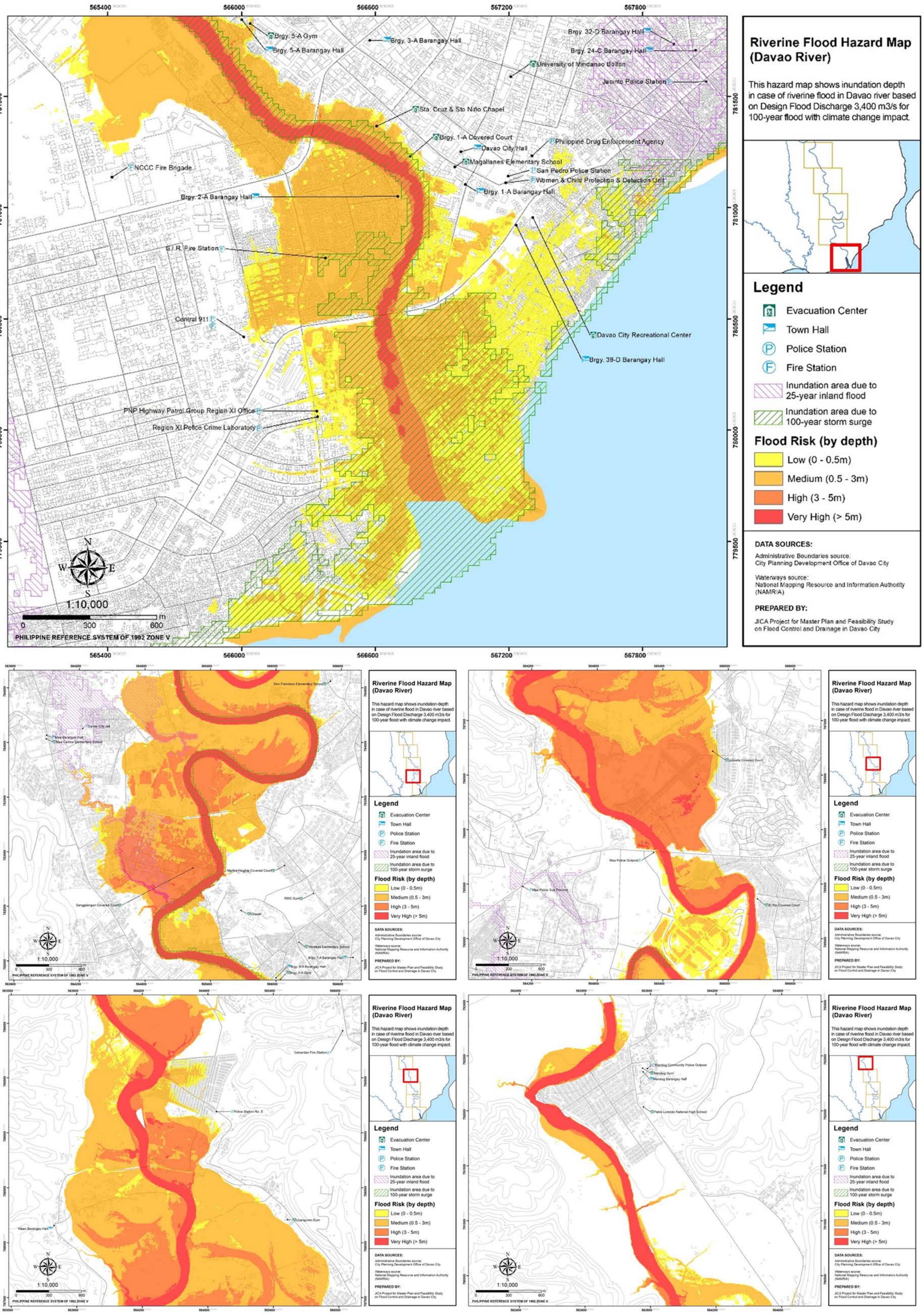
(1) Overview of related existing activities

While there are multiple existing flood hazard maps in Davao City, it is necessary to update them regularly in line with the latest river improvement works by DPWH and the progress of structural measures proposed in the Master Plan. Therefore, the formulation and update of flood hazard maps for riverine flood, inland flood, storm surge and evacuation information was proposed as one of the priority projects for non-structural measures.

As an existing activity related to hazard maps, the University of Philippines (UP) formulated hazard maps for each 5, 25, and 100-year scale flood using the HEC-HMS model and surface data from LiDAR in the DREAM program in 2015. Furthermore, MGB formulated 1: 10,000 scale flood hazard map in 2021 (updated since 2016) through hazard evaluation based on topography, soil quality, disaster historical information, etc.

(2) Results of pre-examination through pilot activity in F/S

In the feasibility study, the first draft of the hazard map was prepared. The hazard map was formulated along Davao River, which integrates three types of disasters, using the results of inundation simulation for riverine flood, inland flood, and storm surge that have been carried out in this project. Information of evacuation centers provided by the city government of Davao was also included in this hazard map. 100-year scale inundation for riverine flood and storm surge, and 25-year scale inundation for inland flood were integrated into 1:10,000 scale hazard map by dividing the area from the mouth of Davao River to 23 km into five areas. The prepared hazard maps are shown in Figure 4.2.17.



Source: JICA Project Team

Figure 4.2.17 Flood Hazard Map Integrating Riverine Flood, Inland Flood, Storm surge and Evacuation Information

(3) Examination of future implementation plan

Based on the Master Plan proposed by this project, it is required to update the hazard map as the river improvement work for Davao River will be continuously implemented until 2045. Table 4.2.6 shows an implementation plan for future updates based on the first draft of the hazard map formulated in this feasibility study.

Table 4.2.6 Implementation Plan for Update of Hazard Maps

Year	Classification of measures	Content of Work
2022	Non-Structural measures (Feasibility Study)	Preparation and distribution of the first draft of hazard maps
2023-2032	Structural measures	Implementation of the short-term structural measures
2033	Non-Structural measures	Update and distribution of hazard maps based on the completion of the short-term structural measures
2033-2045	Structural measures	Implementation of the mid-long term structural measures
2039	Non-Structural measures	Update and distribution of hazard maps based on the progress of the mid-long term structural measures (completion of all planned retarding ponds)
2046	Non-Structural measures	Update and distribution of hazard maps based on the completion of the mid-long term structural measures

Source: JICA Project Team

(4) Estimation of necessary budget

Based on the first draft formulated in the feasibility study, the hazard maps will be distributed three times by the completion of the Master Plan in 2045. These will be distributed to residents who live in the 100-year scale inundation area along Davao river and disaster management related organizations in Davao City. The required budget related to printing hazard maps is calculated to be 39 million Php, which is assumed that the unit cost for printing the hazard map will be 500 Php (1 set of 5 sheets of 300GSM Thickness-Semi Gloss A3 paper) and distributed three times to 26,000 households / organizations. Since most of the distribution target will be residents of Davao city, the cost is expected to be funded by the Davao CDRRMO.

(5) Suggestion for future implementation

As mentioned above, it is required to update the hazard maps as the river improvement work for Davao River will be continuously implemented until 2045 based on the Master Plan proposed by this project. It is expected that the hazard maps will be continuously updated based on the first draft of the hazard maps formulated in this feasibility study.

In this Project, practical technical training sessions such as hydrological and runoff inundation analysis was conducted as part of strengthening the capacity of C/P. Utilizing this experience, it is expected that DPWH officials will carry out the runoff inundation analysis according to the progress of the river improvement work, and update the hazard maps in cooperation with the city government of Davao.

In addition, it was confirmed that some evacuation centers were located within the inundation area, through preparation of the hazard maps in this feasibility study. As shown in Table 4.2.7, six evacuation centers have a possibility to be inundated in the case of 100-year scale riverine flood, and one evacuation center have a possibility to be inundated in the case of 100-year scale storm surge. In the future, it is necessary to consider in evacuation plan how to handle these evacuation centers under the risk of flooding.

Table 4.2.7 List of Evacuation Centers Located in the Inundation Area

List of Evacuation Center					
Name of Barangay	Name of Evacuation Center	Location	Riverine Flood	Inland Flood	Storm Surge
1-A	Brgy. 1-A Covered Court	Prk. 7, Magallanes Riverside, Brgy. 1	×	○	×
1-A	Magallanes ES	Bolton St., Brgy. 1-A	○	○	○
2-A	Sta. Cruz and Sto. Niño Chapel	Prk 2 and 3 respectively, Brgy. 2-A	×	○	○
3-A	University of Mindanao (Bolton	Bolton corner Bonifacio St., Davao City	○	○	○
5-A	Brgy. Gym (5-A)	Brgy. Hall (Brgy. 5-A)	×	○	○
39-D	Davao City Recreational Center	Brgy. 39-D	○	○	○
5-A	Brgy. Gym (5-A)	Brgy. Hall (Brgy. 5-A)	×	○	○
6-A	a. Wireless ES b. School	Fr. Selga St. AMA Computer College, San Pedro Ext.	○	○	○
7-A	RMC Gym	Lopez Jaena St., Brgy. 7-A	○	○	○
8-A	Chapel	Corner Brokenshire Hospital Fr. Selga St.	○	○	○
8-A	Marfori Hgts. Covered Court	Prk . 8 Marfori Heights II, Kingfisher St.	○	○	○
19-B	Don Francisco Dizon ES Multi-purpose Bldg.	F.S Dizon Road, Brgy. 19-B	○	○	○
Maa	Maa Central Elem. School Covered Court	Don Julian Rodriguez Highway	○	○	○
Maa	Sanggilangan Covered Court	Prk. 20, Brgy. Maa	×	○	○
19-B	El Rio Covered Court	Ph. 1, El Rio Subd., Brgy. 19-B	○	○	○
Tigatto	Jullivelle Covered Court	Jullivelle Subd., Tigatto	×	○	○
Tigatto	Uyanguren Gym	Brgy. Tigatto, Buhangin District	○	○	○
Mandug	Pablo Lorenzo National High School	Mandug Highway, Mandug Proper	○	○	○
Mandug	Mandug Gym	Las arenas, Mandug Proper	○	○	○

○ is located outside of estimated inundation area which can be used as evacuation center.
× is located inside of the estimated inundation area.

Source: JICA Project Team

4.2.6 Land use control along the proposed structural measures

(1) Overview of related existing activities

In order for the structural measures such as retarding ponds, cut off works, and river channel widening proposed in the Master Plan to be implemented smoothly, it is important to properly regulate land use on these proposed areas. Therefore, land use control along the proposed structural measures was selected as one of the priority projects for non-structural measures. In particular, it is important to coordinate between the Master Plan proposed by this project and the CLUP, comprehensive land use plan in Davao City.

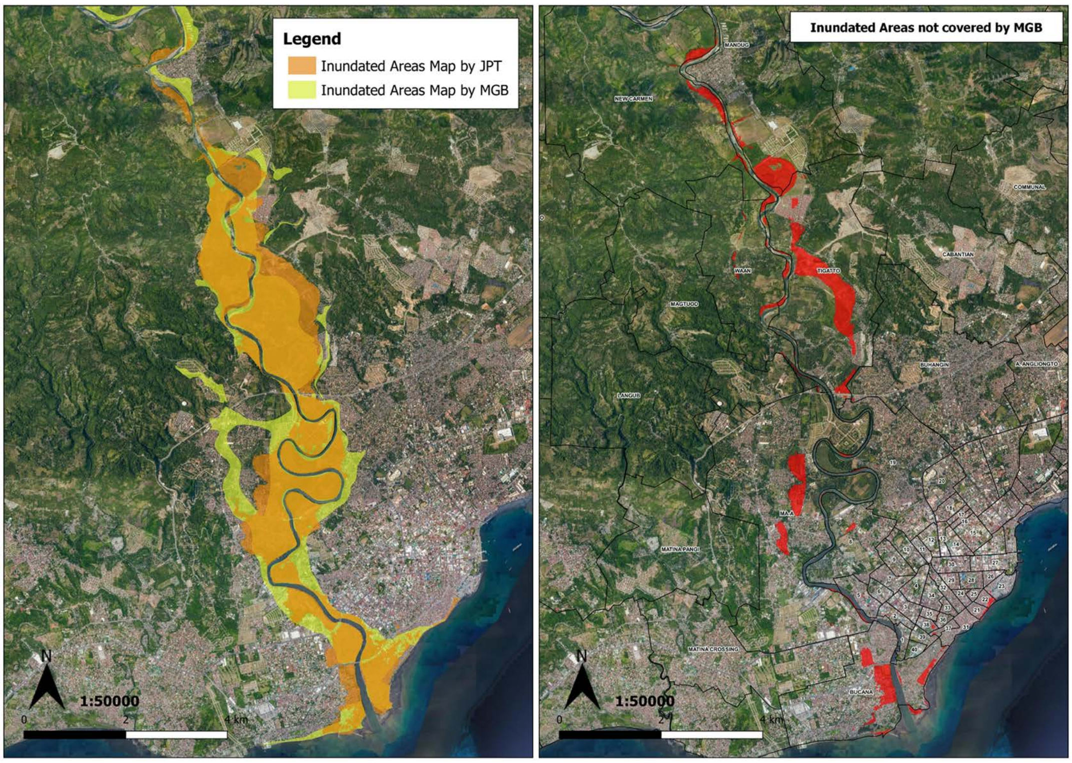
The CLUP 2013-2022 for Davao City was revised during the period of this Project, and CLUP 2019-2028 was officially approved by the Davao City Council in 2022.

Among the main revisions of CLUP, the items mainly related to flood control are as follows.

- The MGB Flood Susceptibility Map (2016) is used for land use control, defining the allowable use and activity in each of the High (inundation depth 1.0 m and above) and Moderate (inundation depth 0.5-1.0 m) flood risk areas.
- Flood control project such as construction of retarding ponds has been newly added as allowable use and activity in the Open Space or Easement Zone.
- In the flood high risk area, 10 m from the riverbank is set as an easement, and 30 m is allowed to develop multiple stories building as C-1 zone, and the first floor is allowed for commercial purposes only.
- From the mouth of Davao River to the Maa Bridge area, 30m on each side of the riverbank shall be an easement for land use, of which 10 m will be for promenade and 20 m for road purpose.

(2) Results of pre-examination through pilot activity in F/S

In order to properly consider the land use plan based on the flood risk assessment, the flood risk information of MGB referred to in CLUP was compared and verified with the flood inundation simulation results conducted in this project through the feasibility study. The flood susceptibility map was updated by MGB in 2021, but CLUP 2019-2028 refers to the old flood susceptibility map created by MGB in 2016. Figure 4.2.18 shows comparison of the 100-year scale flood inundation area calculated by this Project and the MGB flood susceptibility map (2016), and differences which show areas not included in the MGB flood susceptibility map among the 100-year scale flood inundation areas calculated by this Project. The MGB flood susceptibility map classifies it as Moderate Flood in case the inundation depth is 0.5-1.0 m, and High Flood or Very High Flood in case the inundation depth is 1.0 m or more. Since CLUP 2019-2028 covers the Moderate Flood and High Flood areas as land use restrictions, Figure 4.2.18 also shows the inundation area in combination of Moderate and High Flood areas.



Source: JICA Project Team

Figure 4.2.18 Comparison of 100-year Scale Flood Inundation Results Calculated by this Project (orange) and MGB Flood Susceptibility Map (2016) (yellow) and their Differences (red)

As shown in Figure 4.2.18, multiple areas not covered by the MGB Flood susceptibility map can be confirmed among the 100-year scale flood inundation areas calculated by this Project. In particular, the difference can be confirmed in Bucana barangay on the right bank side of the river mouth, Ma-a barangay on the right bank side of the meandering part around the Crocodile Park, and Tigatto barangay on the left bank side upstream of Crocodile Park. Table 4.2.8 shows the number of flood-affected buildings in these barangays that are not covered by the MGB flood susceptibility map. In Bucana barangay, it was calculated by this Project that 2369 buildings would be inundated, while it was not within the inundation area of 0.5 m or more in the MGB flood susceptibility map. In most areas where these differences were confirmed, the inundation depth was 0.5 m or more in the calculation results of this Project.

Table 4.2.8 Number of Flood-affected Buildings not Covered by MGB Flood Susceptibility Map

Barangay	Affected Buildings within flood high risk area not covered by the MGB output
MA-A	1002
BUCANA	2369
TIGATTO	729

Source: JICA Project Team

Through sharing the results of this comparative verification with the officials in charge of MGB-XI, they decided to update the MGB flood susceptibility map with reference to the flood inundation results calculated by this Project. MGB-XI held multiple discussions with the MGB Headquarters from January to February 2022 to revise the inundation areas in the above three barangays, and the flood susceptibility map is planned to be updated and published within 2022. In the future, CLUP will need to be updated in accordance with the updated flood susceptibility map.

(3) Examination of future implementation plan

Based on the Master Plan proposed by this Project, it is required to update the land use plan as the river improvement project for Davao River will be continuously implemented until 2045. Table 4.2.9 shows an implementation plan for future updates.

Table 4.2.9 Implementation Plan for Update of the Land Use Plan

Year	Classification of measures	Content of Work
2022	Non-Structural measures	CLUP revised (from CLUP2013-2022 to CLUP2019-2028)
2023-2024		CLUP revision based on short-term structural measures and flood inundation analysis results by this Project
2025		CLUP revision (from CLUP2019-2028 to CLUP2025-2034)
2032	Structural measures	Implementation of the short-term structural measures
2032-2033	Non-Structural measures	CLUP revision based on the mid to long-term structural measures proposed by this Project
2034		CLUP revision (from CLUP2025-2034 to CLUP2034-2043)
2043	Structural measures	Completion of mid-long term structural measures

Source: JICA Project Team

(4) Estimation of necessary budget

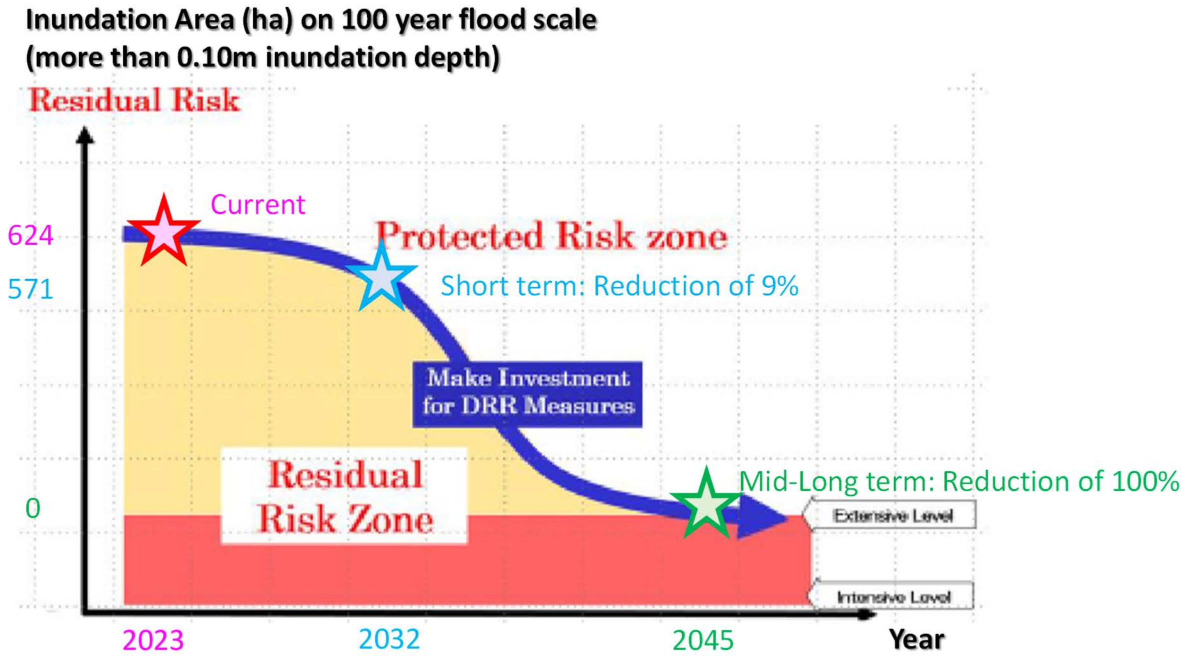
Since the land use plan is updated by the city government of Davao, no specific budget is required for the update. The cost of issuing Zoning certificate for the proposed area of structural measures will also be unnecessary because it is a public project.

It is expected that the city government of Davao will appropriately allocate human resources involved in land use plan updates.

(5) Suggestion for future implementation

The latest CLUP 2019-2028, revised in 2022, includes land use regulations that take flood risk into consideration. On the other hand, it was found that the MGB flood susceptibility map, which is referred to as flood risk information in the CLUP, is not inclusive since there are areas where flood risk is not properly assessed through comparison with the flood inundation calculation results by this Project team. In the future, it is necessary to update the flood risk information in the CLUP with reference to the flood inundation calculation results by this Project team, and to appropriately promote land use restrictions in high risk flood areas.

In addition, although the structural measures will be gradually implemented by 2045 in accordance with the proposed Master Plan, the residual flood risk is still high by 2032 even after the short-term measures are completed. As shown in Figure 4.2.19, the implementation of the short-term structural measures will reduce the inundation area of the 100-year scale inundation from 624 ha to 571 ha, and the rate of decrease is about 9%. Targeting to the residual risk by 2045, it is expected that land use control will be actively promoted in high risk flood areas.



Source: JICA Project Team

Figure 4.2.19 Changes in Residual Flood Risk in Accordance with the Implementation of Structural Measures in Davao River

4.2.7 Capacity enhancement project on riverine flood, rainwater drainage and coastal management in Davao

(1) Overview of related existing activities

Through this project, the Master Plan for riverine flood, rainwater drainage, and coastal flood management has been formulated in Davao City. On the other hand, it is important to promote these implementations and strengthen the capacity of the implementing organizations in the future. In the Philippines, DPWH's flood management budget has been increasing in recent years in line with the BBB program of the Duterte Administration, so the necessity to strengthen the capacity of the implementing organizations is increasing. Therefore, it is considered effective to implement a technical cooperation project on structure design, construction, operation and maintenance, project evaluation, role allocation of related organizations, etc. Finally, the project to strengthen the implementation capacity of riverine flood, rainwater drainage, and coastal flood management was proposed as one of the priority projects for non-structural measures.

As an existing JICA-related projects, the capacity of DPWH and Davao City officials was enhanced to formulate a flood control masterplan for riverine floods in this project. In addition, the project for capacity strengthening on coastal disaster is also ongoing for DPWH.

(2) Results of pre-examination through pilot activity in F/S

As mentioned above, although DPWH's capacity for riverine flood and coastal disasters has been strengthened in recent years, technical support for rainwater urban drainage management is limited. DPWH commented that technical support for urban drainage management is necessary focusing on how urban drainage can be incorporated in flood risk management master plans, considering river basin and ridge-to-reef approach, and integrated water resource management principles. Therefore, Project Team advised assumed necessary activities for capacity enhancement of urban drainage management based on activities in this Project as shown Table 4.2.10.

Table 4.2.10 Assumed Necessary Activities for Capacity Enhancement Related to Urban Drainage Management

Assumed Necessary Activities	• Summarizing lessons and learned from the past and current urban drainage management projects • Evaluating and updating the existing guidelines and manuals for design and construction • Selecting priority urban area for pilot activities of planning, detailed design and construction, considering incorporation into the flood risk management master plans. • Developing maintenance manual and database for urban drainage management structures • Clarifying roles and responsibility on urban drainage management of DPWH Central office, Regional office, District engineering office and City engineering office

Source: JICA Project Team

(3) Examination of future implementation plan

DPWH will prepare an application form and submit/request it to a cooperation agency/donor for realization of the capacity enhancement project and it is expected that the project will be implemented after a few years.

(4) Estimation of necessary budget

Since DPWH will prepare and submit the application form, the budget for proposal of the capacity enhancement project is not necessary. The budget related to the project itself will be examined by DPWH and the cooperation agency/donor.

(5) Suggestion for future implementation

Although the scale of inland flood damage tends to be smaller than that of riverine flood damage, the frequency of inland flood disasters is high, and there are many requests from local governments and residents nationwide to implement countermeasures for inland floods. In Davao City, which is the target area of this project, inland flood damage frequently occurred in the La Verna area, which affected the access between the city area and the airport. Although human damages caused by inland flooding are limited, the impact on the economy is not small, and there are many cities nationwide that suffer from inland floods. Through the implementation of the capacity enhancement project related to urban drainage management, it is expected to create a good practice involving local governments in the pilot area and proceed with efforts with an eye on future nationwide expansion.

4.2.8 Summary of Examination Results for Priority Projects on Non-structural Measures in F/S

The following is a summary of examination results for priority projects on non-structural measures in feasibility study.

Table 4.2.11 Summary of Examination Results for Priority Projects on Non-structural Measures in F/S

No.	Priority project on non-structural measures	Results of pre-examination in F/S	Future implementation plan	Necessary budget	Suggestion for future implementation
1	Additional installation of water level gauges	Examination of specifications and quantity of monitoring systems (water level gauge, camera, siren, data server) for the three retarding ponds proposed as priority project for structural measures	· Detailed examination of the monitoring system specifications and installation location in 2025-2026 • Procurement and installation of the monitoring system in 2032-2033:	42.92 million Php	· Examination of the possibility of budget acquisition through support from Japanese government · Consider expanding monitoring system for four retarding ponds not included in priority project
2	Setting warning water level in Davao River corresponding to the latest river and social conditions	Reexamination and approval of PAGASA flood warning water levels at Waan Bridge and Davao River Bridge	· Reexamination of flood warning water level according to the progress of structural measures in 2023, 2028, 2030, 2032, 2039	0.25 million Php	· Further discussions and examinations among related organizations in consideration of lead time for information dissemination and evacuation
3	Preparation of IEC materials on the proposed structural measures and non-structural measures	Preparation of the first draft of IEC materials for public awareness on flood control measures and for introduction of the flood control Master Plan	· Update and distribution of the IEC materials according to the progress of structural measures in 2022, 2033, 2039, 2046	30.40 million Php	· Utilization of the IEC materials at the Community Integrated DRR Training Institute · Establishment of continuous update system for the IEC materials · Collaboration with existing materials such as for greening programs
4	Formulation and Update of flood hazard map for riverine, inland and coastal with evacuation information	Formulation of hazard map along Davao River that integrates three types of disasters using the inundation simulation results of riverine flood, inland flood, and storm surge	· Update and distribution of hazard maps according to the progress of structural measures in 2022, 2033, 2039, 2046	39.00 million Php	· Establishment of continuous update system for hazard maps · Review of evacuation plan
5	Land use control along the proposed structural measures	Update and revision of MGB flood risk information referenced in CLUP based on the results of flood inundation simulation conducted in this project	· Revision of CLUP according to the progress of structural measures in 2025, 2034	Unnecessar y	· Update of CLUP based on the updated MGB flood risk information · Strong land use regulations in high risk flood areas
6	Capacity enhancement project on riverine flood, rainwater drainage and coastal management in Davao	Advice of necessary activities for capacity enhancement project for urban drainage management	· Implementation of capacity enhancement project in a few years	TBC by DPWH and a cooperation agency/ donor	· Create a good practice involving local governments in the pilot area and promote initiatives with an eye on future nationwide expansion

Source: JICA Project Team

4.3 Operation and Maintenance

4.3.1 Current Operation and Maintenance Practice on Flood Control Works in Davao River

(1) Current Implementation System of Flood Control Projects in Davao River

According to DPWH-DO 2015-23 (Flood Control and Drainage/Slope Protection Projects Policies), DPWH is responsible for implementation of flood control projects for major river basins, principle river basins, main drainage of urban storm water drainage system and drainage attached to national roads in principle.

DPWH District Engineering Office (DEO) has been conducting plan, design and construction for flood control works in the Davao River. Since the project scale DPWH-DEO can deal with is limited to the project cost of 100 million pesos, the entire works has been divided into the project whose cost is less than 100 million pesos. The works has been mainly construction of dyke and revetment.

(2) Current Implementation System of Operation and Maintenance of Flood Control Works in Davao River

1) Operation and maintenance of flood control facilities

According to the interview to DPWH-DEO, the flood control facilities constructed by DPWH project is basically operated and maintained by DPWH.

a) Role of DPWH-RO and DEO

- The maintenance division of DPWH-RO is responsible to secure budget and monitor the operation and maintenance activities.
- The maintenance section of DPWH-DEO is responsible to implement the operation and maintenance activities.

b) Regular operation and maintenance activities

- The regular operation and maintenance activities are implemented by annual maintenance work program.
- Database for inventory of flood control facilities is being developed by Bureau of Maintenance (BOM), which may be used for monitoring of the condition of the existing flood control facilities. The maintenance section of DPWH-DEO inspects the facilities and collects necessary data. The maintenance division of DPWH-RO is facilitating and monitoring the inventory.
- The total number of regular staffs of DPWH Davao City DEO, which manages the lower reach of the Davao River, is 97. Among them, 19 staffs are allocated to the maintenance section. The section is responsible for not only Davao River but also other principal rivers, main drainage of urban storm water drainage system and national roads.

c) Urgent minor repair works

- The urgent minor repair works are implemented by annual maintenance work program. The calamity fund (reserve of 5% of annual maintenance work program) based on disaster report can be released depending on needs to be decided by central office.
- The information of damage condition of the facilities is inspected after disaster incident by the maintenance section of DPWH-DEO and reported to the maintenance division of DPWH-RO.

2) Major repair works of flood control facilities

The major repair works of severely damaged flood control facilities are implemented as asset projects. The planning section of DPWH-DEO conducts plan and design. The planning division of DPWH-RO oversees the plan and design of DPWH-DEO.

3) Maintenance dredging of river channel

According to DPWH-DO 2016-07 (Guidelines on the planning and implementation of DPWH River Dredging Projects by Administration), the dredging work is mainly implemented by administration. The dredging of river channel has been planned and proposed by the planning section of DPWH-DEO and the planning division of DPWH-Regional Office (RO), and has been implemented by the Equipment Management Division (EMD) of DPWH-RO.

In the Davao River, the maintenance dredging had been implemented from 1994 to 2002 and from 2018 to 2020 in the river mouth of Davao River. However, the dredging equipment used is very old and now unserviceable.

The dredging equipment managed by the EMD of DPWH-RO XI as of March 2022 is shown in Table 4.3.1.

Table 4.3.1 Dredging Equipment Managed by EMD of DPWH-RO XI (as of March 2022)

Model	Capacity	Location currently used	Status
DOOSAN, DX225AM SLR	0.5m^3 per bucket	Mandug, Davao River	Operational
DOOSAN DX225LC	0.5m^3 per bucket	Agusan River	Operational
Volvo EC140DL	0.35m^3 per bucket	Matina River, Matina Pangi	Operational
Volvo EC210D	0.5m^3 per bucket	Lasang River	Operational
Volvo EC300DL	0.8m^3 per bucket	Kingking River	Operational
Watermaster Classic V	100m^3/hr	Libuganon River	Operational
Watermaster Classic III	65m^3/hr	Agusan River	Operational
Waterman, WH-750D-12	22m^3/hr	Libuganon River	Under maintenance/ Awaiting Dry-Docking
Waterman, WH-45A	n/a	Libuganon River	Under maintenance
Maebata, M522	n/a	Libuganon River	Awaiting Dry-Docking
DOOSAN DX 225 AM SLR 114	0.5m^3 per bucket	Tuganay River	Idle
DOOSAN DX 225 AM SLR 114	0.5m^3 per bucket	Wason River	Idle
DOOSAN DX 225 AM SLR 114 w/ cutter suction	230m^3/hr	Manat River	Idle

Source: EMD of DPWH-RO XI

It should be noted that the Technical Working Group for coordinating desilting activities in the rivers and streams in Davao City was created in 2018 by Davao City EO 2018-09 (An Order Creating a Technical Working Group (TWG) to Facilitate the Process of Desilting Operations in the Rivers and Streams in the Watershed Areas of Davao City).

4) Control of Illegal Activities along Channel and Quarrying / Mining of Riverbed by Private Sectors

The illegal activities along the Davao River are basically controlled by Davao City. DPWH-DEO can monitor the illegal activities in the river area and recommend necessary actions to Davao City.

The permission of quarrying / mining of riverbed by private sectors in Davao River is issued by Davao City with close coordination to relevant offices including DPWH. The quarrying / mining activities in Davao River is basically controlled by Davao City. DPWH-DEO can monitor the change of river topography and recommend necessary actions to Davao City to prevent adverse effect of the quarrying / mining to river channel stabilization.

5) Problems related to Operation and Maintenance for Flood Control Works based on Current Operation and Maintenance Practice in Davao River

On the basis of the available information, interviews to relevant offices and meetings with DPWH-RO and DEO staffs, the following problems related to operation and maintenance for flood control works based on the current operation and maintenance practice in the Davao River was identified.

a) Operation and maintenance of flood control facilities

- The database for inventory of flood control facilities is just being started operation. Its use should be promoted to ensure proper maintenance.

b) Maintenance dredging of river channel

- Frequent siltation of river mouth
- Unserviceable old dredger for river mouth of the Davao River
- Insufficient budget for dredging project (less than 10% of requested budget is approved.)

c) Control of Illegal Activities along Channel and Quarrying / Mining of Riverbed by Private Sectors

- Possible instability of river channel due to quarrying and mining of riverbed by private company
- Uncontrollable illegal activities including informal settling along the channel
- Insufficient monitoring of river channel change

(3) Experiences on Operation and Maintenance of Flood Control Works in Other Rivers

According to DPWH-FCMC-UPMO, some flood control facilities constructed by the project handled by FCMC-UPMO are handed over to the DPWH-RO and the operation and maintenance of the facilities is mainly conducted by DPWH-RO and DEO. Typical example of this case is Iloilo River flood control project.

In some cases, the flood control facilities are handed over to the relevant LGUs and the operation and maintenance of the facilities is mainly conducted by LGUs based on the agreed Memorandum of Agreement (MOA). It is said that the Ormoc flood control project is the typical good example that LGUs mainly conduct the operation and maintenance successfully. Some other projects such as Cavite flood control project follow this good example.

However, also according to FCMC-UPMO, there have been many cases that the operation and maintenance by LGUs does not function properly as follows.

- Laoag River

  The MOA which shows LGUs is responsible for operation and maintenance was rejected by LGUs.

- Pampanga River

  The flood control facilities constructed by the project handled by FCMC-UPMO are handed over to the relevant LGUs. However, LGUs was not able to conduct the operation and maintenance of the facilities properly.

- Agusan River

  The MOA which shows LGUs is responsible for operation and maintenance was once agreed. However, the LGUs did not conduct the operation and maintenance of the facilities properly. The FCMC-UPMO is currently conducting the operation and maintenance of the facilities.

In major river basin which is relatively large scale, the operation and maintenance mainly by LGUs seems not function properly, in general.

4.3.2 Operation and Maintenance for Proposed Flood Control Works in Davao River

(1) Work Items for Proposed Flood Control Works in Davao River

The proposed flood control works in the Davao River are as follows.

a) Retarding pond

b) River channel improvement
- Dredging
- Cut-off work
- River widening

The operation and maintenance should be properly conducted for these proposed works in addition to the existing facilities.

(2) Assumed Role among DPWH Offices considering Current Practice on Operation and Maintenance for Flood Control Works in Davao River

As for the construction of the proposed flood control works, DPWH suggested that the dredging will be implemented by DPWH-RO and other works will be implemented by FCMC-UPMO.

Considering the current practice on operation and maintenance for flood control works in the Davao River, the role among DPWH offices are assumed as shown in Table 4.3.2.

Table 4.3.2 Assumed Role among DPWH Offices considering Current Practice on Operation and Maintenance for Flood Control Works in Davao River

	Construction	O&M (Regular)	O&M (Major Repair)
Retarding pond / Cut-off Work / Channel Widening	FCMC-UPMO (FS, DD, construction) RO/DEO (assisting for securing ROW)	FCMC-UPMO (Monitoring, Support budgeting) RO (Budgeting, Monitoring) DEO (Implementation)	FCMC-UPMO (Monitoring, Support budgeting) RO/DEO (Plan) DEO (Implementation)
Dredging	Planning Div.-RO (Plan) EMD-RO (Implementation)	FCMC-UPMO (Monitoring, Support budgeting) Planning Div.-RO/ Planning Sec.-DEO (Plan, Monitoring) EMD-RO (Implementation)	

Source: Project Team

(3) Required Regular Operation and Maintenance Activities

Table 4.3.3 shows the required regular operation and maintenance activities for the flood control facilities in the Davao River.

Table 4.3.3 Required Regular Operation and Maintenance Activities for Flood Control Facilities in Davao River.

Type of Works	Items	
	Ordinary time	During/After flood event
Retarding Pond	1) Periodical inspection of structures such as riprap, concrete wall, gates and overflow dike 2) Monitoring of illegal activities inside the retarding pond 3) Periodical cleaning of retarding pond including removal of sediment and garbage	During flood event 1) Sharing information of status of retarding pond including water level around retarding ponds with relevant organizations in real time After flood event 2) Operation of gates and monitoring of drainage of stored water by gravity just after the flood event 3) Checking the status of structures 4) Urgent removal of deposited sediment and garbage, especially around the gates to ensure their proper function
River Channel Improvement	1) Periodical inspection of structures such as riprap, concrete wall and cross drain. 2) Monitoring of illegal activities along the channel 3) Monitoring of quarrying and mining of river by private sector and making recommendation 4) Monitoring and evaluation of change in river topography	During flood event 1) Sharing information of status of channel with relevant organizations in real time After flood event 2) Checking the status of structures

Source: Project Team

(4) Maintenance Dredging

The necessary maintenance dredging volume was preliminary estimated using HEC-RAS One-dimensional quasi-unsteady sediment transport analysis, as follows.

- Model domain is set from river mouth to 22km point for the existing condition
- Simplified cross-section shape based on the current cross-section as well as planned cross-section is applied.
- In the downstream reach from about 15km, the riverbed material is mainly composed by sand/silt, whereas the upper reach from about 15km is characterized by gravel bed. Referring to the riverbed material survey conducted in this Project, the following sediment gradation is given.
  - ✓ For the sand/silt portion, 20% of fine sand (0.125-0.25mm), 40% of very fine sand (0.0625-0.125mm) and 40% of medium silt (0.016-0.032mm)
  - ✓ For the gravel portion, 60% of fine gravel (4-8mm) and 40% of Corse gravel (16-32mm)
- Flow boundary condition
  - ✓ Upstream: Daily discharge for 2002 to 2017 (16 years) is given.
  - ✓ Downstream: MSL is given for constant water level.
- Sediment boundary condition at upstream
  - ✓ Sand/silt: Daily Sediment discharge 2002 to 2017 (16 years) estimated by the rating curve between sediment and flow, which is based on the observed data, is given.
  - ✓ Gravel: Equilibrium sediment transport rate is given
- Meyer-Peter-Muller (MPM) - Toffaleti model is applied for the sediment transport function. This sediment transport function can deal with both bed-load and suspended-load separately, which may be suitable for the case of Davao River.
- Firstly, model parameters are adjusted for reproducing the existing riverbed slope and riverbed material composition, applying flow and sediment inflow for 2002 to 2017 (16years).

- Then, the simulation for 16 years is conducted after the planned cross-section shape with initial dredging is applied. Assuming the maintenance dredging is conducted every three years, the total dredging volume to maintain the planned cross-section is estimated.

The simulation targeted to three scenarios; 1) only dredging, 2) dredging + cut-off work, 3) dredging + cut-off work + channel widening. The following cases are simulated.

- Dredging: Initial dredging and maintenance dredging are implemented except the planned cut-off reach.
- Cut-off work: Cut-off channel with 111m width is applied, and old channel is not retained.
- Channel widening: Standard cross-section is applied.

The estimated volume for annual maintenance dredging is shown in Table 4.3.4.

Table 4.3.4 Estimated Volume for Annual Maintenance Dredging

	Only dredging	Dredging + Cut-off Work	Dredging + Cut-off Work + Channel Widening
Estimated Annual Maintenance Dredging Volume (TCM (Thousand m^3)/year)	125	165	155
Note	No maintenance dredging of the planned cut-off reach.	The maintenance dredging of the old channel is not included.	The maintenance dredging of the old channel is not included.

Source: Project Team

(5) Expected Volume of Sediment Deposition in Retarding Ponds

The expected volume of sediment deposition was also preliminary estimated. The sediment rating curve between sediment and flow, which is based on the observed data, was applied to the design hydrograph to estimate the time series of sediment concentration during the flood event. Then, the expected inflow to the retarding ponds are multiplied to estimate the sediment inflow to the retarding ponds. Assuming that all entered sediment deposits in the retarding ponds, the expected annual volume of sediment deposition in retarding ponds is estimated at about 6 thousand cubic meter(TCM)/year for the three retarding ponds for the priority project (refer to Table 4.3.5).

Table 4.3.5 Expected Volume of Sediment Deposition in Retarding Ponds

	Return Period (Year)						Expected Annual Volume (TCM)
	100	50	25	10	5	3	
Volume of Sediment (TCM)	99	65	35	12	4	1	5.7

Source: Project Team

(6) Issues on Operation and Maintenance for Proposed Flood Control Works in Davao River

In addition to the identified problems based on current operation and maintenance practice in the Davao River, it should be considered that the operation and maintenance for the retarding pond is somehow new for the relevant offices. The issues on operation and maintenance for the proposed flood control works in the Davao River are shown below.

1) Capacity enhancement of regular operation and maintenance

a) Enhancement of human resources in maintenance section of DEO

The operation and maintenance of the newly installed retarding ponds requires human resources more in the maintenance section of DEO since current number of the staffs is limited. Training on operation and maintenance is also necessary.

b) Enhancement of monitoring of river channel

The existing monitoring of river channel is not enough to capture the change in river channel. The cross-section survey is conducted only by project basis. The cross-section survey should be conducted regular basis. In addition to this, the periodical drone video recording should also be conducted.

The situation of illegal activities along river channel and quarrying and mining of riverbed by private sector should also be monitored regularly.

c) Enhancement of information sharing

The situation of river and retarding ponds should be shared with relevant offices. Especially, the real time information during the flood event should be properly share with Davao City-DRRMO and PAGASA.

d) Promotion of newly established databases for inventory of flood control facilities to ensure proper maintenance

The database for inventory of flood control facilities of BOM is just being started operation. Its use should be promoted to ensure proper maintenance.

e) Budget securing for the above activities

The necessary budget for the above-mentioned activities should be secured.

2) Securing budget for major repairs and maintenance dredging

a) Major repair

The structural damage can occur frequently, because the safety level to be achieved by the priority projects is not so high such as 5 to 10 years return period. The necessary budget should be prepared for dealing with the expected damages. The major repair is usually implemented as asset project. The proper fund should be prepared.

b) Maintenance dredging

As shown in Section 4.3.2 (4), it is expected that re-deposition of sediment can occur after the initial dredging work is implemented. The maintenance dredging is crucial to secure the enough channel capacity. The necessary budget for the maintenance dredging should be secured.

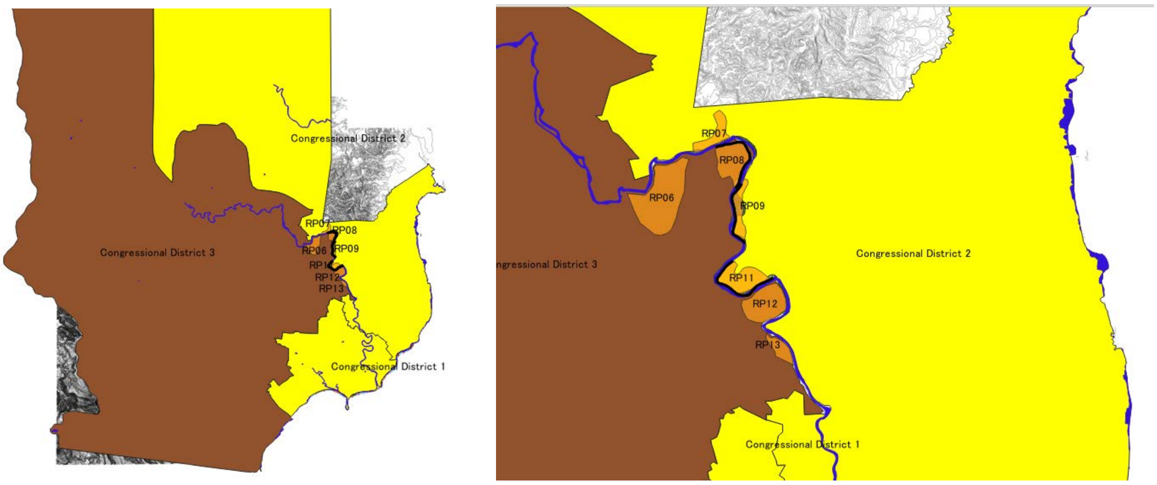
3) Proper coordination among DPWH-RO, DEO and relevant offices

The items of the operation and maintenance requires multi-offices efforts within DPWH and collaboration with other relevant offices. These activities should be properly coordinated. There is already the coordinating unit for flood control and drainage under Regional Director of DPWH RO XI. This function should be enhanced.

4.3.3 Proposed Organizational Framework for Operation and Maintenance for Proposed Flood Control Works in Davao River

(1) DEO to be responsible for the Lower Davao River

The proposed retarding ponds are located somehow between the territory of Davao City DEO and Davao City II DEO as shown in Figure 4.3.1. Usually, the responsible DEO to manage facilities is decided by the location of facilities. If the same practice is applied, some retarding ponds will be managed by Davao City DEO and some others by Davao City II DEO. However, the retarding ponds should be operated in integrated manner to function properly. Considering that the lower Davao River is mostly in the territory of Davao City DEO, it is recommended that Davao City DEO be responsible for all the proposed retarding ponds and the lower reach of the Davao River (Downstream reach from 30km point from the river mouth).



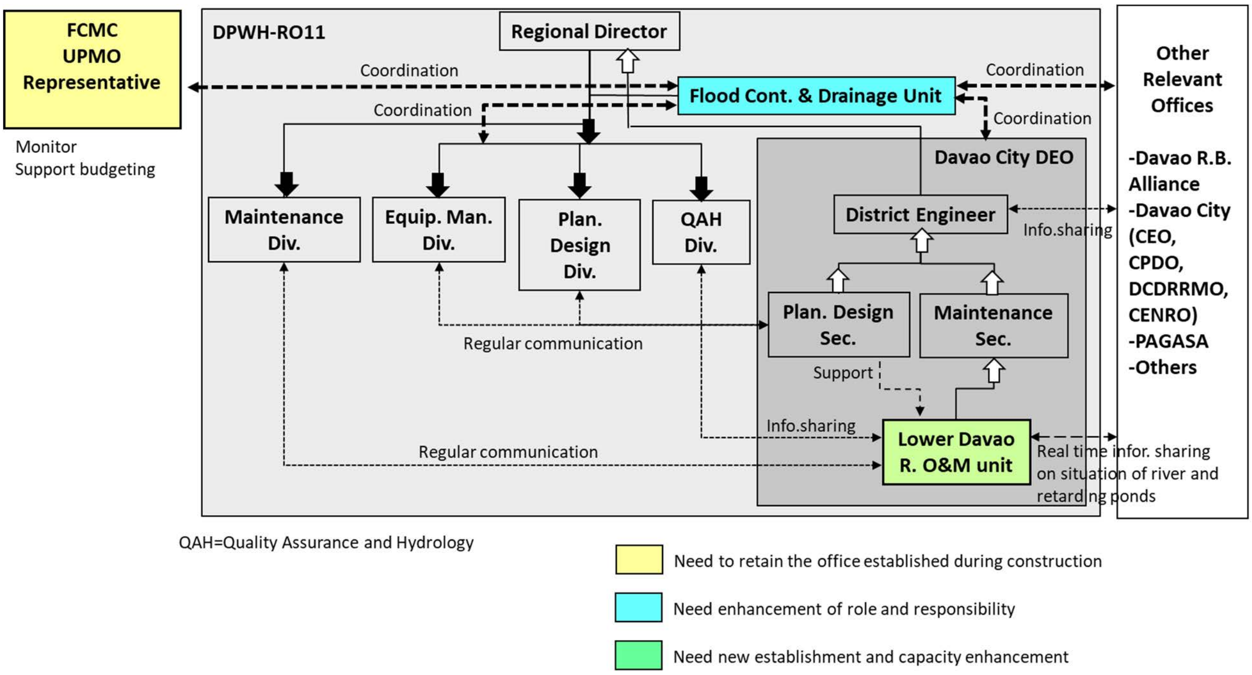
Source: Project Team based on Information from DPWH

Figure 4.3.1 Territory of Davao City DEO and Davao City II DEO

(2) Proposed Organizational Framework for Operation and Maintenance

The proposed organization framework for operation and maintenance is presented in Figure 4.3.2 and the proposed role of each office is shown in Table 4.3.6.

It is proposed to create exclusive new unit which is responsible for the implementation of operation and maintenance of flood control works in the Lower Davao River under the Maintenance Section of Davao City DEO.



Source: Project Team

Figure 4.3.2 Proposed Organization Framework for Operation and Maintenance

Table 4.3.6 Proposed Role of FCMC-PMO, Relevant Divisions, Sections and Units in DPWH-RO and DEO

	UPMO/Division / Section / Unit	Role
FCMC	UPMO	• Monitor O&M activities of the Lower Davao River • Support budgeting for O&M activities, especially for major repair work
RO	Flood Control & Drainage Unit	• Coordinate O&M activities on flood control and drainage among DPWH FCMC-UPMO, RO/DEO and with other relevant offices
	Maintenance Division	• Coordinate and monitor the regular maintenance activities of flood control facilities, including managing inventory of flood control facilities and securing budget for regular and emergent maintenance work • Secure budget for all O&M activities by MOOE (Maintenance and Other Operating Expenses)
	Equipment Management Division	• Maintain dredging equipment • Implement dredging operations
	Planning and Design Division	• Coordinate and monitor the planning and design of major repair works of flood control facilities and maintenance dredging
	Quality Assurance and Hydrology Division	• Manage hydrological data
DEO	Lower Davao River O&M unit	• Conduct regular operation and maintenance activities for Lower Davao River
	Maintenance Section	• Supervise the activities of Lower Davao River O&M unit
	Planning and Design Section	• Support the activities of the Lower Davao River O&M unit, especially for monitoring of river channel • Plan and design of major repair works of flood control structures and maintenance dredging

Source: Project Team

4.3.4 Recommendation

(1) Securing Budget for Operation and Maintenance

To secure necessary budget for the operation and maintenance is one of key issues. On the basis of the discussions with FCMC-UPMO, DPWH-RO XI and Davao City DEO, the followings are recommended.

- Periodic maintenance of major river basins, particularly for maintenance dredging shall be included/funded under MOOE (Maintenance and Other Operating Expenses).
- Standby funds for emergency repair of damaged major flood control facilities due to calamities shall be allocated.
- FCMC-UPMO established during construction shall be retained to monitor and support to secure necessary budget for Operation and Maintenance, especially for major repair work.

(2) Enhancement of Regular Operation and Maintenance

1) Monitoring of river channel change

The cross-section survey should be conducted regular basis. The recommended timing of the cross-section survey is as follows.

- Cross-section survey: every 3 years for 500 m interval from the river mouth to 30km point

In addition to this, the periodical drone video recording should also be conducted. The recommended timing of the drone video recording is as follows.

- Drone video recording: every year and after severe flood event from the river mouth to 30km point

The monitoring of river channel change should be supported by planning section of Davao City DEO.

2) Inspection of flood control facilities

Inspection of flood control facilities should be conducted periodically. The database for inventory of flood control facilities of BOM is just being started operation. Its use should be promoted to ensure proper maintenance. The results of the periodic inspection should be properly stored in the database for further decision making for appropriate maintenance.

3) Monitoring of illegal activities along river channel and quarrying and mining of riverbed by private sector

When periodical inspection of flood control facilities is conducted, situation of illegal activities along river channel and quarrying and mining of riverbed by private sector should also be monitored. Based on the monitoring, necessary recommendation should be provided to the responsible offices for the control of the illegal activities along river channel and quarrying and mining of riverbed by private sector.

4) Collaboration with other relevant offices

The collaboration with other relevant offices is inevitable for the following activities.

a) To control the illegal activities along river channel and quarrying and mining of riverbed by private sector

b) To share information of situation or river and retarding pond

To enhance the collaboration, it is recommended that Memorandum of Agreement (MOA) which describes the responsibility of the relevant offices and Standard Operation Procedure (SOP) for information sharing among relevant offices be prepared and agreed when the project will be implemented.

(3) Procurement of Appropriate Dredging and Other Support Equipment for Davao River

1) River dredger for river mouth of Davao River

The dredger for river mouth of the Davao River, which has been used for long time, is very old and unserviceable. It is recommended to procure the new dredger. The following type is recommended, considering the condition of river mouth for the Davao River.

a) Backhoe on Barge : 1 set

- General specification of backhoe

  Minimum bucket capacity: 4.5m^3, Digging reach: up to 10 to 11m, Digging depth: up to 6m

b) Dumping Scow barge (capacity 300 m^3): 2 units

2) Other Support Equipment

It is recommended to introduce the following equipment to implement proper operation and maintenance of the proposed three retarding ponds.

- Road Grader (Rated power:112kW, Blade length: 12ft) 1unit
- Hydraulic Excavator (Crawler type, Bucket Cap: 1.1m^3） 2units
- Hydraulic Excavator (Wheel Type, Bucket Cap: 0.8m^3） 1unit
- Dumptruck (Capacity 15m^3) 3units
- Payloader Bucket cap.:2.7m^3) 1unit
- Diesel Power Generator (250kW) 1unit
- 4x4 Pick-up (2,400cc)2units
- Multi-purpose Van (2,800cc)1unit
- Orange Peel Grapple (Attachment for Backhoe Crawler Type: Capacity 1.1m^3） 1 unit
- Hydraulic Grapple (Attachment for Backhoe Crawler Type: Capacity 1.1m^3） 1unit

(4) Organizational Strengthening

1) Amendment of roles of Flood Control and Drainage Unit in DPWH-RO XI

The roles of the existing Flood Control and Drainage Unit in DPWH-RO XI is shown in Table 4.3.7.

Table 4.3.7 Roles of Existing Flood Control and Drainage Unit in DPWH-RO XI

1.	Conduct inspection and review of the existing Flood Control and Drainage facilities in coordination with the Planning and Design Division of the Regional Offices, District Offices and Local Governments.
2.	Coordinate with the different District Engineering Offices and LGU's to come up with an inventory of existing Flood Control and Drainage facilities and in the formulation of their Flood Control and Drainage Master Plans.
3.	Come up with recommendations/proposals based on the Master Plan and studies/inspections conducted.
4.	Coordinate and consult with LGU's, district offices and local offices in the formulation of programs and projects to avoid duplication.
5.	Formulate a short and long term Flood Control and Drainage program in coordination with the Planning and Design Division for funding and implementation.
6.	Monitor the implementation of Flood Control and Drainage Projects and maintenance of existing Flood Control and Drainage facilities.
7.	Determine enhancement, mitigating measures that will address drainage problems.

Source: : DPWH-RO XI

To enhance the function of the coordination on the operation and maintenance of flood control works in the Davao River, it is recommended to amend the following role.

- Coordinate operation and maintenance activities on Flood Control and Drainage Works among DPWH-FCMC-UPMO, DPWH Regional Offices and District Offices, and other relevant offices.

2) Allocate funds for additional manpower in view of creation of Lower Davao River Basin O&M Unit in Davao City DEO and enhancement of Flood Control and Drainage Unit in DPWH-RO XI

It is necessary to allocate budget to ensure the following manpower.

a) Lower Davao River Basin O&M Unit

The following new human resources are necessary for proper operation and maintenance for newly installed three retarding ponds as well as Lower Davao River channel.

- 2 Civil Engineers
- 2 Mechanical Engineers
- 2 Service Drivers
- 1 Road Grader Operator
- 1 Payloader Operator
- 3 Backhoe Operators
- 3 Dumptruck Drivers
- 2 Mechanics
- 1 Automotive Electrician
- 12 Labourer/Maintenance Personnel

Among these, if possible, it is recommended that the personnel who lives in/around the project sites are hired for some positions.

b) Flood Control and Drainage Unit in DPWH-RO XI

The following human resources are to be considered for enhancement of the Flood Control and Drainage Unit in DPWH-RO XI.

- 1 clerk
- 2 facilitators
- 2 civil engineers
- 4 surveyors
- 2 database operators (including GIS and CAD)

4.4 Construction Plan and Cost Estimate

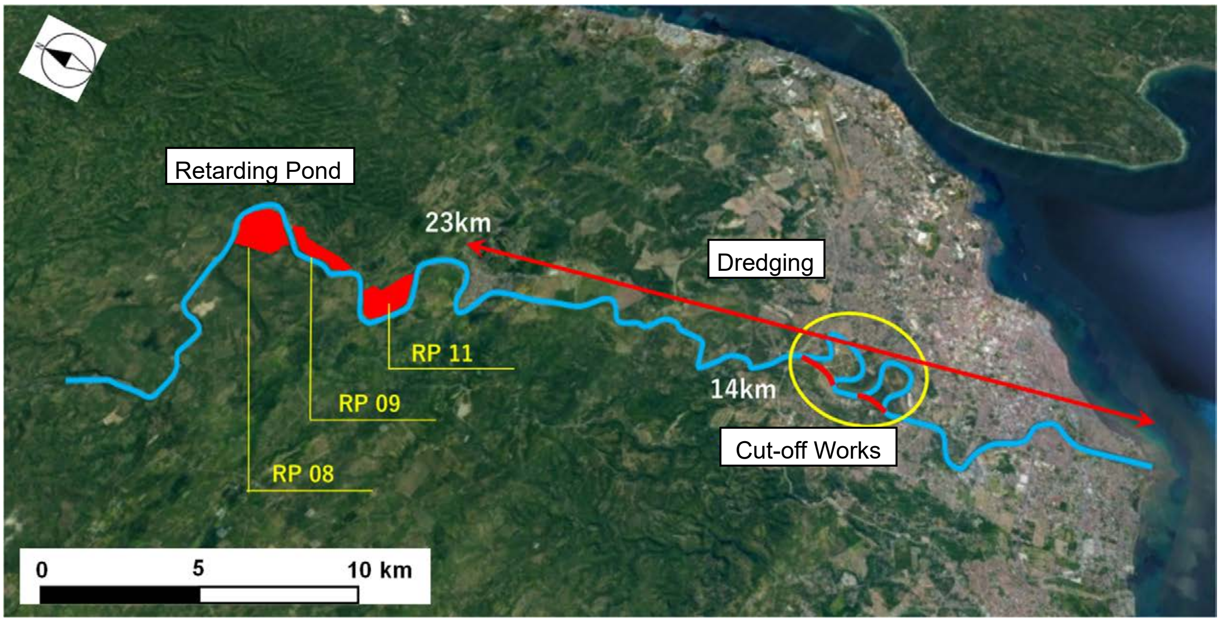
4.4.1 General

This chapter describes the construction plan and cost estimation for the River Channel Dredging, Cut-off and Retarding Pond in the flood control area selected as the priority project for the Davao River, after clarifying the construction procedures based on the local conditions. In the construction planning and cost estimation, the process and construction method should be reviewed in consideration of necessary construction conditions, such as access to the construction site and the method of procurement of materials and equipment. In addition, the applicability and appropriateness of the conditions for the use of Japanese technology (STEP: Special Terms for Economic Partnership) will be investigated. The part of the widening river project subject to pre-F/S (pre-F/S is a pilot study of a part of the project (1.5-4 km and 2.5 km from the river mouth) before the full-scale F/S (F/S of the river channel widening project (1.5-14 km)) is conducted) will be described in Chapter 5.

4.4.2 Construction Plan and Schedule

(1) Scope of Work

For the major works in this project, i.e., River Channel Dredging, Cut-off, and Retarding Pond, the scope of work is shown in Figure 4.4.1, the Summary of the project (Contents of major works) are shown in Table 4.4.1, and the major construction quantities are shown in Table 4.4.2, respectively.



Source: Project Team

Figure 4.4.1 Location of the Project

Table 4.4.1 Summary of the Project

Item	Descriptions	
Dredging	Scope：River Mouth ~ 23km	
	Dredging Volume：1,270,000m^3	
Cut-off	Scope：6+500 – 12+700, Cut-off in meandering river section	
	Excavation Volume： 1,010,100 m^3	
Retarding Ponds	Scope、Location （Distance from River Mouth, Right/ Left bank）：	RP 08: 29.0km (Right bank)
		RP 09: 27.2km (Left bank)
		RP 10: 23.8km (Left bank)
	Excavation Volume：Total 12,171,000 m^3	

Source: Project Team

Table 4.4.2 Quantity of Major Works of the Project

	Item	Unit	Quantity			
			Dredging	Cut-off	Retarding Basin	**Total**
1	Dredging-soils (using Backhoe on Barge)	m3	686,000			686,000
2	Dredging-soils (using Pump Dredger)	m3	584,000			584,000
3	Channel Excavation (Loading and Transportation)	m3	890,000			890,000
4	Embankment (at Disposal area)	m3	890,000	1,001,100	12,090,000	13,981,100
5	Channel Excavation (Excavation-Loading-Transportation)	m3		1,010,100	12,171,000	13,181,100
6	Embankment (for Dike)	m3		9,000	81,000	90,000
7	Concrete Revetment (t=30cm)	m3		14,287	38,001	52,287
8	Gabion (t=50cm) - Foot Protection	m3		6,684	269,841	276,525
9	Concrete Block - Slope Toe Protection	m3		2,001	2,516	4,517
10	RC Wall (Reinforced concrete)	m3		7,514	47,000	54,514
11	RC Wall back-filling (crushed stone)	m3		4,704	268,663	273,367
12	RC Wall base (crushed stone)	m3		729	21,150	21,879
13	Steel Sheet Piles , Furnished	m		8,125		
14	Steel Sheet Piles, for temporary works, without materials	m		8,125		
15	Bridge	LS		1		1
16	Sheet Pile (Slope Protection), Type-3	m			47,000	
17	Sheet Pile (Slope Protection), Type-2	m			268,663	
18	Impermeable Liner	m2			297,151	297,151
19	Installing Drainage Gate	m2			48	48

Source: Project Team

(2) Basic Conditions of Construction Plan

1) Weather Conditions

The climate of the study area belongs to the tropical climate and is classified as a type IV climate classification on the PAGASA climate classification map. Type IV is generally a climate in which precipitation is evenly distributed throughout the year and does not have a dry season similar to climate classification type II, which is distributed along the eastern coast of the Philippines. In addition, Davao City's rainfall trend is heavy from May to late October, and the period with relatively little rainfall is from November to April, but looking at the monthly rainfall, there are years where the rainfall trend differs from the average monthly rainfall trend mentioned above, and the distinction between the rainy season and the dry season is not clear.

2) Working Days

The working days is determined in consideration of Sundays (6 days per week), national holidays, maintenance days for machinery, etc., and days when it is suspended due to rainfall. A list of holidays in the Philippines (example 2022) is shown in Table 4.4.3. The suspension due to rainfall was made in consideration of overlapping days for non-earthmoving work types, with rainfall days of 10 mm/day or more being considered from the rainfall data of the Davao region over the past 30 years (The meteoblue climate diagrams). The probability of rain on the working day was calculated and subtracted from the working day. Table 4.4.4 shows the rainfall data for Davao City over the past 30 years. Table 4.4.5 shows the number of days that can be constructed by month for each type of work excluding earthwork determined by the above method. Holidays are determined in consideration of local conditions as shown in Table 4.4.3, and the one day per a month for maintenance was also considered.

As for earthworks (excavators, embankments, sheet work, drainage canal work, road work), if the daily rainfall is 20 to 50 mm (20 mm or more), the next day's construction will not be possible, and 8 days/year will be added to the non-working day.

Table 4.4.6 summarizes the number of days that can be constructed per year to be used in the preparation of the construction plan for this project. The target types of work were excavation work, dredging work, embankment work (including soil disposal work), concrete work, revetment work, drainage work, and road work.

Table 4.4.3 Holidays in the Philippines (As an example in 2022)

Event	Date		Event	Date
A. REGULAR HOLIDAYS			**B. SPECIAL (NON-WORKING) HOLIDAYS**	
New Year's Day	January 1 (Sat)		Chinese New Year	February 1 (Tue)
Araw ng Kagitingan	April 9 (Sat)		EDSA People Power Revolution Anniversary	February 25 (Fri)
Maundy Thursday	April 14		Black Saturday	April 16
Good Friday	April 15		Ninoy Aquino Day	August 21 (Sun)
Labor Day	May 1 (Sun)		All Saints' Day	November 1 (Tue)
Independence Day	June 12 (Sun)		Feast of the Immaculate Conception of Mary	December 8 (Thu)
National Heroes Day	August 29 (Mon)		**C. SPECIAL (WORKING) HOLIDAYS**	
Bonifacio Day	November 30 (Wed)		All Souls' Day	November 2 (Wed)
Christmas Day	December 25 (Sun)		Christmas Eve	December 24 (Sat)
Rizal Day	December 30 (Fri)		Last Day of the Year	December 31 (Sat)

Source: https://www.officialgazette.gov.ph/nationwide-holidays/

Table 4.4.4 Rainfall Data for Davao City over the Past 30 Years

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
50-100mm	0.1	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	1
20-50mm	0.7	0.7	0.6	0.3	0.6	0.9	0.3	0.5	0.4	0.3	0.8	0.5	7
10-20mm	2.0	1.5	1.5	2.2	3.0	4.0	2.5	2.1	2.3	2.7	2.8	1.9	29
5-10mm	3.2	2.5	2.4	3.3	6.2	5.6	5.0	3.9	3.7	5.5	5.2	4.0	51
2-5mm	3.7	3.5	4.4	4.6	7.2	7.4	7.5	6.2	5.7	7.6	7.5	5.2	71
<2mm	6.7	5.9	7.2	8.1	8.3	6.9	8.5	9.2	8.7	8.2	7.9	7.1	93
Dry days	14.6	13.7	14.7	11.5	5.7	5.0	7.2	9.1	9.2	6.6	5.7	12.3	115
>10mm	2.8	2.3	2.3	2.5	3.6	5.0	2.8	2.6	2.7	3.0	3.7	2.4	36

Source: https://www.meteoblue.com/

Table 4.4.5 The Number of Workable Days per Month Excluding Earthwork

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1)	Calendar Days	31	28	31	30	31	30	31	31	30	31	30	31	365
2)	Sunday or National Holiday	5	6	5	8	5	6	4	6	5	4	7	9	70
	Reglar holidays	1	0	0	3	1	1	0	1	0	0	1	2	10
	Special (non-working) holidays	0	2	0	1	0	0	0	1	0	0	1	1	6
	Special (working) holidays (in Dec only)	0	0	0	0	0	0	0	0	0	0	0	2	2
	Sunday	4	4	5	4	4	5	4	4	5	4	5	4	52
3)	Machine Maintenance Day	1	1	1	1	1	1	1	1	1	1	1	1	12
4)	Rainy Days(>10mm)	2.8	2.3	2.3	2.5	3.6	5.0	2.8	2.6	2.7	3.0	3.7	2.4	36
5)	Rainy Days on Non-Working Day 4) x Ratio of rainiy day (=0.1~ 4)/1))	0.3	0.2	0.2	0.3	0.4	0.5	0.3	0.3	0.3	0.3	0.4	0.2	4
6)	Total Unable Working Days 2)+ 3)+ 4)- 5)	9	9	8	11	9	12	8	9	8	8	11	12	114
7)	Workable Days 1) - 6)	22	19	23	19	22	19	23	22	22	23	19	19	251

Source: Project Team

Table 4.4.6 Workable Days of Each Type of Work in a Year

	Sunday	Holiday	Machine Maintenance Day	Rainy Day (>10mm)	Rainy Days on Non-Working Day	Rainy Days on Working Day	Additional Suspended Day	Workable Day / Year
Structural Excavation	52	18	12	36	4	32	8	243
Dredging	52	18	12	36	4	32	0	251
Embankment/ Backfill	52	18	12	36	4	32	8	243
Concrete Works	52	18	12	36	4	32	0	251
Revetment Works	52	18	12	36	4	32	0	251
Drainage Works	52	18	12	36	4	32	8	243
Road Works	52	18	12	36	4	32	8	243

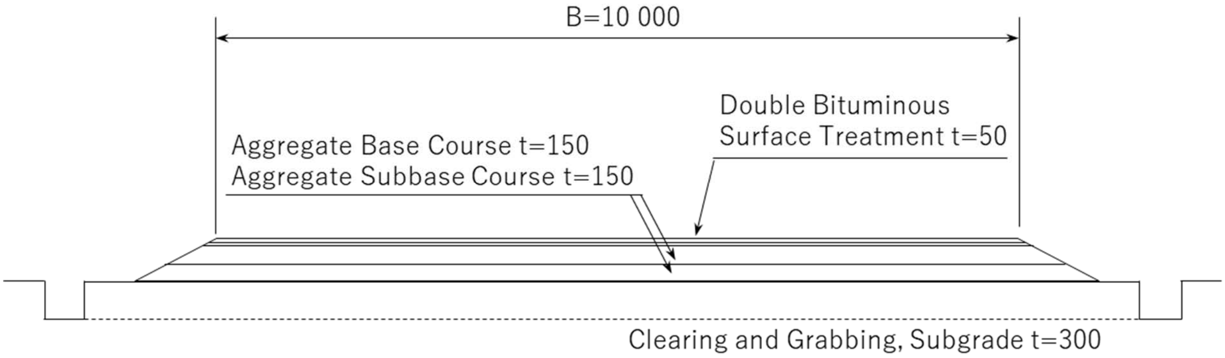
Source: Project Team

3) Working Hours

In consideration of the normal working hours in the Philippines, the working hours shall be set at 8 hours per day. The actual work time for each type of work takes into account the time required for preparation and tidying up works.

4) Access Road

The construction site under this plan is located along the Davao River, and a construction access road will be required from the main road to the construction site and along the river. The width of the road is assumed to be 10 m. Due to the large volume of earthwork in this project, the road will need to be widened and repaired as necessary to allow smooth operation of the required number of dump trucks. In particular, a construction road to carry out excavated soil from the Retarding Pond will be planned as an important temporary facility for the construction. The typical cross section of the construction access road is shown in Figure 4.4.2.



Source: Project Team

Figure 4.4.2 Typical Cross Section of the Construction Access Road

5) Disposal Sites

The project will generate a large amount of excavated sediment due to the large amount of excavation work to be performed. The total volume is about 14 million m^3 in Dredging, Cut-off, and Retarding Pond.

The locations of the disposal sites are to be determined by DPWH prior to the start of construction. However, candidate sites are proposed here for reference. During the Dredging, sediment is temporarily placed in the vicinity of the construction site to dry, but a final soil disposal area will be needed to dispose of the excavated soil and dry dredged material. Currently, possible candidate soil dumping sites are Option 1 through Option 4, and a summary of each is shown below.

Option 1: Existing/Planned Disposal Sites

The existing or planned disposal sites are determined on a construction-by-construction basis and are already assigned to each project; therefore, they will be difficult to be used for this project.

Option 2: Residential Land Development and Other Future Projects

Potential embankment sites may arise that could be used for future residential land development or other projects. In particular, the potential for use in residential land development may be high, but it is not possible to identify the location or predict the amount of soil to be used at this time.

Option 3: Coastal Reclamation

A proposal for coastal reclamation in Davao City was considered. For the eight low elevation coastal reclamation parcels shown in Figure 4.4.3, the amount of soil used would be approximately 940,000 m^3 if fill were to be placed to 1.5 m above mean sea level. This is very small compared to the total excavation volume and cannot be used as the main soil disposal site.

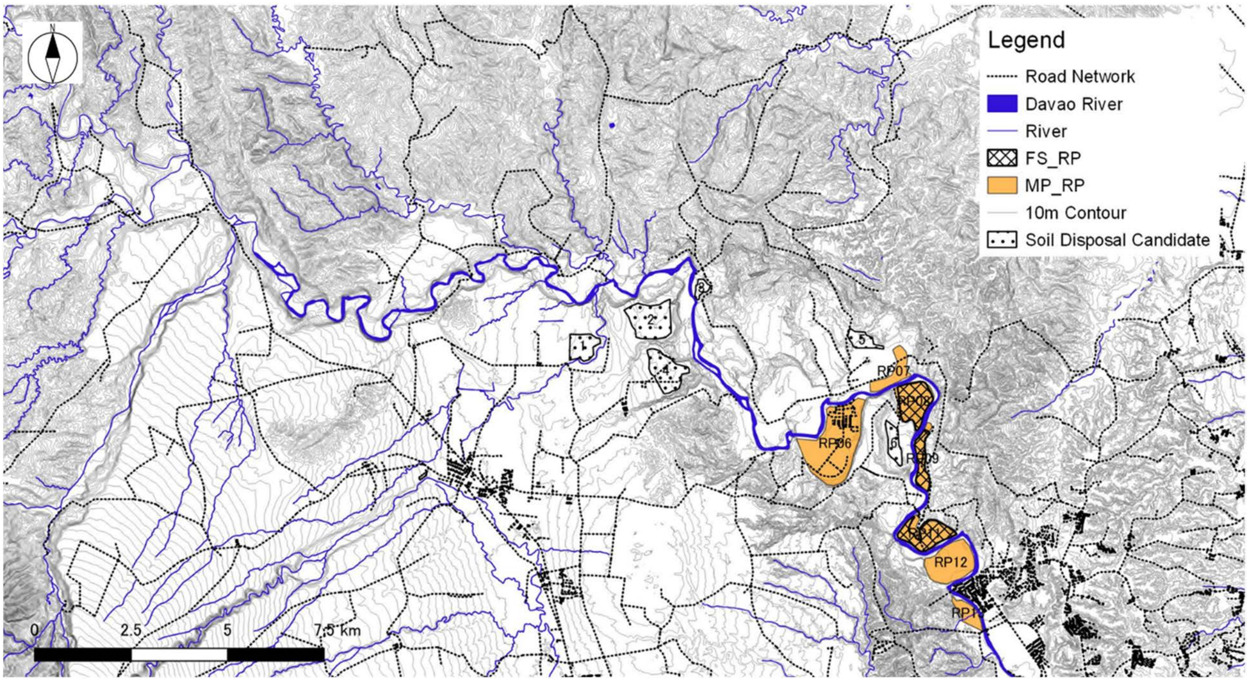
Source: Project Team

Figure 4.4.3 Potential Reclamation Locations along the Davao Coast

Option 4: New Disposal Sites

New disposal sites were considered, and the current proposed candidates (first preference candidates) are shown in Figure 4.4.4 and their list is shown in Table 4.4.7. In the study, natural environmental sensitivity, social environmental considerations, current land use, future land use (CLUP 2019-2028), inundation conditions during major floods, and the fact that the area can be used as natural floodplain and should not be developed were taken into account. The total area of No. 1 to No. 6 shown in the figure is 2,680,000 m^2, which provides a capacity of about 15,000,000 m^3.

If it is considered difficult to secure these disposal sites, which are the first preference candidates, we further propose No. 7 to 10 as second candidates (Figure 4.4.5). These candidate areas will pose somewhat more difficulties than the first preference candidate due to the longer hauling distances, slightly higher natural environmental sensitivity, and more expensive drainage measures due to reclamation into the valley.



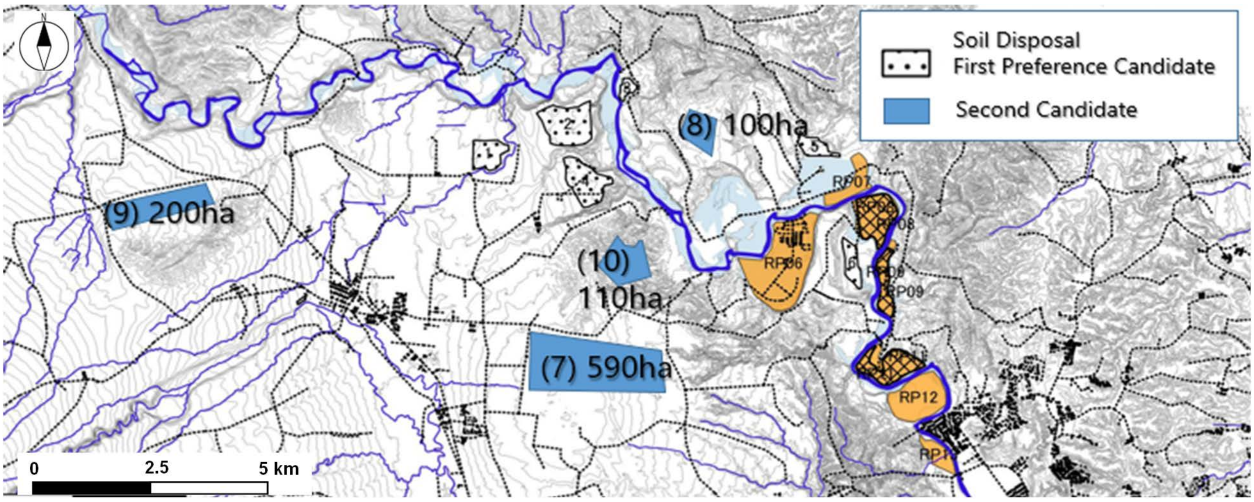
Source: Project Team

Figure 4.4.4 Potential Disposal Sites upstream of the Davao River (First Preference Candidate)

Table 4.4.7 List of the New Disposal Sites (First Preference Candidate)

	1	2	3	4	5	6
Plane View						
Area (m^2)	420,000	900,000	120,000	700,000	250,000	290,000
	2,680,000					

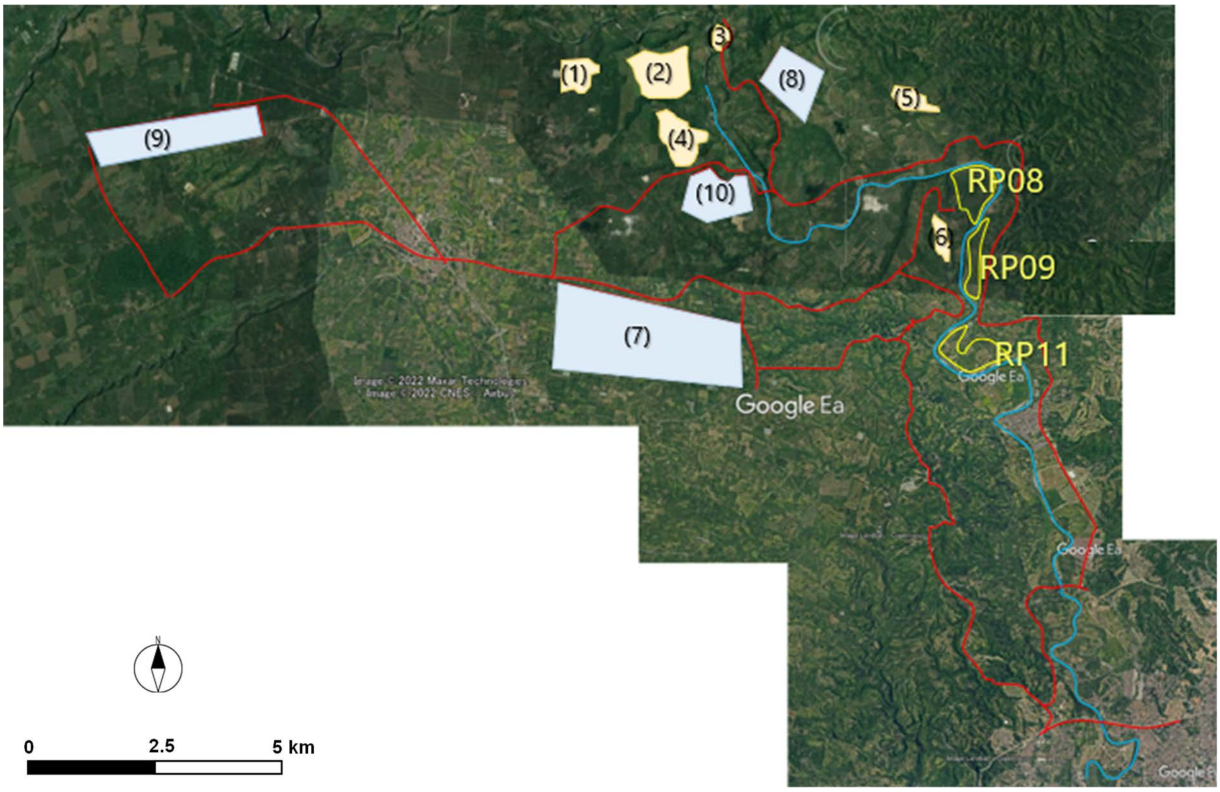
Source: Project Team



Source: Project Team

Figure 4.4.5 Potential Disposal Sites upstream of the Davao River (Second Candidate)

The access roads to each of these potential disposal sites are shown in Figure 4.4.6. The largest amount of excavation is in the Retarding Ponds, with RP08 on the right bank side and RP09 and RP10 on the left bank side, with about half of the excavated sediment divided between the left and right banks. The most of the current candidate disposal sites are on the right bank side, and it is necessary to develop an optimum soil transport plan for the disposal sites that become available. The left bank has a main road suitable for the transport of dump trucks, but the right bank is currently difficult to access by dump trucks in large numbers. Therefore, it is necessary to construct a construction road using the materials excavated at the sites.



Source: Project Team

Figure 4.4.6 Access Road to the Disposal Sites

Although the above four options have been discussed, from the viewpoint of certainty, the use of the six new disposal sites (plus additional four sites will also be considered) indicated in Option 4 is the basic approach, and if the timing of construction allows for effective use of excavated earth in the future, such as in the development of residential land in Option 2, then such soil transportation plan will be conducted.

(3) Labor, Equipment and Material for Construction

1) Labor

All labor can be procured in Davao City and surrounding cities.

2) Equipment

Most of the equipment can be procured in Davao City, surrounding cities, and in the Philippines. As for dredgers and dredging machines, it is possible to obtain them from Japan or third countries from the viewpoint of construction efficiency.

3) Material

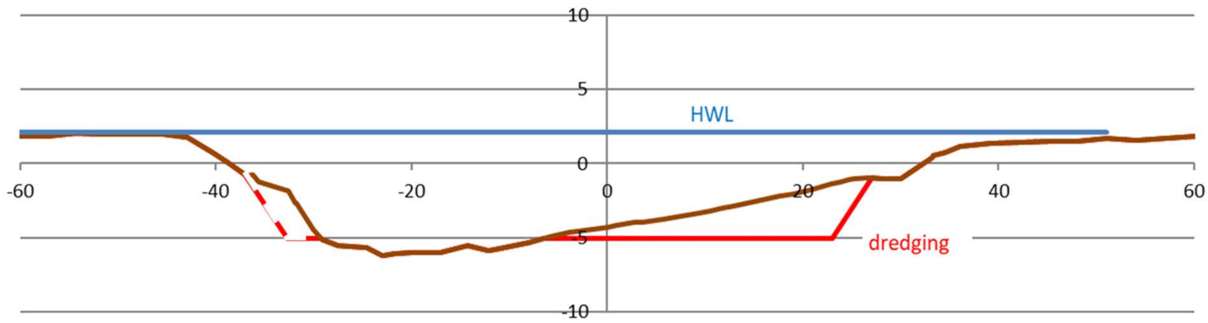
Most of the materials such as revetment can be procured in Davao City, surrounding cities, and in the Philippines. However, materials that are not manufactured in the Philippines, such as through-slap gates made of steel or duplex stainless steel, hat-type steel sheet piles, etc., which may be possible by utilizing foreign technology, shall be obtained from Japan or a third country.

(4) Construction Method

1) Dredging

a) General

The dredging area is 23 km from the mouth of the river. The dredging will be performed at each cross-section of the river to excavate a section higher than the design riverbed to provide the required cross-section. A typical cross-section is shown in Figure 4.4.7. Table 4.4.8 shows the dredging quantities calculated from the cross-sections every 500 m. There are six bridges in the construction area, and dredging will not be conducted for 100m upstream and downstream of the bridges for safety reasons.



Source: Project Team

Figure 4.4.7 Typical Cross-section for Dredging

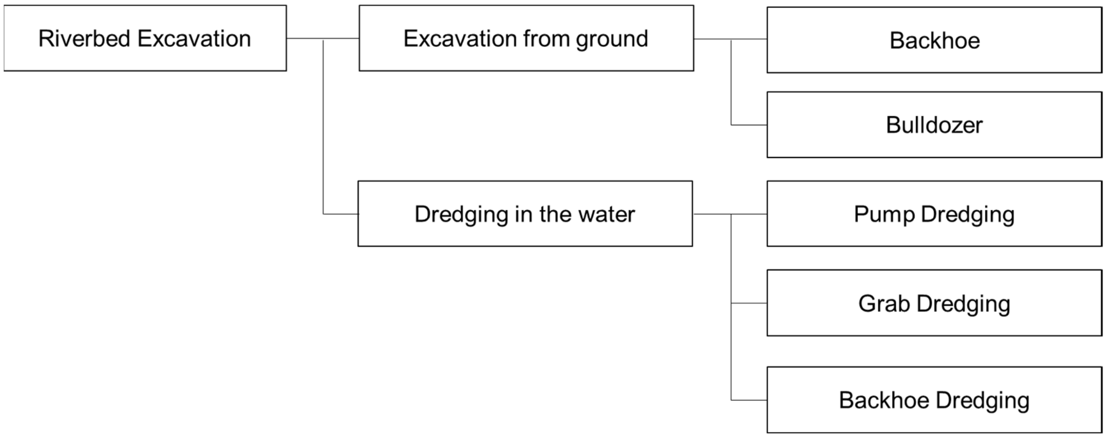
Table 4.4.8 Quantity of Dredging

No	station	Structures	Design Sectional Distance (m)	Cumlative Distance (m)	Dredging Area (m2)	Dredging Volume (m3)	No	station	Structures	Design Sectional Distance (m)	Cumlative Distance (m)	Dredging Area (m2)	Dredging Volume (m3)
1	STA 0+000		0	0	0.000		28	STA 12+675		237	8,386	161.950	112,555
2	STA 0+500		500	500	306.556	76,639	29	STA 12+975	Davao River Brd.	300	8,686	161.950	48,585
3	STA 1+000		500	1,000	92.820	99,844	30	STA 13+500		525	9,211	14.751	46,384
4	STA 1+522	Bolton Brd. D	522	1,522	38.066	34,161	31	STA 14+000		500	9,711	31.209	11,490
5	STA 1+561	Bolton Brd. U	39	1,561	46.896	1,657	32	STA 14+500		500	10,211	92.820	31,007
6	STA 2+000		439	2,000	59.645	23,386	33	STA 15+000		500	10,711	76.520	42,335
7	STA 2+500		500	2,500	168.292	56,984	34	STA 15+500		500	11,211	123.558	50,020
8	STA 2+664	Gov.Generoso Brd. D	164	2,664	58.721	18,615	35	STA 16+000		500	11,711	87.545	52,776
9	STA 2+710	Gov.Generoso Brd. U	46	2,710	57.046	2,663	36	STA 16+500		500	12,211	55.876	35,855
10	STA 3+000		290	3,000	143.321	29,053	37	STA 16+750		250	12,461	35.576	11,432
11	STA 3+500		500	3,500	161.201	76,131	38	STA 17+147	Waan Brd.	397	12,858	42.929	15,583
12	STA 4+000		500	4,000	137.450	74,663	39	STA 17+500		353	13,211	66.977	19,398
13	STA 4+500		500	4,500	79.255	54,176	40	STA 18+000		500	13,711	28.964	23,985
14	STA 5+000		500	5,000	73.928	38,296	41	STA 18+500		500	14,211	14.144	10,777
15	STA 5+500		500	5,500	54.380	32,077	42	STA 18+980		480	14,691	9.742	5,733
16	STA 5+929	F.Torres Brd.	429	5,929	14.828	14,845	43	STA 19+132	Sta.Lucia Brd.	152	14,843	33.379	3,277
17	STA 6+500		571	6,500	34.756	14,156	44	STA 19+500		368	15,211	8.056	7,624
18	(STA 7+030.2)		90	6,590	397.646	Short-Cut	45	STA 20+000		500	15,711	51.070	14,782
19	(STA 7+573.4)		90	6,681	449.969	Short-Cut	46	STA 20+500		500	16,211	20.523	17,898
20	(STA 8+116.6)		90	6,771	489.886	Short-Cut	47	STA 21+000		500	16,711	35.770	14,073
21	(STA 8+659.8)		90	6,862	563.485	Short-Cut	48	STA 21+500		500	17,211	125.708	40,370
22	(STA 9+260)		102	6,964	346.132	Short-Cut	49	STA 22+020		520	17,731	80.566	53,631
23	STA 9+480		220	7,184	346.132	Short-Cut	50	STA 22+500		480	18,211	16.788	23,365
24	(STA 9+873)		393	7,577	346.132	Short-Cut	51	STA 23+000		500	18,711	17.847	8,659
25	(STA 10+472.2)		172	7,749	628.423	Short-Cut							
26	(STA 11+188.4)		200	7,949	633.705	Short-Cut							
27	(STA 11+904.7)		200	8,149	787.617	Short-Cut			Average Area			79.1	
									Sub-Total	17,062		7,911	1,349,000
									Diduction around Bridges		79.1x5x200=		79,000
									Total Dredging Volume				1,270,000

Source: Project Team

b) Dredging Method

The dredging will be estimated to taken up to 7 years. The amount of dredging is approximately 1,270,000 m^3, which means that approximately 200,000 m^3 will be dredged per year. The construction period is 251 days, which means that more than 800m^3/day will be dredged. The methods of riverbed excavation are classified as shown in Figure 4.4.8 as an example, but in this project, underwater dredging will be the main type of work. Underwater dredging may be performed by either a pump dredger (Cutter Suction Dredger), grab dredger, or backhoe dredger as shown in Figure 4.4.9.



Source: River Structure Design Guidelines, Chubu Regional Development Bureau & Project Team

Figure 4.4.8 Methods for Riverbed Excavation


Pump Dredger


Grab Dredger


Backhoe Dredger

Source: River Structure Design Guidelines, Chubu Regional Development Bureau

Figure 4.4.9 Images of Riverbed Excavation

In selecting a dredging method for riverbed excavation, conditions such as water depth, daily construction volume, and physical properties of the sediment to be dredged, i.e., maximum grain size and hardness of the ground, are considered. Table 4.4.9 shows a summary of these conditions, based on data from the Sediment Research Institute and the Ministry of Land, Infrastructure, Transport and Tourism. Regarding the daily workload, pump dredgers are advantageous in terms of efficiency and economy when the daily workload exceeds 1,000 m^3 per day. However, backhoe dredging can also be used if the number of sets is increased. As for the method selection based on the soil type and N-value of the riverbed, in general, any method is applicable for silt and sandy soil, while backhoe dredging, and grab dredging are applied when gravel is included. However, "Sand Pump (Submerged Dredging Pump)" that can dredge with gravel are also used in practice.

Table 4.4.9 Applicable Range of Dredging Method

Water Depth	～1m	1～5m	5～10m	10～20m	Over 25m	
Backhoe Dredger	←	—	→			
Grab Dredger	←	—	—	—	→	
Small Pump Dredger	←	—	→			
Dredging volume per day	50m^3～	100m^3～	500m^3～	1000m^3～	Over 3000m^3	
Backhoe Dredger	←	—	→			
Grab Dredger	←	—	→			
Small Pump Dredger			←	→		
Diameter of Sediment (mm)	～0.005 Clay	～0.075 Silt	～0.25 Fine	～2 Coarse	～75 Gravel	
Backhoe Dredger	←	—	—	—	→	
Grab Dredger	←	—	—	—	→	
Small Pump Dredger	←	—	—	—	→	
Properties of Sediment	Clay-based Sediment		Sand-based Sediment		Graveled Sediment	
N Value	<30	30-50	<30	30-50	<30	30-50
Backhoe Dredger	←	—	—	—	—	→
Grab Dredger	For ordinary ground ←	For hard ground —	For ordinary ground —	For hard ground —	For ordinary ground —	For hard ground →
Small Pump Dredger	←	—	—	→		

Source: "River Structure Design Guidelines" , Chubu Regional Development Bureau, MLIT, "Outline of Dam Sediment Control Methods", Japan Sediment Research Institute (https://doshaken.com/event/images/pdf/H26_presen2.pdf) and Project Team

In the case of the Davao River, generally upstream of 15 km from the river mouth, the D50 (50% passing grain size, average grain size) is 2 to 10 mm in areas where gravel is abundant, and D50 is about 0.1 mm in other areas composed of clay, silt and sand; some coarse-grained material is also present around 10 km. The geologic data around 0+800k (right bank) shows loose silty sand with N values of 4 ~ 13 at about 6 m below the surface, and medium to hard silty sand with N values of 14 ~ 41 about 5m below that. (Refer to 2.6.1)

Based on the above, pump dredging is applied to the section of silty and sandy soil up to 10 km from the river mouth, and backhoe dredging, which is considered to be versatile and easy to obtain equipment, is applied to the section upstream of that where gravel is mixed, as a recommended proposal. The dredged material is dried in a temporary storage area, loaded onto dump trucks, transported to a designated soil disposal sites, and spread out (or compacted, depending on the location) for fill and reclamation. These types of work, i.e., loading and hauling, and the quantity of soil to be spread and filled, are considered as 30% loss during dredging processes. The payment of the dredging shall be based on the profile survey of the riverbed for dredging of the riverbed, and on the profile survey at the fill location for loading and transportation and leveling fill. Table 4.4.10 shows the dredging quantities by dredging method.

Table 4.4.10 Quantities by Dredging Method

Item	Unit	Dredging (Using Cutter Suction Dredger)	Dredging (Using Backhoe on Barge)
Scope		River Mouth ～ 10.0km	10.0 ～ 23.0km
Sub-Total	(m^3)	647,000	702,000
Deduction (Bridge Area)	(m^3)	63,000	16,000
Dredging Total Quantity	(m^3)	584,000	686,000
		1,270,000	
Loading, Transportation	(m^3)	890,000	
Embankment (at Disposal area)	(m^3)	890,000	

Source: Project Team

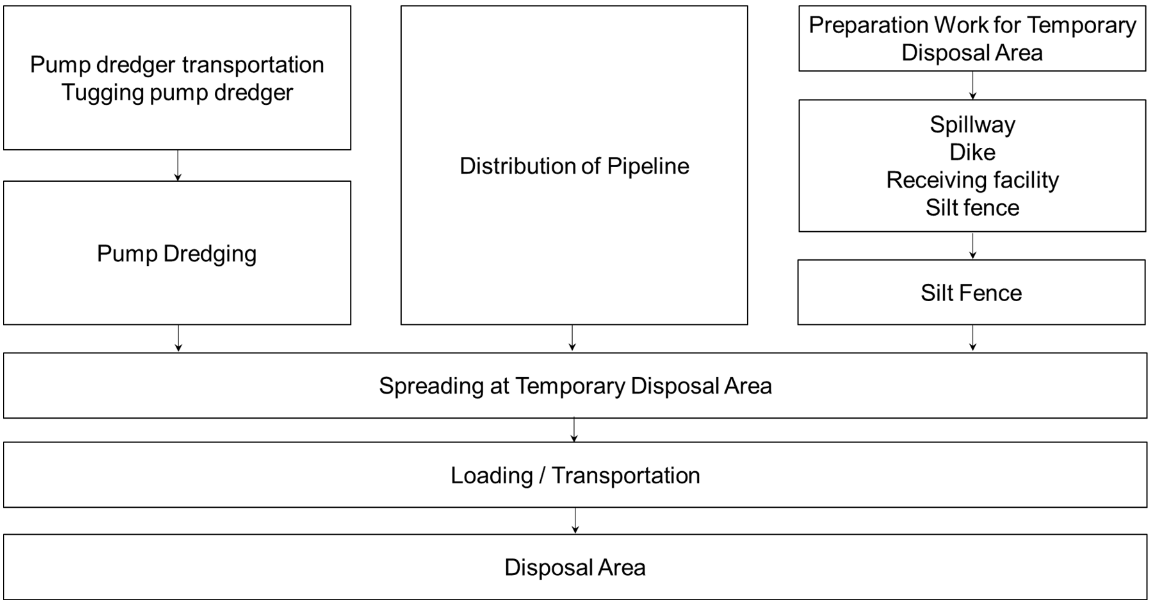
Since the dredging method will actually be adopted by the contractor's specialty, other methods such as Grab Dredging and Sand Pump Dredging (Submerged Dredging Pump) that can dredge gravel are also likely to be used. Ejector pump, a Japanese technology, may also be applied.

Maintenance dredging is planned after the F/S project is implemented.

In discussions with DPWH BOE and RO XI, backhoe dredging is recommended because of the difficulty of flood countermeasures for pump dredging, and the purchase of backhoe deck barges and dump trucks are being considered. Although backhoe dredging is more expensive due to its lower construction efficiency, it can be adopted as a reliable method. On the other hand, if other construction methods, such as dredgers owned by the contractor, can be used at a lower cost, then the adoption of these methods should be actively considered.

c) Pump Dredging (River mouth ~ St. 10 km)

The construction flow of pump dredging is as follows: Transport and Setting of Pump Dredger → installation of Sediment Discharge Basin → Dredging by Pump Dredger → Transfer to Sediment Discharge Basin by Discharge Pipeline → Loading of Dredged Soil (Dry Soil) by Backhoe → Transport of Dredged Soil → Levelling and Compaction at the Disposal Site. Figure 4.4.10 shows the Flow Chart of dredging by pump dredger.



Source: River Earthworks Manual, Japan Institute of Country-ology and Engineering, (JICE) & Project Team

Figure 4.4.10 Implementation Flow Chart of Pump Dredging

In addition to the Cutter Suction Dredgers which DPWH possesses, Micro-Pump Dredgers as shown in the left figure in Figure 4.4.11 and Mud-Pump Dredger as shown in the right can be also applied to this river. Micro-pump dredgers can excavate and remove soft bottom sediments, and have the ability to excavate, discharge sediment, and operate the barge using a single motor. Mud-Pump Dredger is somehow larger dredger, and depending on the pumping and transportation method, they are classified as Sludge Pumping Dredgers, High Concentration Pumping Dredgers or Pneumatic Transmission Pumping Dredgers, etc.

Micro-Pump Dredger

Mud-Pump Dredger

Source: River Earthworks Manual, Japan Institute of Country-ology and Engineering, (JICE) & Project Team

Figure 4.4.11 Images of Other Pump Dredgers

The diameter of the sand distribution pipe from the pump dredger is 200 mm to 400 mm, depending on the scale of dredging pump. Depending on the location (above water, in shallow water, or on land), the sand discharge pipe should be equipped with an appropriate setting frame.

The dredged material is transported to a temporary sand basin. The sand basin will be located along the river, but the maximum length of the sand drainage pipe will be about 1500 m because too long pipe length will reduce the construction efficiency due to resistance in the pipe. Therefore, if dredging is to be conducted in a 10 km section from the mouth of the river, four sand removal ponds should be installed. Assuming that the daily construction volume is 800m^3, the capacity of the sand drainage ponds is 16,000m^3 for one day, assuming a sand content of 5%. Assuming a depth of 2 m on average, the size would be 20 m x 400 m. Figure 4.4.12 shows an image of the sand drainage basin and piping. The sand drainage basin will also be equipped with a surplus water discharge for surplus water treatment. The excess water will be discharged into the river after appropriate treatment, such as installing a separate sedimentation tank or using a coagulant.

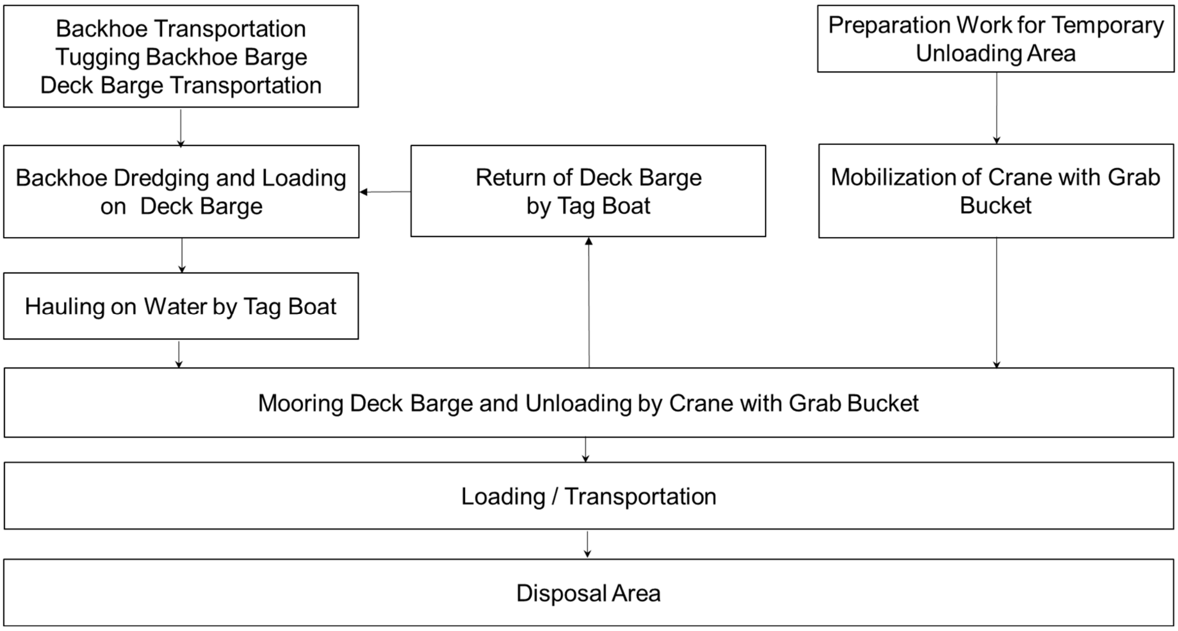
Source: River Earthworks Manual, Japan Institute of Country-ology and Engineering, (JICE) & Project Team

Figure 4.4.12 Images of Sediment Transportation Pipeline

d) Backhoe Dredging (St. 10 km ~ 23 km)

The backhoe dredging process is as follows: Backhoe Dredger Transport → Installation of Sediment Pond → Installation of Anti-pollution (Silt) Fences → Dredging by Backhoe → Transport of Sediment to Landing site by Sediment Transport Barge → Landing by Grab Bucket (or Pumping with Air) → Loading of (Dry Sediment) Dredged Sediment into Dump Truck by Backhoe → Transport of Dredged Sediment by Dump Truck → Spreading and Compaction at the Disposal Site. Figure 4.4.13

shows the implementation flow chart by Backhoe Dredging. Then, Figure 4.4.14 shows an image of the Backhoe Dredging.



Source: River Earthworks Manual, Japan Institute of Country-ology and Engineering, (JICE) & Project Team

Figure 4.4.13 Implementation Flow Chart of Backhoe Dredging

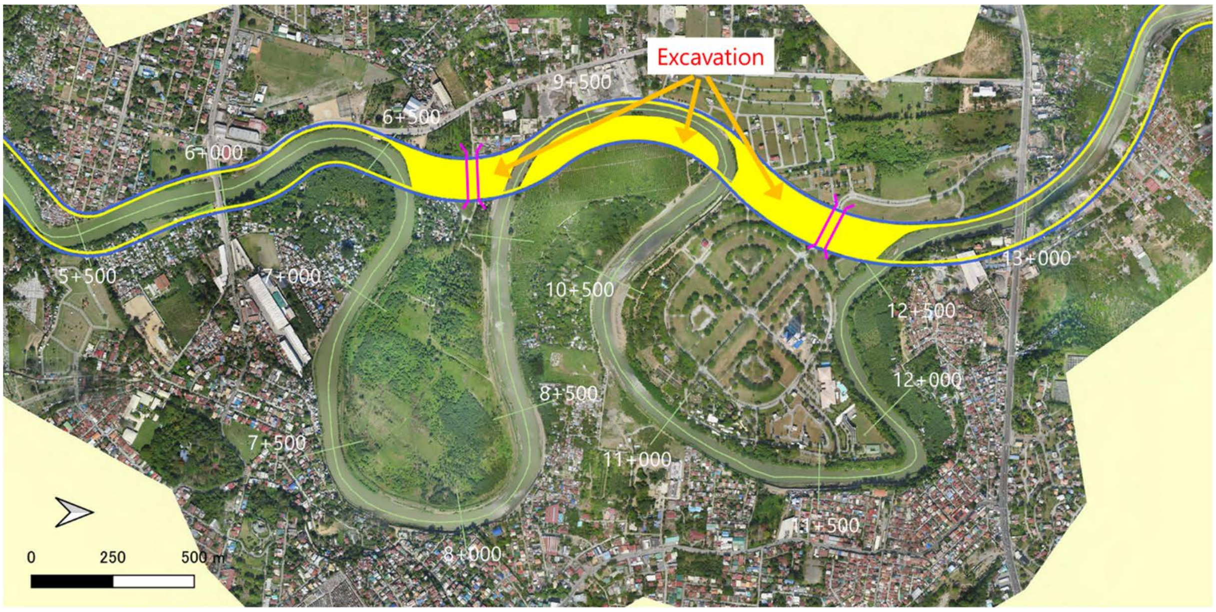
Source: River Earthworks Manual, Japan Institute of Country-ology and Engineering, (JICE) & Project Team

Figure 4.4.14 Image of Backhoe Dredging

2) Cut-off

a) General

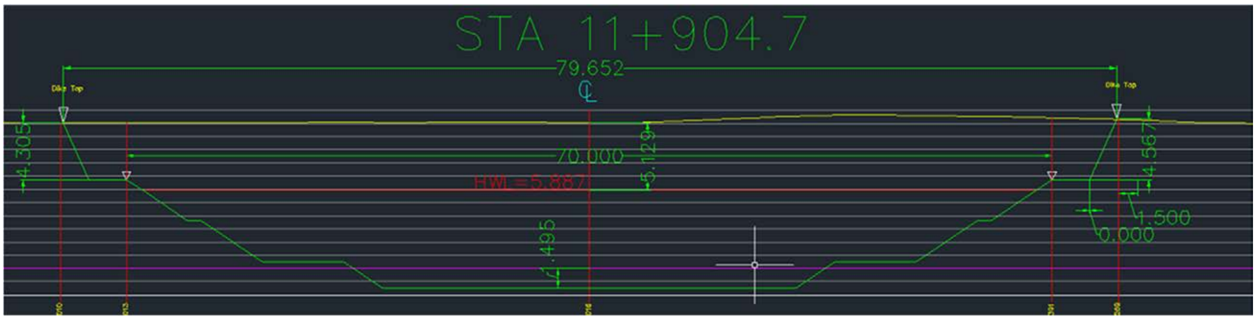
The Cut-off is a project for the meandering sections of the river, and the targeted section is from 6+500 to 12+700. The construction area is divided into three major blocks: upstream Cut-off, middle left bank channel widening, and downstream Cut-off. Figure 4.4.15 shows the scope of the Cut-off.



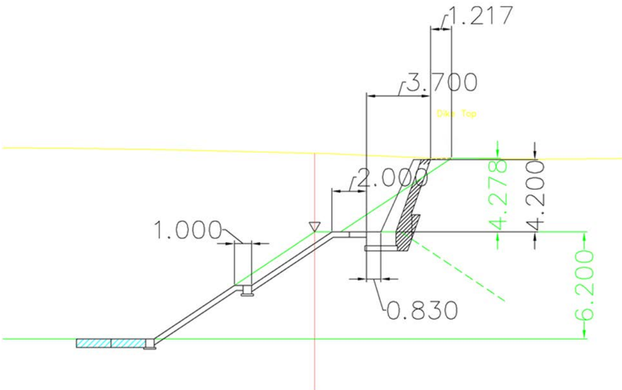
Source: Project Team

Figure 4.4.15 Location of Cut-off

Typical cross sections of the River Widening and Cut-off sections are shown in Figure 4.4.16. The construction quantities for the shortcut sections are also shown in Table 4.4.11.



(General)



(Revetment in Detail)

Source: Project Team

Figure 4.4.16 Typical Cross-section of Cut-off

Table 4.4.11 Quantity of Cut-off

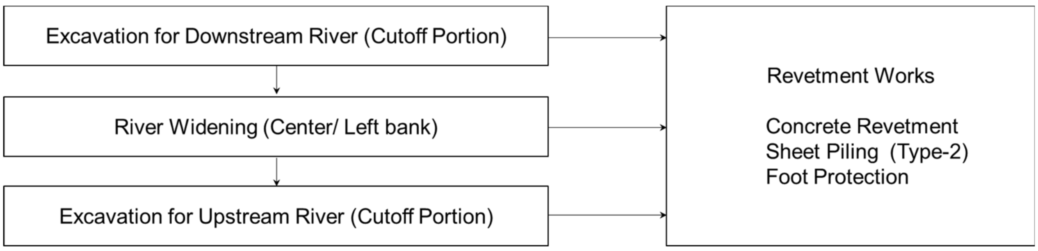
Item			Total
1	Channel Excavation (Excavation-Loading-Transportation)	m3	1,010,100
2	Embankment (for Dike)	m3	9,000
3	Embankment (at Disposal area)	m3	1,001,100
4	Concrete Revetment (t=30cm)	m3	14,287
5	Gabion (t=50cm) - Foot Protection	m3	6,684
6	Concrete Block - Slope Toe Protection	m3	2,001
7	RC Wall (Reinforced concrete)	m3	7,514
8	RC Wall back-filling (crushed stone)	m3	4,704
9	RC Wall base (crushed stone)	m3	729
10	Steel Sheet Piles , Furnished	m	8,125
11	Steel Sheet Piles, for temporary works, without materials	m	8,125

Source: Project Team

b) Construction Flow Chart

In the area where the Cut-off is to be implemented, the roads will be divided by the river, so that bridges will be constructed. To ensure economical way, construction should be performed prior to the diversion.

Construction of the Cut-off section will be done from the downstream side. The channel widening and Cut-off will be done by excavation followed by installing revetment. During the construction, the procedure should be carried out to prevent water from entering the construction area, and excavation should be conducted in the driest condition possible. Figure 4.4.17 shows the construction flow chart. The construction procedure for the revetment work in the channel widening section will be carried out according to the method shown in the Master Plan (Figure 3.11.5 River Widening Work). Since excavation is to be carried out in dry conditions, temporary closure using steel sheet piles, etc., should be implemented as necessary to complete the excavation of the portion necessary to construct the revetment. The sediment remaining on the riverbed will be dredged underwater after the temporary closure is removed. After excavation of the revetment area is completed, revetment mats and concrete revetment will be constructed.

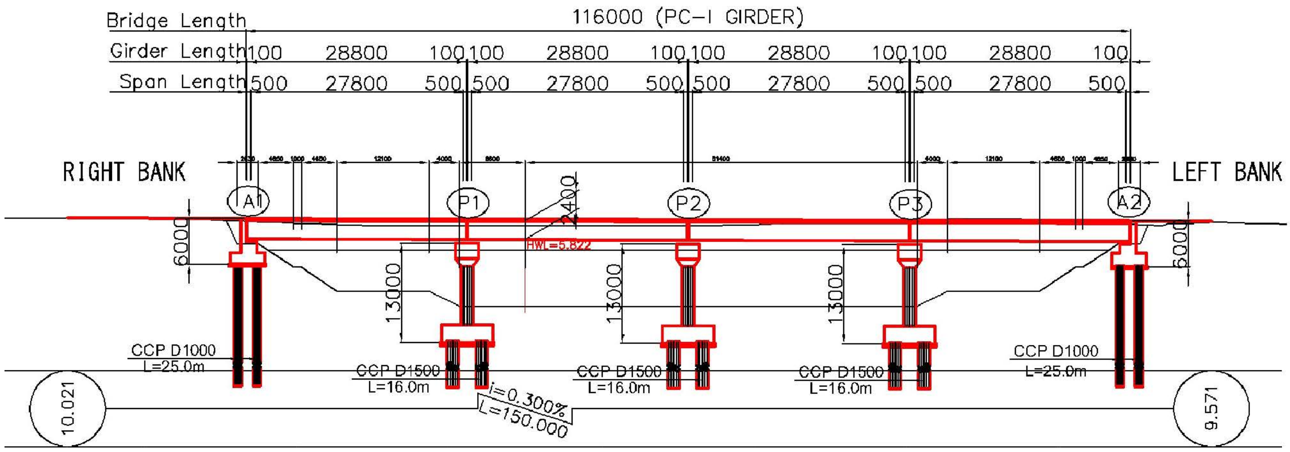


Source: Project Team

Figure 4.4.17 Implementation Flow Chart for Cut-off

c) Installation of Bridges

A longitudinal section of the bridge (upstream side) is shown in Figure 4.4.18. Bridge erection is initially carried out in dry conditions. After excavation and substructure construction (pile work, footings, and pier concrete), shoring is installed and concrete is taken place for the girders.



Source: Project Team

Figure 4.4.18 Cross-section of Bridge (Upstream)

The Quantity of Bridge work is shown in Table 4.4.12.

Table 4.4.12 Quantity of Bridge Work

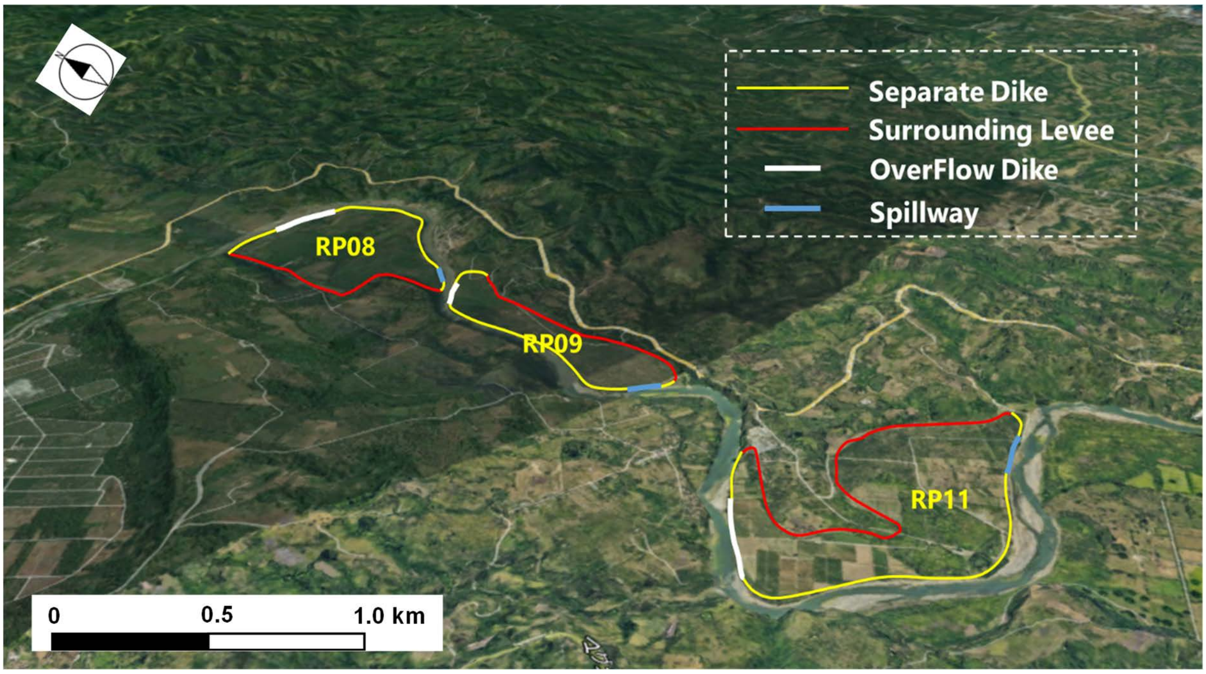
ITEM NO.	DESCRIPTION	UNIT	QUANTITY		
			STA 8+116.6	STA 11+188.4	TOTAL
PART C	**EARTHWORK**				
102(1)	Unsuitable Excavation	cu.m	0	0	0
103(1)a	Structure Excavation	cu.m	9,771	9,771	19,542
104(3)b	Embankment (Selected Granular Materials)	cu.m	4,035	0	4,035
104(5)a	Structure Backfill	cu.m	9,033	9,033	18,066
105(1)	Subgrade Preparation	sp.m	3,457	0	3,457
PART D	**SUBBASE AND BASE COURSES**				
200	Aggregate Subbase Course	cu.m	691	0	691
PART E	**SURFAE COURSES**				
302(2)	Bituminous Tack Coat, Emulsified Asphalt, SS-1	sq.m.	1,040	1,091	2,131
310(1)	Anti Rutting Bituminous Concrete Binder Course, Hot Laid (t=4 cm)	sq.m.	1,040	1,091	2,131
310(2)	Anti Rutting Bituminous Wearing Concrete Course, Hot Laid (t=4 cm)	sq.m.	1,040	1,091	2,131
311(2)c	Portland Cement Concrete Pavement, 230mm thk	sq.m.	2,535	0	2,535
PART F	**BRIDGE CONSTRUCTION**				
400 (17)a	Concrete Piles cast in Drilled Holes, (1200mm Ø)	lm	1,179	1,179	2,357
400 (17)b	Concrete Piles cast in Drilled Holes, (1500mm Ø) with Permanent Casing	lm	566	251	817
400(22)a	Low Strain Pile Integrity Test (PIT), dia. =1200-3000mm	each	5	5	10
400(22)b-2	High Strain Dynamic Testing (P.D.A.), dia = 1500mm	each	1	1	3
404(4)	Reinforcing Steel Bars, Grade SD 390	kg	392,412	392,412	784,824
405(1)a-1	Structural Concrete Class "AA2" (30 Mpa) for Column, Copings, Wingwalls, Backwalls and Shear Keys	cu.m	477	477	955
405(1)a-4	Structural Concrete Class "AA2" (28 Mpa) for Pile Cap	cu.m	582	582	1,164
405(1)a-6	Structural Concrete Class "AA2" (30 Mpa) for Abutment, Retaining U-Wall	cu.m	155	155	310
406(1)a	PSCG GIRDER AASHTO TYPE V (30.000 M SPAN - PIER TO PIER)	pc	24	24	47
406(3)	Prestressed Concrete Class "PP1" (38 Mpa) for PC Voided Slabs, Φ1,200 Form	cu.m	1,603	1,603	3,205
406(3)a	Prestressing Steel	kg	4,714	4,714	9,429
407(1)	Lean Concrete	cu.m	30	30	60
407(2)	Expansion Joint (Type A)	lm	31	31	63
412(1)b	Elastomeric Bearing Pad (300 x 400 x 60 Duro 60)	each	47	47	94
-	Waterproofing on Bridge deck Slab	sq.m	1,040	1,091	2,131
PART G	**DRAINAGE**				
500(1)j	Reinforced Concrete Pipe Culvert (1220mm diameter), Class IV	l.m.	530	0	530
502(4)	Catch Basin (1.5x1.5x15)	each	29	0	29
515	Mechanical Stabilized Earth Wall excluding Back Fill (TERRE ARMEE)	sq.m	384	0	384
PART H	**MISCELLANEOUS ITEMS**				
-	Steel guardrail	lm	681	223	904
600(2)	Concrete Curb and Gutter Type A	lm	681	0	681
601	Sidewalk	sq.m	936	235	1,171

Source: Project Team

3) Retarding Pond

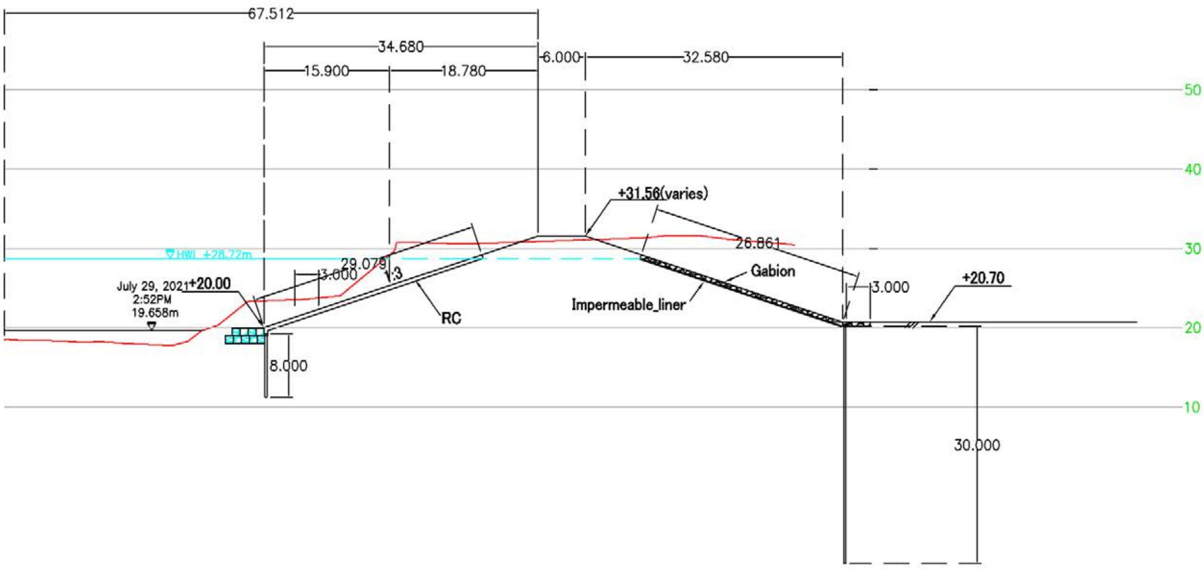
a) General

Construction of Retarding Pond is planned at three locations, 29.0 km (RP-8, Right bank), 27.2 km (RP-9, Left bank), and 23.8 km (RP-11, Left bank) from the river mouth, with a total area of 200 ha and a total excavation volume of 12.7 million m^3. Figure 4.4.19 shows the location of the Retarding Pond, Figure 4.4.20 shows the typical cross section of the Separate Dike, and Table 4.4.13 shows the quantity of construction for each location.



Source: Project Team

Figure 4.4.19 Location of Retarding Ponds



Source: Project Team

Figure 4.4.20 Typical Cross-section of Separate Dike

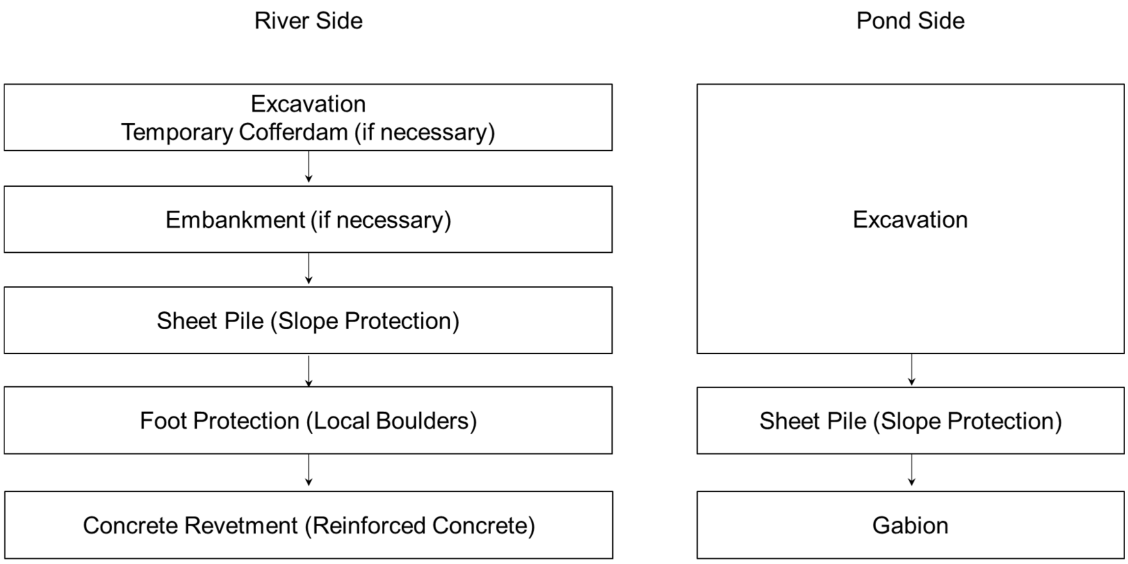
Table 4.4.13 Quantity of Retarding Pond

Item			RP08	RP09	RP11	Total
1	Channel Excavation (Excavation-Loading-Transportation)	m3	5,893,700	1,931,500	4,345,700	12,171,000
2	Embankment (for Dike)	m3	31,100	38,200	11,900	81,000
3	Embankment (at Disposal area)	m3	5,862,613	1,893,240	4,333,752	12,090,000
4	Concrete Revetment (Reinforced Concrete t=50cm)	m3	38,001	0	0	38,001
5	Gabion (t=50cm)	m3	54,641	83,944	131,256	269,841
6	RC wall for heightening the crest (from 25.30 to 27.50)	m3	2,516	0	0	2,516
7	Steel Sheet Pile - riverside (SP-III)	m	47,000	0	0	47,000
8	Steel Sheet Pile - pond side (SP-II)	m	176,250	22,563	69,850	268,663
9	Foot Protection (Local Boulders - max size)	m3	21,150	0	0	21,150
10	Impermeable Liner	m2	55,600	85,629	155,922	297,151
11	Installing Drainage Gate	m2	16	16	16	48

Source: Project Team

b) Construction Flow Chart

Because of the large amount of excavation in the Retarding Pond, it is recommended to construct at least RP08 and RP11 of which excavation volume are large at the same time. The excavation should be carried out from the river side. Temporary cofferdam shall be taken place with steel sheet piles, etc., if necessary. Then, revetment blocks and revetment concrete are installed at the bottom of the slope, and after the excavation on the floodplain side is completed, the impermeable sheets are set over the slope and the gabion revetment is implemented on it. Figure 4.4.21 shows the Implemented Flow Chart of Retarding Pond.



Source: Project Team

Figure 4.4.21 Implementation Flow Chart of Retarding Pond

(5) Efficiency of Construction Equipment

1) Dredging

a) Pump Dredging

The standard capacity of Pump Dredging is shown in the Table 4.4.14. Depending on the model available locally, the construction capacity is 90-300 m^3/h (630 - 2100 m^3/day with 7-hour operation); the minimum daily dredging volume is about 800 m^3 together with backhoe dredging, so one set can be enough to use for the project. The rate analysis "Dredging-soils (using Cutter Suction Dredger, 8 "φ)" in "DPWH's Detailed Unit Price Analysis (DUPA) (2017)" shows 88 m^3/h (616 m^3/day for 7-hour operation). Hence, the standard progress is 600 m^3/day for one set here. The total pump dredging volume is 583,000 m^3, which means a construction period of approximately 4 years.

Table 4.4.14 Capacity of Pump Dredging

		Dredging Capacity			Spec of Dredger				
		Depth	Capacity	Distance	Length (Total)	Length (Ship)	Width	Depth	Draft at full load
		(m)	(m^3/h)	(m)	(m)	(m)	(m)	(m)	(m)
Electric Dredger	E200	8	92	500	23.0	15.0	6.6	1.5	0.9
	E500	12	160	1,000	36.0	23.0	8.2	1.9	1.3
Disel Dredger	D250	8	92	500	28.5	16.0	6.4	1.6	1.5
	D420	10	120	850	35.0	19.0	7.2	1.8	1.8
	D600	12	160	1,000	40.0	23.0	8.0	2.0	2.0
	D1350	15	300	1,200	56.0	37.0	12.2	2.7	2.7

Source: River Earthworks Manual, Japan Institute of Country-ology and Engineering, (JICE) & Project Team

b) Backhoe Dredging

The standard capacity for Backhoe Dredging is shown in Table 4.4.15. The capacity varies depending on the soil type and bucket capacity, then they range from 170 to 630 m3/day. The rate analysis "Dredging-soils (using Backhoe on Barge)" in DPWH's "Detailed Unit Price Analysis (DUPA) (2017)" is 16 m3 /h (112 m3/day for a 7-hour operation), which requires 5 sets. The standard progress would be 4 sets of 448 m3/day. Since total volume for Backhoe Dredging is 686,000 m3 , the construction period will be approximately 6 years.

Table 4.4.15 Capacity of Backhoe Dredging

Soil Condition		Bucket Capacity (m^3)	
		1.0	2.0
Clay Soil	N<10	310	630
Sandy Soils and Sand	10<N<30	210	430
Gravel Soil	30<N<50	170	350

Source: River Earthworks Manual, Japan Institute of Country-ology and Engineering, (JICE) & Project Team

c) Sediment Transportation

890,000m^3 of dredged sediment will be loaded on the dump truck and transported in 6 years. Assuming an annual workable 243 days, the daily construction volume is approximately 560 m^3. By using a 0.8 m^3 class backhoe, the daily volume is approximately 500 m^3, which means one or two sets of backhoes are required.

Dump trucks (12 yd^3) will be used to transport the dredged sediment. The amount of work depends on the hauling distance. The average number of dump trucks required is about 15 for a hauling distance of 20 km (36.2 m^3/day) and about 10 for 10 km (63.0 m^3/day).

21-ton bulldozer will be used to spread the soil at the disposal site, with a work rate of 127 m^3 per hour (cycle time of 1.08 minutes at a horizontal distance of 20 m), or 890 m^3 per day. The number of sets required is 1 set.

2) Cut-off

a) Soil Excavation

The excavation of Cut-off will be 1,010,100 m^3 over a period of 1 to 2 years. Assuming that the number of workable days per year is 243 days, the amount of work per day would be 2,000 to 4,000 m^3; using a 0.8 m^3 backhoe, approximately 500 m^3 per day, 4 to 8 sets of backhoes would be required. Since construction will be carried out sequentially from the downstream side, four sets of backhoes will be used, and the daily construction volume will be 2,000 m^3. The construction period will be approximately two years.

Dump trucks (12 yd^3) will be used to transport the dredged sedimentation. The amount of work will depend on the hauling distance. The number of dump trucks required is about 55 for a hauling distance of 20 km (36.2 m^3/day) and about 35 for 10 km (63.0 m^3/day).

21-ton bulldozer will be used to level the soil at the dumping site, with a work rate of 127 m^3 per hour (cycle time of 1.08 minutes at a horizontal distance of 20 m), or 890 m^3 per day. The number of sets required is 3 sets.

b) Steel Sheet Pile

The installation shall be done by electric and normal type Vibro Hammer method.

3) Retarding Pond

a) Soil Excavation

The excavation of Cut-off will be 12,171,000 m^3 over a period of 7 years. Assuming that the number of workable days per year is 243 days, the amount of work per day would be 7,200 m^3 approximately; using a 0.8 m^3 backhoe, approximately 500 m^3 per day, 15 sets of backhoes would be required.

Dump trucks (12 yd^3) will be used to transport the excavated soil. The amount of work will depend on the hauling distance. The number of dump trucks required is about 200 for a hauling distance of 20 km (36.2 m^3/day) and about 120 for 10 km (63.0 m^3/day).

21-ton bulldozer will be used to level the soil at the dumping site, with a work rate of 127 m^3 per hour (cycle time of 1.08 minutes at a horizontal distance of 20 m), or 890 m^3 per day. The number of sets required is 9 sets.

b) Steel Sheet Pile

Approximately 315,000 m of steel sheet piles will be installed over a five-year period. The machines to be used are a Crawler Crane (36-40 mt) and a Vibro Hammer (201 hp). The rate analysis of "Steel Sheet Piles (Slope Protection), Type 2" of the DPWH's “Detailed Unit Price Analysis (DUPA) (2017)” is 10 m/hr (70 m/day for 7-hour operation). The total length of the project is 250 m, therefore, 3 - 4 sets is required for the work.

4) Summary of the work efficiency

Table 4.4.16 shows the equipment combinations and work efficiencies for the main types of work for the projects covered by F/S.

Table 4.4.16 Work Efficiency of Equipment

Work Item	Equipment	Productivity per hr	Productivity per day		Remarks
Excavation	Bulldozer (140 HT)	50	350	m3	
Loading	Backhoe (0.8 m3)	71	500	m3	
Transportation	Dump Truck (12Yd3)	9 ～ 5.2	63 ～ 36	m3	10km～20km
Spreading	Motorized Road Grader, 140hp	50	350	m3	
	Bulldozer (140 HT)				
Embankment	Vibratory 10mt SD100DC	50	350	m3	
Dredging-soils (using Backhoe on Barge)	Backhoe (0.8m3～)	16 ～ -	112 ～ 630	m3	Dredging
	Deck Barge (600mt DWT～)				
	Scow, 10 m3～				
	Tugboat, 500hp～				
	Payloader (1.5m3)- at Temporary yard				
	Crawler Crane (36-40m)190hp with Bucket				Unloading from
Dredging-soils (using Cutter Suction Dredger, 8"ϕ)	Dredger, 8"ϕ, 225hp～, 1.5km	88 ～ 300	616 ～ 2,100	m3	Dredging
	Motorized Banca, 20 hp				
	Payloader (1.5m3)				at Temporary Yard
Steel Sheet Piles (Slope Protection)	Crawler Crane (36-40mt)	10	70	m	
	Vibro Hammer (201 hp)				

Source: Project Team

(6) Packaging of Contract

International or domestic bidding shall be applied for construction contractor procurement. The contracted construction areas have been compiled into three packages, taking into consideration the construction cost, layout of construction structures, and traffic condition. The results are shown in the Table 4.4.17. For the dredging, Local Competitive Bidding process is assumed here because dredging is a stand-alone type of work and maintenance dredging is still being performed locally. Cut-off include bridges and river widening, so International Competitive Bidding is assumed here. In addition, International Competitive Bidding is anticipated for the retarding pond works as well due to the large scale and size of the construction project. .The construction costs indicated by the project size in the table are discussed in 4.4.3 Project Cost Estimation below.

Table 4.4.17 Packaging of Contract

	Dredging	Cut-off	Retarding Pond
Package	Package 1	Package 2	Package 3
Descriptions	River mouse ~ 23km	Cut-off in meandering river section	Construction of three retarding ponds
Project size (Construction cost, Philippine peso)	1.1 Billion	1.7 Billion	12 Billion
Anticipated bids	Local Competitive Bidding	International Competitive Bidding	International Competitive Bidding
Remarks	Currently implemented locally	Including bridge and river widening	Large-scale earthwork

Source: Project Team

(7) Proposed Construction Schedule

Construction schedule is shown in Table 4.4.18.

Table 4.4.18 Construction Schedule

Unit		Unit	Quantity	Workable days pre Year	Year	Progress per Day	Year									
							1	2	3	4	5	6	7	8	9	10
1 Dredging																
1-2	Preparation, (Land acquisition, Compensation)	LS	1		3											
1-3	Construction															
1-3-0	Tendering, etc.	LS	1		1											
1-3-1	Dredging-soils (using Backhoe on Barge)	m3	686,000	251	6	448										
1-3-2	Dredging-soils (using Pump Dredger)	m3	584,000	251	4	600										
1-3-3	Channel Excavation (Loading soils from Temporary yard)	m3	890,000	243	4	890										
1-3-4	Embankment (at Embankment area, Disposal area)	m3	890,000	243	4	890										
1-4	Design, Construction Management	LS	1													
2 Cut-off																
2-2	Preparation, (Land acquisition, Compensation)	LS	1		1											
2-3	Construction															
2-3-0	Tendering, etc.	LS	1		1											
2-3-1	Channel Excavation (Excavation-Loading-Transportation)	m3	1,010,100	243	2	2,078										
2-3-2	Embankment (for Dike)	m3	9,000	243	2	19										
2-3-3	Embankment (at Disposal area)	m3	1,001,100	251	2	1,994										
2-3-4	Concrete Revetment (t=30cm)	m3	14,287	251	1	114										
2-3-5	Gabion (t=50cm) - Foot Protection	m3	6,684	251	0	266										
2-3-6	Concrete Block - Slope Toe Protection	m3	2,001	251	0	40										
2-3-7	RC Wall (Reinforced concrete)	m2	7,514	251	1	37										
2-3-8	RC Wall back-filling (crushed stone)	m3	4,704	251	0	40										
2-3-9	RC Wall base (crushed stone)	m2	729	251	0											
2-3-10	Steel Sheet Piles , Furnished	m2	8,125	251	0	62										
2-3-11	Steel Sheet Piles, for temporary works, without materials	m3	8,125	251	0											
2-3-12	Bridges	LS	1	251	1											
2-4	Design, Construction Management	LS	1		0											
3 Retarding Pond																
3-2	Preparation, (Land acquisition, Compensation)	LS	1		1											
3-3	Construction															
3-3-0	Tendering, etc.	LS	1		1											
3-3-1	Channel Excavation (Excavation-Loading-Transportation)	m3	12,171,000	243	7	7,155										
3-3-2	Embankment (for Dike)	m3	12,090,000	243	7	7,108										
3-3-3	Embankment (at Disposal area)	m3	54,491	251	3	72										
3-3-4	Concrete Revetment (Reinforced Concrete t=50cm)	m3	236,285	251	3	314										
3-3-5	Gabion (t=50cm)	m3	9,506	251	1	38										
3-3-6	RC wall for heightening the crest (from 25.30 to 27.50)	m2	60,000	251	5	48										
3-3-7	Sheet Pile (Slope Protection), Type-3	m2	268,663	251	5	214										
3-3-8	Sheet Pile (Slope Protection), Type-2	m3	9,506	251	3	28										
3-3-9	Foot Protection (Local Boulders - max size)	m3	21,150	251	3	324										
3-3-10	Impermeable Liner	m2	243,790	251	3	324										
3-3-11	Installing Drainage Gate	LS	1	251	1	0										
3-4	Design, Construction Management	LS	1		0											

Source: Project Team

4.4.3 Cost Estimate

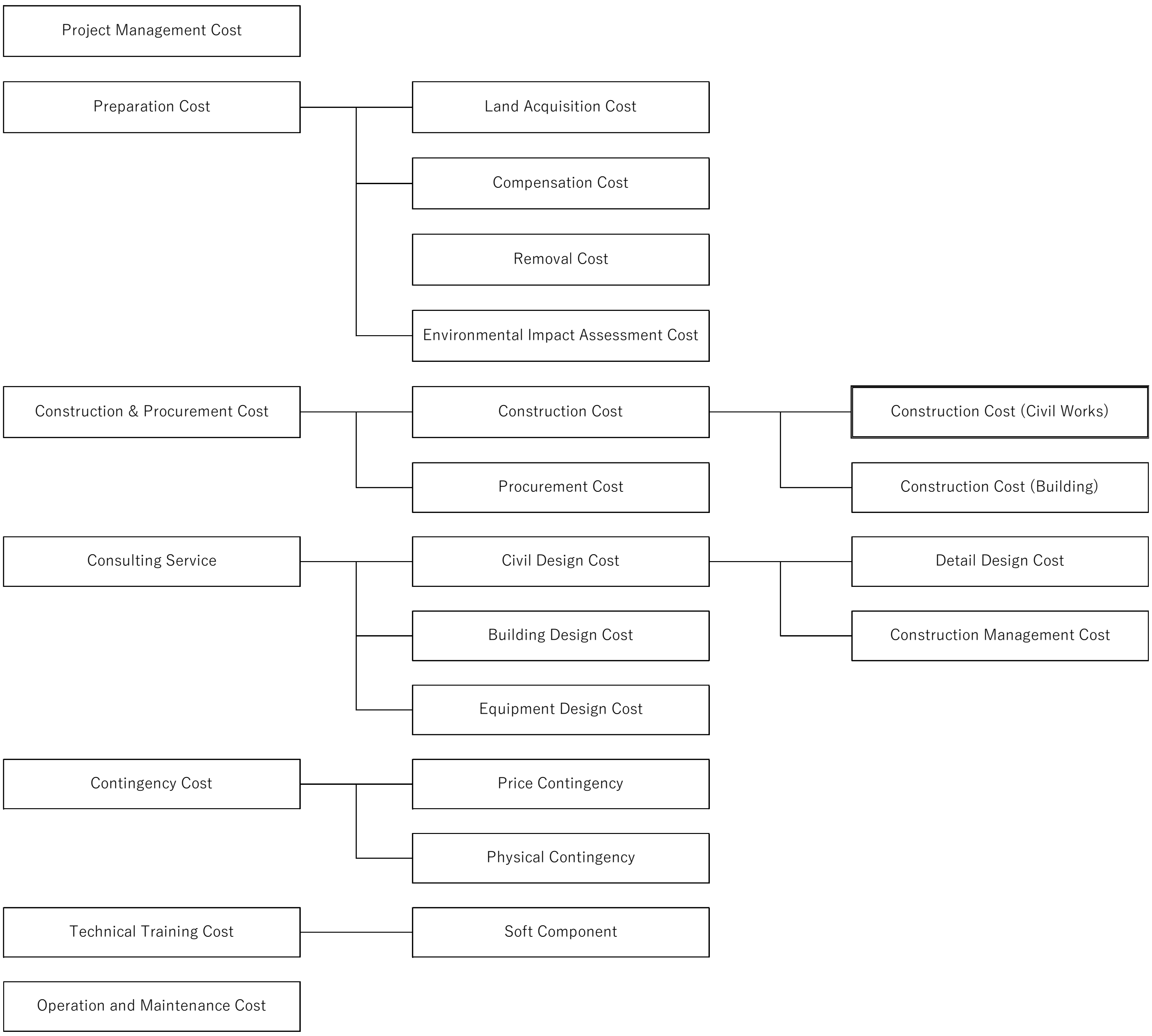
(1) Conditions and Assumptions for Cost Estimate

1) Components of Project Cost

The construction cost was estimated using the construction unit cost method, referring to the Manual for Design and Estimation of Preparatory Studies for Cooperation, Trial Version (JICA, March 2009). Figure 4.4.22 shows the composition of the construction cost.

The main cost items of the project cost consist of Project Management Cost, Preparation Cost, Construction & Procurement Cost, Consulting Service Cost, Contingency Cost, Technical Training Cost, Operation and Maintenance Cost.

Unit rate was basically referenced to DPWH data. The following is an explanation regarding project costs.



Source: Manual for Design and Estimation of Preparatory Studies for Cooperation, Trial Version (JICA, March 2009) & Project Team

Figure 4.4.22 Structure of the Project Cost

2) Date of Implementation of Cost Estimation

The date for cost estimation shall be as of June 1, 2022. DPWH data for 2021 was used as the main base unit price for the cost estimation.

3) Currency Conversion

For currency conversion, the base foreign exchange rate (U.S. dollar) shall be 126 Japanese yen for every 1 U.S. dollar of the U.S. currency, as the figure to be applied during June 2022, as announced by the Bank of Japan.

The arbitrage foreign exchange rate (for Philippine peso) shall be US$0.0192 per Philippine peso as the market rate of the relevant currency against the U.S. currency during April 2022, as arbitrated by the reference foreign exchange rate.

Based on the above, 1 Philippine peso = (126 x 0.0192=) 2.419 yen.

4) Currency

Local and foreign currencies will be used in this project, but the evaluation will be made in terms of local currency. The distinction between local and foreign currencies will generally be as follows

a) Local currency
- Labor cost
- Part of material cost
- Part of equipment cost
- Taxes

b) Foreign currency
- Cost of materials requiring high quality comparable to foreign products
- Cost of equipment requiring high quality comparable to foreign products

The allocation between local and foreign currencies was set with reference to other JICA projects in the Philippines. Table 4.4.19 shows the ratio adopted for this project with reference to the currency ratios of other projects.

Table 4.4.19 Currency Allocation and Ratio Adopted

Item	Agno	Iloilo	Laoag	Piatubo Bamban Abacan	West Pinatubo	Cavite Lowland	Kagayan	Davao	
								LC Portion	FC Portion
Labor	0	0	0	0	0	0	0	100	0
Equipment	100	70	70	70	70	70	70	30	70
Material									
Fuel	50	-	-	-	-	-	-	-	-
Fuel and Lubricant	-	80	70	80	70	70	70	30	70
Wood/Stone/Sand	-	10	-	-	-	10	0	100	0
Crushed/Uncrushed Stone material	-	-	40	40	40	-	40	60	40
Lumber	-	-	40	40	40	-	40	60	40
Cement	65	70	70	70	70	70	70	30	70
Re-bar	65	90	80	80	80	90	90	10	90
Structural Steel	100	90	90	90	-	90	90	10	90
Chemical Product	-	90	-	-	-	90	90	10	90
Bituminous Material	-	-	-	60	-	-	90	10	90
Others	0	-	-	-	50	-	0	100	0

Source: Project Team

5) References

The following guidelines and criteria were used in the estimation process.

- Manual for Design and Estimation of Preparatory Studies for Cooperation, Trial Version (JICA, March 2009)
- DPWH, Flood Control and Drainage Construction Cost Estimation Manual (2017)
- DPWH, Standard Labor Rates for DPWH Regional/District Engineering Office (December 31, 2021)
- DPWH, Construction Material Price Data (DPWH, 4 Quarter, 2021)
- DPWH, List of Equipment Adopted in the Standard Dupa for Road, Bridge and Building (Low & High Rise) Construction Cost Estimation Manuals with Make, Model, Capacity and Operated Rental Rate per Hour Based on the Prevailing Acel Equipment Guidebook, Edition 26 (October 20, 2021)
- Ministry of Land, Infrastructure, Transport and Tourism, Estimation Standard for Civil Engineering Works 2022
- Japan Institute of Country-ology and Engineering, (JICE), River Earthworks Manual

(2) Project Management Cost

Project management costs are the costs required for project execution and management, such as verification and approval of detailed design documents, construction supervision as the owner (site inspection, attendance of various inspections, approval of design changes, etc., office management, meetings, etc.). As in the Master Plan, the project management cost was set at 3.5% of the total amount of Construction & Procurement Cost, Consulting Service cost, and Contingency Cost.

(3) Preparation Cost

1) General

Preparation Cost consist of Site Acquisition Cost, Compensation Cost, removal, and Environmental Impact Assessment (EIA) Cost.

2) Site Acquisition Cost

Land acquisition costs were calculated using the unit cost of land established for each land category. The unit price for agricultural land was set at 60 PhP/m^2 (30 PhP/m^2 for Retarding Pond and Disposal Site), while the unit price for commercial, planned development, and residential areas was set at 12,180 PhP/m^2 , 6,860 PhP/m^2 , and 2,150 PhP/m^2 , respectively. In the design phase, a qualified Philippine appraiser (IPA) will perform the calculation based on market prices in accordance with RA10752 and the DRAM by DPWH.

3) Compensation Cost

Compensation cost is the cost of "compensation" incurred in relocating residents and protecting the environment due to land acquisition, securing detour routes for construction, etc. In other words, the cost was assumed to be the cost required to construct a new building at the relocation site that is equivalent to the site area of the building existing in the area required for the implementation of the measures. In this case, the cost was set at PhP130,000 per building unit. While compensation costs are calculated in this manner at the F/S stage, they are calculated in more detail at the design stage. That is, the compensation cost for the building and other ancillary facilities (Structure and Improvement) is first prepared as the replacement cost (Just Compensation), and the IPA or implementing agency prepares the BOQ. The BOQ will be a sum of material costs, removal costs, and indirect construction costs, plus VAT.

4) Removal Cost

As with the Master Plan, 20% of the cost of the building relocation was set as the Removal Cost.

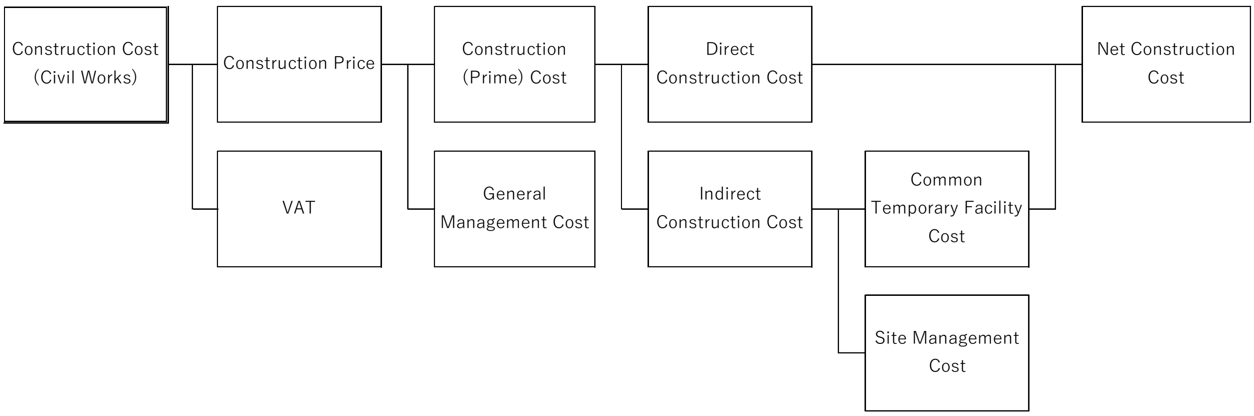
5) Environmental Impact Assessment (EIA) Cost

EIA Cost is an expense to support the proper implementation of environmental and social considerations in compliance with the law on environmental impact assessment; in the F/S, it was assumed to be included in the Common Temporary Cost of Construction and Procurement cost.

(4) Construction and Procurement Cost

1) General

Construction and Procurement Costs consist of Construction Cost, consisting of Civil and Building Construction Cost, and Equipment Procurement Costs. The main component of this project is the Civil Construction Cost. The Civil Construction Cost consists of the sum of Direct Construction Cost and Indirect Construction Cost (Common Temporary Cost and Site Management Cost), plus General and Administrative Cost. Figure 4.4.23 below shows the composition of Construction Cost (Civil Works).



Source: Ministry of Land, Infrastructure, Transport and Tourism, Estimation Standard for Civil Engineering Works 2022 & Project Team

Figure 4.4.23 Structure of the Construction Cost

2) Direct Cost

Direct Construction Cost are classified by construction type and consist of labor, material, and machinery costs for each type of construction required for the project. In this project, labor, equipment, rental, and material costs were accumulated based on DPWH's "Flood Control and Drainage Construction Cost Estimation Manual (2017)," which describes standard construction cost estimates. Rental and material costs were accumulated. Modifications were made to the application as necessary depending on the scope of work.

a) Labor Cost

Labor rates were taken from the DPWH memorandum, "Standard Labor Rates for DPWH Regional/District Engineering Office (December 31, 2021)." The main labor rates per hour are shown in Table 4.4.20.

Table 4.4.20 Construction Schedule

Labor		Rate per hour (PhP)
1	Foreman	109.44
2	Leadman	100.39
3	Heavy Equipment Operator	91.33
4	Highly Skilled Operator	91.33
5	Light Skilled Operator	85.21
6	Driver	79.17
7	Skilled Laborer	79.17
8	Semi-Skilled Laborer	73.14
9	Unskilled Laborer	61.07

Source: Standard Labor Rates for DPWH Regional/District Engineering Office (December 31, 2021)

b) Material Cost

Material costs are surveyed by DPWH and updated quarterly. Here, the figures from "Construction Material Price Data (DPWH, 4 Quarter, 2021)" were used as the material unit cost table. The main material costs are shown in Table 4.4.21.

For the gate for drainage of the recreational area, a unit cost of 8 million yen/m^2 (3.31Mil. pesos/m^2) per area of gate to be installed was used as the unit construction cost, including equipment costs, with reference to in Japan.

Table 4.4.21 Unit Rate of Major Materials

ID	Materials	Rate (PhP)	Unit	Description
M900. 0005	Fuel	77.50	/L	75-80 (as of June 2022)
M900. 0008	Lubricant	194.38	/L	Average
M400. 0008	Steel Sheet Piles FY50	63.50	/kg	Davao City
M700. 0003	Cement	275	bag	Advised by DPWH
M405. 0011	Sand	647.14	m3	Average
M1002. 0068	Weep Holes (PVC)	291	m	50mm
M511. 0013	Filter Cloth	175	m2	Davao City
M405. 0010	Gravel	798.57	m3	G3
M201. 0006	Granular Filter	644	m3	Davao City
M404. 0003	Reinforcing Steel Bar	68	kg	Advised by DPWH
M405. 0022	Marine Plywood 1/2" x 4'x8'-4	565	pc	Davao City
M405. 0014	Lumber (-4 uses)	45	bd-ft	Davao City
M404. 0006	#16 GI Tie Wire (2% of RSB)	75.38	kg	Average
M405. 0002	Assorted CWN (1kg/100bd-ft of Lumber)	66.88	kg	Average
M511. 0003	Gabion Wire Mesh (1mx1mx2m)	2500	pc	Davao City
M104. 0004	Boulders (Boulder, Rock)	760	m3	Davao City
-	Impermeable Sheet	610	m2	Avarage rate 23 Suppriers in Japan

Source: Construction Material Price Data (DPWH, 4 Quarter, 2021)

c) Equipment Cost

Hourly equipment rental costs are compiled by the Association of Carriers and Construction Equipment Lessors (ACEL) in a guidebook, and DPWH project costs are organized in the form of DUPAs based on that guidebook. Note that equipment rental rates for equipment not listed in the ACEL have been prepared by the Bureau of Equipment. In addition, the unit prices for special equipment, such as dredging equipment, were confirmed with local construction companies. These rental rates included operator labor, fuel oil, and maintenance.

The DPWH memorandum, List of Equipment Adopted in the Standard Dupa for Road, Bridge and Building (Low & High Rise) Construction Cost Estimation Manuals with Make, Model, Capacity and

Operated Rental Rate per Hour Based on the Prevailing Acel Equipment Guidebook, Edition 26 (DPWH, October 20, 2021) is used for the equipment cost. The machine rental costs are listed in Table 4.4.22.

Table 4.4.22 Unit Rate of Major Equipment

ID	Rental Equipment	Rate per hour (PhP)	Description
1.1	Bulldozer DX175, D6H	3642.00	
1.3	Payloader (1.5m3)	1733.00	
1.4	Motorized Road Grader, 140hp	2173.00	
2.2	Vibratory 10mt SD100DC	1846.00	
3.2	Crawler Crane (36-40m)190hp	1902.00	
3.3	Crawler Crane (36-40m)190hp with Bucket	2282.40	
4.1	Backhoe(0.8m3)	2096.00	
4.3	Backhoe, Wheel Mounted (0.28m3)	922.00	
5.4	Vibro Hammer(60ton)201hp	2123.00	
7.3	One Bagger Mixer	172.00	
8.1	Dump Truck (12yd3)	1420.00	
8.4	Cargo Truck (9-10mt)	1212.00	
8.5	Water Truck/Pump	2450.00	
10.2	Water Pump, 100mm suction (16hp)	266.25	
12.1	Welding Machine (Gas, 300A, 48hp)	371.00	
16.1	Dredger(8inch)	8327.27	Jun-18
16.4	Deck Barge	546.00	Jun-18
16.5	Tugboat(500hp)	160.00	Jun-18
16.6	Scow(10m3)	222.07	Jun-18

Source: List of Equipment Adopted in the Standard Dupa for Road, Bridge and Building (Low & High Rise) Construction Cost Estimation Manuals with Make, Model, Capacity and Operated Rental Rate per Hour Based on the Prevailing Acel Equipment Guidebook, Edition 26 (DPWH, October 20, 2021)

d) Other Cost

Work items that would be listed as necessary for the detailed design stage were included as other cost. These include tree cutting, removal of existing structures at the detailed design stage, relocation of utilities, and installation of road signs and streetlights. In addition, Direct Construction Cost (defined as preparatory construction costs) for construction of site offices and dormitories (for the Employer and the Engineer), relocation site improvements, construction of access roads, replacement of surrounding facilities, etc. were also included. These costs were set at 10% for Dredging and Cut-off areas, and 5% for Retarding Pond areas with high construction volumes.

3) Indirect Cost

Indirect Construction Cost is construction costs and expenses other than Direct Construction Cost classified by work items, and consists of Common Temporary Construction Cost and Site Management Cost.

a) Common Temporary Facility Cost

Common Temporary Facility Cost is not directly required to construct the object of construction, but is commonly required for each construction project to indirectly construct the object.

Common Temporary Facility Cost = Direct Construction Cost x Common Temporary Construction Cost rate + Accumulated amount

The composition of common temporary construction cost is shown below. Some items need to be accumulated, but as described in each item, they are unknown at this stage, so the amount of accumulation is added to the rate portion. In the case of river works in Japan, the rate portion is 4.77% for those exceeding 1 billion yen (contract amount).

- Transportation Cost
  This category covers transportation of construction machinery and equipment and plant products that are not included in the Direct Construction Cost. Steel sheet piles, lining plates, vehicles weighing 20 tons or more, etc. are to be stacked, while other items are to be added to the rate portion. In this section, the accumulated cost is calculated as an addition to the rate portion.

- Preparation cost
  Preparation cost is the cost of preparation, clean-up, investigation, surveying, etc., and is included in the rate portion here.

- Project loss prevention facility cost
  This is the cost of temporary facilities and investigations necessary to prevent project losses caused by noise, vibration, etc., which may occur during construction, and is accumulated based on an accurate understanding of site conditions. Since considerable costs are expected to be incurred in this project for measures to prevent the generation of turbid water, the accumulated amount will be calculated as an addition to the rate portion.

- Safety cost
  Safety cost is the cost required for safety facilities and safety management, and is included in the rate portion here.

- Service cost
  Costs for land lease, basic electricity charges, and construction costs for electricity facilities shall be added up based on an understanding of the situation at the site. The cost of land lease shall be included in the cost of acquiring temporary site, and the amount accumulated here shall be calculated as an addition to the rate portion.

- Technical management cost
  This covers the cost of testing for quality control, surveying for form control, and preparation of documents for process control, etc. Normal management costs are included in the rate portion, but special quality control, surveys that require accumulation due to site conditions, etc., are accumulated and calculated here as an addition to the rate portion.

- Repair and Maintenance Expenses
  This covers the cost of setting up, removing, and maintaining site offices, laboratory, labor quarters, material storage areas, the Engineers' site offices, etc. These costs are included in the rate. Here, they shall be included in the rate portion.

  In the Philippines, the common temporary construction cost is D.O. 72 and 0.5% of the direct construction cost shall be charged as event costs for meetings, coordination with stakeholders, advertising boards, and ground breaking ceremonies. In addition, about 0.5% will be estimated for expenses incurred in quality control testing, etc. Other than the above, there is no specific provision for so-called common temporary construction costs, which are added separately. Temporary facilities required for the construction itself are the same as those for in Japan, and here the rate portion of common temporary facilities cost was assumed to be 4% of the Direct Construction Cost. In addition, the accumulated amount was adopted as 2% of the Direct Construction Cost.

b) Site Management Cost

Site Management Cost is the cost to manage the entire construction site for smooth execution of the construction project, and consists of salaries and allowances for on-site employees, labor management costs for on-site workers, costs related to safety training, etc., and insurance premiums. Site Management Cost is calculated by multiplying the net construction cost, which is the total of Direct Construction Cost and Common Temporary Construction Cost, by the site management cost rate.

Site Management Cost = Net Construction Cost (Direct Construction Cost + Common Temporary Facility Cost) x site management cost ratio

In the case of river construction projects in Japan, the rate is 14.75% for those exceeding 1 billion yen (contract amount).

In the Philippines, 8-15% of the direct construction cost is charged as indirect cost, etc., and 5% of the direct construction cost is charged as general management cost at D.O. 72 for construction management, transportation, office expenses, insurance premiums, etc.

Although there are differences in items, employee salaries, etc., To calculate Site Management Cost, it is considered more reasonable to multiply the total of Direct Construction Cost and Common Temporary Construction Costs by a rate. Here, the site management cost rate is calculated as 15%, which is multiplied by the Net Construction Cost (Direct Construction Cost + Common Temporary Facility Cost).

4) General Management Cost

General Management Cost is the costs necessary to carry out the corporate activities of the contractor constructing the construction project, i.e., the expenses and profit portion of the head office and branch offices. General Management Cost is calculated by multiplying the Construction (Prime) Cost, which is the sum of Direct Construction Cost and Indirect Construction Cost (Common Temporary Facility Cost and General Management Cost), by the general management ratio.

General Management Cost = Construction (Prime) Cost (Direct Construction Cost + Indirect Construction Cost (Common Temporary Facility Cost + Site Management Cost)) x general management rate

In Japan, the rate is 9.74% (in 2022) for an advance payment expenditure of 35-40% for an amount exceeding 3 billion yen.

In the Philippines, 8 - 10% is applied to Direct Construction Cost the contractor's profit portion. Here, General Management Cost is calculated as 10% of the Construction (Prime) Cost (Direct Construction Cost + Indirect Construction Cost (Common Temporary Facility Cost + Site Management Cost)).

(5) Consultant Service Cost

1) General

The Consultant Service Cost is the cost of the consultant's technical services (detailed design and construction supervision) during the project implementation phase. The design and supervision fee consists of the implementation Detailed Design Cost and Construction Management Cost.

2) Detailed Design Cost

The Detailed Design Cost consists of topographical surveying, geotechnical investigation, soil investigation and testing, and other natural condition investigation costs, as well as the cost of the consultant's technical services for design and preparation of bidding documents. As in the Master Plan, the implementation design cost was set at 10% of the Construction and Procurement cost.

3) Construction Management Cost

The Construction Management Cost consists is the cost of the consultant's technical services for construction supervision during the project implementation phase. As in the Master Plan, the Construction Management Cost was set at 8% of the Construction and Procurement Cost.

(6) Contingency Cost

1) General

The cost is to cover uncertainties such as the accuracy of the schematic design, changes in construction conditions, and items that cannot be anticipated at the time of the survey. It is composed of Price Contingency Cost and Physical Contingency Cost.

2) Price Contingency

The Philippines has a price inflation rate of 2.6% in 2020 (Source: worldbank.org - International Monetary Fund, International Financial Statistics and data files.). Since unit prices in 2021 were used for construction costs, we took into account price increases six years after the middle of the construction period and assumed 16.6% (compounded over six years at 2.6% per annum) for the sum of construction and procurement costs and design and supervision costs. The price increase in foreign currency was assumed to be 3.0% (0.5% per annum compounded over 6 years) on the sum of construction, procurement, and design and supervision costs.

3) Physical Contingency

Physical Contingency Cost is set aside to cover costs for unforeseeable events. In the aforementioned DPWH Secretary's Memorandum dated October 3, 2013, it is stated that the total reserve shall not exceed 10% of construction and consultant costs. Since the concern for this project is the availability of soil dumping sites due to the large amount of soil excavation, the Physical Contingency Cost is set at 10% of the total Construction and Procurement Costs and Consulting Service Cost.

(7) Technical Cost

This is the cost required to provide technical guidance to keep the construction structure above a certain level for a long period of time. As with the Master Plan, it was decided not to take this into account for structures subject to F/S.

4.4.4 Operation and Maintenance Cost

Maintenance Cost is for the operation, maintenance, and renewal of the subject structure. The project plans 171,000 m^3 of maintenance dredging per year, for which the necessary construction and procurement costs and design supervision costs were computed. For the Cut-off and Retarding Pond, 0.5% of the Construction and Procurement Costs is considered as the annual required Operation and Maintenance cost, as well as the Master Plan. Since Operation and Maintenance Cost is required after the construction period, no costs are incurred during construction.

4.4.5 Project Cost

(1) Project Cost estimated based on Methodology, Conditions and Assumptions set in the Previous Sections of 4.4.3 and 4.4.4

The estimated project costs are shown in Table 4.4.23. In addition, preparation costs are shown in Table 4.4.24 and construction and procurement costs are shown in Table 4.4.25. Project costs were calculated using the method described above, and the total project cost for the project as an F/S target is shown at the bottom of the table. Maintenance and management costs are the costs required annually after the construction work is completed. Except for preparation costs, the other costs were calculated as a percentage of construction and procurement costs. Construction and procurement costs were calculated by each work item, and the total amount is shown at the bottom of the table.

Table 4.4.23 Project Cost for F/S Project

Item			LC	FC	Total	Description
			(Unit: Million Philippines Pesos)			
1	Project Management Cost		282	418	700	3.5% of the amount of Construction & Procurement Cost, Consulting Service Cost and Contingency Cost.
		Subtotal	282	418	700	
2	Preparation Cost		0	0	0	
2-1	Land Acquisition Cost		889	0	889	Same as Master Plan
2-2	Compensation Cost		8	0	8	Relocating buildings located on the site to implement the measures.
2-3	Removal Cost		2	0	2	20% of the cost required for building transfer
2-4	Environmental Impact Assessment Cost		0	0	0	Included in Common Temporary Facility Cost
		Subtotal	899	0	899	
3	Construction & Procurement Cost		5,619	9,359	14,978	See Construction & Procurement Cost
		Dredging	419	698		7.5%
		Cut-off	639	1,064		11.4%
		Retarding Pond	4,561	7,597		81.2%
		Subtotal	5,619	9,359	14,978	
4	Consultant Service Cost					
4-1	Consultant Service Costfor Civil Work					
	4-1-1	Detail Design Cost	562	936	1,498	10 % of Construction & Procurement Cost
	4-1-2	Construction Management Cost	449	749	1,198	8 % of Construction & Procurement Cost
4-2	Consultant Service Cost for Building		0	0	0	
4-3	Consultant Service Cost for Equipment		0	0	0	
		Subtotal	1,011	1,685	2,696	
5	Contingency Cost		0	0	0	
5-1	Price Contingency		1,104	335	1,439	The price increase cost was assumed to be 16.6% and 3.0% of the total construction and procurement cost and design and supervision cost, respectively, in domestic and foreign currency (compounded over 6 years, respectively, as an average).
5-2	Physical Contingency		332	552	884	5% of the total Construction & Procurement and Consultant Service Cost.
		Subtotal	1,435	888	2,323	
6	Technical Training Cost		0	0	0	
		Subtotal	0	0	0	
7	Operation and Maintenance Cost		0	0	0	
		(1) Dredging (Implementation)	61	122	183	Construction & Procurement Cost for Maintenance Dredging
		(2) Dredging (Consultation)	11	22	33	Consultant Service Cost for Maintenance Dredging
		(3) Cut-off & Retarding Pond	26	43	69	Operation and Maintenance Cost for Cut-off and Retarding Pond
		Subtotal	98	187	285	
Total (Excluding OM Cost)			9,246	12,349	21,595	

Source: Project Team

Table 4.4.24 Preparation Cost for F/S Project

Item		Unit Price	Quantity	LC	FC	Total	LC with VAT	FC with VAT	Total with VAT
		(PhP)	(m2)	(PhP)	(PhP)	(PhP)	(PhP)	(PhP)	(PhP)
2 Preparation Cost									
2-1 Land Acquisition Cost									
2-1-1	Dredging	0	0	0	0	0			
2-1-2	Cut-off								
	Agricultural	60	22,856	1,371,381	0	1,371,381			
	Open Space	60	49,500	2,969,973	0	2,969,973			
	Commercial	12,180	4,441	54,093,565	0	54,093,565			
	Residential	2,150	21,587	46,411,100	0	46,411,100			
	Planned Unit Developm	6,860	68,258	468,253,107	0	468,253,107			
2-1-3	Retarding Basin	30	1,995,681	59,870,430	0	59,870,430			
2-1-4	Disposal	30	5,360,000	160,800,000	0	160,800,000			
	Sub Total	0	0	793,769,555	0	793,769,555	889,021,902	0	889,021,902
2-2 Compensation Cost									
2-1-1	Dredging	0	0	0	0	0			
2-1-2	Cut-off	130,000	55	7,150,000	0	7,150,000			
2-1-3	Retarding Basin	0	0	0	0	0			
2-1-4	Disposal	0	0	0	0	0			
	Sub Total			7,150,000	0	7,150,000	8,008,000		8,008,000
2-3 Removal Cost				1,430,000	0	1,430,000	1,601,600		1,601,600
2-4 EIA Cost				0	0				0
Total				802,349,555	0	802,349,555	898,631,502	0	898,631,502

Source: Project Team

Table 4.4.25 Construction Cost for F/S Project

Item		Unit	Quantity	Unit Rate		Amount		Total
				LC(PhP)	FC(PhP)	LC(PhP)	FC(PhP)	PhP
1 Dredging								
1-1	Dredging-soils (using Backhoe on Barge)	m3	686,000	155	282	106,444,202	193,574,983	300,019,185
1-2	Dredging-soils (using Pump Dredger)	m3	584,000	41	78	23,689,776	45,464,014	69,153,789
1-3	Channel Excavation (Loading and Transportation)	m3	890,000	96	219	85,308,928	195,046,545	280,355,474
1-4	Embankment (at Disposal area)	m3	890,000	11	20	9,560,179	17,497,939	27,058,118
	Additional Cost of Dredging (10% of Major Direct Cost)					22,500,308	45,158,348	67,658,657
	Sub Total					247,503,393	496,741,829	744,245,222
2 Cut-off								
2-1	Channel Excavation (Excavation-Loading-Transportation)	m3	1,010,100	116	262	117,222,566	264,422,473	381,645,039
2-2	Embankment (for Dike)							
2-3	Embankment (at Disposal area)	m3	1,001,100	11	20	10,753,590	19,682,233	30,435,823
2-4	Concrete Revetment (t=30cm)	m3	14,287	3,893	3,795	55,615,920	54,223,656	109,839,576
2-5	Gabion (t=50cm) - Foot Protection	m3	6,684	2,778	0	18,565,809	0	18,565,809
2-6	Concrete Block - Slope Toe Protection	m3	2,001	3,893	3,795	7,788,714	7,593,735	15,382,449
2-7	RC Wall (Reinforced concrete)	m	7,514	3,893	3,795	29,251,716	28,519,442	57,771,158
2-8	RC Wall back-filling (crushed stone)	m	4,704	1,062	89	4,993,869	417,204	5,411,073
2-9	RC Wall base (crushed stone)	m3	729	1,062	89	773,928	64,656	838,584
2-12	Bridge	LS	1	245,878,000	130,455,000	245,878,000	130,455,000	376,333,000
	Additional Cost of Short-cut (10% of Major Direct Cost)					49,669,149	53,388,609	103,057,758
	0					546,360,640	587,274,699	1,133,635,339
3 Retarding Basin								
3-1	Channel Excavation (Excavation-Loading-Transportation)	m3	12,171,000	116	262	1,412,450,108	3,186,106,245	4,598,556,353
3-2	Embankment (for Dike)	m3	81,000	33	65	2,637,323	5,278,382	7,915,706
3-3	Embankment (at Disposal area)	m3	12,090,000	11	20	129,868,048	237,696,727	367,564,774
3-4	Concrete Revetment (Reinforced Concrete t=50cm)	m3	54,491	3,893	3,795	212,126,500	206,816,221	418,942,721
3-5	Gabion (t=50cm)	m3	236,285	2,778	0	656,316,748	0	656,316,748
3-6	RC wall for heightening the crest (from 25.30 to 27.50)	m3	9,506	3,893	3,795	37,007,438	36,081,011	73,088,449
3-7	Sheet Pile (Slope Protection), Type-3	m	60,000	572	3,852	34,328,133	231,138,138	265,466,271
3-8	Sheet Pile (Slope Protection), Type-2	m	268,663	491	3,118	131,794,956	837,721,456	969,516,413
3-9	Foot Protection (Local Boulders - max size)	m3	21,150	1,062	89	22,452,529	1,875,758	24,328,287
3-10	Impermeable Liner	m2	243,790	689	4	168,085,822	1,034,157	169,119,979
3-11	Installing Drainage Gate	LS	48	0	3,310,000	0	158,880,000	158,880,000
	Additional Cost of Retarding Pond (5% of Major Direct Cost)					140,353,380	245,131,405	385,484,785
	Sub Total					2,947,420,985	5,147,759,500	8,095,180,485
Direct Construction Cost						3,741,285,018	6,231,776,028	9,973,061,046
Common Temporary Facility Cost								
Accumulated Portion (4% of Direct Construction Cost)						74,825,700	124,635,521	199,461,221
Rate Portion (4% of Direct Construction Cost)						149,651,401	249,271,041	398,922,442
Total of Common Temporary Facility Cost						224,477,101	373,906,562	598,383,663
Net Construction Cost (Direct Construction Cost +Common Temporary Facility Cost)						3,965,762,119	6,605,682,590	10,571,444,709
Site Management Cost (15% of Net Construction Cost)						594,864,318	990,852,388	1,585,716,706
Indirect Construction Cost (Common Temporary Facility Cost＋Site Management Cost)						819,341,419	1,364,758,950	2,184,100,369
Construction (Prime) Cost (Direct Construction Cost＋Indirect Construction Cost)						4,560,626,437	7,596,534,978	12,157,161,416
General Management Cost. etc. (10% of Construction (Prime) Cost)						456,062,644	759,653,498	1,215,716,142
Construction Cost for Civil Work (Construction (Prime Cost)＋General Management Cost)						5,016,689,081	8,356,188,476	13,372,877,557
Construction Cost for Building Work						0	0	0
Construction Cost						5,016,689,081	8,356,188,476	13,372,877,557
Procurement Cost						0	0	0
Construction & Procurement Cost without VAT						5,016,689,081	8,356,188,476	13,372,877,557
VAT (12%)						602,002,690	1,002,742,617	1,604,745,307
Construction & Procurement Cost with VAT						5,618,691,771	9,358,931,093	14,977,622,864

Source: Project Team

Based on the results of the study on the priority projects for the measures of riverine flood of Davao River in the F/S stage, the project cost was reviewed only for the M/P of the measures of riverine flood of Davao River. The reviewed project cost is shown in Table 4.4.26 In the calculation of the project cost for M/P, the construction and procurement cost of the river channel widening and the retarding ponds for the project subject to M/P was first calculated by applying the amount calculated for each facility type in the F/S stage as a percentage according to the facility size. Then, the construction and procurement costs for dredging, cut-off, and retarding pond for F/S subject projects calculated in the F/S stage were added to the construction and procurement costs. Next, preparation costs (land acquisition and compensation) were accumulated in the same manner as in the F/S stage, and design and supervision costs, etc. were calculated as a percentage of construction and procurement costs. The total project costs for the projects subject to M/P for the riverine flood control of Davao River are shown at the bottom of the table. Maintenance and management costs are those required annually after the construction work is completed.

Table 4.4.26 Construction Cost for M/P Project

Item				LC	FC	Total	Description
				(Unit: Million Philippines Pesos)			
1	Project Management Cost			788	1,166	1,954	3.5% of the amount of Construction & Procurement Cost, Consulting Service Cost and Contingency Cost.
			Subtotal	788	1,166	1,954	
2	Preparation Cost			0	0	0	
	2-1	Land Acquisition Cost		1,821	0	1,821	Same as Master Plan
	2-2	Compensation Cost		609	0	609	Relocating buildings located on the site to implement the measures.
	2-3	Removal Cost		122	0	122	20% of the cost required for building transfer
	2-4	Environmental Impact Assessment Cost		0	0	0	Included in Common Temporary Facility Cost
			Subtotal	2,552	0	2,552	
3	Construction & Procurement Cost						See Construction & Procurement Cost
		FS	Dredging	419	698	1,118	
		FS	Cut-off	639	1,064	1,703	
		FS	Retarding Pond	4,561	7,597	12,157	
		MP	River Widening	749	1,248	1,997	
		MP	Retarding Pond	9,323	15,528	24,851	
			Subtotal	15,690	26,135	41,826	
4	Consultant Service Cost						
	4-1	Consultant Service Costfor Civil Work					
		4-1-1	Detail Design Cost	1,569	2,614	4,183	10 % of Construction & Procurement Cost
		4-1-2	Construction Management Cost	1,255	2,091	3,346	8 % of Construction & Procurement Cost
	4-2	Consultant Service Cost for Building		0	0	0	
	4-3	Consultant Service Cost for Equipment		0	0	0	
			Subtotal	2,824	4,704	7,529	
5	Contingency Cost			0	0	0	
	5-1	Price Contingency		3,083	937	4,019	The price increase cost was assumed to be 16.6% and 3.0% of the total construction and procurement cost and design and supervision cost, respectively, in domestic and foreign currency (compounded over 6 years, respectively, as an average).
	5-2	Physical Contingency		926	1,542	2,468	5% of the total Construction & Procurement and Consultant Service Cost.
			Subtotal	4,008	2,479	6,487	
6	Technical Training Cost			0	0	0	
			Subtotal	0	0	0	
7	Operation and Maintenance Cost			0	0	0	
			(1) Dredging (Implementation)	61	122	183	Construction & Procurement Cost for Maintenance Dredging
			(2) Dredging (Consultation)	11	22	33	Consultant Service Cost for Maintenance Dredging
			(3) Cut-off & Retarding Pond	28	47	75	Operation and Maintenance Cost for Cut-off and Retarding Pond
			Subtotal	100	191	291	
Total (Excluding OM Cost)				25,864	34,484	60,348	

Source: Project Team

(2) Project Cost applying land acquisition cost and compensation cost calculated in the RAP study as well as land unit price applied in the RAP study

For the F/S target project, the project cost was estimated in the above (1) under the conditions specified in Section 4.4.3. On the other hand, in this Project, land acquisition cost and compensation cost were calculated in the RAP study (see Section 4.6.3). Although the land acquisition cost and compensation cost should be studied and examined in detail at the detailed design stage, as reference value for future implementation, the preparation cost was calculated applying the land acquisition cost and compensation cost calculated in the RAP study as well as land unit price applied in the RAP study, and then the project cost was estimated. Table 4.4.27 shows the estimated project cost.

Table 4.4.27 Project Cost for F/S Project (when RAP Study Results are applied)

Item	LC	FC	Total	Description
	(Unit: Million Philippines Pesos)			
1 Project Management Cost	282	418	700	3.5% of the amount of Construction & Procurement Cost, Consulting Service Cost and Contingency Cost.
Subtotal	282	418	700	
2 Preparation Cost				
Subtotal	21,026	0	21,026	
3 Construction & Procurement Cost	5,619	9,359	14,978	See Construction & Procurement Cost
Dredging	419	698		7.5%
Cut-off	639	1,064		11.4%
Retarding Pond	4,561	7,597		81.2%
Subtotal	5,619	9,359	14,978	
4 Consultant Service Cost				
4-1 Consultant Service Costfor Civil Work				
4-1-1 Detail Design Cost	562	936	1,498	10 % of Construction & Procurement Cost
4-1-2 Construction Management Cost	449	749	1,198	8 % of Construction & Procurement Cost
4-2 Consultant Service Cost for Building	0	0	0	
4-3 Consultant Service Cost for Equipment	0	0	0	
Subtotal	1,011	1,685	2,696	
5 Contingency Cost	0	0	0	
5-1 Price Contingency	1,104	335	1,439	The price increase cost was assumed to be 16.6% and 3.0% of the total construction and procurement cost and design and supervision cost, respectively, in domestic and foreign currency (compounded over 6 years, respectively, as an average).
5-2 Physical Contingency	332	552	884	5% of the total Construction & Procurement and Consultant Service Cost.
Subtotal	1,435	888	2,323	
6 Technical Training Cost	0	0	0	
Subtotal	0	0	0	
7 Operation and Maintenance Cost	0	0	0	
(1) Dredging (Implementation)	61	122	183	Construction & Procurement Cost for Maintenance Dredging
(2) Dredging (Consultation)	11	22	33	Consultant Service Cost for Maintenance Dredging
(3) Cut-off & Retarding Pond	26	43	69	Operation and Maintenance Cost for Cut-off and Retarding Pond
Subtotal	98	187	285	
Total (Excluding OM Cost)	29,373	12,349	41,722	

Source: Project Team

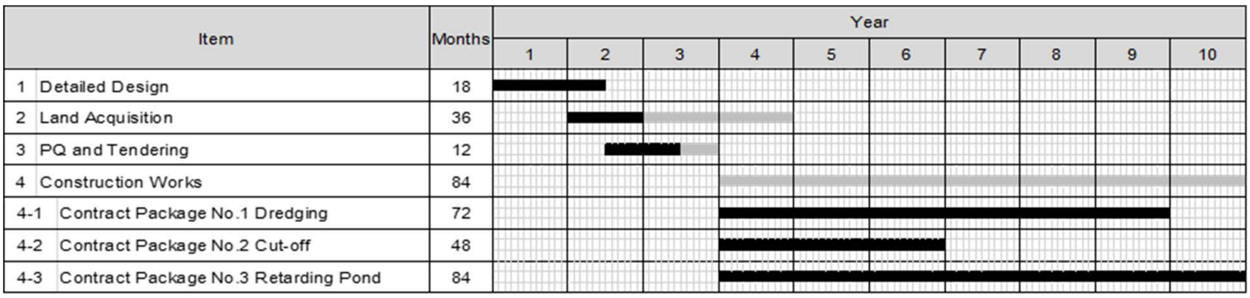
In this Project, two types of project costs were calculated as mentioned above and the economic evaluation was also conducted for two types of project costs (see Section 4.5.4). In the next stage following this Project, it is necessary to carry out necessary surveys, examinations, and discussions for determining the land unit price to be applied, reflect it in the project cost, and improve the accuracy of the project cost.

4.4.6 Implementation Schedule

The project implementation schedule is shown in Table 4.4.28.

After the detailed design, bidding for construction work will begin in the second year, with a target completion date of all the construction works of 10th year. Resettlement and land acquisition are planned to be started in the second year, in conjunction with the detailed design and construction work.

Table 4.4.28 Schedule of the F/S Project



Source: Project Team