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
(1 of 2)

JULY 2023

JAPAN INTERNATIONAL COOPERATION AGENCY

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

GE
JR
23-075

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
(1 of 2)

JULY 2023

JAPAN INTERNATIONAL COOPERATION AGENCY

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

Foreign Exchange Rate:
Master Plan
US$ 1 = JPY 126
PHP 1 = US$ 0.0192
(Rate reported by the Bank of Japan in June 2022)

FINAL REPORT (1 of 2)
ON
THE PROJECT FOR MASTER PLAN AND FEASIBILITY STUDY ON FLOOD CONTROL AND DRAINAGE IN DAVAO CITY

TABLE OF CONTENTS

LIST OF TABLES

<Part I Master Plan Study and Feasibility Study>

LIST OF FIGURES

<Part I Master Plan Study and Feasibility Study>

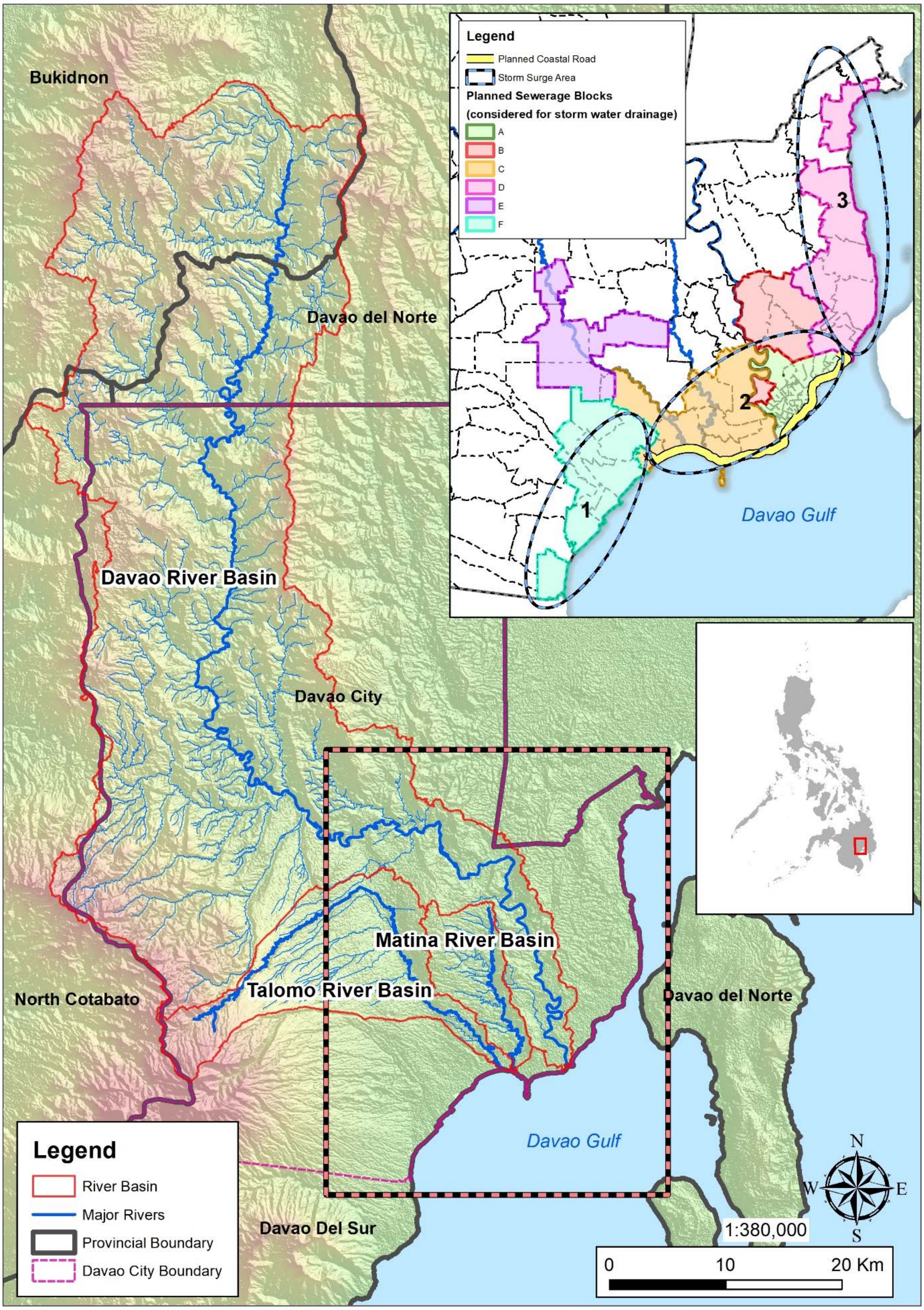
ABBREVIATIONS AND TERMINOLOGY

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



Project Area

＜Part I : Master Plan Study and Feasibility Study＞

Chapter 1 Introduction

1.1 Background of the Project

The Philippines has suffered devastating damage from natural disasters. During the 10 year-period from 2005 until 2015, a total of 20,000 people were dead and missing, 75 million people have been affected, and the economic loss has reached 182 billion pesos. The main cause of disaster is strong wind and flooding in which 70% of the affected people suffered damage by typhoons and monsoons, and 24% suffered damaged by storm surges and high waves.

The Project site, Davao City, located in the southern part of Mindanao Island, is the third largest city in the Philippines, and the largest city on Mindanao Island. Davao City had been less affected by flooding in the past, but flood damage has recently increased due to changes in typhoon tracks. In 2011, 30 people were killed by the flooding of the Davao and Matina Rivers, more than 2,500 people were affected by the flooding of Davao River in 2013, and 22,911 families were affected by flooding due to Typhoon Vinta in December, 2017. In addition, there are several problems such as inland flooding, insufficient drainage systems, and storm surges due to the geographical features of the 60 km coastline.

Even though flood disaster has occurred frequently in Davao City, a Master Plan for integrated flood control has not been developed. Although the budget for flood control in the Department of Public Works and Highways (hereinafter referred to as DPWH) has increased, the budget has not been fully used due to the lack of development of the Master Plan. Ten of 18 major river basins in the Philippines have developed Master Plans for flood control from the 1980s to the early 1990s. After that, 5 rivers (Cagayan, Agusan, Pasig-Marikina-Laguna Bay, Tagoloan, and Cagayan de Oro) have reviewed and updated their Master Plans, and the preparation of the Master Plan and Feasibility Study for the 5 rivers was conducted by DPWH with the support of JICA through technical cooperation projects as of 2017. For the improvement of drainage systems, although a Master Plan for the six districts inside Davao City had been developed by Davao City, a Master Plan for flood control in Davao River has not been developed. Further, it is highly expected to develop the Master Plans for flood control of major rivers/principal rivers including Davao River, and to enhance DPWH's capacity for development of the Master Plans for flood control by DPWH themselves.

Under the above circumstances, the Government of the Republic of the Philippines (GOP) requested assistance from the Japanese Government on the Master Plan and Feasibility Study on Flood Control and Drainage in Davao City. In response to the official request of the Government of the Republic of the Philippines, JICA conducted a detailed planning survey on the Project and confirmed and signed the minutes of meetings (M/M) on the 11th of August 2017, and signed the Record of Discussion (R/D) on the 23rd of April 2018.

<u>Signification of flood management and flood control measures in the development plans of the Philippines and Davao City</u>

In the development plan of the Philippines, flood management is positioned as one of the targets for promoting infrastructure development as one of the fields of water resources. Timely investment to flood management based on the master plan is required, using the ratio of countermeasure implementation areas to flood risk areas as an index. In addition, the development plan of Davao City stipulates disaster-resistant urban management and a comfortable urban environment as one of the development strategies. This Project is directly related to this strategy and contributes to the reduction of flood damage in Davao City, which in turn contributes to the development of Davao City.

1.2 Objective of the Project

Objective of the Project is to mitigate flood damage in Davao City by the implementation of flood control measures through development of the Master Plan for Davao River, Matina River and Talomo River basin and conducting the Feasibility Study on urgent and/or priority project(s).

(1) Goal of the Proposed Plan

The Master Plan and the results of Feasibility Study will be approved by GOP.

(2) Goal which will be attained by utilizing the Proposed Plan

Flood damage in Davao City will be mitigated.

(3) Outputs

1. The Master Plan of the flood control and drainage in Davao City which includes a flood control Master Plan for Davao River, Matina River and Talomo River basins.
2. The Feasibility Study on urgent and/or priority project(s).
3. Capacity enhancement of concerned DPWH personnel/Officials in the development of Flood Control and Drainage Master Plan

1.3 Project Area

Target area of the Project is Davao City, Davao River Basin, Matina River Basin and Talomo River Basin with about 2,444 km^2 including (in Davao City urbanized area of approximately 131 km^2.

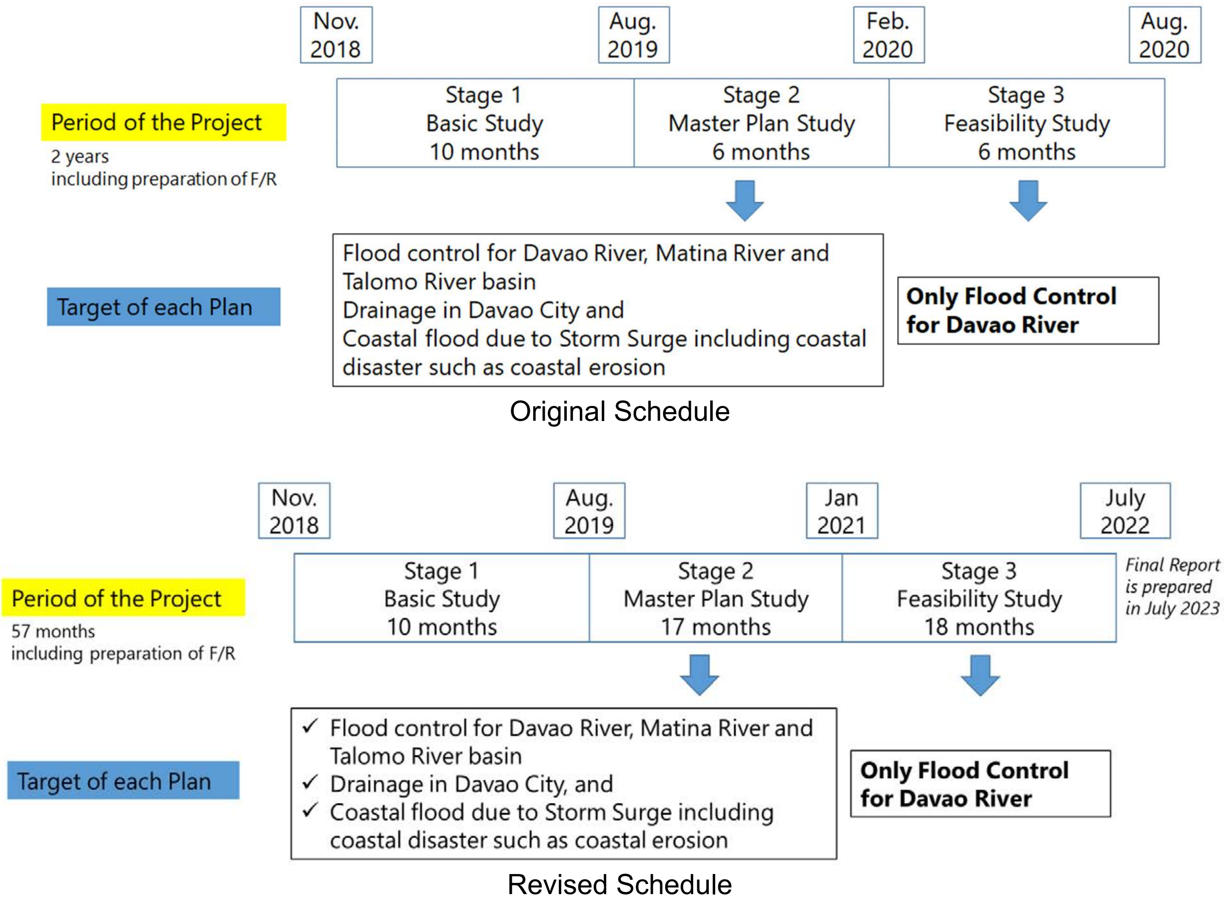
1.4 Implementation Structure

Counterpart agencies of the Project are DPWH and Davao city.

1.5 Project Schedule

1.5.1 Overall Schedule

The Project was commenced in November 2018 and originally was planned to be carried out for about 24 months until October 2020 as shown in the upper figure of Figure 1.5.1, but it was rescheduled for about 57 months until July 2023 as shown in the figure below of Figure 1.5.1.



Source: Project Team

Figure 1.5.1 Overall Schedule of the Project

The Project activity in the Philippines was commenced, after preparatory work in Japan, on November 11, 2018 upon arrival of the JICA Mission Team and the Project Team. Discussion with DPWH and Davao city on the Inception Report had been done from November 12 to November 15, 2018 with respect to objectives, schedule and approaches for successful implementation of the Project. In addition, explanation and discussion on the Inception Report to the Steering Committee was conducted on January 23, 2019 as the first Steering Committee meeting.

After the series of discussion and exchange of views in the meeting, DPWH, the Steering Committee and JICA Project Team agreed upon the contents of the Inception Report.

The Project schedule have been divided into the following three stages:

[Stage 1] Basic Study Stage :	November 2018 to August 2019 (10 months)
[Stage 2] Master Plan Study Stage :	September 2019 to February 2020 (6 months) (Original) September 2019 to January 2021 (17 months) (Revised)
[Stage 3] Feasibility Study Stage :	March 2020 to August 2020 (6 months) (Original) February 2021 to July 2022 (18 months) (Revised) (Final Report was prepared in July 2023 after discussion on DFR, EIS process and the Advisory Committee for Environmental and Social Considerations in Japan)

1.5.2 [Stage 1] Basic Study Stage

(1) Activity

The Project activities for the Basic Study Stage were conducted for Work Item 1-1 to 1-20 as enumerated in Table 1.5.1 in accordance with the scope of the works including data collection, various surveys, evaluation of existing countermeasures, basic analysis, examination of design level, preparation of draft policy of setting of river boundary and so forth during a period from November 2018 to August 2019.

(2) Reports

The Progress Report was prepared based on the results of surveys and investigations executed by July 2019 covering all the Work Items for the Stage 1 (Item 1-1 to 1-19).

(3) Steering Committee

The first Steering Committee Meeting was held to explain and have discussion on the Inception Report on January 23, 2019 in Manila. The second Steering Committee Meeting was held to have discussion on the Progress Report on September 3rd, 2019 in Manila with respect to the results of surveys and investigations incorporated in the Progress Report including findings, evaluation and analyses results. After the series of discussion and exchange of views in the meeting, DPWH, the Steering Committee and JICA Project Team agreed upon the contents of the Progress Report and Main Points Discussed.

Table 1.5.1 Work Items (Stage1, Stage2, Stage 3 and Entire period)

Work Items	Content of Work	
Stage 1: Basic Study		
1-1	Review of existing documents and preparation of the Inception Report	
1-2	Introduction of the Inception Report (IC/R)	
1-3	Collection and arrangement of basic information, survey of damage situation	
1-4	【Riverine Flood】	Evaluation of existing flood control measures
1-5	【Riverine Flood】	River/Topographic survey (longitudinal profile and cross-sectional survey, riverbed material survey, spot elevation survey, etc.)
1-6	【Riverine Flood】	Hydro-meteorological statistical analysis
1-7	【Riverine Flood】	Estimation of sediment discharge
1-8	【Riverine Flood】	Discussion on target design level and design rainfall
1-9	【Riverine Flood】	Proposal of design criteria
1-10	【Riverine Flood	Research for implementation of project / operation and maintenance management framework
1-11	【Riverine Flood	Preliminary survey of river boundary
1-12	【Inland Flood	Evaluation of existing drainage improvement plan and activities
1-13	【Inland Flood】	Rainfall and runoff analysis
1-14	【Inland Flood】	Discussion on target design level
1-15	【Inland Flood】	Research for implementation of project / operation and maintenance management framework
1-16	【Coastal Flood】	Coastal area survey (wave, tide level, tidal flow etc.)
1-17	【Coastal Flood】	Discussion on the target design condition for oceanographic features such as tide level, target waves and target return period for storm surges
1-18	【Coastal Flood】	Survey on the status of existing facilities and houses along coastal areas
1-19	Proposal of evaluation criteria for alterative countermeasures	
1-20	Preparation, submission, explanation and discussion of Progress Report (P/R)	
Stage 2: Master Plan Study		

Work Items	Content of Work
2-1	Collection and arrangement of additional data and information, and setting of target design level
2-2	Study on alternatives for structural measures
2-3	Study and proposal on non-structural measures
2-4	【Riverine Flood】 Run-off and flood inundation analysis
2-5	【Riverine Flood】 River bed variation analysis
2-6	【Riverine Flood】 Geotechnical investigation
2-7	【Riverine Flood】 Preliminary facility plan of proposed structural measures
2-8	【Inland Flood】 Analysis of inundation
2-9	【Inland Flood】 Study on countermeasures for each drainage district
2-10	【Inland Flood】 Geotechnical investigation
2-11	【Inland Flood】 Preliminary facility plan of proposed structural measures
2-12	【Coastal Flood】 Evaluation of the impact of existing projects and future development plans in coastal areas
2-13	【Coastal Flood Numerical analysis on storm surges and coastal erosion from the view point of coastal protection
2-14	【Coastal Flood】 Preliminary facility plan of structural measures
2-15	Comparison of alternatives considering environmental and social consideration based on Strategic Environmental Assessment concept
2-16	Formulation of Integrated Flood Control Master Plan
2-17	Preliminary cost and benefit analysis
2-18	Additional survey on existing structures
2-19	Selection of priority project(s) and clarification of necessity of change in category under JICA's Environmental and Social Consideration Guidelines
2-20	Scoping on environmental monitoring items for selected priority project(s)
2-21	Support for preparation of a simple resettlement action plan
2-22	Preparation, submission, explanation and discussion of Interim Report (IT/R)
2-23*	Examination of measures to promote implementation of Master Plan – grand design of relocation site development
(*Work item 2-23 was added as a new work item by the amendment of the contract in February 2021.)	
Stage 3: Feasibility Study of the Priority Project	
3-1	Preliminary design of structural measures
3-2	Setting of implementation schedule
3-3	Formulation of construction plan and procurement plan
3-4	Proposal of operation and maintenance plan and cost estimation
3-5	Preliminary project cost estimation and disbursement schedule
3-6	Project evaluation
3-7	Prediction and evaluation of important environmental impact and proposal of mitigation measures and monitoring plan
3-8	Preparation, submission, explanation and discussion of the Draft Final Report (DF/R)
3-9	Preparation, discussion and submission of the Final Report (F/R)
Entire period	
4-1	On-the-job training (OJT) and technology transfer
4-2	Support for organizing meetings such as Steering Committee
4-3	Counterpart training sessions in Japan

Source: Project Team

1.5.3 [Stage 2] Masterplan Study Stage

(1) Activity

The Project activities for the Master Plan Stage were conducted for Work Item 2-1 to 2-22 as enumerated in Table 1.5.1 in accordance with the scope of the works including formulation of integrated flood control plan targeting to riverine flood, inland flood and coastal flood during a period from September 2019 to January 2021.

(2) Reports

The Interim Report was prepared based on the results of surveys and investigations executed by January 2021 covering all the Work Items for the Stage 2 (Item 2-1 to 2-22).

(3) Steering Committee

The third Steering Committee Meeting was held to explain and have discussion on the Interim Report including findings, evaluation and analyses results, proposed Master Plan and selection of priority projects in November 2020, and the fourth Steering Committee Meeting was held to discuss the priority projects in February 2021.

1.5.4 [Stage 3] Stage of Feasibility Study of the Priority Project

(1) Activity

The Project activities for the Stage of Feasibility Study of the Priority Project were conducted for Work Item 2-6, 2-20, 2-21 and 2-23 as remaining works from Stage 2 and Work Item 3-1 to 3-9 as enumerated in Table 1.5.1 in accordance with the scope of the works including supplementary study of Master Plan and various studies for priority projects during a period from February 2021 to July 2022. Activities for Work Item 4-1 to 4-3 for the entire period have been also carried out following Stage 1 and 2.

(2) Reports

The Draft Final Report was prepared based on the survey results from Stage 1 to Stage 3 in September 2022. The Final Report was prepared in July 2023, reflecting the comments from stakeholders of the Philippine side to the Draft Final Report and adding information, data and recommendations.

(3) Steering Committee

The fifth Steering Committee Meeting was held to explain and have discussion on the Draft Final Report in November 2022.

1.6 Composition of Steering Committee and Technical Working Group

(1) Composition of Steering Committee

The Steering Committee was agreed to be organized in the M/M on the 11th of August 2017, and its composition was set by DPWH Special Order No. 167, Series of 2018, which was issued on December 10th, 2018, as follows:

(a) Chairperson

- EMIL K. SADAIN, CESO I, Undersecretary for UPMO Operations

(b) Co-Chairperson

- CONSTANTE A. LLANES JR., Director, Planning Service of DPWH

(c) Members on Philippine side

- PATRICK B. GATAN, CESO III, Project Director, Flood Control Management Cluster
  Changed to RAMON A. ARRIOLA III, CESO III (by Special Order No. 103 Series of 2019)
- LEA N. DELFINADO, CESO IV, OIC - Director, Bureau of Design
  Changed to EDWIN C. MATANGUIHAN
- ALLAN S. BORROMEO, Regional Director for Region XI
  Changed to REY PETER B. GILLE (by Special Order No. 102 Series of 2020)
- ALMARIO M. MONTON, Project Manager, DPWH - Regional Project Management Office
- WILFREDO G. AGUILAR, OIC - District Engineer, Davao City 1st District Engineering Office
  Changed to RICHARD A. RAGASA (by Special Order No. 95 Series of 2019)
- National Economic Development Authority (NEDA) Representative
- Department of Interior and Local Government (DILG) Representative
- Department of Environment and Natural Resources (DENR) Representative
- Department of Science and Technology (DOST) Representative
- Philippine Atmospheric Geophysical and Astronomical Services Administration (DOST-PAGASA) Representative
- Climate Change Commission (CCC) Representative
- Mindanao Development Authority (MinDA) Representative
- Local Government Unit (LGU of Davao City) Office of the City Engineer, Representative
- Local Government Unit (LGU of Davao City) Office of the City Planning and Development, Representative
- Davao City Disaster Risk Reduction Management Office, Representative
- National Economic Development Authority (NEDA Region Office XI) Representative

(d) Members on Japanese side

- Japan International Cooperation Agency (JICA) Headquarters and JICA Philippines Office, Representative
- DPWH – JICA Flood Management Expert

The main functions of the Steering Committee written in the Special Order are as follows:

a) To review, discuss and approve the reports;
b) To review the progress of the Project;
c) To exchange views and ideas on major challenges that may arise during the implementation period of the Project;
d) Ensure the success and desired outcome of the Study.

As described in Section 1.5, the Steering Committee meeting was held five times on the 23rd of January 2019, the 3rd of September 2019, the 24th November 2020, the 10th of February 2021 and the 8th of November 2022.

(2) Composition of Technical Working Group (TWG)

TWG was agreed to be organized in the M/M on the 11th of August 2017, aiming at assisting the Steering Committee, and its composition was set by DPWH Special Order No. 167, Series of 2018, as follows:

(a) Chairperson

- ALEJANDRO A. SOSA, CEO VI, Project Manager III, UPMO – FCMC

(b) Co-Chairperson

- NENITA R. JIMENEZ, Division Chief, DPD – Planning Services

(c) Members

- DOLORES M. HIPOLITO, Project Manager III, UPMO – FCMC
  (Added to members by Special Order No. 32 Series of 2019)
- ROSEMARIE B. DEL ROSARIO, DSD, Division Chief, Environmental And Social Safeguards Division–Planning Service
- MAXIMINA M. RAZON, Project Manager I, UPMO – FCMC
- NEDA Representative
- OCD Representative
- DENR – RBCO Representative
- PAGASA Representative
- NWRB Representative
- NIA Representative
- Planning Service of DPWH
- Region XI of DPWH
- Regional Project Management Office of DPWH
- Davao City 1st District Engineering Office of DPWH
- Office of City Engineer, Davao City
- Office of the City Planning and Development, Davao City
- Davao City Disaster Risk Reduction Management Office

The TWG meeting was held three times on the 25th of January 2019, the 29th of August 2019 and the 21st of November 2019.

Chapter 2 Basic Study and Analysis on Present Conditions

2.1 Project Location

Most of the target area of the Project, which consists of Davao City urbanized area, Davao River Basin, Matina River Basin and Talomo River Basin, is situated in the Davao Region that is one of six Regions in the Mindanao Islands. The target area administratively spreads mostly to Region XI, and partially to Region X and Region XII, and is specifically located under Davao City and the three provinces of Bukidnon, Davao del Norte and Cotabato (Refer to page xxiii of location map of the Project Area). Most of the target area is dominated in Davao city that is a chartered city and the third largest city in the Philippines. Urbanized area of the Davao City is located in the coastal area in the Southern part of the target area.

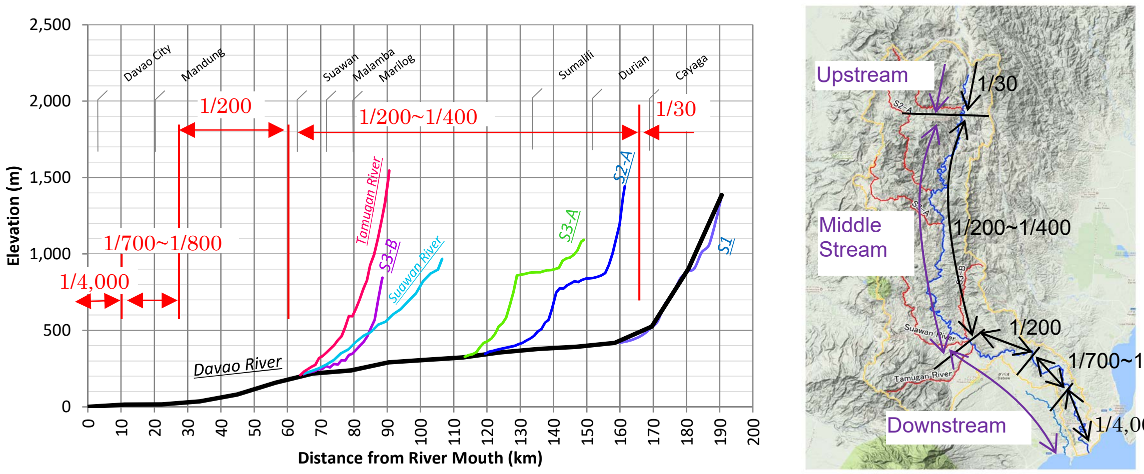
2.2 Natural Condition

2.2.1 River Condition

The southeastern part of the target area where the urban area of Davao City spreads, the lower part of the Davao River, the Matina River Basin and the southeastern part of the Talomo River Basin are relatively flat low-lying areas. The lower reaches of the three rivers and most of the urban areas targeted by inland drainage are at an altitude of 100 m or less. The Davao River originates in the mountains of southeastern Bukidnon Province and passes through towns such as Marilog, Lacson, New Valencia, and Mandug while taking up tributaries. Flowing down the urbanized area of Davao city, the Davao River finally reaches to the Davao Gulf after passing about 191 km from the origin. The basin area of the Davao River is 1,755 km^2, and 66% of the basin belongs to Davao City, and the remainder belongs to Davao del Norte, Bukidnon and Cotabato Provinces.

The stretch has a steep riverbed slope of more than 1/30 in the upstream area 170 km (where the Confluence S1 join the main stream of Davao River) from the river mouth, a mild slope of 1/200-1/400 between 67 km (at the confluence of Davao River and Tamugan River) and 170 km, 1/200 between 67 km and 40 km, a gentle slope of 1/700-1/800 between 15 and 40 km and a quite gentle slope of about 1/4000 in the urbanized downstream area between 15 km and the river mouth.

In this Study, "Downstream" indicates the Section from the River Mouth to Tamugan, "Middle Stream" the Section from Tamugan to Confluence S1 and "Upstream" the Section from Confluence S1 to the River Source.



Source: Project Team

Figure 2.2.1 Riverbed Slope of Davao River

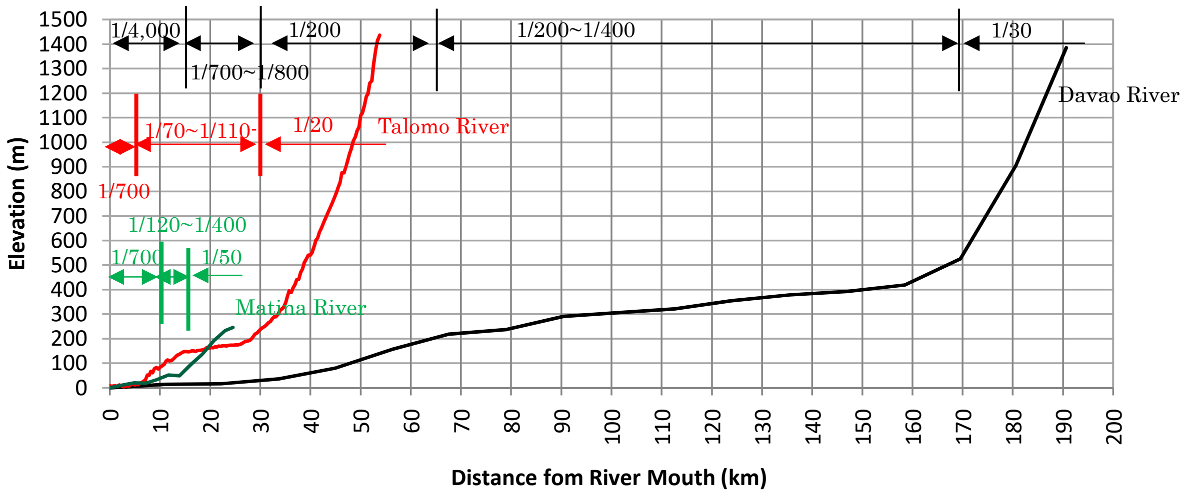
The Matina River originates in the hilly area in the northwestern part of Davao urbanized areas, runs through barangays such as Matina Biao, Tacunan, Matina Pangi and Matina Crossing, and the urbanized area of Davao city, and finally reaches the Davao Gulf. At present, the river mouth is united with the Talomo River. The Matina River is 24 km long from its origin to the river mouth. The basin area of the Matina River is about 70 km^2, and all the basins belong to Davao City.

The stretch has a steep riverbed slope of more than 1/50 in the upstream area 15 km from the river mouth, a mild slope of 1/120-1/400 between 10 and 15 km, and a gentle slope of about 1/700 in the downstream area 10 km from the river mouth.

The Talomo River originates in Apo mountain and flows through the barangays such as Wangan, Calinan, Los Amigos and Tugbok while taking up tributaries mainly from the right bank side. Flowing down the western part of Davao urbanized area, the Talomo River finally reaches Davao Gulf. The Talomo River is 54 km long from its origin to the river mouth. The basin area of the Talomo River is about 204 km^2, and almost all of the basin belongs to Davao City.

The stretch has a quite steep riverbed slope of more than 1/20 in the upstream area 30 km from the river mouth, a mild slope of 1/70-1/110 between 6 and 30 km, and a gentle slope of about 1/700 in the urbanized downstream area 6 km from the river mouth.

Figure 2.2.2 shows the riverbed slope of the three rivers targeted by this Project.



Source: Project Team

Figure 2.2.2 Riverbed Slope of Davao River, Matina River and Talomo River

Basic data for Davao, Matina and Talomo rivers are summarized in Table 2.2.1.

Table 2.2.1 Basic Data for Targeted Three Rivers

River	Length (km)	Basin Area (km^2)	Specific Discharge during Flood * (m^3/s/km^2)					
			Return Period (years)					
			2	5	10	25	50	100
Davao	191	1755	0.84	0.96	1.06	1.22	1.35	1.47
Matina	24	70	3.66	4.18	4.59	5.30	5.85	6.39
Talomo	54	204	2.42	2.76	3.04	3.50	3.86	4.22

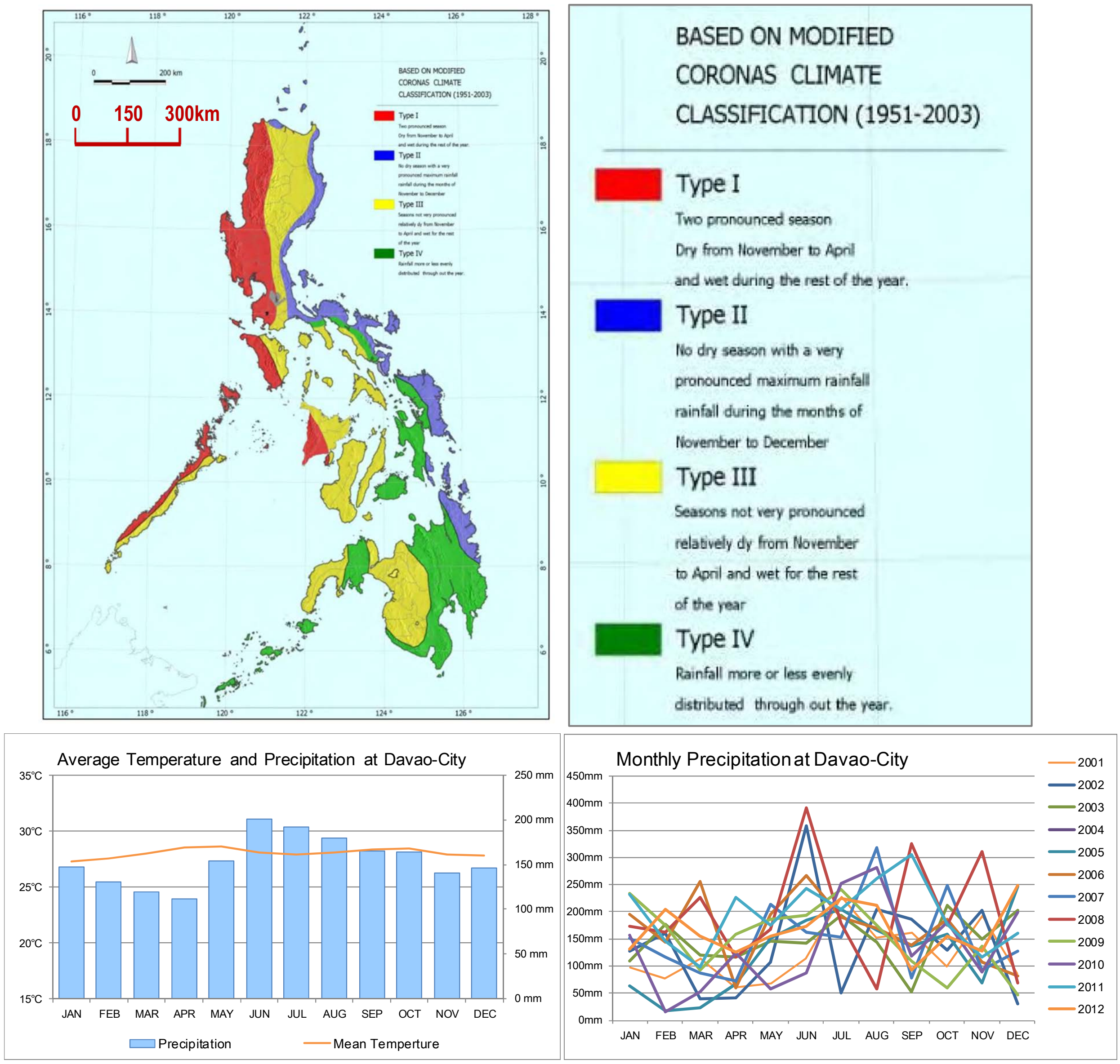
*: Calculated by using method in “Specific Discharge Curve, Rainfall Intensity Duration Curve, Isohyet of Probable 1-day Rainfall, March 2003, DPWH & JICA”

Source: Project Team

2.2.2 Climate Condition

The climate of the project area belongs to the tropical climate, and it is classified into Type IV climate classification on the climate classification map of PAGASA. Type IV is generally a climate where precipitation is evenly distributed throughout the year and has no dry season, as does Type II, which is distributed along the eastern coast of the Philippines.

The annual rainfall pattern of Davao City is shown in Figure 2.2.3. According to the meteorological data of Davao City, DAVAO DEL SUR Meteorological Observatory in PAGASA from 2008 to 2012, the annual average temperature is 28 °C, and the average temperature in each month is 27 °C to 29 °C. The annual variation in temperature is small and the precipitation is about 100 mm or more every month throughout the year. The average annual rainfall is about 1850 mm. The average monthly rainfall in April, when the rainfall is the lowest, is 110 mm, and the average monthly rainfall in June, when the rainfall is high, is about 200 mm. The rainfall trend in Davao City is that the period from May to late October has high rainfall and the period from November to April has relatively low rainfall. On the other hand, the monthly rainfall shows different trends by year, and the distinction between rainy and dry seasons is not clear.



Source: Project Team based on data/information from PAGASA

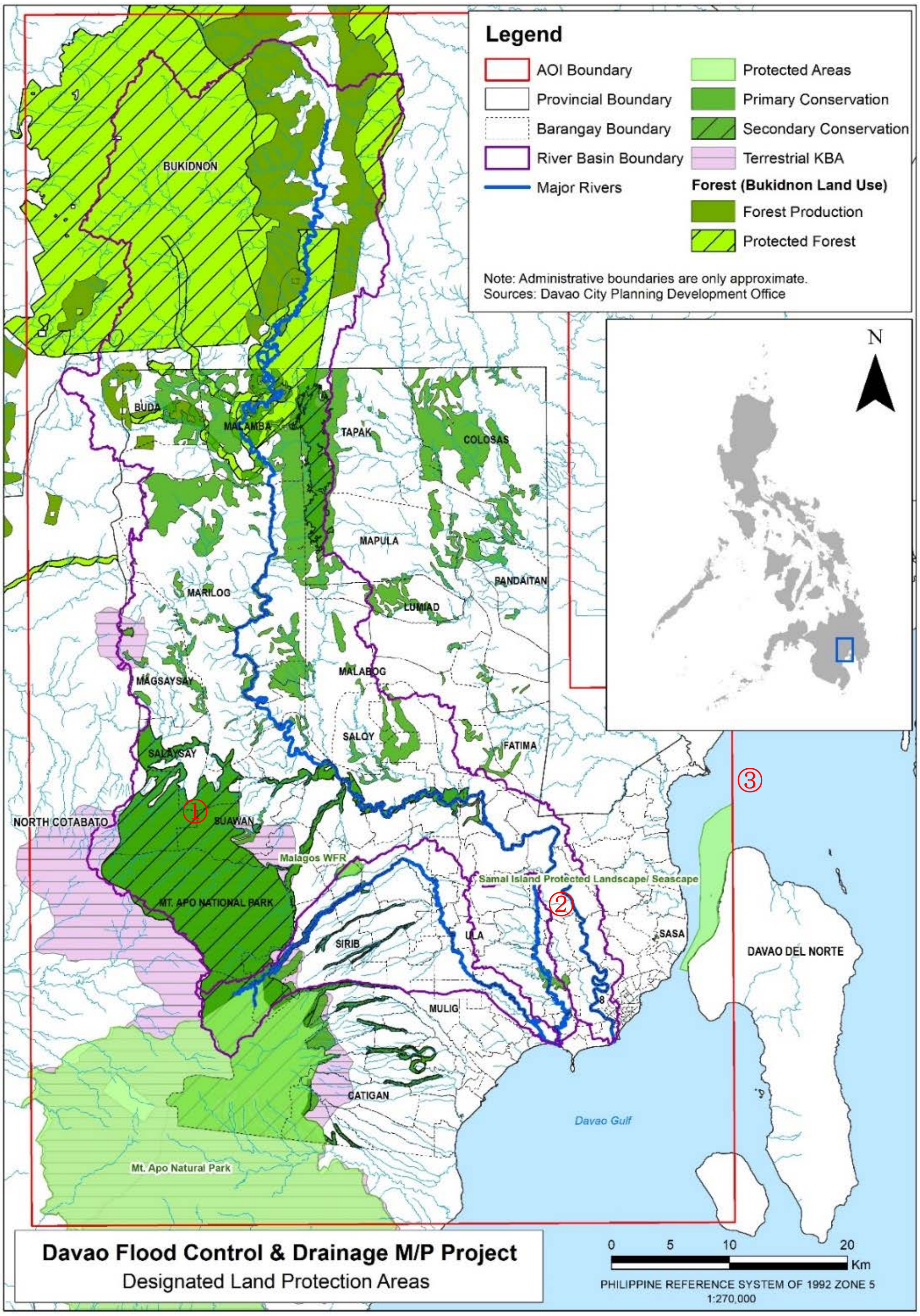
Figure 2.2.3 Climate Pattern of Davao City

2.2.3 Natural Environmental Condition

(1) Natural Resources

The Study Area, Davao City and surroundings, enjoys a tropical rain forest ecosystem, and has rich natural resources and biodiversity. However, recent rapid development and urbanization have led to the degradation of forest resources and biodiversity. Coverage area of forest (open and closed forest) decreased by 16% in the Study Area in 2016.

DENR cooperated with Davao City and other LGUs to conserve forest resources. According to the Conservation Areas of DENR, the forests in the City are classified as "Primary Conservation Areas" and "Secondary Conservation Areas", and Management Basic Policies are formulated for each class. The land use plan of Davao City has been under updating;, classification of forest is proposed as "Protection Forest" and "production Forest". Secondary conservation forest is adapted to be used for sustainable development for eco-tourism. The Figure 2.2.4 describes designated land protection area, National Park, Conservation Forest, IBA/KBA[1], etc.



Source: Project Team Based on DENR, CPDO

Figure 2.2.4 Protected Areas and Forest in the Study Area

In the Study Area, three protected areas (two in terrestrial, one in marine) have been designated as follows:

1 IBA: Important Bird and Biodiversity Areas, Key Biodiversity Areas (KBA) are 'sites contributing significantly to the global persistence of biodiversity', in terrestrial, freshwater and marine ecosystems. (IUCN 2016)

Table 2.2.2 Protected Areas

Name	Area (ha)	Year of Proclamation	Description
Mt. Apo National Park	64,000	1936/ 1996/ 2004	It is located in the highest mountain in the Philippines, and is listed in the UN List of National Parks and Equivalent Reserves and acknowledged as an ASEAN Heritage Site. Over 272 bird species, 111 of which are endemic, are recorded. It is also famous as the habitat for one of the world's largest eagles, the critically endangered Philippine Eagle.
Malagos Protected Landscape	235	1933	It is also a famous tourism site with the tourist garden resort. The Philippine Eagle Center is located there. Watershed reservation site which is a source of water supply to Davao City is in this protected area.
Samal Island Protected landscape/ Seascape	7,050	1981	It is located between Davao City and Samal Island which is known for pearl culture and tourism. DENR has established a marine protected area mostly of seagrass beds along the shore of Davao Gulf.

Source: DENR

According to the IUCN Red Data List, total of 282 wildlife have been reported as protected species (threatened, endangered); the following are categorized as threatened species.

Table 2.2.3 Endangered Species in the Study Area

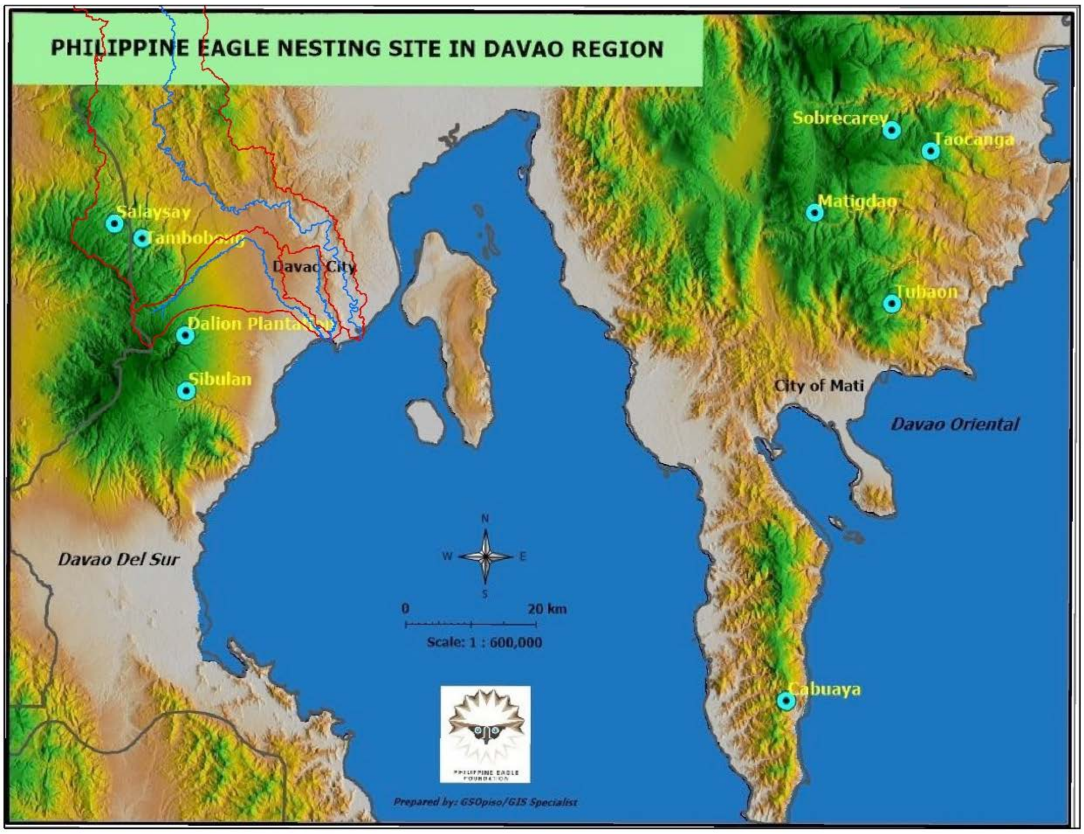
Common Name	Species	Scientific Name	Category in IUCN[1)]
Philippine Cockatoo	Birds	*Cacatua haematuropygia*	CR
Philippine Eagle	Bird	*Pithecophaga jefferyi*	CR
Largetooth Sawfish	Fish	*Pristis pristis*	CR
Philippine Crocodile	Reptile	*Crocodlus mindorensis*	CR
Philippine Woodland Frog	Amphibia	*Limnonectes magnus*	NT
Hawksbill Turtle	Reptile	*Eretmochelys imbricata*	CR

Source: Project Team based on DENR, IUCN (https://www.iucnredlist.org/) and Mount Apo Foundation, Inc. (http://www.mafi.org.ph/information/featured_topics/ft_sub_04.html)

1) CR: Critically Endangered, NT: Near Threatened

Narra (IUCN category: EN. It is mostly planted by communities), Mangapaho (IUCN NT) and Philippine dawn bat (IUCN NT), e.g. are confirmed along the Davao River according to the EIS Study for the priority projects. It is expected to observe those species along the Matina/ Talomo River.

Philippine Eagle is designated as a national bird of the Philippine; their habitat area where is located the closest form the Project site is surroundings of Mt. Apo (see Figure 2.2.5). Since headwater of the Talomo River and river basin of upper stream of the Davao River overlap the habitat area; the M/P does not recommend any structural measures in these areas.



Source：PEF, Davao City

Figure 2.2.5 Major Habitat Area of Philippine Eagle

Philippine Eagle

Principle

The Philippine Eagle, the country's national bird, is the largest forest raptor in the Philippines. In the Philippines it is visible in Luzon, Samar, Leyte, and Mindanao. They are also listed as critically endangered by the International Union for Conservation of Nature (IUCN), with only 400 pairs left in the wild.

Philippine Eagle bled in the PEF (Source; Project team)

Though it was known as the Monkey-eating Eagle; they also prey on a whole host of animals, bats, civets, flying squirrels, and macaques. The Philippine Eagles are usually under large dipterocarp trees like the native lauan to nest. The Philippine Eagle pairs need about 4000-1100 hectares of land forest to thrive in the wild. Mt. Apo is one of the important habitat; it has primary and upper hill dipterocarp trees above approximately 2,000 m. The mossy upper montane forest, dominant genera include *Lithocarpus*, *Melastoma*, *Caryota*, etc., generally is found at elevations from 1,200 m to 1,500 m, is also major habitat area.

Issues

The main issues which affect the Philippine Eagles are:

- Deforestation
- Illegal hunting
- Landscape change
- Problematic Disease

Challenges by PEF

Philippine Eagle Foundation (PEF) is a private. Non-stock, non-profit organization dedicated to saving the endangered Philippine Eagle and its rainforest habitat. Organized in 1987. They have taken the following actions for Philippine Eagle conservation.

1. Conservation Breeding Program

PEF has produced captive-bred Philippine Eagles, which will either be released into the wild or kept in the PEC for breeding purposes. The program also involves giving aid to injured Philippine Eagles who recovered from the wild. PEF focuses on natural breeding and pairing Philippine Eagles whenever possible but employs cooperative artificial insemination whenever necessary.

2. Research

The PEF's research agenda focus on:

- Hands-on management of eagles in the wild by studying several aspects of the bird's life history.
- Designing and executing habitat management plans and establishing forest corridors to bridge the small patches of forests remaining in Mindanao.

The research team also responds to the retrieval and rescue of wildlife captured by locals. Research projects are currently continuing in Mindanao, Luzon, and Leyte.

3. Conservation/ Environmental Education

The PEF's conservation education program targets urban and rural communities to develop public awareness and understanding of wildlife conservation issues.

4. Foundation Partners:

The PEF has cooperated to establish Philippine Eagle Conservation funds with, for instance, the following organization:

NGOs:

- Peregrine Fund
- Interfacing Development Interventions for Sustainability

Universities:

- University of the Philippines Mindanao
- Ateneo de Davao University (Eco Ateneo)
- University of Southeastern Philippines

Governments:

- Davao City Local Government Unit
- Department of Environment Natural Resources (Forest Management Bureau and Biodiversity Management Bureau)

Challenges by Davao City

The LGU engages Indigenous communities through its "Bantay Bukid" (Forest Guard) initiative. 200 Indigenous men are working as volunteer forest guards, for which they get a monthly allowance of 2,000 pesos to patrol four identified nesting sites. And they keep watch over some 25,000 hectares of forest.

Challenges by DENR

DENR program deals with the conservation and protection of wildlife and maintenance, restoration, and enhancement of their habitats under Republic Act 9147 on the Wildlife Resources Conservation and Protection, 2001. Priority activities under this program are the following:

(i) Sustainable wildlife resource use;
(ii) management of invasive alien species (IAS); and
(iii) enforcement of wildlife laws, rules, and regulations.

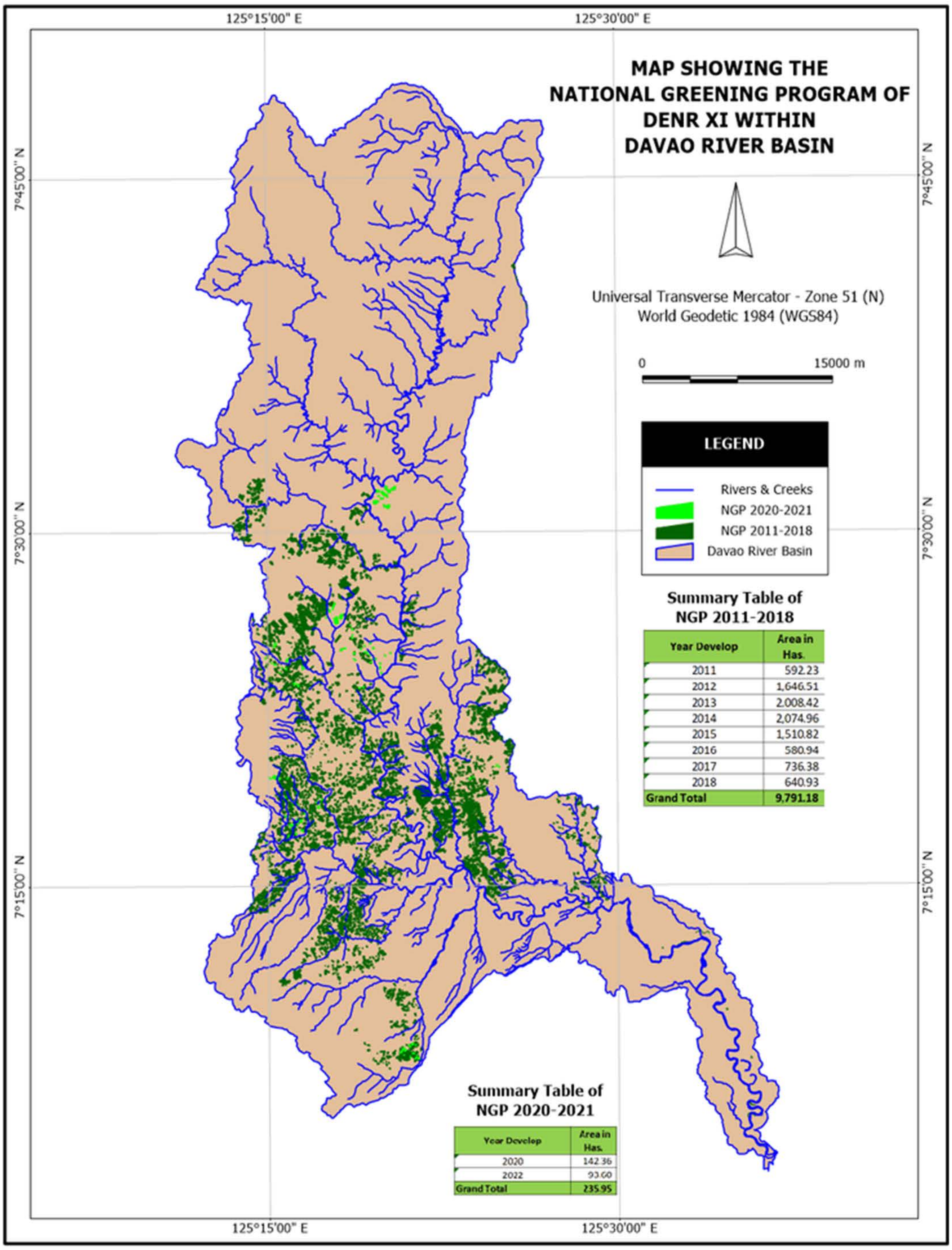
Mangrove is observed near the river mouth of Matina and Talomo River as shown in Figure 2.2.6. It was reported that recent improper development and change of landuse have decreased and aggravated mangroves. A NGO group has taken actions for conservation in the manner of reforestation, nursery, etc. “Mangroves as high flood prevention” was introduced un the stakeholder meetings; and participants agreed it. In addition, mangroves could be useful for natural conservation, recreation (bathing, walking, fishing, etc.), eco- tourism, etc.

Source: Project Team

Figure 2.2.6 Mangrove in the Project Area

In the Philippines as a whole, forest area has been recovering in recent years through efforts of greening program. This is because the National Greening Program (NGP) was promoted from 2011 to 2016 based on Executive Order / E.O. No. 26. It is estimated that 1.3 billion seedlings were planted on 1.7 million hectares of land over a six-year period by the program. In addition, the NGP was extended to 2028 and named the Expanding the National Greening Program (ENGP) under Administrative Order No. 193 (E.O. 193). The purpose of this program is to green 7.1 million hectares of unproductive, devastated and degraded forest land that remains nationwide.

The greening program is also being promoted in the Davao River basin, which is the target of this project. As shown in the figure below, the greening program has been continuously promoted since 2011, and it was promoted on 2074.9 hectares in 2014 which was the largest in the past. Although the scale has been reduced since 2016, it is still active as of 2022. Since the greening program is mainly carried out in the middle stream of the Davao River, the impact of the flood control measures of the Project targeting the downstream of the Davao River is limited.



Source: DENR

Figure 2.2.7 Implementation Status of Greening Program in Davao River Basin

(2) Geology and Topography

The topographical future of the Study Area is composed of mountains in northern and western parts and lowlands in southern part. Mt. Apo, the highest mountain in the Philippines, of which the highest point is 2,954 m from the sea level, lies on the western area. The elevation of this area is mostly 1,000 m or higher above sea level. The northern area is classified as mountains dominant. On the other hand, flat areas are distributed in the southern area along the coastline facing Samal Island and Davao Gulf. Those areas are urbanized and/or have been rapidly developed.

Due to the Mountainous topographical feature, most of the Study Area is steep, with slopes more than 18% in which the area development/activity are limited. While low land, in the southern area, shows flat features.

Figure 2.2.8 shows in the Top, the Geology Map of the river mouth area of the Davao River prepared by the U.S Army in the 1940s. In the Bottom, the River bank and Seashore Lines are superimposed on Google Map. As illustrates in this Figure, the River Channel was meandering from the place where the Bolton Bridge (around 2 km from the actual River Mouth) is currently built, and in 1940, the river channel swung eastward. Consequently, it can be remarked that the actual urbanized left side of the current Davao River was originally an unused lowland highly exposed to flood risk.

Geology Map prepared by the U.S Army in the 1940's superimposed on Google Map

River and seashore lines (Yellow Lines) of the Geology Map prepared in the 1940's superimposed on Google Map

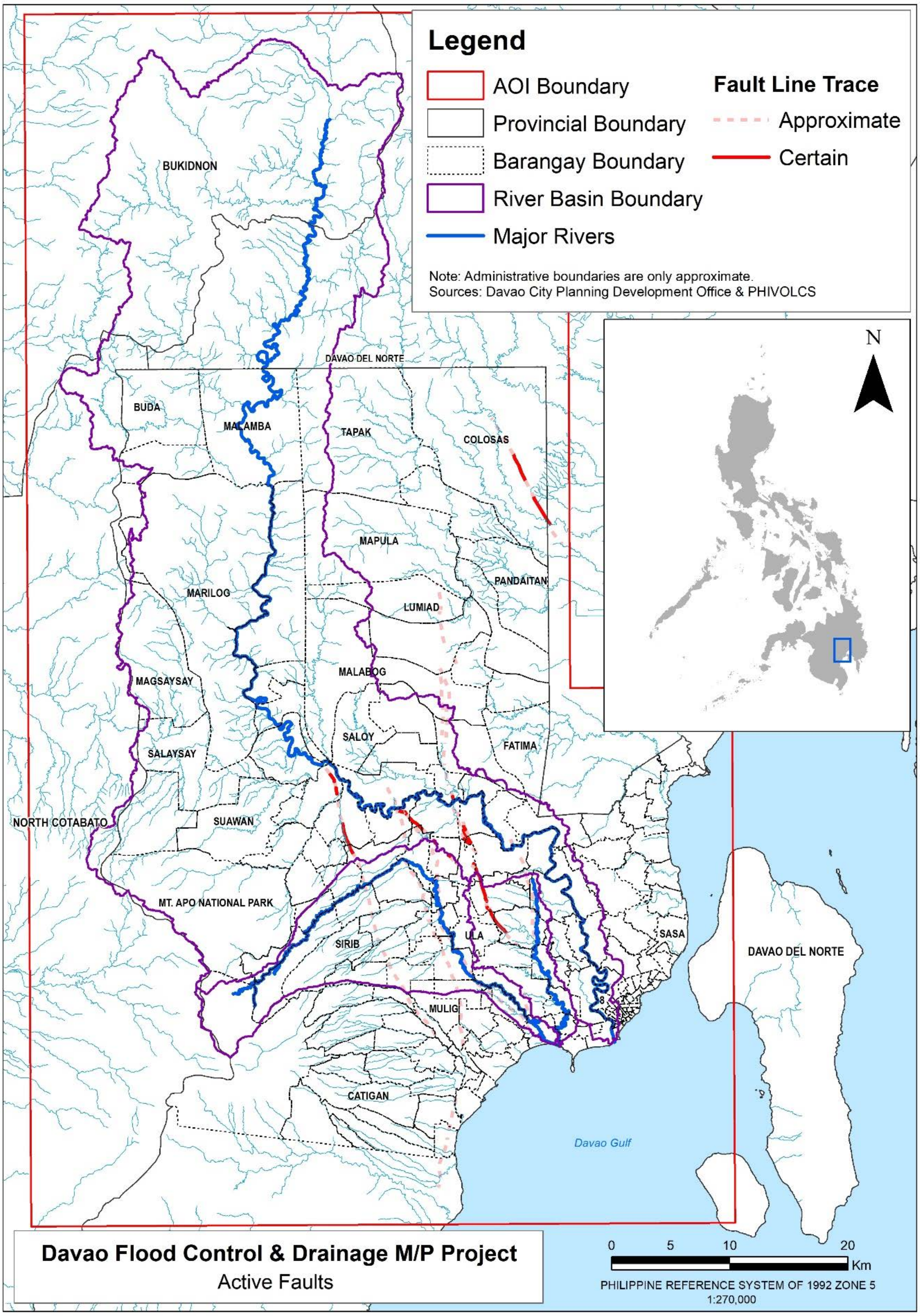
Source: U. S. Army, Google Earth

Figure 2.2.8 Comparison between the Actual and 1940's Situation of the River Mouth

(3) Natural Disaster

1) Earthquake

Figure 2.2.9 shows the location of active faults. Significant earthquakes in 2013 and 2018 (magnitude 5.7 and 7.2 respectably) occurred at the east-south-east sea bed form the Davao; whereas in recent years the seismic point of recent earthquake happened between October and December 2019 is located around Mt. APO (Active volcano, but no record of eruption in the recorded history); monitoring network has been strengthened.

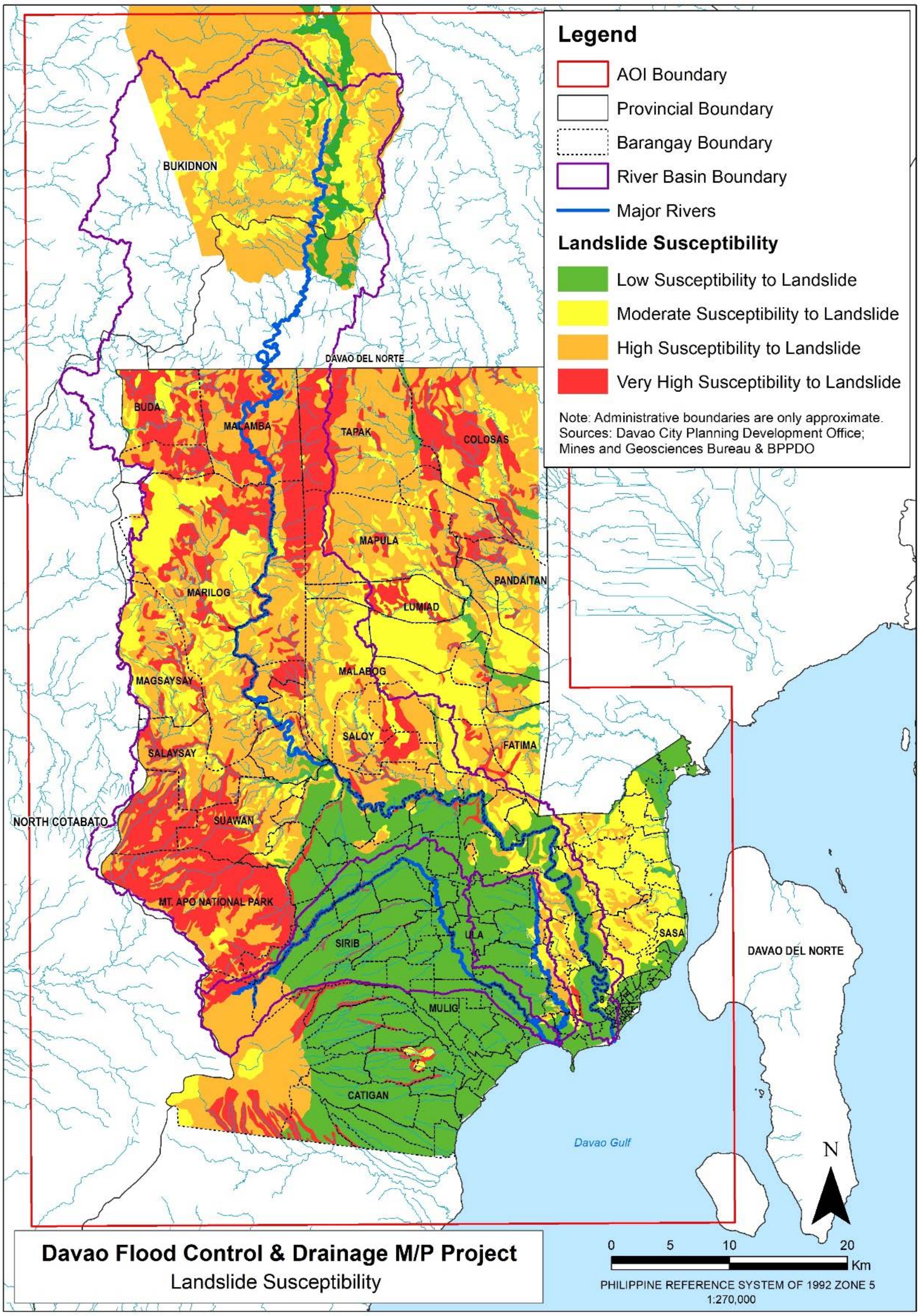


Source: PHIVOLCS

Figure 2.2.9 Location of Active Faults in the Study Area

2) Landslide

Mechanism of Landslide depends on natural topographical conditions, such as soil, slope, elevation, etc.; therefore, the high risk area lies on northern area as shown in Figure 2.2.10.



Source: MGB

Figure 2.2.10 Landslide Susceptibility in the Study Area

2.2.4 Pollution

(1) Air Pollution

Figure 2.2.11 shows locations of ambient air quality survey in the F/S for Davao City Bypass Construction Project; Table 2.2.4 results air quality level. And Figure 2.2.12 shows annual trend of PM10 in ambient in Tril.

Source: Project Team: Davao City Bypass Construction Project; 2015

Figure 2.2.11 Locations of Ambient Air and Water Quality Survey

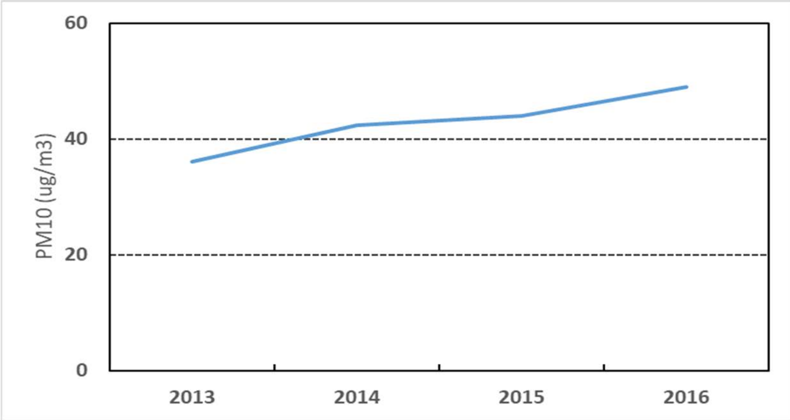
Table 2.2.4 Results of Air Quality Survey

Items / Location	TSP (ug/m^3)	NO_2 (ug/m^3)	SO_2 (ug/m^3)	CO (ppm)
A3	128.1	2.4	4.6	<1.0
A7	82.0	0.9	1.1	1.0
Standard in Philippine[1)]	300	260	340	30
Standard in japan[2)]	$200ug/m^3$ (as SPM)	0.04-0.06ppm ($82\text{-}123ug/m^3$)	0.1ppm ($172ug/m^3$)	10ppm

Source: Davao City Bypass Construction Project; 2015

1) DENR National Ambient Air Quality Standards for Source Specific Air Pollutants

2) MOE Japan Notification No. 25, 1970



Source: EMB XI

Figure 2.2.12 Annual Trend of PM10 (2013 - 2016)

Recent population increase has led increase of traffic volume; and this situation has caused increase of air pollution. The condition, however, in Davao City could be said appropriate air environmental level.

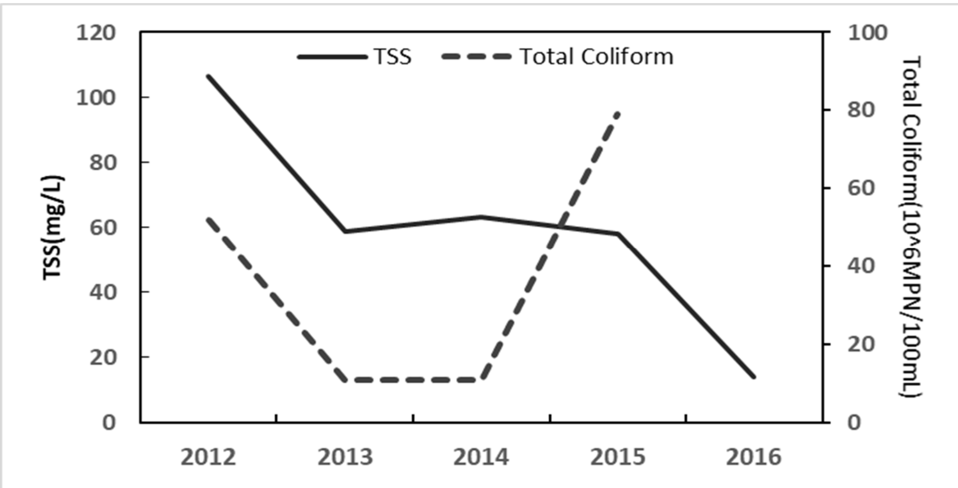
(2) Water Quality

The following table shows water quality in the three (3) rivers, Figure 2.2.13 describes annual trend of TSS and Total Coliform in the entire Davao River.

Table 2.2.5 Water Quality Condition in the Davao City

Items / Location	DO (mg/L)	TSS (mg/L)	BOD (mg/L)	Fecal coliform (MPN/100mL)
W2-Davao	7.6	82.0	0.5	9,200
W3-Matina	7.3	2.0	2.0	9,200
W4-Talomo	7.5	3.9	3.9	16,000
Davao River[1)]	6.9	14.1	1.3	107,562
Standard in Philipoine[2)]	> 5.0	30	7	1,000
Standard in Japan[3)]	> 5.0	25	3	5,000

Source: Project Team: Davao City Bypass Construction Project; 2015
1) Average of water quality in the downstream of the Davao River, EMB XI, 2016
2) DENR Administrative Oder (DO) No34-series of 1990
3) MOE Japan Notification No. 25, 1971

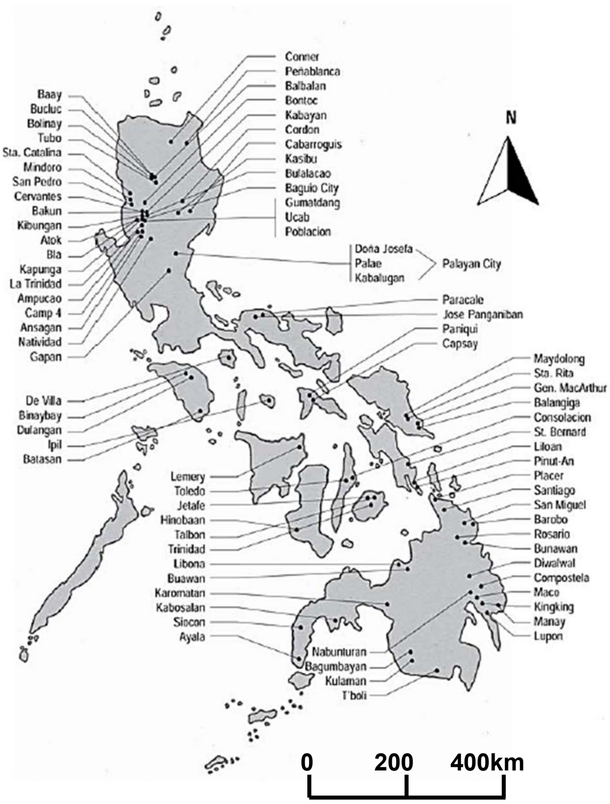


Source: EMB XI

Figure 2.2.13 Annual Average of TSS and Fecal Coliform (2012 - 2016)

Level of Fecal Coliform showed higher value and exceeded the standard level because of source of domestic water discharge to the river; other items showed appropriate level. It was found high level of TSS concentration. Since no significant gap of TSS between upstream and downstream or higher concentration of TSS happened in the upstream where less significant human activity was found: such high concentration may be caused by some geological and geographical features (inflow of the sand from the mountainous area, e.g.).

Mercury Pollution by Small scale gold mining



Small scale gold mining in Philippines
Source : MGB

There were many artisanal and small scale gold mining (ASGM) operated in various locations in the Philippines; it was counted over 100 locations in the end of 1980's (MGB, 1998). Most of the ASGM were operated in family or community level; no sufficient working condition nor environmental prevention were obtained; such situation caused degradation of aquatic biota and human health problems.

Since Tagum City, North Davao Province located at the closed-off section of the Davao Bay had been known as export port of mining production inc.; gold; many ASGMs were operated along the Agusan River. Serious mercury poisoning cases were reported form the hospitals.

Study in 2005 by the DOH estimated that 13.5 metric tons of toxic mercury flow annually through rivers into the Davao Gulf, and fish sample from the markets revealed that they have mercury contents higher than the allowable limit.

The MGB-Region XI has been taken monitoring the rehabilitation of Naboc River where mercury contamination and pollution was present in the river. And then it was reported that mercury contamination in sediment sample has been significantly reduced according to the test results of the processed sand and gravel and laboratory test.

Operation of the ASGM has been banned this time; MGB reported that over 100 ASGMs operated in 1980's had reduced near zero (0) in 2000's.

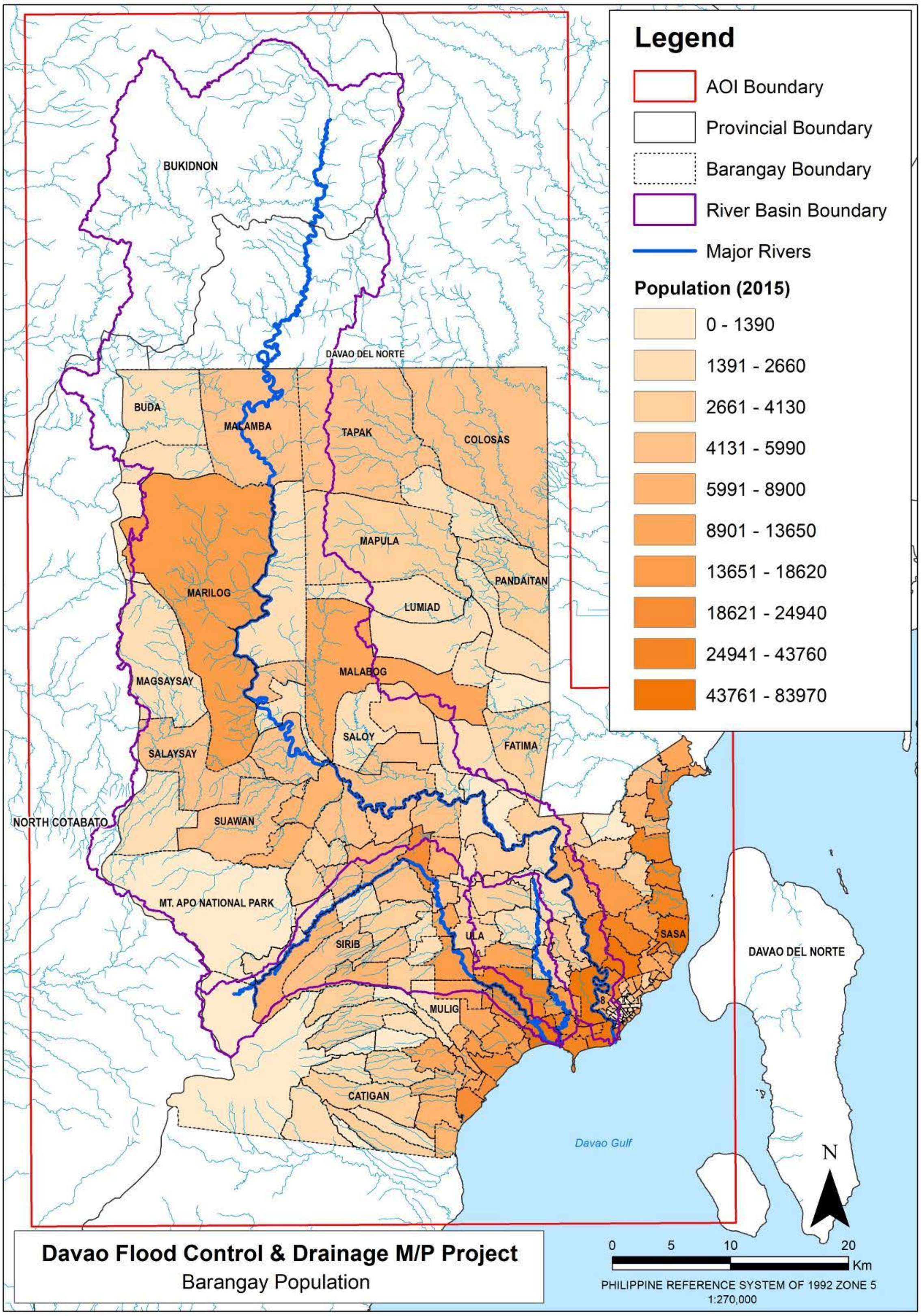
Such operation of the ASGMs and mercury pollution in the Davao/ Talomo and Matina River have not been reported. Ambient water quality monitoring in 2017 by the EMB reported mercury detection of 0.003mg/L, slightly higher than standard limit (<0.002mg/L), in Barangay Mandug and Ma-a; while no cases of detection have been recorded since 2017.

2.3 Social Condition

2.3.1 Socio-economic Condition

(1) Population

Davao region consists of Davao City, the third biggest city (the largest administration boundary), is popular as an economic central area in Mindanao Island. This area, especially Davao City, has enjoyed a rapid population increase and urbanization. The population increase from Year 2010 to 2015 was estimated at approximately 2.3%. Figure 2.3.1 shows the population pattern in Davao City.



Source: DCPDO

Figure 2.3.1 Population Pattern in Davao City

In addition, the Table 2.3.1 indicates Davao City and three LGUs (Kitaotao, Quezon and San Fernando).

Table 2.3.1 Population in the Study Area

Name of LGU	Population (thousand)	Average Annual Growth (%)
Davao City 1)	1,633	2.3
Kitaotao[2)]	49	2.8
Quezon[2)]	91	1.4
San Fernando[2)]	50	2.3

1) Year 2015, 2) Year 2010

Source: Davao City CLUP, Bukidnon Provincial Statistical Profile, NSO.

Population density in the urban area/barangays was 43 persons/ha on average compared to 1.5 persons/ha on average in rural area. The most dense area was Poblacion, where the average is about 61 persons/ha.

(2) Economy

Major economic sources in the Study Area are listed below:

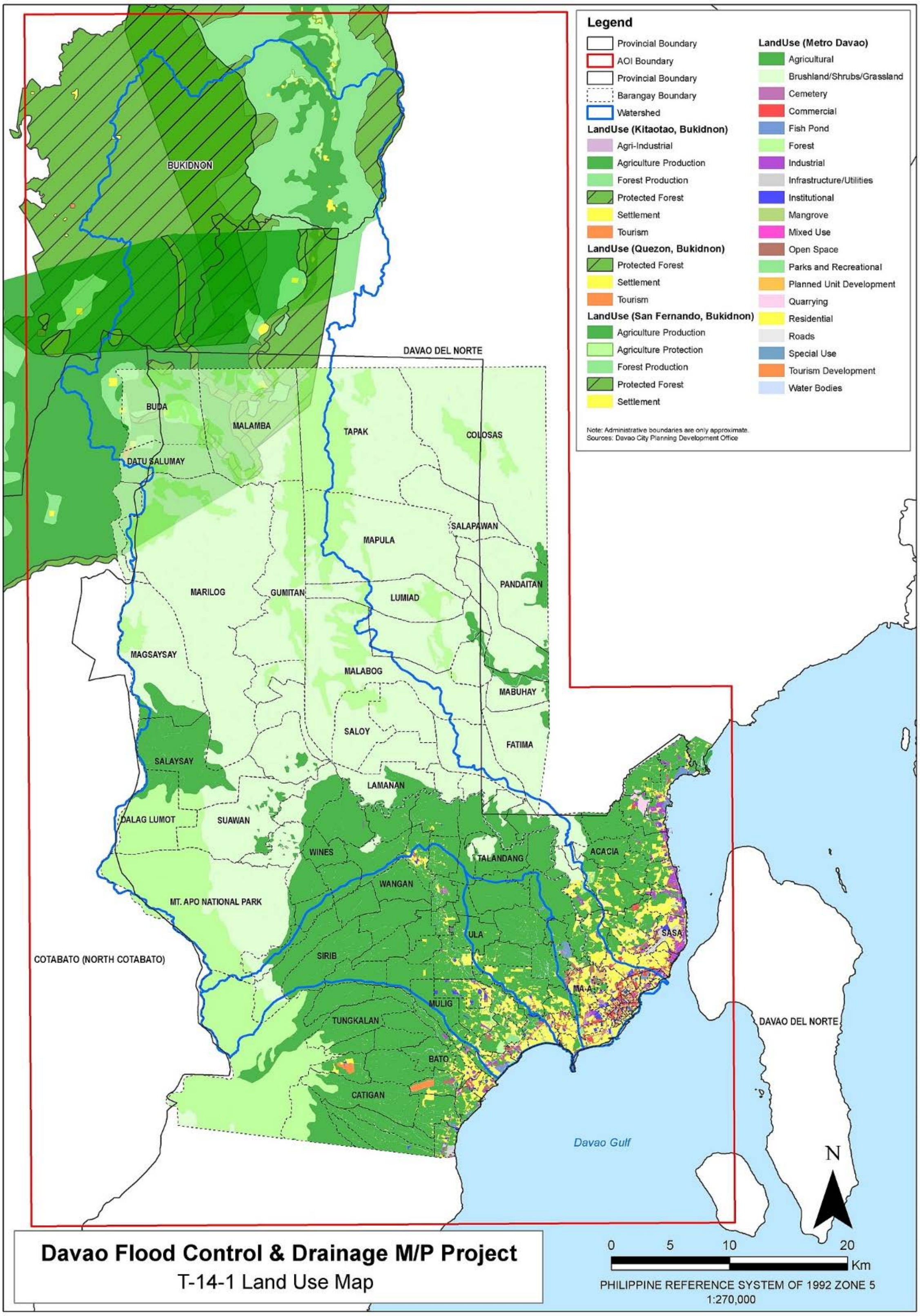
- Services (consisting of 50.2% in Davao City[2])
- Industry (32% in Davao City)
- Agriculture and Fishery (17.8% in Davao City)

Agriculture and fishery are two of the key economic activities in Davao, which could be affected by either floods or its control measures.

1) Agriculture

Figure 2.3.2 describes land use in the Study Area.

[2] NSO, 2017



Source: DCPDO and other LGUs

Figure 2.3.2 Land Use in the Study Area

The agricultural production areas are concentrated in the inner and upper portions of Davao City, particularly in Marilog, Calinan, Baguio, etc., which areas are known for rice/ crop, corn, coconuts, banana, etc. Kitaotao, which topographic condition shows gently sloping, undulating areas, is known as traditional production areas for corn, sugarcane and banana. San Fernando also produces rice, corn, cassava and high-value crops. Table 2.3.2 summarizes agricultural productions.

Table 2.3.2 Types of Agricultural Production

Name of LGU	Crops	Fruits/ Vegetable	Others
Davao City	Rice, Corn	Banana, Pineapple, Citrus, Durian, Rambutan, Pomelo	Coconut, Coffee, Cacao, Rubber
Kitaotao	Rice, Corn, Sugarcane, Cassava	Durian, Mango, Lanzones, Rambutan, Jackfruit, Banana	Rubber, Coconut, Peanuts/ Beans
San Fernando	Rice, Corn, Cassava	Banana, Durian, Lanzones, Mango	Abaca, Coffee, Coconut, Rubber, Falcata
Quezon	Rice, Corn, Sugarcane	Banana, Durian, Vegetables, Legumes, Rootcrops, Mango	Rubber, Coffee, Coconut

Source: CLUPs of Davao City, Kitaotao, San Fernando, Quezon

2) Fishery

Davao Gulf is known as important fishing grounds in the country. The Davao Regional Development Plan reported the annual fisheries production in the whole of Davao region approximately at 67,468 tons (in 2012 total of commercial and municipal fishing, aquaculture). Among the valuable catch in the gulf are yellow fin tuna, anchovy, and herring. Tilapia and Hito in fresh/ blackish water are also typical fishing production in this area. According to the Registration Program by BFAR, approximately 22.7 thousand fisher folk have been registered; around 9.9 thousand of them have been in Davao del Sur including Davao City.

DENR XI as well as BFAR have warned that water pollution, sedimentation and improper fishing practices degrade coral and sea grass area where are important habitats of aquatic biota.

Major fishing areas are around the Aplaya Peninsula, opposite side of Davao City near the Samal Island as delineated in Figure 2.3.3. Migratory fish, Tuna, e.g., is mainly migrating eastern Samal. Fishing villages is not located at mouth of Davao River; some fishmen have resided; and go out of the mouth for fishing.

Source: Project team

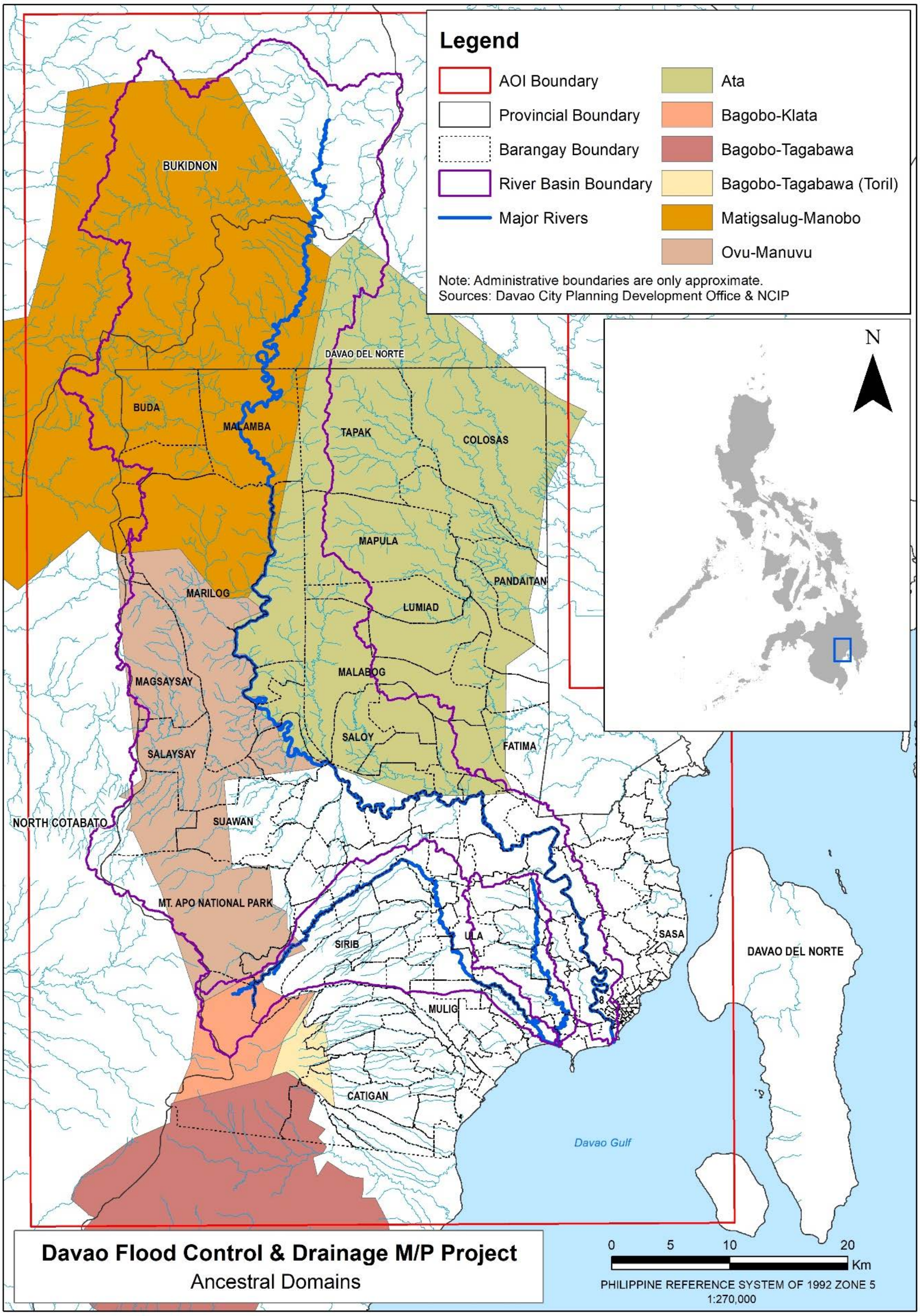
Figure 2.3.3 Major Fishing Areas

(3) Indigenous Peoples

The Indigenous Peoples (IPs) communities are the largest and most important stakeholders especially in the upstream of Davao River.

The following five (5) groups have resided in six (6) ancestral domains lands located in mostly the northern area and ridge of Mt. Apo (Figure 2.3.4).

- Ata
- Klata/ Giangan
- Maligsalug
- Obu-Manuvu
- Tagabawa



Source: NCIP

Figure 2.3.4 Ancestral Domains

The land in the ancestral domains is secured by legal right to be used by the IPs groups based on the RA 8371: "The Indigenous Peoples Rights Act of 1997" (IPRA); they have used and managed natural resources (forest, watershed) based on the Ancestral Domain Sustainable Development and Protection Plan (ADSDPP) supported by the NCIP in their territory. In case any development activity including flood control measures is planned and implemented in those areas (traditionally used by the IPs group, NCIP issues Certificate of Ancestral Land Title (CALT) [3]), coordination meetings with IPs organization/committee must be undertaken in order to build consensus with them. And then a Certification of Precondition (CP), issued by the NCIP, shall be obtained. Table 2.3.3 summarizes the profiles of major IPs groups.

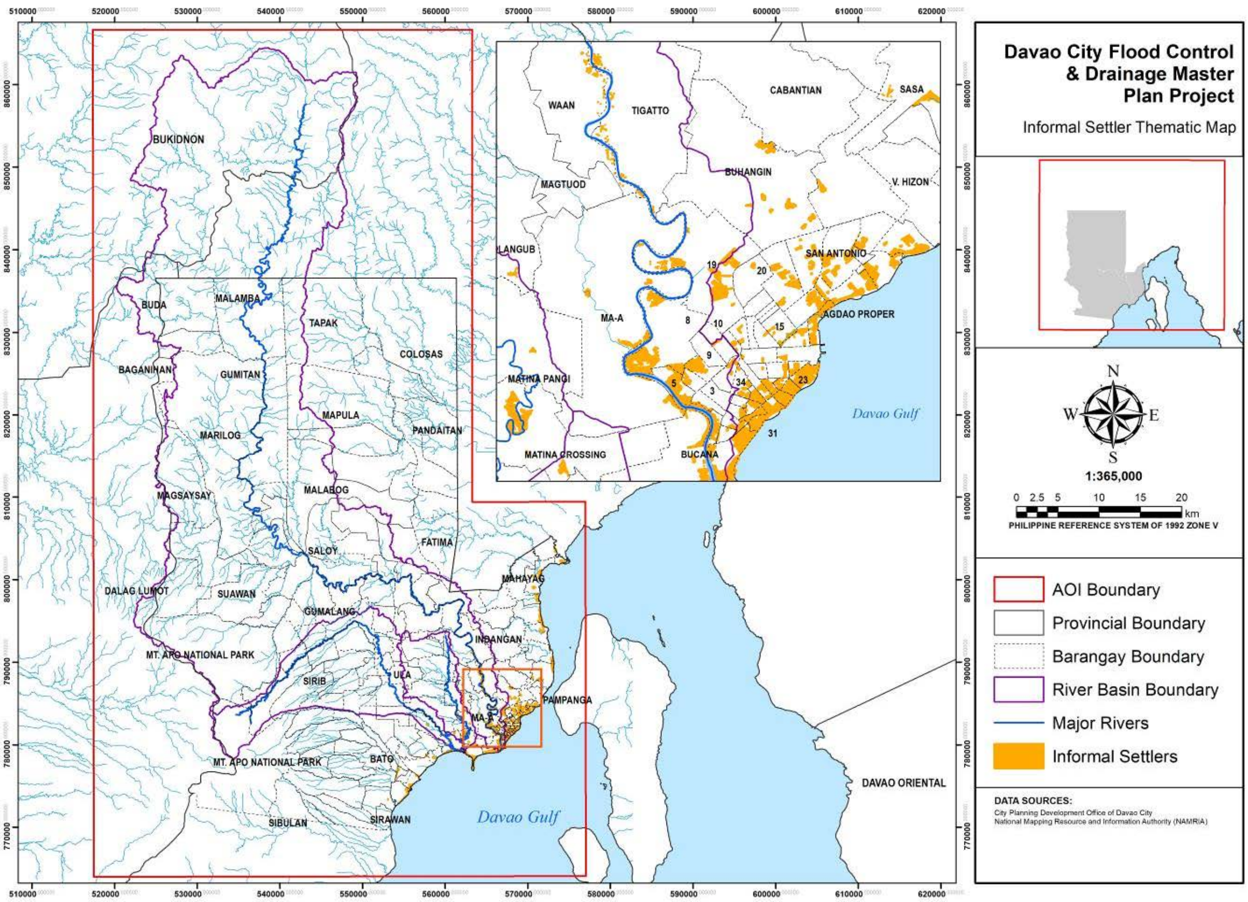
Table 2.3.3 Profile of Indigenous Peoples Groups

Name of IPs Group	Population (thousand)	Area (km^2)	Major Livelihood
Ata	14.1	876.7	Farming, hunting, fishing, carpenter
Klata/ Giangan	3.7	68.4	Farming, plantation workers
Maligsalug	-	877.0	
Obu-Manuvu	22.4	351.7	Farming, plantation workers, fishing, hunting
Tagabawa	14.4	239.8	Farming, carpenter, laborer

Source: Ancestral Domain Sustainable Development and Protection Plan

(4) Resettlement, Informal Settlers

Figure 2.3.5 shows description of the dwellings of informal settlers (ISFs) in the Davao City. Approximately 60 thousand of households were confirmed as of 2017 (Davao City and NAMRIA）.



Source: Davao City, NAMRIA

Figure 2.3.5 Area Informal Settler Families Residing

3 CADT (Certificate of Ancestral Domains Title) is also issued in case of control of development.

Dwelling area of the ISFs are mostly observed along the rivers and the coastal area. The Davao City issued ordinance in 1992 to take action of relocation of the ISFs from the viewpoint of encouragement of public development and disaster prevention. The ordinance declares compensation of their asset, income recovery support and provision of relocation site with houses and infrastructures for the ISFs who had resided before 1992. However, the number of ISFs has still increased. It is said barangay cannot properly control the informal migration in their territory because their budget allocation from the central government depends on the population.

Table 2.3.4 Shows approximate number of buildings to be relocated which include ISFs' dwellings. The number was estimated based on the GIS data provided by the Davao City, Google map and drone survey. Actual number of persons/ households in the area of the priority projects are estimated in the F/S and resettlement study.

Table 2.3.4 Approximate Number of Buildings to be Relocated

Project Site	River Flood			Inland Flood	Coastal Flood
	Davao River	Talomo River	Matina River		
No. of Buildings[1)]	1,600[2)]	160	210	10	None

1) It is not number of households.

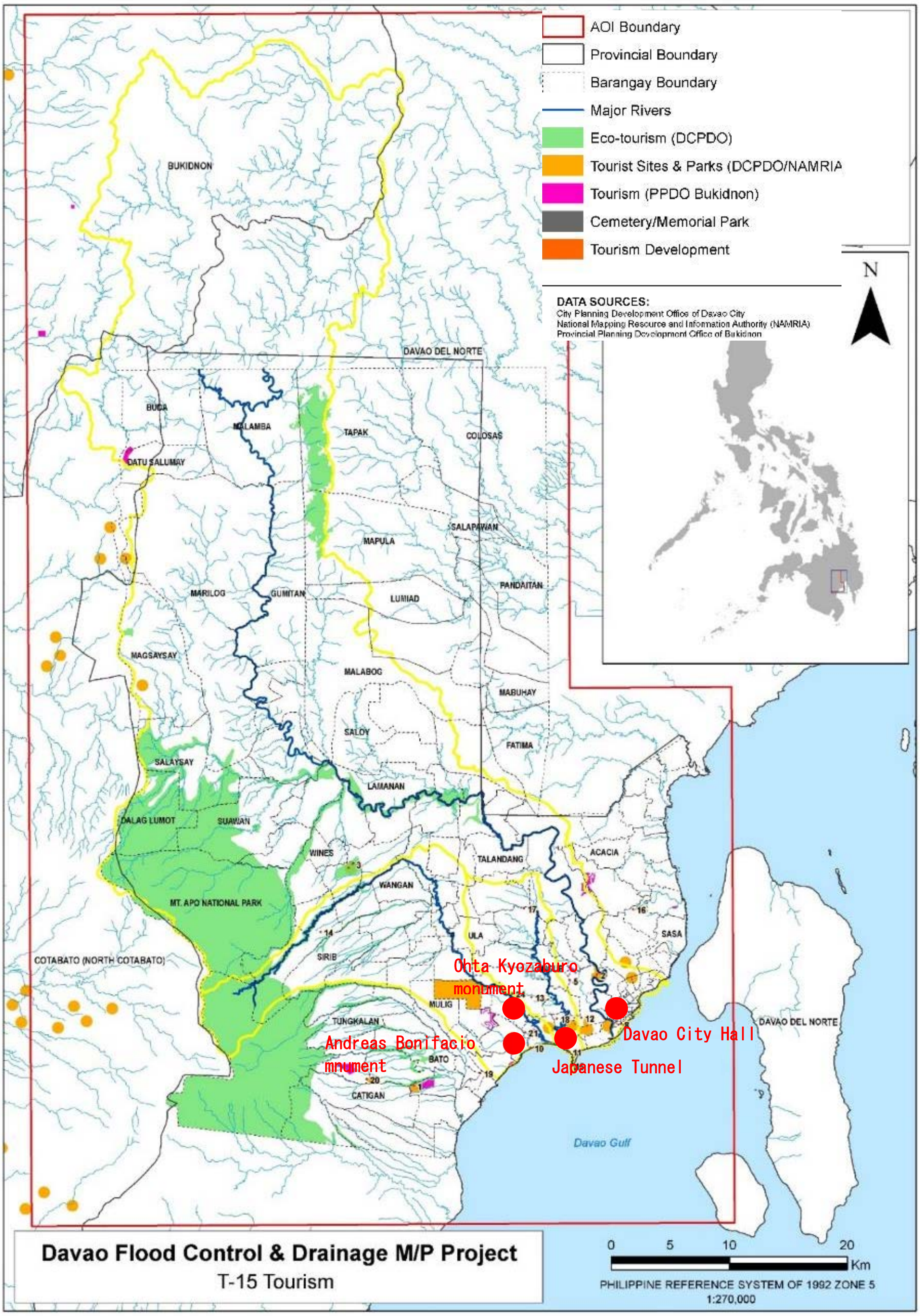
2) By project: 1,400 by river widening (inc. 45 by cut-off works, and 3,500 in case inc. easement), 200 by retarding ponds.
Source: Project Team

(5) Tourism and Recreation

Popular nature tourism sites are the Philippine Eagle Center, Davao Crocodile Park and the Davao Butterfly Garden, Malagos Garden Resort; more than 120,000 tourists visit annually. A number of beach resorts operate along the Davao City coast line and on the opposite side in Samal Island. Many private resort spots have been rapidly built along the river side. Davao City as well as other LGUs in the Study Area have concentrated on establishing eco-tourism; CPDO has designated a forest conservation area which is utilized for community-based sustainable eco-tourism in cooperation with IPs groups.

There is no World Heritage to be designated; National Historical Commission of the Philippines, on the other hand, declared "Davao City Hall", "Monument of Andreas Bonifacio (Tril district Office)", "Monument of Ohta Kyozaburo (Mintal)", "Japanese Tunnel (Talomo) as National Cultural Heritage.

Figure 2.3.6 illustrates tourism sites/ spots in the Study area (red circles in the map above heritages).

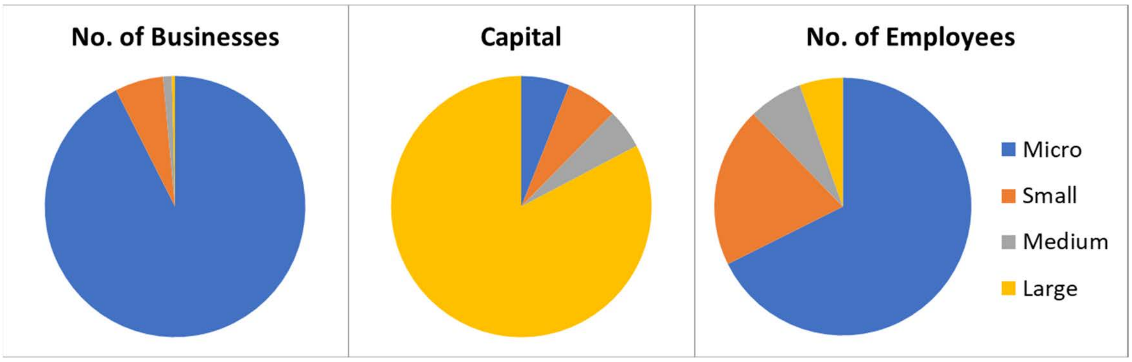


Source: CPDO

Figure 2.3.6 Tourism Sites/ Spot in the Study Area

(6) Commercials, Services and Industries

Approximately 31,500 business establishments are operated in Davao City. Figure 2.3.7 shows the share of each business enterprise, capital and number of employees.



Source: DCPDO

Figure 2.3.7 Share of business enterprises by scale

93% of these are micro-enterprises (average number of employees: 3 workers and capital: less than 500,000 Pesos), engaged mainly in handicrafts, food processing, trading and services.

Major large scale enterprises are involved in processing agricultural and forest products such as Mt. Apo Fruits, Davao Fruits, Lapanday Agricultural and Development Corp., which are all located in Buhangin. The city's secondary centers for instance Buhangin, Calinan, and Malagos, function as some medium-scale urban facilities and services, such as secondary or tertiary schools, sub-government centers, hospitals, and integrated food and transport terminals.

(7) Gender

Gender Mainstreaming or Gender and Development (GAD) mainstreaming is the major global strategy for ensuring that the government pursues gender equality in all aspects of the development process to achieve the vision of a gender-responsive society where women and men equally contribute to and benefit from development.

Philippines is known as "the most advanced respected gender in Asian countries"; it was evaluated the 16th out of the 153 countries (Japan: 121st) and top 1 in ASEAN countries according (Global Gender Gap 2020). The most highly evaluated factor was "high participation level in social-economic activities". The Philippines Commission on Women (PCW) has been established as one of the institutions under the direct control of the president; it has been regulated that any ministries/ departments, LGUs, national universities must allocate 5% or more of the budget to gender management. In addition, approval of PCW is required to use the budget.

Table 2.3.5 is a list of major legal framework for the gender mainstreaming.

Table 2.3.5 Legal Framework for the Gender Mainstreaming

Law/ Regulation	Description
The Magna Carta of Women (Republic Act No. 9710)	Define Gender and Development Program (GAD) as the development perspective and process that is participatory and empowering, equitable, sustainable, free from violence, respectful of human rights, supportive of self-determination and actualization of human potentials.
Approving and Adopting the Philippine Plan for Gender-Responsive Development (PPGD) 1995-2025	Executive Order (EO) 273, issued on September 9, 1995 and signed by President Fidel V. Ramos, adopted the Philippine Plan for Gender Responsive Development IPPGD) 1995-2025. The PPGD 1995-2025 is a 30-year perspective plan that outlines the policies, strategies, programs and projects that the government must adopt to enable women to participate in and benefit from national development
The Responsible Parenthood and Reproductive Health Act of 2012	Guarantee the human rights of all persons including their right to equality and non-discrimination of these rights, the right to sustainable human development, the right to health which includes reproductive health, the right to education and information, and the right to choose and make decisions for themselves.
105-Day Expanded Maternity Leave Law	Amendment of the maternity Leave Law issued by Former President Duterte to extend the previous 60-day paid maternity leave to 105 days.
RA 6725 or the Prohibition on Discrimination Against Women	Prohibit discrimination with respect to terms and conditions of employment solely on the basis of sex.
RA 7882: Assistance for Small-scale Women Entrepreneurs	State the provision of assistance to women engaging in micro and cottage business enterprises.

Source: Project team

On the other hand, evaluation score on welfare and security fields has been decreased. Disadvantage of care to especially handicapped females comparing to males has been pointed out. It is also pointed out that female voice cannot properly reach in rural communities.

Therefore participation of female in the stakeholder meetings must be encouraged during a planning stage.

The Davao City is the one of the first pioneer to take actions for Gender mainstreaming recognized by the PCW; currently the following four (4) programs have been implemented.

A) Establishment of an Integrated Gender and Development Division (IGDD)

It was created through City Ordinance No. 5004 to oversee the full implementation of the Women Development Code. The primary task is to ensure gender mainstreaming in the City of Davao through the integration of gender and development in all areas of local governance.

B) Office of the Special Counsel on “violence against women (VAW)”

This office provides free legal assistance dedicated to VAW victim-survivors seeking justice or redress from perpetrators of abuse/violence. counseling is undertaken by lawyer, psychologist, or technical staff; and then provided feedback to IGDD. It is also provided counseling to the men who violate to women.

C) Child-Minding Center

It was established in 1998 to cater to the children of Davao City local government employees. The Center prioritizes the children of solo, and poor parents who are not capable of hiring babysitters/caretakers of their children.

D) Ray of Hope Village

The Ray of Hope Village was established in 2008 as a separate detention facility for female persons deprived of liberties. The facility has 20 cottages that accommodates 10-15 inmates per cottage.

DPWH has also taken actions for the gender mainstreaming. The followings are key legal framework under the DPWH.

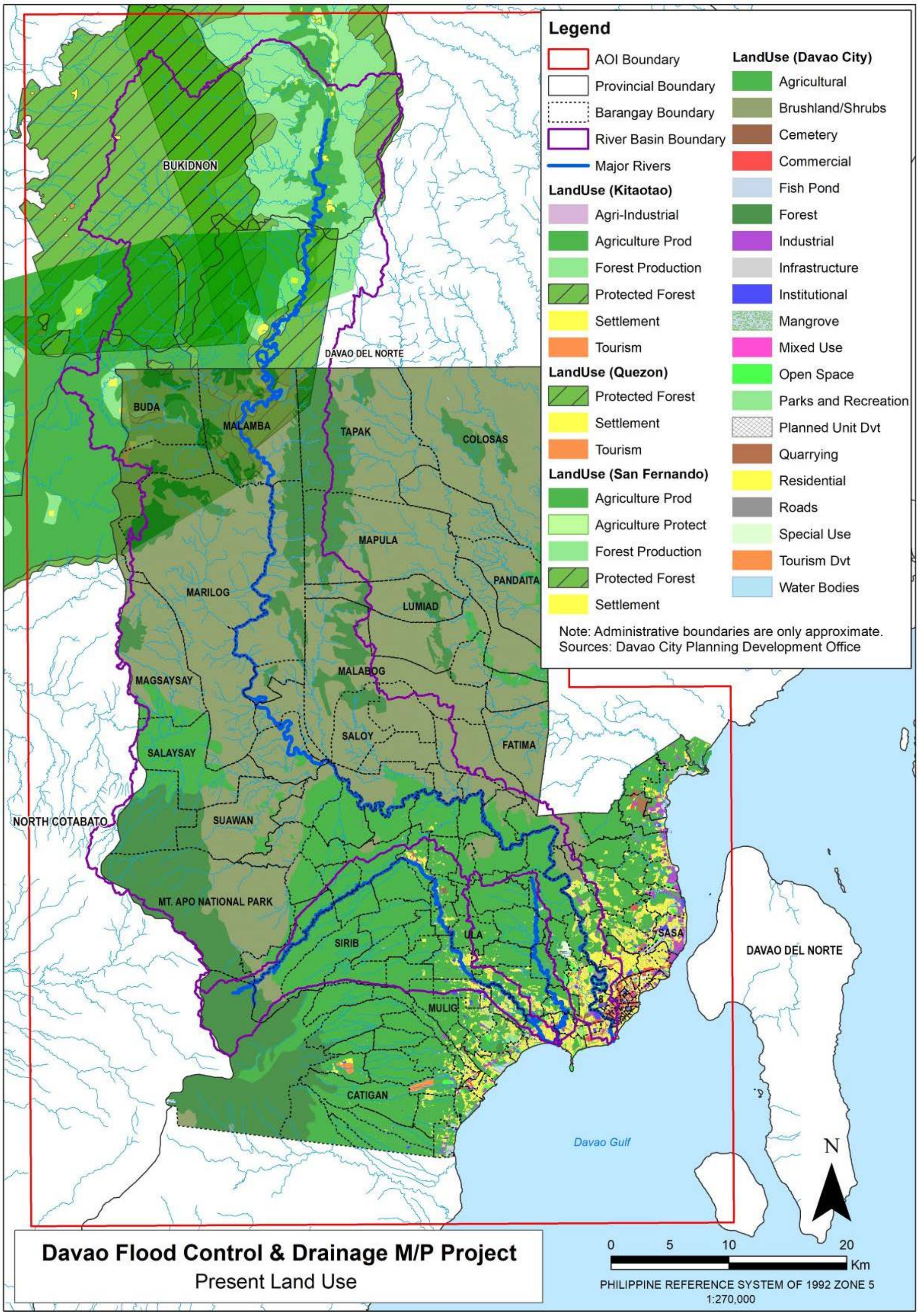
Table 2.3.6 Legal Framework under the DPWH

D.O. Number, Year Issued	Description
D.O. 165, 1989 D.O. 158, 1992	Establishment and reconstruction of the DPWH on Women in Development.
D.O. 192, 2003	Designation of PREMIUMED - PMO to undertake the Implementation of the Projects for the Handicapped and Infrastructure Support to Gender and Development.
D.O. 048, 2011	Guidelines for Mainstreaming Gender Equality Actions in Road Infrastructure Projects.
D.O 093, 2012	Guidelines for the Preparation of Annual Gender and Development (GAD) Plan and Budget and Accomplishment Report.
D.O. 022, 2012	Establishment of The DPWH Committee on Gender and Development
D.O 015, 2013	Reconstitution of The DPWH Committee on Gender and Development
D.O 043, 2015	Reconstitution of the DPWH Committee on Gender and Development
D.O 111, 2016	Guidelines for the Implementation of the DPWH Anti-Tip Policy to Attain Zero-Tolerance Against Trafficking in Persons

Source: Project team

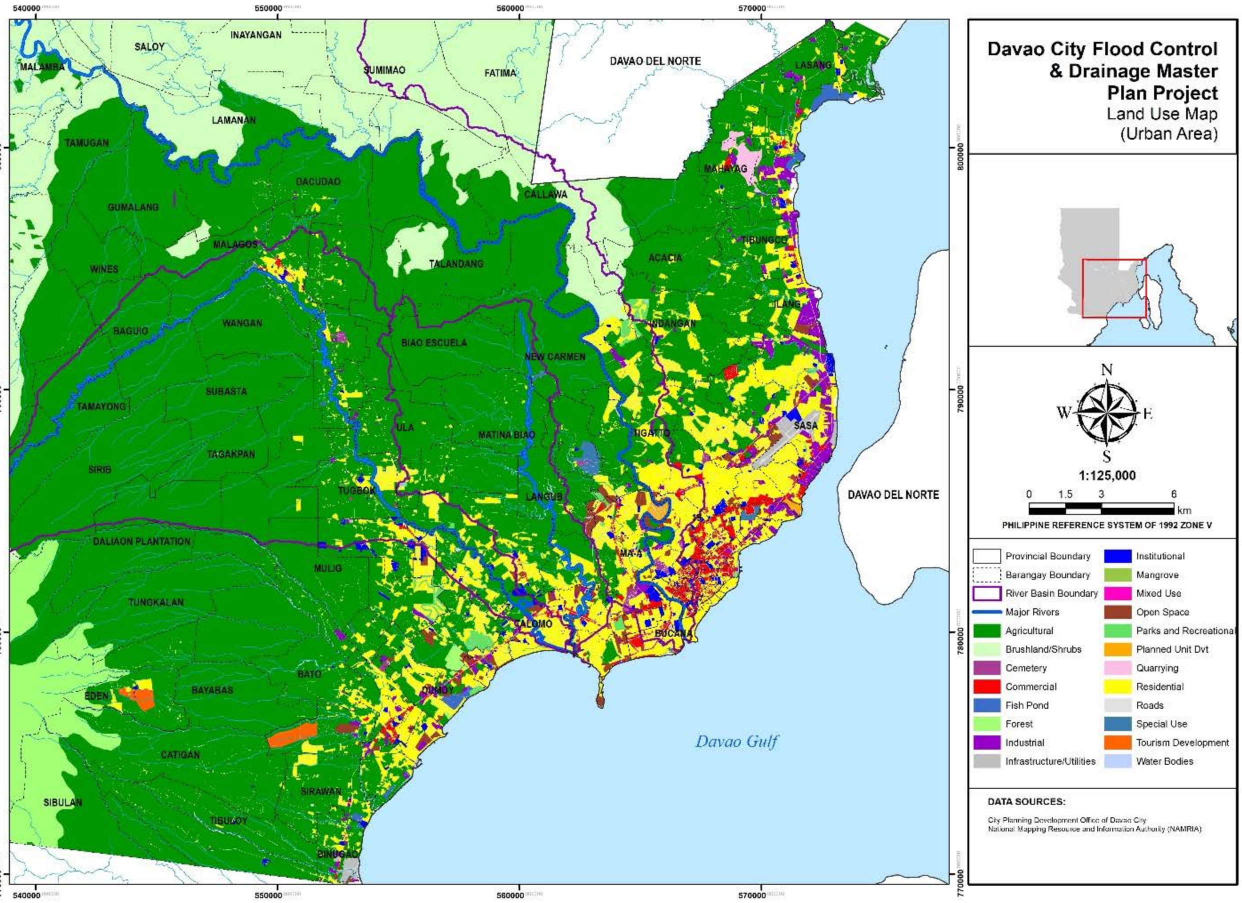
2.3.2 Land Use

In the Davao City Infrastructure Development Plan and Capacity Building Project (JICA, 2018), a present land use map for Davao City in 2017 was prepared as shown in Figure 2.3.8. In this Project, in addition to the land use data for Davao City in 2017, land use data of the river upstream collected through the Project will be combined and treated as the present land use condition for this Project.



Source: Davao City Infrastructure Development Plan and Capacity Building Project, June 2018

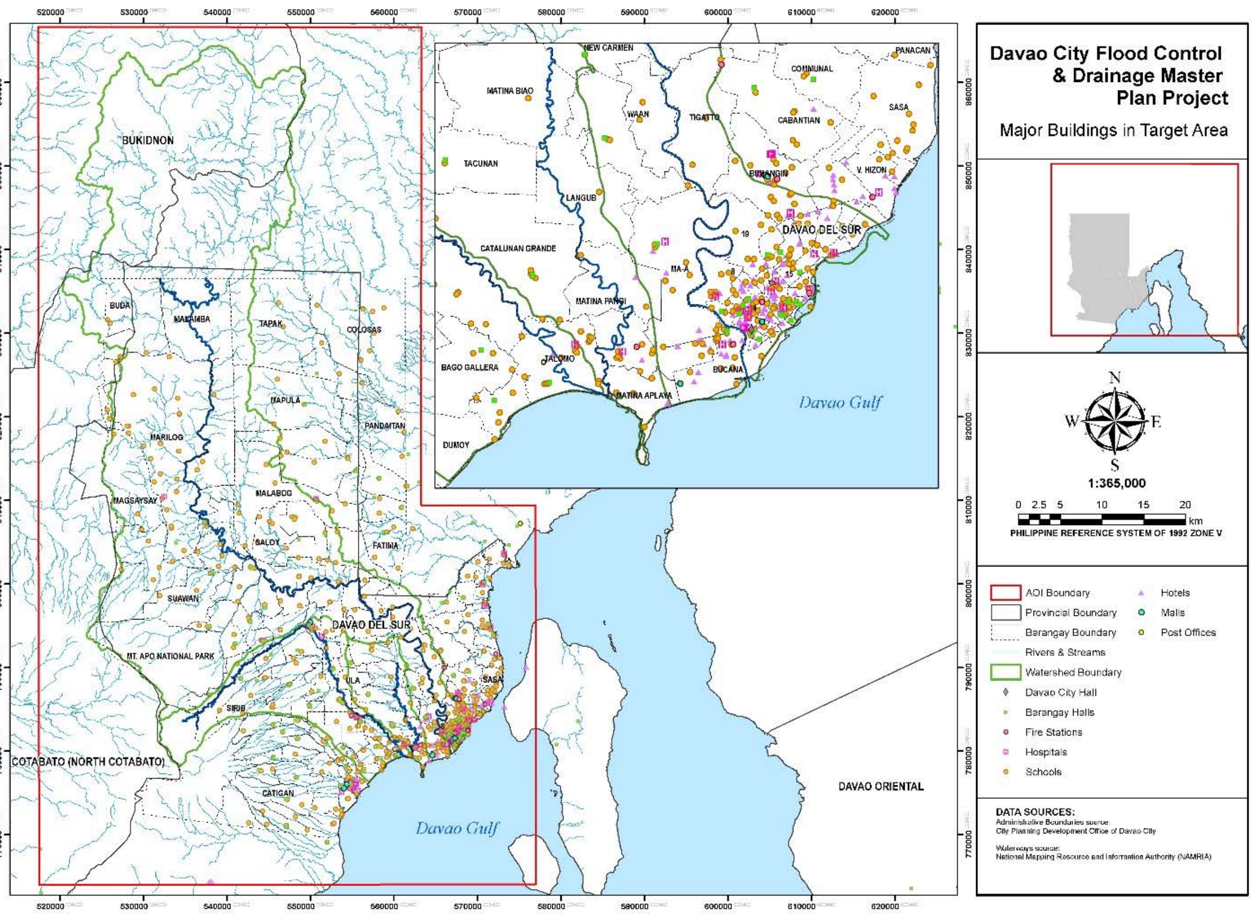
Figure 2.3.8 Present Land Use in Davao City-Overall City (2017)



Source: Davao City Infrastructure Development Plan and Capacity Building Project, June 2018

Figure 2.3.9 Present Land Use in Davao City-Urbanized Area (2017)

Figure 2.3.10 shows the location of major buildings in Davao City.



Source：Project Team

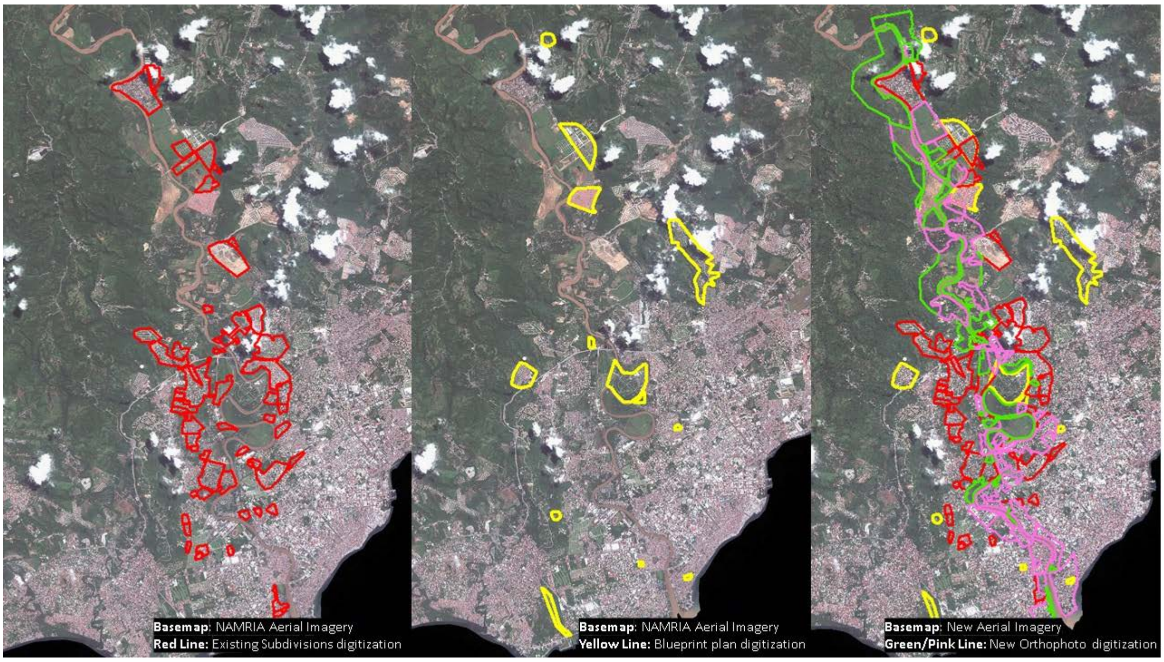
Figure 2.3.10　Major Buildings located in Davao City

2.4 Development Plan

(1) Subdivision Development

Urban development is rapidly advancing in the target area, and large-scale residential area development is currently in progress along the river in the section from 13 to 25 km from the mouth of the Davao River.

Figure 2.4.1 shows the area enclosed by the red line in the left figure is approved Subdivisions digitized based on the point shapefile provided by CPDO. The area enclosed by the yellow line in the middle is approved Subdivisions digitized based on the collected blue-prints from CPDO. The area surrounded by pink lines in the right figure is areas digitized based on the new aerial imagery that has development. That is, in the right figure, the area surrounded by red, yellow and pink lines is the existing or approved development area, and, the area surrounded by green lines is the area where development as a residential area can be regarded as unimplemented and unapproved.



Source: Project Team

Figure 2.4.1 Areas with/without Development in Downstream Part of Davao River

(2) Transport Infrastructure

There are many transport infrastructure development plans in the target basin. Besides the road construction implemented by DPWH RO / DEO, there are the following four projects that have bridges crossing the target river and are considered to be related to this Project. These four projects are regarded as the flagship projects in the Davao Region of the Regional Development Council (RDC) XI. (These projects are listed up in Annex B: Davao Region's Flagship Projects, 2019-2022 of RDC XI Resolution No. 66, Series of 2018.)

Table 2.4.1 List and Status of Flagship Transport Infrastructure Projects

Project Title *1	IA *2	Funding Source *2&*3	Present Status *3
A. Davao City Bypass Construction Project	DPWH	ODA (Japan Loan) & Locally Funded	Under Construction
B. Davao City Coastal Bypass Road Project	DPWH	Locally Funded	Under Construction / Detailed Design
(Davao River Bridge (Bucana Bridge))	DPWH	ODA (China grant) & Locally Funded	Detailed design started in 2022 and will complete on 2025.
C. Mindanao Railway Project	DOTr	ODA	ROW acquisition completed 2021in the segment of Tagum-Davao-Digos.
D. Davao City Expressway Project	DPWH	ODA (China grant)*3	F/S finished in June, 2020. Under NEDA Board`s ICC approval

*1: RDC XI Resolution No. 66, Series of 2018
*2: Presentation material (2017) by NEDA
*3: Interview to DPWH

Locations of the above four projects are shown in Figure 2.4.2.

A to D in the Figure is corresponded to projects of A to D in Table 2.4.1.

Source: Project Team based on collected data/information

Figure 2.4.2 Location Map of Flagship Projects

Further, the following three projects are also considered to have relation to this Project although these projects are not listed in the NEDA XI.

Project Title	Present Status
Davao Riverside Boulevard *(Road project)*	M/P
Davao Monorail (Mass Transit Line)	M/P
Davao City River Development *(Road project)*	Proposal

Details of the projects listed above are described below.

1) Road Improvement by DPWH RO / DEO

In Davao City, road improvement projects by DPWH RO / DEO are actively carried out, and bridges that cross the target river are also newly constructed. The list of bridges that are on-going and planned to be constructed for the three target rivers is shown in Table 2.4.2.

Table 2.4.2 On-going and Proposed Bridges by DPWH RO

No.	Bridge Name	Location	Type	Length (m)	Span	Status
1	Davao River (Bucana) Bridge	Davao R. Bgy. Bucana	Box Girder	540	9	Proposed for Funding Part of Davao City Coastal Bypass Road Project
2	Davao River Bridge 3	Davao R. Bgy. Riverside	PSGS	130	3	Proposed for Funding
3	Davao River Bridge II	Davao R. Bgy. Tigatto	PSGS	120	3	On-going
4	Lower Fatima Bridge	Davao R. Bgy. Pangyan	PSGS	100	3	Proposed for Funding
5	Talandang Bridge	Davao R. Bgy. Talandang	PSGS	125	3	Proposed for Funding
6	Dalagdag Bridge	Davao R. Bgy. Dalagdag	PSGS	90	3	On-going
7	Matina Aplaya Bridge	Matina R. Bgy. Matina Aplaya	PSGS	45	1	Proposed for Funding
8	Matina Pangi Bridge 1	Matina R. Bgy. Matina Pangi	PSGS	40	1	On-going
9	Matina Pangi Bridge 2	Matina R. Bgy. Matina Pangi	PSGS	30	1	On-going
10	Talomo-Matina Bridge	Matina-Talomo R. Bgy. Talomo	Box Girder	660	11	On-going Part of Davao City Coastal Bypass Road Project
11	Mintal Bridge	Talomo R. Bgy. Mintal	PSGS	45	1	On-going

Source: DPWH Regional Office XI

Note: Bridges planned in C) Davao City Coastal Bypass Road Project are included in the above table

2) Davao City Bypass Construction Project

It is a 45 km national road construction project that links Panabo city to Sirawan through the northern part of the Davao city area. The southern and central sections are about 28.8 km for package I and about 15.8 km for northern sections in package II. Package I is funded by a JICA Yen Loan, and Package II is funded by the Government of Philippines.

In the context of this Project, the structures in Table 2.4.3 are planned for the target three rivers in Package I section.

Table 2.4.3 Structure Plan related to Target Rivers

Bridge No.	Creek/ Valley Location (Sta)	Name of River/Creek	Design Discharge (m^3/sec)	Review by Consultant for D/D		
				Revised Length (m)	Span (m)	Revised Structure Type
I-9	11+587	Talomo River	100	87	3 (26+35+26m)	PSCG
II-2	12+300	Talomo River	856	105	4 (22.5+30+30+22.5m)	PSCG
II-5	17+096	Matina River	No data	-	-	Box Culvert
II-6	17+763	Matina River	No data	-	-	Box Culvert
II-7	18+429	Matina River	No data	280	7 (7x40m)	PSCG
II-8 L	18+837	Matina River	No data	136.5	6(18.25+4x25+18.25m)	PSCG
II-8 R				161.5	7(18.25+5x25+18.25m)	PSCG
II-9	22+950	Davao River	2,645	200	5 (5x40m)	PSCG

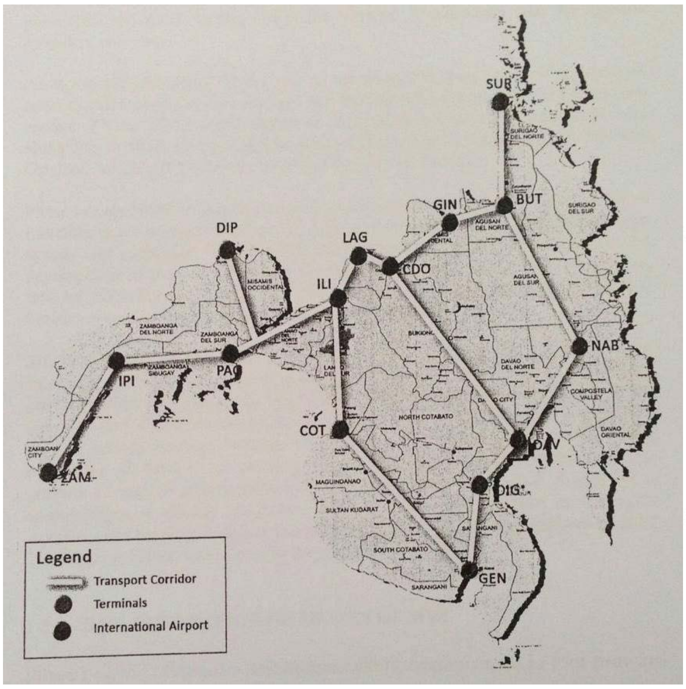
Source: Table 2.5 & 2.6 of Monthly Report No.29 (May 2019), Consulting Services for the Detailed Design and Tender Assistance of the Davao city Bypass Construction Project (South and Central Sections) (LA No. PH-P261), provided by DPWH-UPMO-RMC1

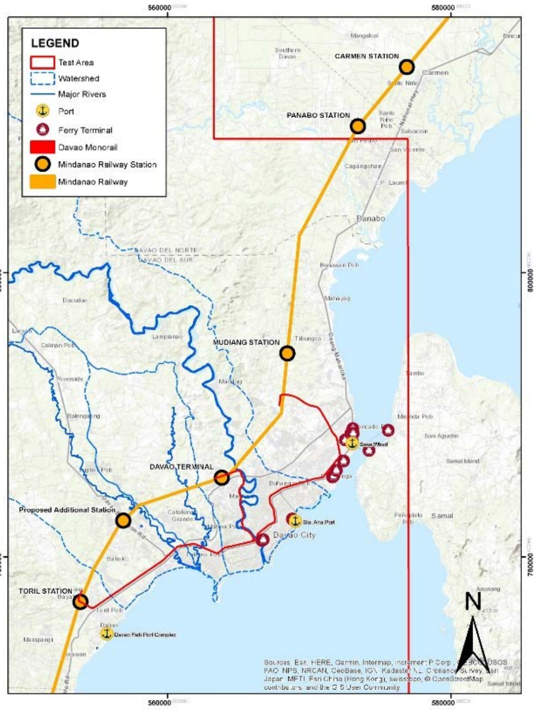
3) Davao City Coastal Bypass Road Project

It is a road construction project with a distance of approximately 12 km along the coastline of Davao City. Currently, construction work is being carried out in parallel with the design of the future section by the regional office (RO) of DPWH Region XI. Bridges will be installed at the mouths of the 3 target rivers. The bridge is planned to cross both of Talomo and Matina Rivers at their mouth, and is a beam bridge with a length of 660 m and 10 piers. The bridge to be installed at the mouth of the Davao River is still at the conceptual design stage, but it will be an extradosed cable-stayed bridge with a bridge length of 470 m and five piers.

4) Mindanao Railway Project

It is a railway construction project with the total length of 1,532 km connecting cities in Mindanao Island (see Figure 2.4.3). The 102km section connecting Tagum-Davao-Digos (MRP-TDD) is related to this Project. This section is the first section of the entire project divided into 3 sections and ROW acquisition for this section completed in 2021. The assumed route crosses the Davao River at about 14 km from the mouth of the Davao River and crosses the Matina River and the Talomo River in the east-west direction. A single track is planned for the railway.





Source: https://www.facebook.com/MindanaoRailway/(left), Davao city (right)

Figure 2.4.3 Concept of Mindanao Railway Project (left) and Assumed Route of the Railway (Orange line) around Target Area (right)

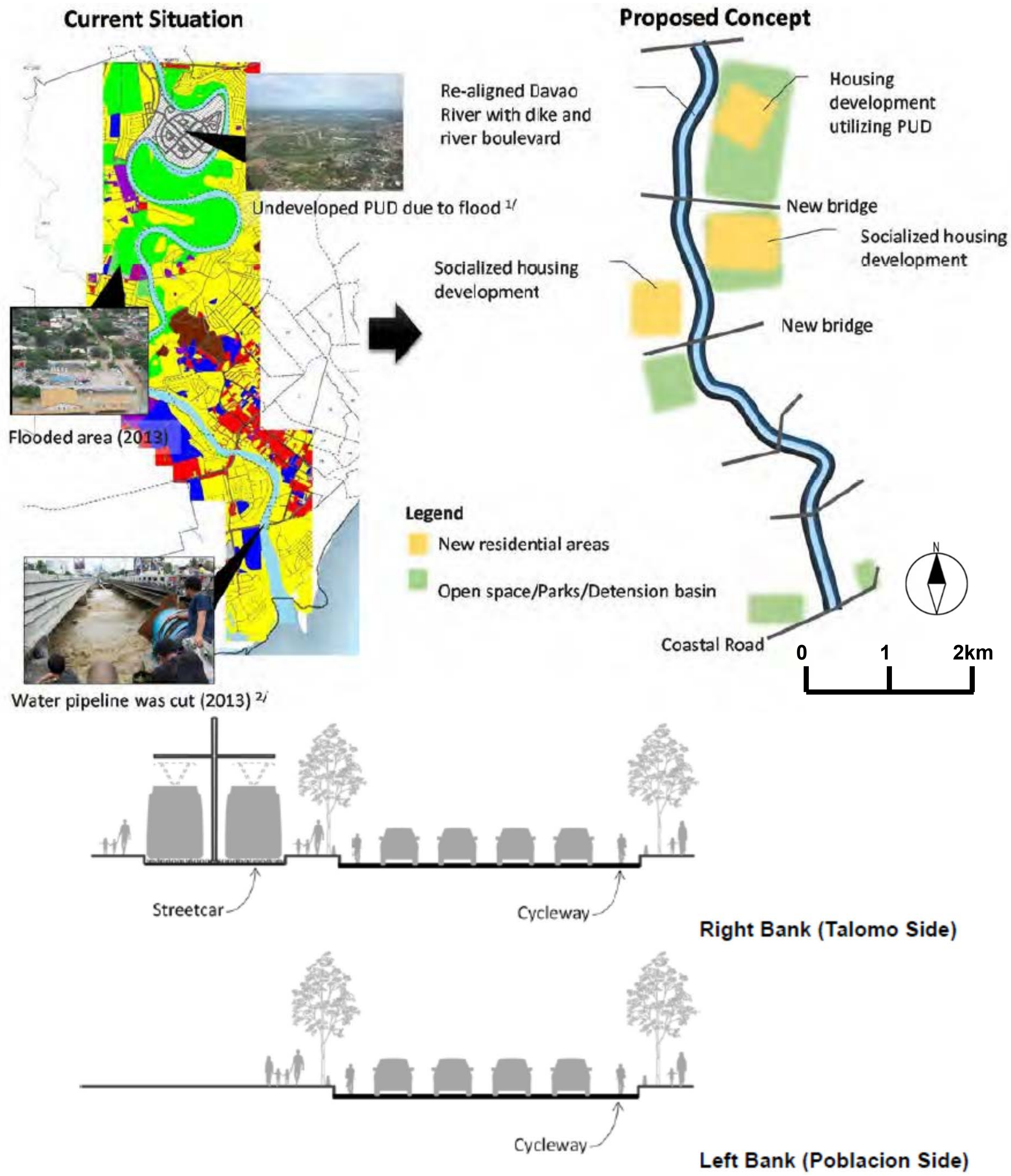
5) Davao City Expressway Project

It is a road construction project that combines an elevated viaduct and new road. A preliminary F/S was conducted in 2017, and F/S started in December 2018 and completed in 2020. Several bridges are planned to cross the Davao River, but in the interview with the consultant in charge, it is said that all bridges are viaducts, and sufficient clearance should be secured in flood management.

6) Davao Riverside Boulevard

It is a road construction plan on both sides of the Davao River proposed in the Davao City Infrastructure Development Plan and Capacity Development Project (JICA, 2018), which also includes cut-off works of Davao River. The concept of the plan is shown in Figure 2.4.4.

It may be an issue that the road structure continuous with the dike is planned but the dike's maintenance road is not examined, and the relocation of 1.2 thousand people is assumed.



Note: PUD: planned unit development
Source: Davao City Infrastructure Development Plan and Capacity Building Project, June 2018

Figure 2.4.4 Concept of Davao Riverside Boulevard

7) Davao Monorail

It is a monorail construction project in the city that was initially proposed by a Korean company and then re-proposed by a Chinese investor. According to the interview with Davao City, the project is regarded as an unsolicited proposal, and no particular progress has been made until now.

8) Davao City River Development by Korean Engineering Corporation (KEC)

It is a road construction plan on both sides of the lower Davao River that was proposed by a Korean company in February 2017 based on the survey results of the latter half of 2016. According to the interview with Davao City conducted by the Project Team, the project is regarded as an unsolicited proposal, and no particular progress has been made until now.

(3) River Basin and Watershed Management and Development

DENR formulated the Davao River Basin Management and Development Plan in 2015, and necessary measures and funds for 15 years ahead are considered in this plan. Among them, as the infrastructure development related to this project, the development of irrigation system, water retarding basin to mitigate flooding and hydropower development are proposed.

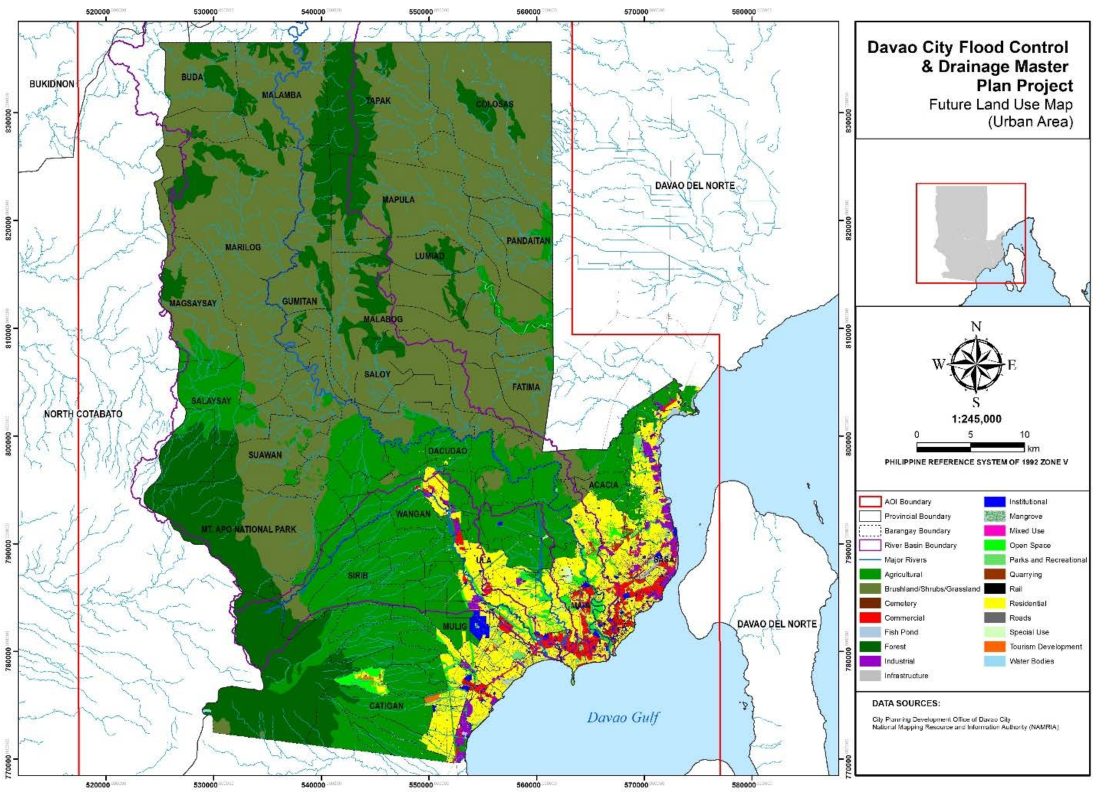
For the irrigation systems, a total of 13 systems with an area of about 1,250 ha have been proposed. If all systems are developed, it is estimated that when all the systems become fully operational, a maximum of 17,028 tons per year will be added to the annual rice production in the basin. Development of the irrigation system may have impacts such as changes in runoff rate due to changes in land use conditions, which needs to be taken into consideration when formulating the flood control plan.

For the water retarding basin to mitigate flooding, five possible sites have been proposed, and early implementation is recommended in this plan. For the implementation, it is proposed that site identification / investigation and feasibility study shall be conducted. One of the five sites is located at the same site as the proposed retarding basin in the M/P of this project. DENR estimated that the construction of the retarding basin at this site will require 315 million pesos, but no specific studies or investigations have been conducted thereafter. During discussions with related organizations and local residents at the F/S stage of this Project, these progresses were not confirmed. Therefore, there will be no overlap with this Project since it seems stopped at the conceptual stage.

For the hydropower development, it is reported that private companies are investigating for construction, at Lamanan Barangay located in the middle of the Davao River. It is estimated that the power generation of 160 MW is expected, and 17,748 million pesos of funds are needed. Since the output capacity is exceeding 50MW, this power project is an “environmentally critical” project and will require a full-blown EIA Study following the DENR’s procedure. In addition to the Environmental Impact Statement system, the hydropower operator will have to comply with the minimum environmental flow, which is estimated at 4.5 m^3/s for Davao River at the diversion point, under the Philippine Water Code. The hydropower plant is planned in Lamanan Barangay which is located in the middle stream of Davao River, and outside the target area to be protected by structural measures of this Project, there will be no direct impact with each other.

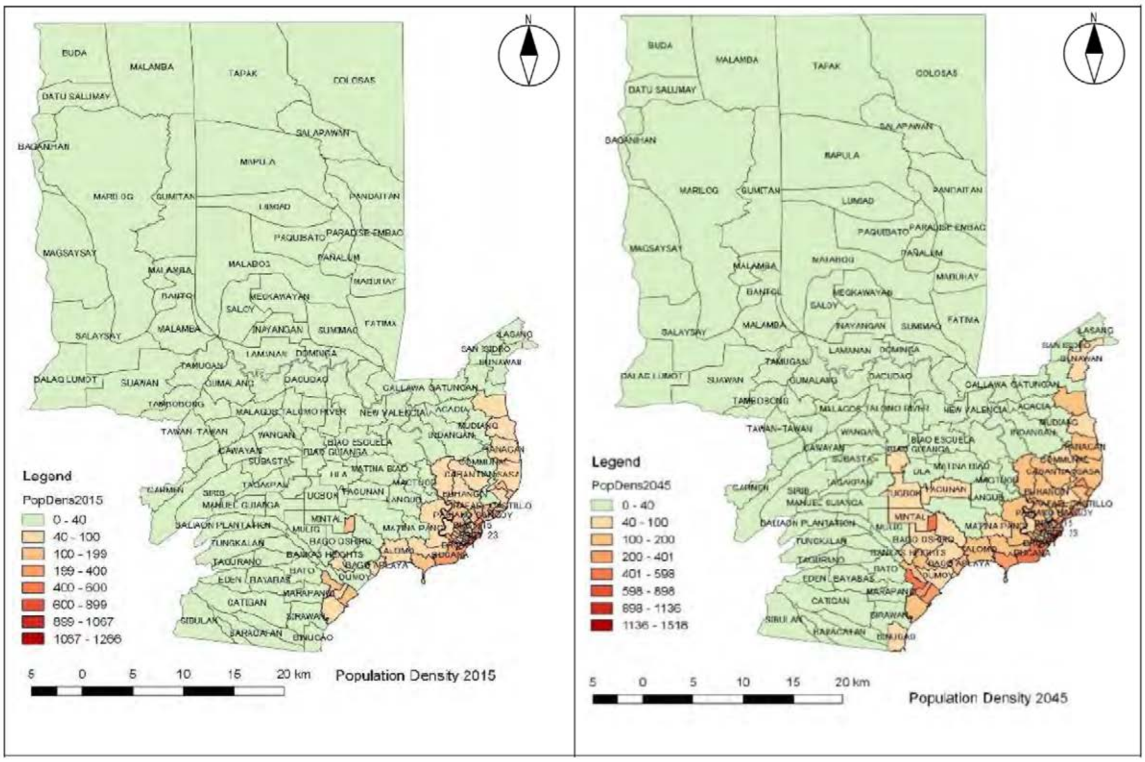
(4) Future Land Use Plan

In the Davao City Infrastructure Development Plan and Capacity Building Project (JICA, 2018), a land use map in 2045 was prepared as shown in Figure 2.4.5. In this Project, future land use condition is set referencing this information. Figure 2.4.6 shows the estimated future population distribution of Davao City by barangay.



Source: Davao City Infrastructure Development Plan and Capacity Building Project, June 2018

Figure 2.4.5 Land Use Plan Map in 2045

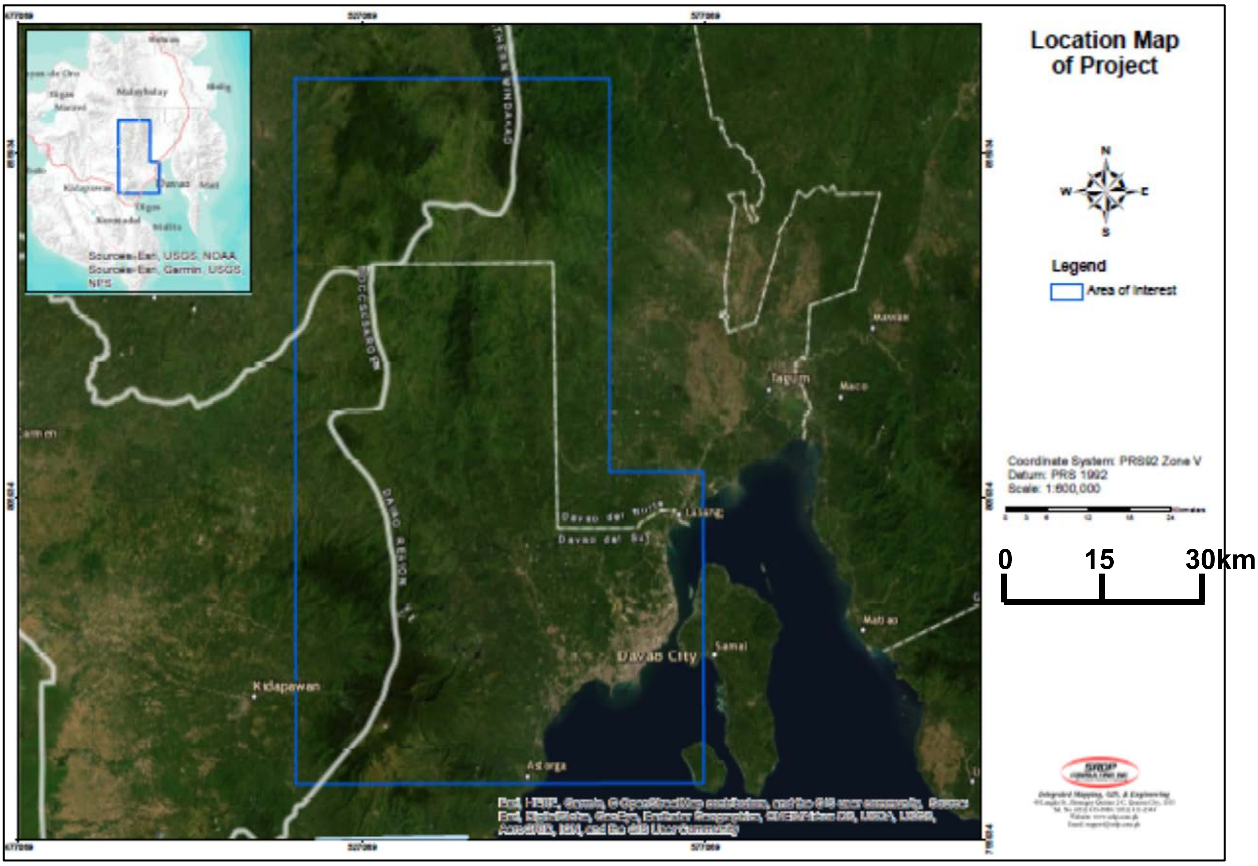


Source: Davao City Infrastructure Development Plan and Capacity Building Project, June 2018

Figure 2.4.6 Comparison of Population in Davao City (Left: 2015, Right: 2045)

2.5 Topographic and River Surveys

The JICA Project Team has conducted the topography and river surveys including riverbed material survey (the Works), to acquire river cross and profile section, ground height, city drainage, shoreline, bathymetric and ortho-photo data, etc., necessary to implement the MP / FS survey on this Project. The Works is subcontracted to a local survey firm and carried out for the period from January 2019 to May 2019. The Project Area is as shown in Figure 2.5.1.



Source: Project Team

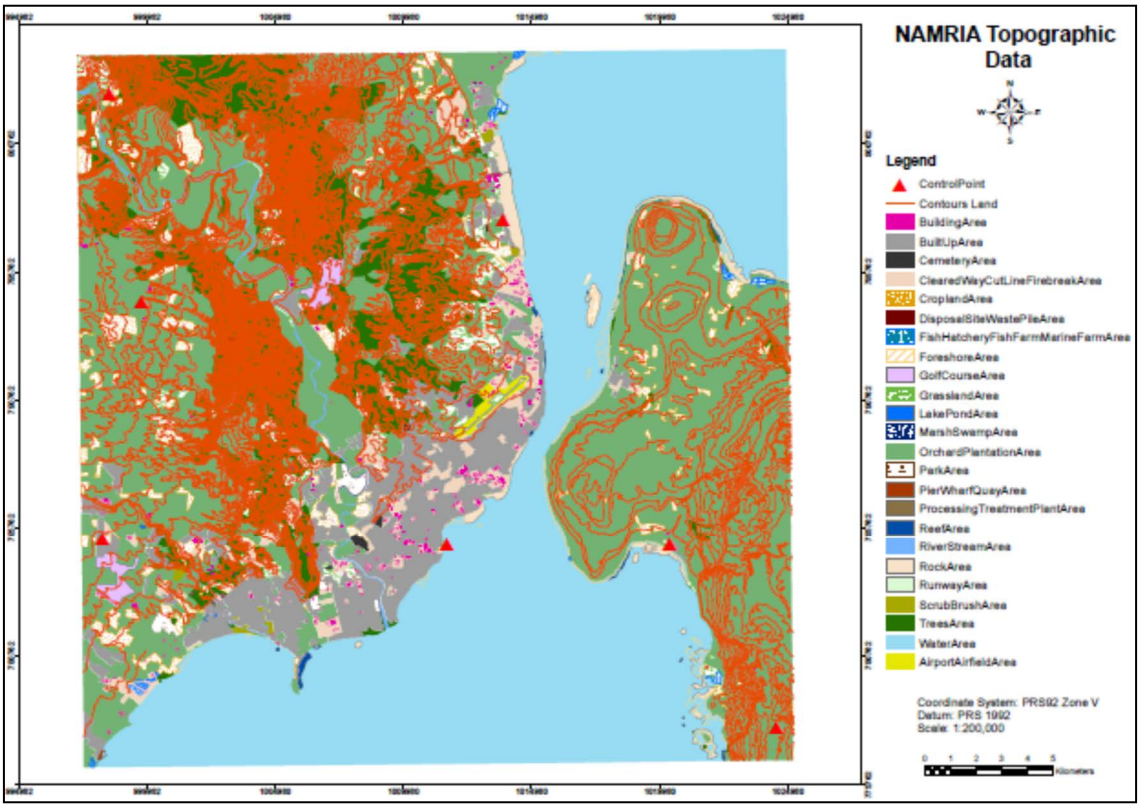
Figure 2.5.1 Location Map of Project Area

(1) Collection of available Existing Maps and Relevant Survey Data

Prior to the commencement of the actual work, the existing topographic map, ortho-photo imagery, ground control point, bench mark, sea chart and tide observation data collected from National Mapping and LiDAR data from University of Philippines was collected. Of the collected data, under-listed existing map and survey data and information have been used for the topographic and river survey works, the preparation of Terms of Reference of Subcontract Agreement and the preparation of a GIS database in the Project.

1) Digital Topographic Maps at Scale of 1/50,000

Digital topographic map at scale of 1/50,000 covering the project area was prepared by NAMRIA/JICA during the period from 2010 to 2013 and NAMRIA has been reedited into the digital topographic map at scale of 1/50,000 data on 2013～2018. The digital map information is as follows:



Source：NAMRIA

Figure 2.5.2 Digital Topographic Map at scale of 1/50,000 (Davao City)

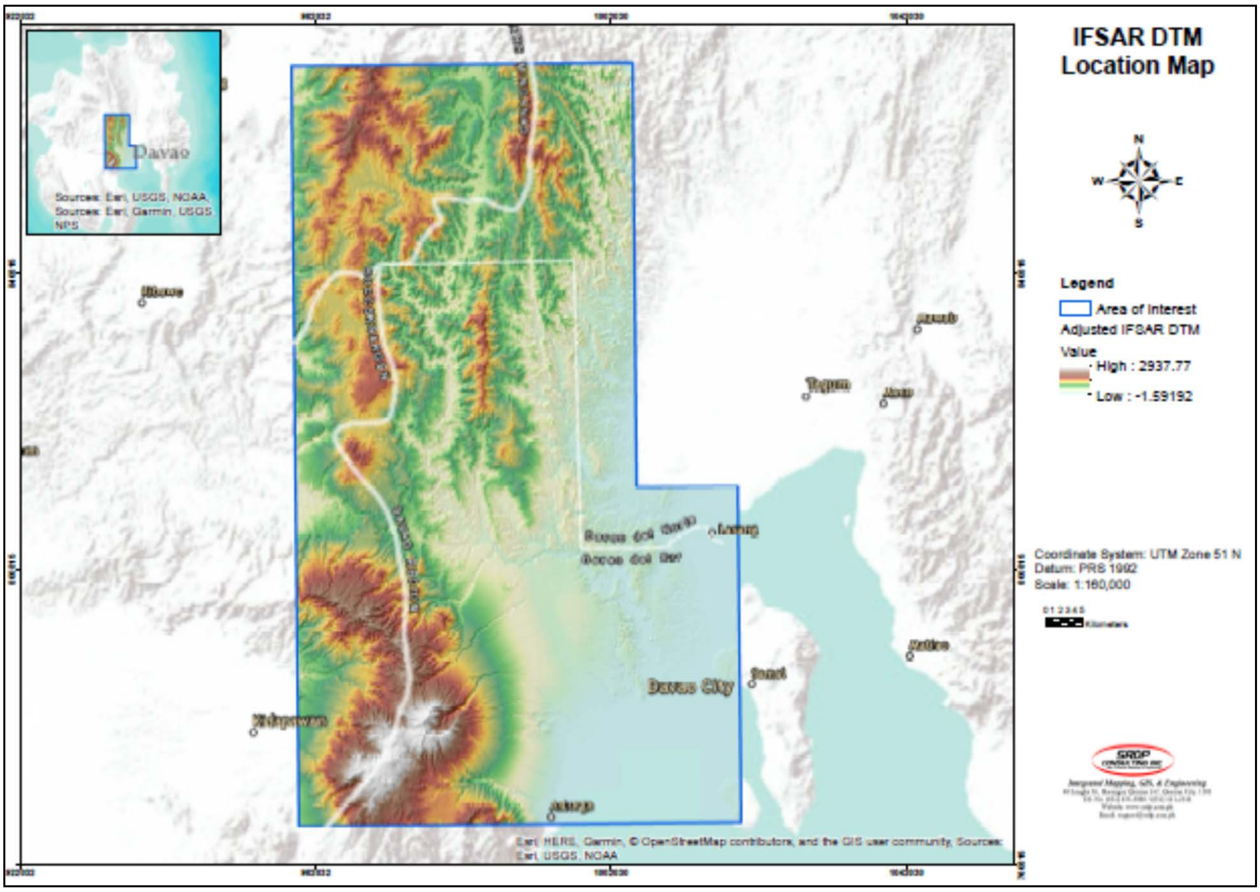
Table 2.5.1 Information of Digital Topographic Map at Scale of 1/50,000

Topographic Map information	Preparing Authority	NAMRIA/JICA
	Prepared year	2010~2018
	Mapping Method	Digital Photogrammetric Mapping
	Horizontal Datum	PRS92
	Map Projection System	UTM (Zone 51)
	Vertical Datum	Mean Sea Level of Philippines
	Map Scale	1 / 50,000
	Coverage Area	Whole the project area
	Contour Line	Index：20m、 Supplementary：10m
	Expected Precision	Horizontal:0.2mm on the Map Vertical: half of contour Line
	No. of Map Sheets	4014-1, 4014-4, 4015-1, 4015-2, 4015-3, 4015-4, 4016-2, 4016-3, 40164, 4114-4, 4115-4, 415-3=12 map sheets
	Data Contents	Digital Topographic Map data
	Data Format	DWG File, SHAPE File

Source：Project Team

2) IFSAR Data

Airborne IFSAR Data covering whole the project area prepared for Topographic Mapping at scale of 1/10,000 by NAMRIA on 2013. Information of the IFSAR Data is as follows.



Source: Project Team

Figure 2.5.3 Area Map of IFSAR

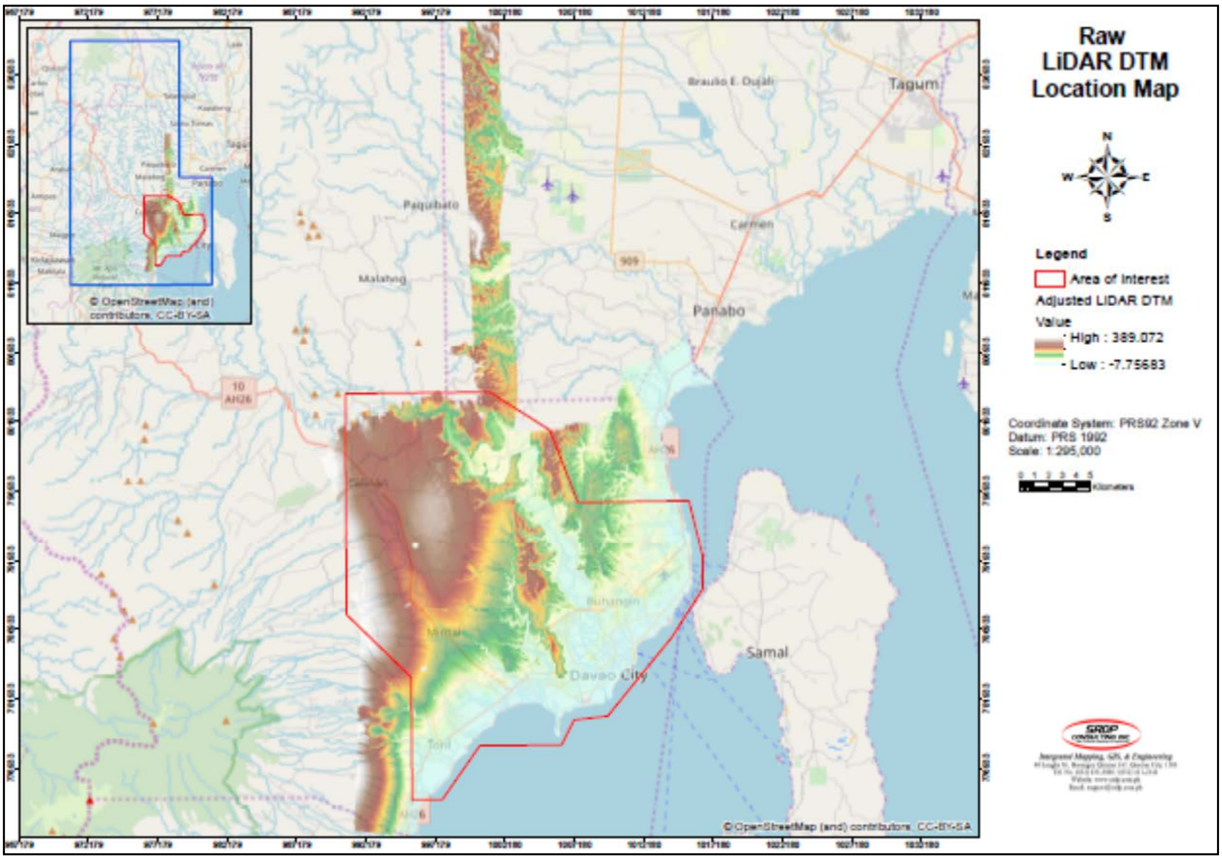
Table 2.5.2 Information of IFSAR Data

Ortho-photo Map information	Preparing Authority	NAMRIA
	Prepared year	2013
	Mapping Method	Airborne IFSAR Survey
	Horizontal Datum	PRS92
	Map Projection System	PTM (Zone 51)
	Vertical Datum	Mean Sea Level of Philippines
	Map Scale	1 / 10,000 (supportable)
	Coverage Area	Whole the project area
	Data Contents	DSM/DTM:2mx2m mesh, ORI: Ortho-photo
	Expected Precision	DSM/DTM:0.01m, ORI: 1m
	Data Format	GEOTIFE File, PRJ File, BIL File

Source：Project Team

3) LiDAR Data

Airborne LiDAR Data covering the downstream of Davao River, Matina River and Talomo River of the project area prepared by University of Philippines (UP) and Department of Science and Technology (DOST) on 2013. Information of the LiDAR Data is as follows.



Source: UP and DOST

Figure 2.5.4 Area Map of LiDAR Data

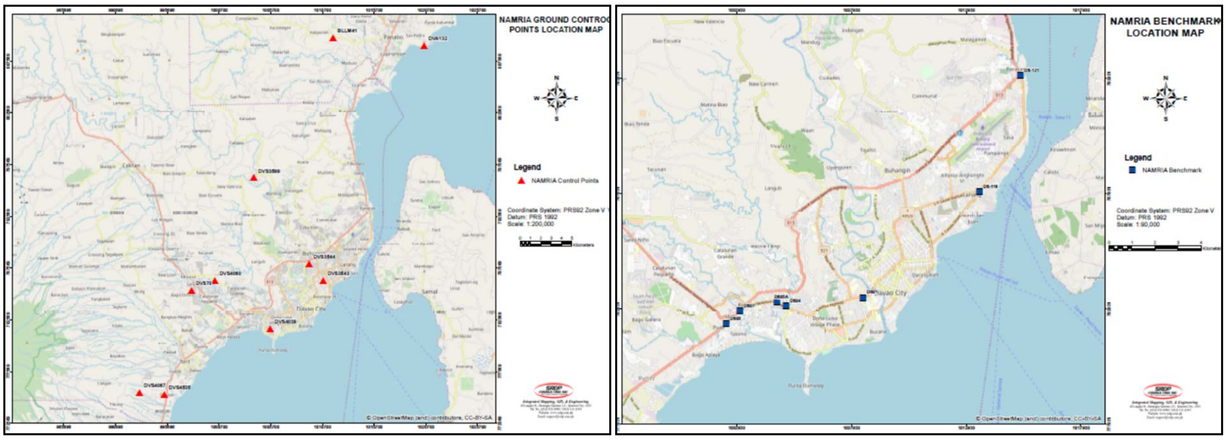
Table 2.5.3 Information of LiDAR Data

Ortho-photo Map information	Preparing Authority	UP/DOST (UP-DREAM Project)
	Prepared year	2013
	Mapping Method	Airborne LiDAR Survey
	Horizontal Datum	PRS92
	Map Projection System	WGS 1984, PTM (Zone 51N)
	Vertical Datum	Mean Sea Level of Philippines
	Map Scale	1 / 10,000 (supportable)
	Coverage Area	Downstream of Davao River, Matina River and Talomo River.
	Data Contents	DSM/DTM:2mx2m mesh, ORI: Ortho-photo
	Expected Precision	DSM/DTM:0.01m, Ortho-photo:0.1m
	Data Format	GEOTIFE File, JPG File

Source：Project Team

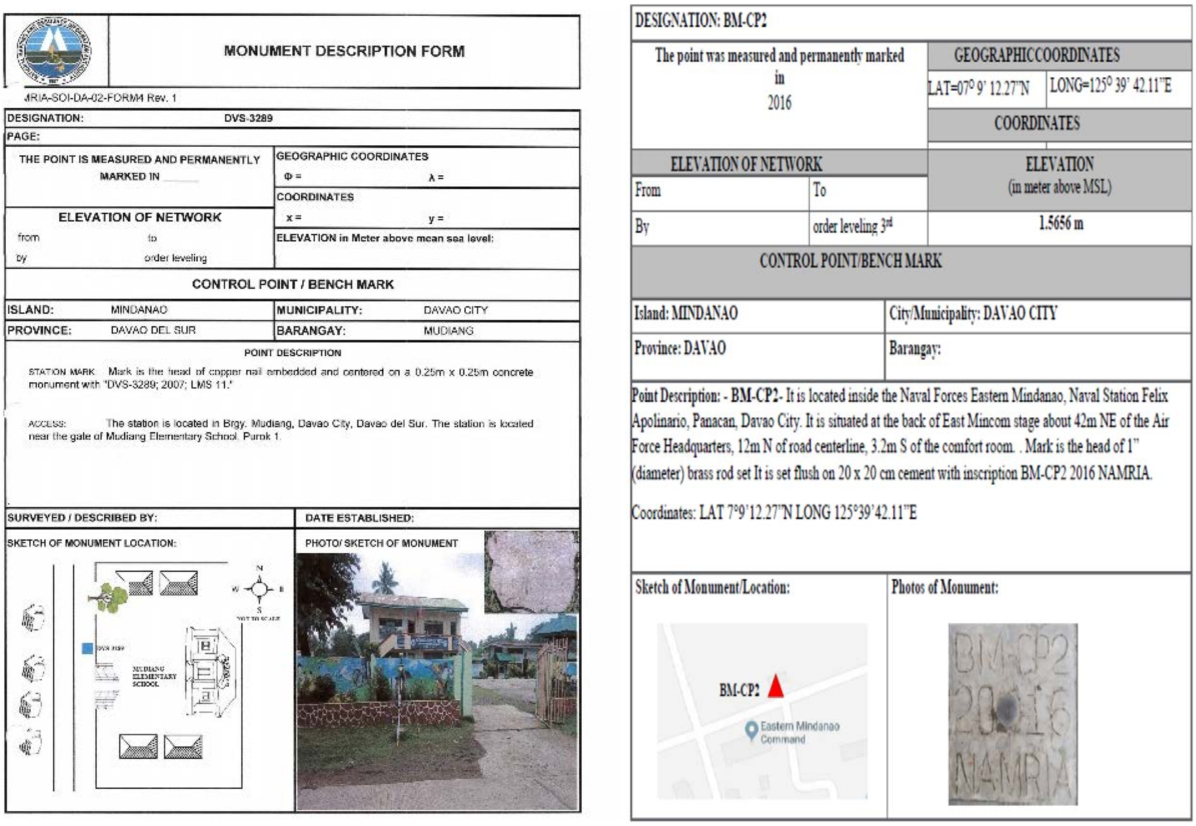
4) Horizontal and Vertical Control Point

Used Horizontal and Vertical Control Point (Ground Control Point and Benchmarks) for the Works of the project were established by Mapping and Geodesy Department of NAMRIA. Information of Ground Control Point GCP) and Benchmarks (BMs) is as follows.



Source: NAMRIA

Figure 2.5.5 Location Map of GCP and BMs



MONUMENT DESCRIPTION FORM			
.IRIA-SOI-DA-02-FORM4 Rev. 1			
DESIGNATION:	DVS-3289		
PAGE:			
THE POINT IS MEASURED AND PERMANENTLY MARKED IN		GEOGRAPHIC COORDINATES Φ = λ =	
		COORDINATES x = y =	
ELEVATION OF NETWORK from to by order leveling		ELEVATION in Meter above mean sea level:	
CONTROL POINT / BENCH MARK			
ISLAND:	MINDANAO	MUNICIPALITY:	DAVAO CITY
PROVINCE:	DAVAO DEL SUR	BARANGAY:	MUDIANG
POINT DESCRIPTION			
STATION MARK: Mark is the head of copper nail embedded and centered on a 0.25m x 0.25m concrete monument with "DVS-3289; 2007; LMS 11."			
ACCESS: The station is located in Brgy. Mudiang, Davao City, Davao del Sur. The station is located near the gate of Mudiang Elementary School, Purok 1.			
SURVEYED / DESCRIBED BY:		DATE ESTABLISHED:	
SKETCH OF MONUMENT LOCATION:		PHOTO/ SKETCH OF MONUMENT	

DESIGNATION: BM-CP2			
The point was measured and permanently marked in 2016		GEOGRAPHIC COORDINATES	
		LAT=07° 9' 12.27"N	LONG=125° 39' 42.11"E
		COORDINATES	
ELEVATION OF NETWORK		ELEVATION (in meter above MSL)	
From	To		
By	order leveling 3rd	1.5656 m	
CONTROL POINT/BENCH MARK			
Island: MINDANAO		City/Municipality: DAVAO CITY	
Province: DAVAO		Barangay:	
Point Description: - BM-CP2- It is located inside the Naval Forces Eastern Mindanao, Naval Station Felix Apolinario, Panacan, Davao City. It is situated at the back of East Mincom stage about 42m NE of the Air Force Headquarters, 12m N of road centerline, 3.2m S of the comfort room. . Mark is the head of 1" (diameter) brass rod set It is set flush on 20 x 20 cm cement with inscription BM-CP2 2016 NAMRIA. Coordinates: LAT 7°9'12.27"N LONG 125°39'42.11"E			
Sketch of Monument/Location:		Photos of Monument:	

Source：NAMRIA

Figure 2.5.6 Descriptions of GCP and BMs

Table 2.5.4　Information of GCP and BMs

GCP and BMs information	Preparing Authority	NAMRIA
	Established year	GCP：2011～2018 BMs：2015～2016
	Survey Method	GCP：GNSS Survey BMs：Direct Leveling
	Horizontal Datum	PRS92
	Map Projection System	WGS 1984, PTM (Zone 51N)
	Vertical Datum	Mean Sea Level of Philippines
	Data Contents	GCP：Survey Mark Description and Coordinates list table BMs: Survey Mark Description and Elevation list table
	Data Format	Excel File, DWG File, PDF File

Source：Project Team

Table 2.5.5　List of GCP

NAMRIA GCP	Northing(m)	Easting(m)	Location
DVS-70	783,460.709	776,600.888	Brgy. Sto. Nino, Davao City, inside the elem. School
DVS-3543	784,347.394	789,308.856	Brgy. Poblacion, Davao City, near an open canal along Loyola St.
DVS-3544	786,040.219	787,960.339	Brgy. Buhangin, Davao City, at Spring Valley Subdivision
DVS-3599	794,311.554	782,671.772	Brgy. Mandug, Davao City, near the chapel of Sitio Lapoy
DVS-4039	779,791.766	784,187.904	Brgy. Matina Aplaya, Davao City, at Alpha Homes Subdivision
DVS-4060	784,405.654	778,881.546	Brgy. San Gabriel Village, Calman, Catalunan Grande, Davao City, near the mini bridge
DVS-4067	773,628.613	771,552.385	Brgy. Binugao District, Davao City, inside NRDD Elem. School Compound
DVS-4535	773,484.696	773,951.078	Brgy. Sirawan, Davao City, at Sirawan Elementary School

Source：NAMRIA

Table 2.5.6　List of BM

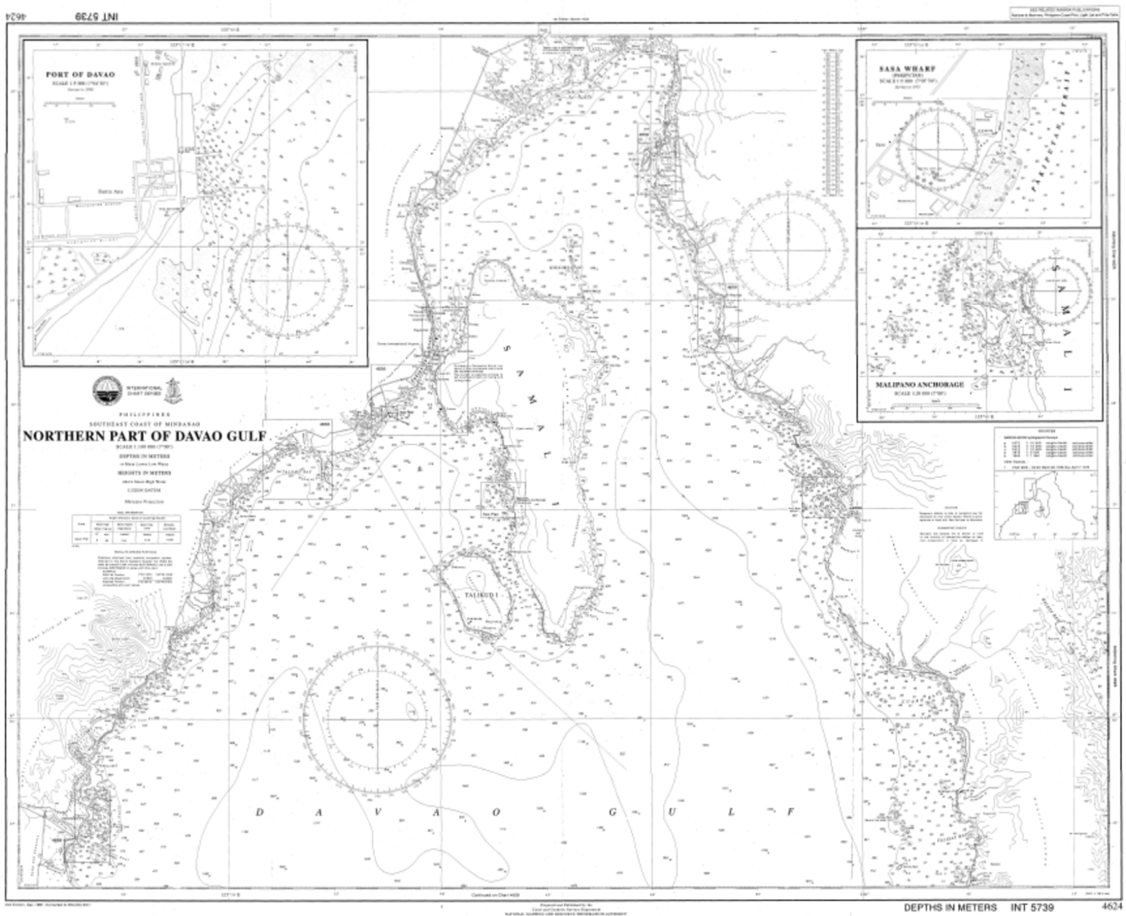
NAMRIA BM	Latitude	Longitude	Elevation(m)	Location
DS-01	7°3'45"	125° 35'50"	5.677	Province of Davao Del Sur, City of Davao, Barangay Matina, at Ateneo de Davao High School Department
DS-04	7°3'34"	125° 34'1"	7.922	Province of Davao Del Sur, City of Davao, Barangay Matina Pangi, near Matina Bridge
DS-05A	7°3'40"	125° 33'49"	6.6936	Province of Davao Del Sur, City of Davao, Barangay Matina Pangi, near the waiting shed at the corner of Tahimik Avenue
DS-07	7°3'28.6"	125° 32'56.4"	6.1472	Province of Davao Del Sur, City of Davao, Barangay Talomo (Pob.), near Talomo Bridge
DS-08	7°3'10"	125° 32'37"	5.1115	Province of Davao Del Sur, City of Davao, Barangay Ula, near Davao Ice Plant
DS-16A	7°0'47"	125° 29'24"	11.7718	Province of Davao Del Sur, City of Davao, Barangay Toril (Pob.), near Gaisano Mall
DS-21A	6°58'9"	125° 28'38"	11.7625	Province of Davao Del Sur, City of Davao, Barangay Binugao, near Southern Feed Mill Corporation
DS-116	N/A	N/A	4.1352	Province of Davao Del Sur, City of Davao, Barangay Lanang, near Veterans Kris Monument
DS-121	7°8'56.6"	125° 39'36.6"	2.5321	Province of Davao Del Sur, City of Davao, Barangay Panacan, near Davao Lions Club

Source：NAMRIA

Above the NAMRIA's GCP and BMs data have used for horizontal control and vertical control of the Works.

5) Sea Chart Data

Sea Chart of Davao Gulf was prepared by Hydrography Branch of NAMRIA in 1991. The Sea Chart information is as follows.



Source：NAMRIA

Figure 2.5.7 Sea Chart at Scale of 100,000 (Davao Gulf)

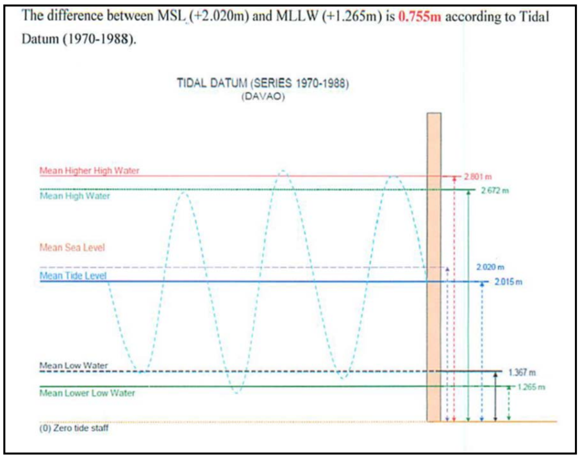
Table 2.5.7 Information of Sea Chart at Scale of 100,000

Sea Chart information	Preparing Authority	NAMRIA
	Prepared year	1991
	Survey Method	Bathymetric Survey
	Horizontal Datum	PRS92
	Map Projection System	WGS 1984, PTM (Zone 51N)
	Vertical Datum	Mean Sea Level of Philippines
	Chart Scale	1/100,000
	Coverage Area	Northern Part of Davao Gulf
	Depth Line	10m、200m 1000m
	Data Contents	Sheet No. INT 5739
	Data Format	Hard copy

Source：Project Team

6) Tide Data

Tide data of Davao Gulf has been observed by the Hydrography Branch of NAMRIA since 1948. Information of Tide observation is as follows.




```
0  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21 22 23 SNDDMMYY

179182180175165152137123112108108113120129138146150151150149150152155158LM 1 116
162165166166162153140127118114113115119126135145152154153152151150148147LM 2 116
148150152153152147141134128122118119124132142151159163165164162156150144LM 3 116
141139139138138137135132129125122122125132141151162170175175171164156147LM 4 116
138132129129129130131132132131130129131135144155166177183186183177166153LM 5 116
140129122118117119122126129131131131132136144156170183193198198193183167LM 6 116
148132119111107108112119127132134133133136143155168182195205210207196179LM 7 116
158136118105 98 97100107117126132133133134139149162177193208218220214198LM 8 116
176151128109 96 91 93 99109119127131131130132139151167184201214222222212LM 9 116
192166137112 94 83 81 86 96108117124126125125128137150169189208220224219LM10 116
205181152122 98 83 77 79 86 96108119124125123124129141157176196213224226LM11 116
217199173145118 96 83 80 85 96108118125128128128129133144160182202216222LM12 116
220210192167138112 94 87 89 97107117126133135133130130135147165183198209LM13 116
213211200181156130110 98 95 98106116127136140139136133134140151165180191LM14 116
199202199187168145124111104103106114125137144146143138135136142150159170LM15 116


LEGEND
0-23 Hours
SN   Station Name
DD   Day
MM   Month
YY   Year
```

Source：NAMRIA

Figure 2.5.8 Tide Observation Data

Table 2.5.8 Information of Tide Observation

Tide information	Preparing Authority	Hydrography Branch of NAMRIA
	Prepared year	1948~
	Survey Method	Zero Staff Level Observation
	Location of Tide Observation Station	Old Station（1945～2017）: Inside Sasa Wharf Ferry Port, Davao City
		New Station (2017～Present）: Inside Naval Station Felix Apoinario, Davao City
	Vertical Datum	Mean Sea Level of Philippines : M.S.L, Zero Staff Level ＝M.S.L.-2.02m (M.S.L. Series：1970～1988 Series)
	Coverage Area	Northern Part of Davao Gulf
	Data Format	Text File

Source：Project Team

2.5.1 Summary of Topographic and River Survey

(1) Topographic and River Survey Works and Its Quantity

All the Topographic and River Survey (the Works) were carried out by a local survey firm, SRDP Consulting, Inc., 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 TOR was prepared making reference to “Specifications of Overseas Surveying Works for Development Study by JICA in 1982”. The Works consisted the following work items and quantity.

Table 2.5.9 Work Items and Quantity (Topographic and River Survey)

Work Item	Quantity/Unit
1. River Topographic Survey (River Longitudinal and Cross Sectional Survey along 23km of Davao River, 13.5km of Matina River and 11km of Talomo River)	
1.1 River Longitudinal (Profile) Survey	
(1) Davao River (Station No. 0+000 – 23+000)	23.0 km
(2) Matina River (Station No. 0+000 – 13+500)	13.5 km
(3) Talomo River (Station No. 0+000 – 11+000)	11.0 km
1.2 River Cross Sectional Survey	
(1) Setting up of 500m Station No. Peg (Cross Section Points)	96 points
(2) Davao River (Interval: 500m along the River, Width: 200m)	46 sections
(3) Matina River (Interval: 500m along the River, Width: 100m)	28 sections
(4) Talomo River (Interval: 500m along the River, Width: 100m)	22 sections
1.3 Ortho-photo Mapping by UAV (Davao River: 23km+ Matina River 13.5km + Talomo River 11km = 47.5km x width: 1km=47.5 km2)	47.5 km2
2. **Topographic Survey 1** (Ground Height Survey) (Confirmation of ground height on DOST LiDAR and NAMRIA IFSAR data covering the Davao, Matina and Talomo River Basin)	
(1) Davao River Basin (Leveling from 500m Station No. Peg)	50 points
(2) Matina River Basin (Leveling from 500m Station No. Peg)	10 points
(3) Talomo River Basin (Leveling from 500m Station No. Peg)	30 points
3. **Topographic Survey 2** (City Drainage Survey in Pabliacion and Agdao Districts)	
3.1 Setting up of Drainage Cross Section points and Inventory Ground Control Points	50 points
3.2 Drainage Cross Sectional Survey (5 drainage x 5 cross sections = 25 cross sections in total)	25 sections
3.3 Inventory Survey for Manhole/Culvert (5 drainage x 5 sites=25 locations in total)	25 locations
4. Topographic Survey 3 (Shoreline Survey along the Coastal Road and Davao North Coast)	
4.1 Ortho-photo Mapping by UAV (Length:40km x width: 1km = 40km2)	40 km2
4.2 3D Sectional Measurement for Profile Sections	
(1) From South of Davao City to the entry points of Coastal Road (Ground Survey 3D measurement)	10 km
(2) Construction site of Coastal Road to the North of Davao City (Ground Survey 3D measurement)	12 km
(3) From the End of Coastal Road to the North of Davao City (Photogrammetric 3D measurement)	18 km
4.3 Cross Sectional Survey	
(1) Setting up of Cross Section Points (Interval: 500m along the Shoreline)	84 points
(2) From South of Davao City to the entry points of Coastal Road (Interval: 500m along the Shoreline, Width: 100m)	21 sections
(3) Construction site of Coastal Road to the North of Davao City (Interval: 500m along the Shoreline, Width: 100m)	25 sections
(4) From the End of Coastal Road to the North of Davao City (Interval: 500m along the Shoreline, Width: 100m)	37 sections
5. Topographic Survey 4 (Bathymetric Survey along the Coastal Road and Davao North Coast)	
5.1 Sounding Survey (Length:40km x Width: 250m=10 km2)	10 km2
5.2 Preparation of Sounding Cross Sections (Width=250m)	
(1) From South of Davao City to the entry points of Coastal Road (Interval: 500m along the Shoreline, Width: 250m)	21 sections
(2) Construction site of Coastal Road to the North of Davao City (Interval: 500m along the Shoreline, Width: 250m)	25 sections
(3) From the End of Coastal Road to the North of Davao City (Interval: 500m along the Shoreline, Width: 250m)	37 sections
6. Survey Report (Including all Outputs)	2 sets

Source：Project Team

2.5.2 Elevation Check Survey

Elevation check survey between benchmarks of D116 along the National Road of Davao City established by NAMRI Mapping and Geodesy Department of NAMRIA and BM GNSS, BM CP2, BM CP3, TGBM at Davao Tide Observation Station having MSL of 1970-1988 series established by the Hydrography Branch of NAMRIA were carried out by a local sub-contractor for confirming the NAMRIA's Vertical Datum value on May 5, 2019. The results of the elevation check survey is as follows.


Source：Project Team

Figure 2.5.9 Photos of Davao Tide Observation Station and D116

The Elevation check survey was performed by BMs of the NAMRIA tide station from the NAMRIA benchmark DS 116 (elevation: 4.1352 m) by leveling. As a result of the leveling, the difference in elevation was 0.018 m (18 mm) and within the tolerance of the leveling（40ｍｍ√5km（observation distance between DS116 and BMs of the NAMRIA tide station）＝89mm）specified in the TOR of the Sub-contractor Agreement. From the result of the elevation check survey, it hasn't been confirmed that the elevation of both benchmarks have a gap. From the result of the elevation check survey, it wasn't confirmed that elevation of both benchmarks have a gap. It was also confirmed from NAMRIA that the benchmark of Mapping and Geodesy Department of NAMRIA and benchmarks of the Hydrography Branch of NAMRIA in Mindanao have used the same mean sea level (MSL: 1970-1988 series)

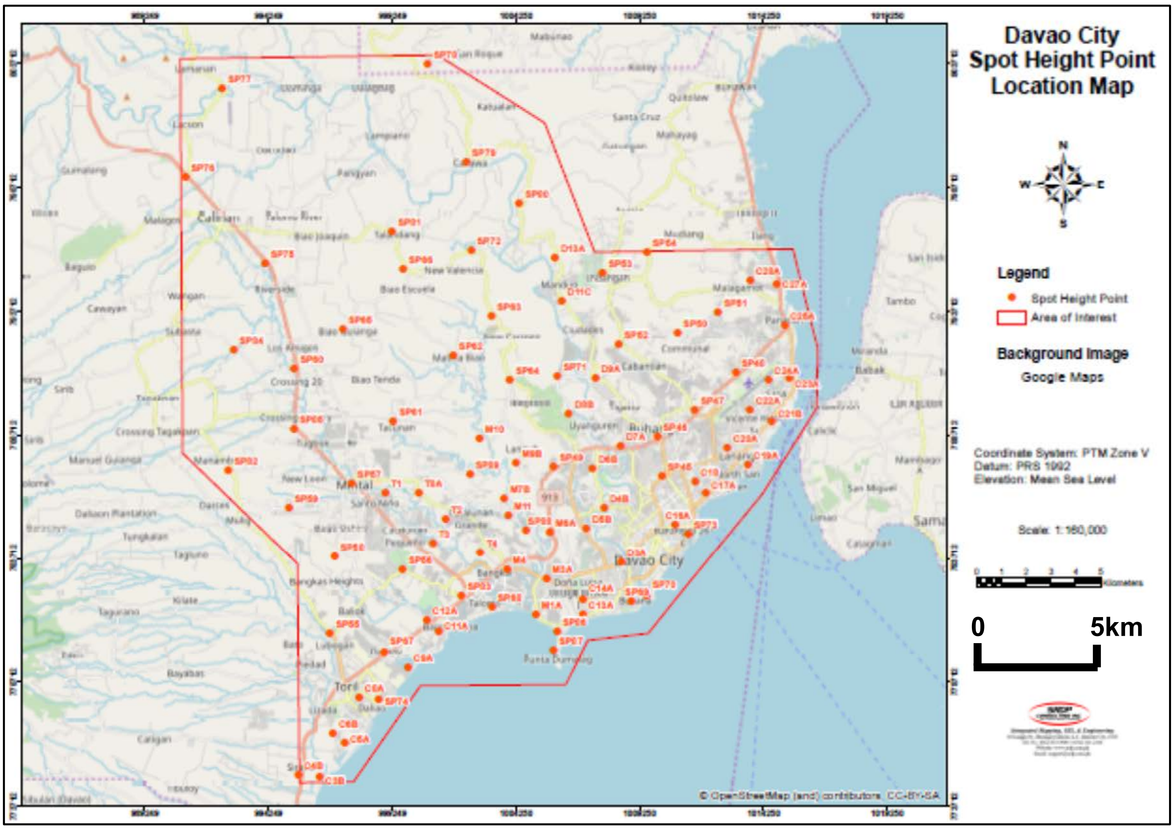
Table 2.5.10 Results of Elevation Check Survey

NAMRIA BM	Elevation (MSL：1970～1988 Series)		Difference(m)
	NAMRIA(m)	Leveled from DS116(m)	
DS116	4.1352		
NAMRIA Tidal BM			
GNSS BM	2.9015	2.886	0.015
BM CP2	1.5656	1.545	0.021
BM CP3	2.8337	2.813	0.021
TGBM	2.4839	2.470	0.014
		Average	0.018

Source：Project Team

2.5.3 Topographic Survey (Ground Height Survey)

Ground Height Survey was carried out for confirming 90 ground height points on the UP/DOST LiDAR data and NAMRIA IFSAR data covering Davao River, Matina River and Talomo River Basin. And using the ground height survey (Spot survey) data, the UP/DOST LiDAR data and NAMRIA IFSAR data was adjusted to be used for the Project database data. And using the ground height points data, the UP/DOST LiDAR data and NAMRIA IFSAR data was adjusted and have been used for the database of the Project. Information of a location map of Ground Height Survey and location map of 90 spot points, survey method and output are as follows.

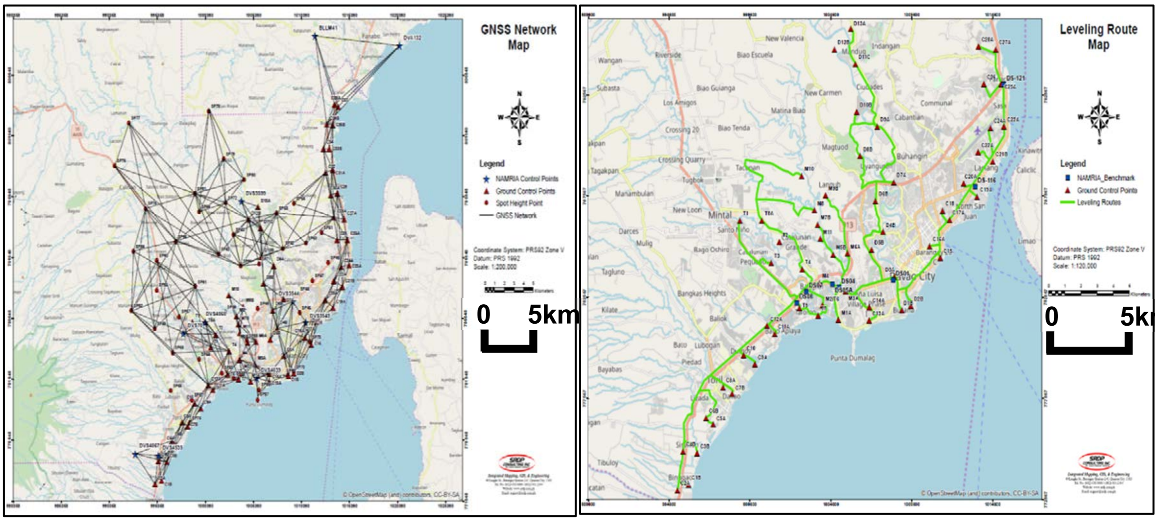


Source：Project Team

Figure 2.5.10 Location Map of Ground Height Survey and 90 Spot Points

(1) Spot Survey

Spot survey consists of GNSS survey and leveling were carried out to obtained geo-coordinates and elevation of 90 spot points. The following GNSS GCP Network and Leveling Network were established by the spot survey.

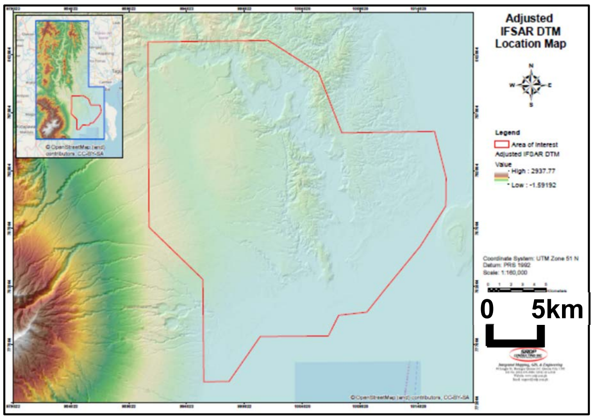


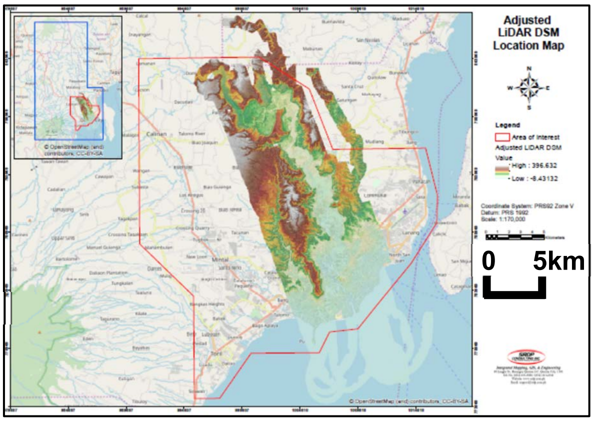
Source：Project Team

Figure 2.5.11 Location map of GNSS GCP Network (Left）and Levelling network (Right)

(2) Output

1) Adjusted LiDAR and IFSAR Data





Source：Project Team

Figure 2.5.12　Adjusted IFSAR Data（Left）and LiDAR Data（Right）

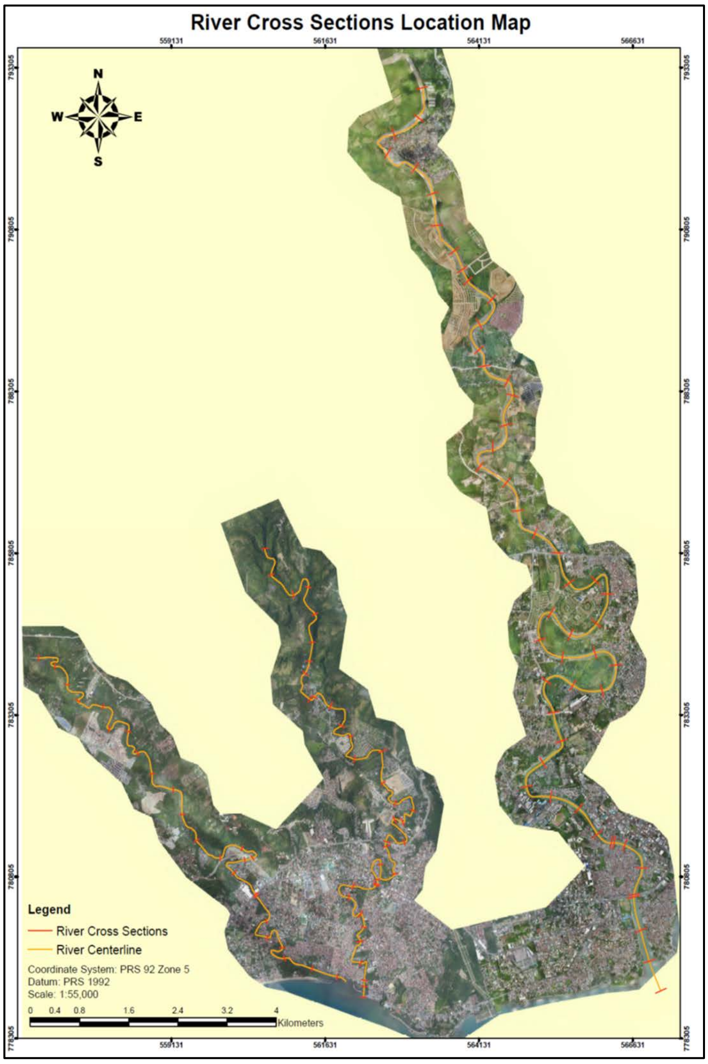
Table 2.5.11　Coordinate and Elevation List of Spot Points

Spot Height Point	Northing	Easting	Elevation
C3B	772516.592	553862.591	2.09
C4B	772628.975	552997.683	14.662
C5A	773931.448	554873.732	2.181
C6B	774256.573	554416.719	2.942
C8A	775758.075	555482.166	10.416
C9A	776891.153	557458.051	3.698
C11A	778362.738	558693.136	2.703
C12A	778772.354	558226.154	3.644
C13A	778974.697	564527.749	3.629
C14A	779628.57	564540.184	6.027
C16A	782603.98	568279.121	2.102
C17A	783890.804	569511.952	2.817
C18	784337.9	569086.955	2.505
C19A	785007.004	571220.661	2.118
C20A	785674.981	570402.385	6.881
C21B	786747.832	572198.252	3.337
C22A	787215.098	571312.305	10.06
C23A	788476.67	572912.218	3.596
C24A	788385.53	572082.266	20.652
C25A	790563.264	572755.596	2.404
C27A	792261.556	572438.605	4.15
C28A	792413.946	571371.961	6.958
D3A	781106.476	566086.416	4.843
D4B	783330.483	565406.15	10.058
D5B	782458.794	564691.638	9.212
D6B	784856.227	564964.665	14.14
D7A	785770.501	566090.86	32.189
D8B	787077.058	564024.249	30.739
D9A	788515.108	565101.818	18.707
D11C	791617.262	563785.246	23.794
D13A	793361.776	563507.855	57.92
M1A	779030.327	562625.974	2.267
M2/T6	779737.579	561644.918	2.347
M3A	780423.651	563072.759	8.517
M4	780834.371	561470.43	7.306
M6A	782295.519	563206.731	69.499
M7B	783722.313	561386.139	20.053
M9B	785164.027	561880.779	125.129
M10	786124.967	560417.425	84.438
M11	783025.304	561540.159	16.363
SP45	784590.695	567751.357	5.999
SP46	786131.948	567592.025	34.2
SP47	787200.853	569100.458	37.98
SP48	788699.178	570755.215	40.465
SP49	784974.003	563393.799	32.792
SP50	790300.167	568435.551	65.389
SP51	791146.647	570071.68	20.14
SP52	789905.106	566054.915	106.382
SP53	792792.113	565429.567	102.499
SP54	793570.049	567222.75	88.414
SP55	778310.824	554318.067	54.06
SP56	780863.277	557272.209	35.516
SP57	784401.804	555248.212	114.86
SP58	781450.748	554534.451	109.577
SP59	783429.125	552703.859	195.947
SP60	788999.936	552971.286	170.397
SP61	786846.234	556946.427	152.779
SP62	789458.826	559388.021	114.391
SP63	791087.221	560932.174	186.415
SP64	788501.429	561658.511	219.961
SP65	790571.582	554942.853	238.172
SP66	792977.336	557389.313	192.497
SP67	777568.943	556500.894	11.518
SP68	779323.491	560858.266	1.749
SP69	779493.323	566467.586	1.694
SP70	779759.175	567092.789	1.572
SP71	788636.388	563580.68	17.607
SP72	793705.842	560152.078	159.942
SP73	782227.363	568781.84	1.807
SP74	775676.474	556264.859	3.224
SP75	793289.368	551834.325	178.755
SP76	796805.113	548650.876	228.296
SP77	800295.757	550162.78	148.667
SP78	801217.763	558457.452	207.786
SP79	797285.72	559979.053	40.304
SP80	795587.773	562092.231	45.462
SP81	794488.994	556965.548	199.53
SP82	784931.412	550281.264	279.665
SP83	779745.994	559642.454	4.916
SP84	789806.924	550538.883	214.799
SP85	786597.946	552930.312	159.159
SP86	778335.79	563470.026	4.189
SP87	777544.026	563320.533	1.614
SP88	782392.779	562238.849	17.744
SP89	784718.142	560015.199	80.215
T1	783961.328	556601.285	111.101
T2	782906.869	559020.796	65.56
T3	781873.404	558508.733	47.383
T4	781536.23	560415.53	79.559
T8A	783960.632	557946.916	92.71

Source：Project Team

2.5.4 River Survey

River Topographic Survey consists the setting up of river cross section points (96 points), river longitudinal (profile) survey (total length : 47.5km), river cross sectional survey (96 sections）, and UAV survey (40km^2） covering Davao River (from the river mouth to 23 km upstream), Matina River (from the river mouth to 13.5km upstream) and Talomo River (from the river mouth to 11 km upstream) was carried out. Information of a location map of River topographic survey, survey method and output are as follows.



Source：Project Team

Figure 2.5.13 Location Map of River Topographic Survey (Including a location map of River Profile, River Cross Sectional and UAV Survey)

(1) Setting up of river cross section points

Ninety-six river cross section points were set up at 500 m pitches along the Davao River (from the river mouth to 23 km upstream), Matina River (from the river mouth to 13.5 km upstream) and Talomo River (from the river mouth to 11 km upstream). Setting up of the river cross section points were carried out by GNSS survey and leveling, and it obtained the geo-coordinates and elevation of the river cross section 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, observed twice）

(2) River Longitudinal (Profile) Survey

River Longitudinal (Profile) Survey were carried out to obtain the coordinates and elevation of the river center line of Davao River (from the river mouth to 23 km upstream), Matina River (from the river mouth to 13.5 km upstream) and Talomo River (from the river mouth to 11 km upstream). The location map of the river profile section is as shown in Figure 2.5.13 Location Map of River Topographic Survey. 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

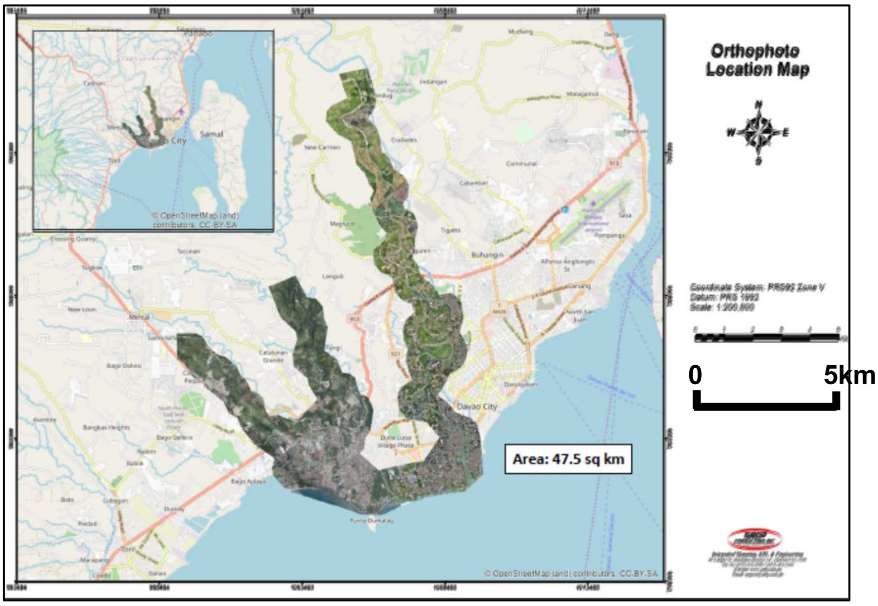
(3) River Cross Sectional Survey

The River Cross Sectional Survey was carried out to obtain geo-coordinate and elevation of the river cross section of Davao River (46 sections, width: 200 m), Matina River (28 sections, width: 100 m) and Talomo River (22 sections, width: 100 m). The location map of the river cross section is as shown in Figure 2.5.13 Location Map of River Topographic Survey. 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) UAV Survey

UAV Surveys were carry out covering 500 m width on the right and left from each river center line of Davao River (from the river mouth to 23 km upstream), Matina River (from the river mouth to 13.5 km upstream) and Talomo River (from the river mouth to 11 km upstream). Ground Resolution of Aerial photos by UAV Survey was 10 cm and covreage area was 47.5 km^2. Ortho-photos were prepared using coordinates and elevation data of spot points by the Ground Height Survey data (Spot Survey) .

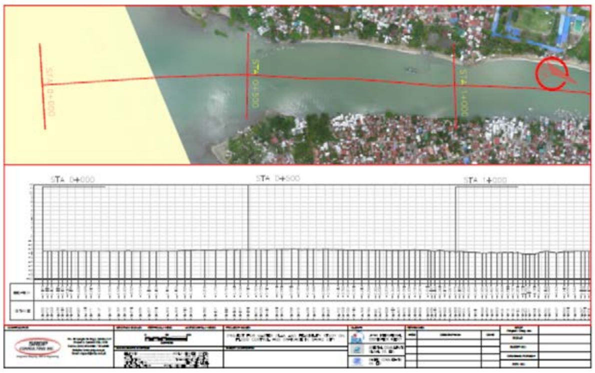
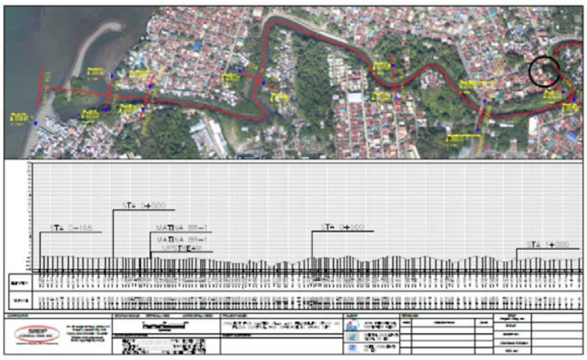
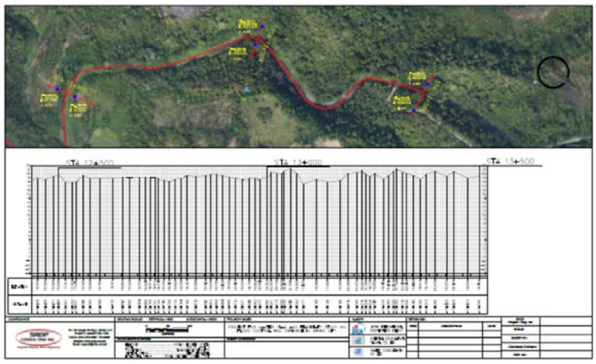
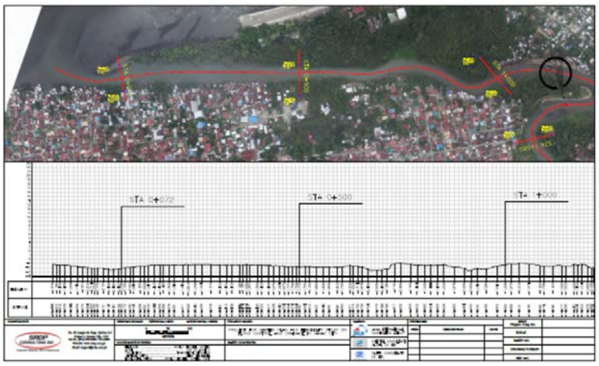
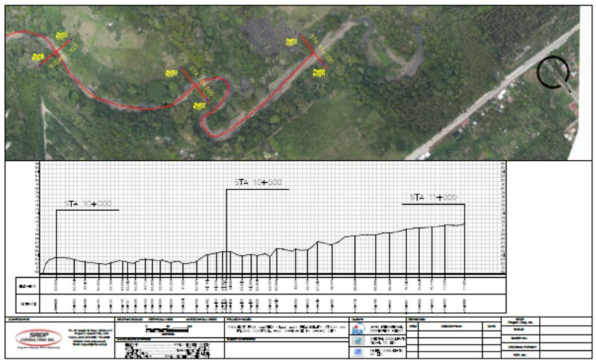


Source：Project Team

Figure 2.5.14 Area Map of Ortho-photo (River Survey)

(5) Output

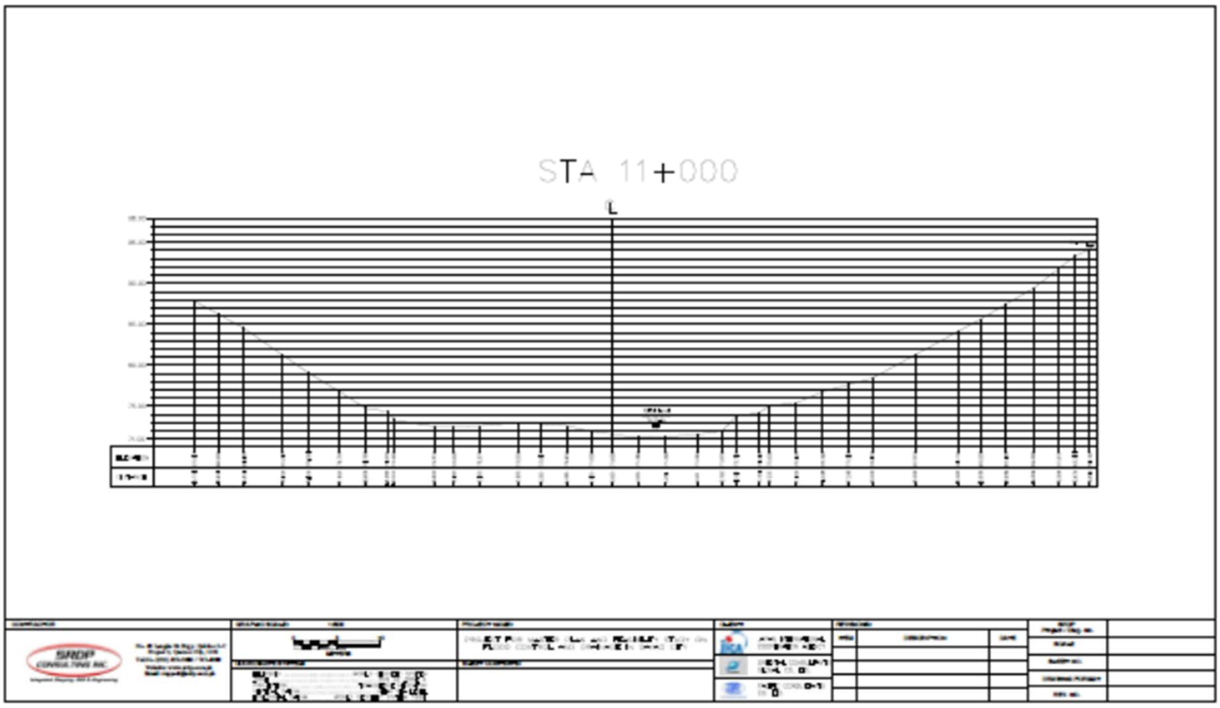
1) River Profile

Beginning point of river profile section	Davao River	Endpoint of river profile section
		
Beginning point of river profile section	**Matina River**	**Endpoint of river profile section**
		
Beginning point of river profile section	**Talomo River**	**Endpoint of river profile section**
		

Source：Project Team

Figure 2.5.15 River Profile Sections of Davao River, Matina River and Talomo River

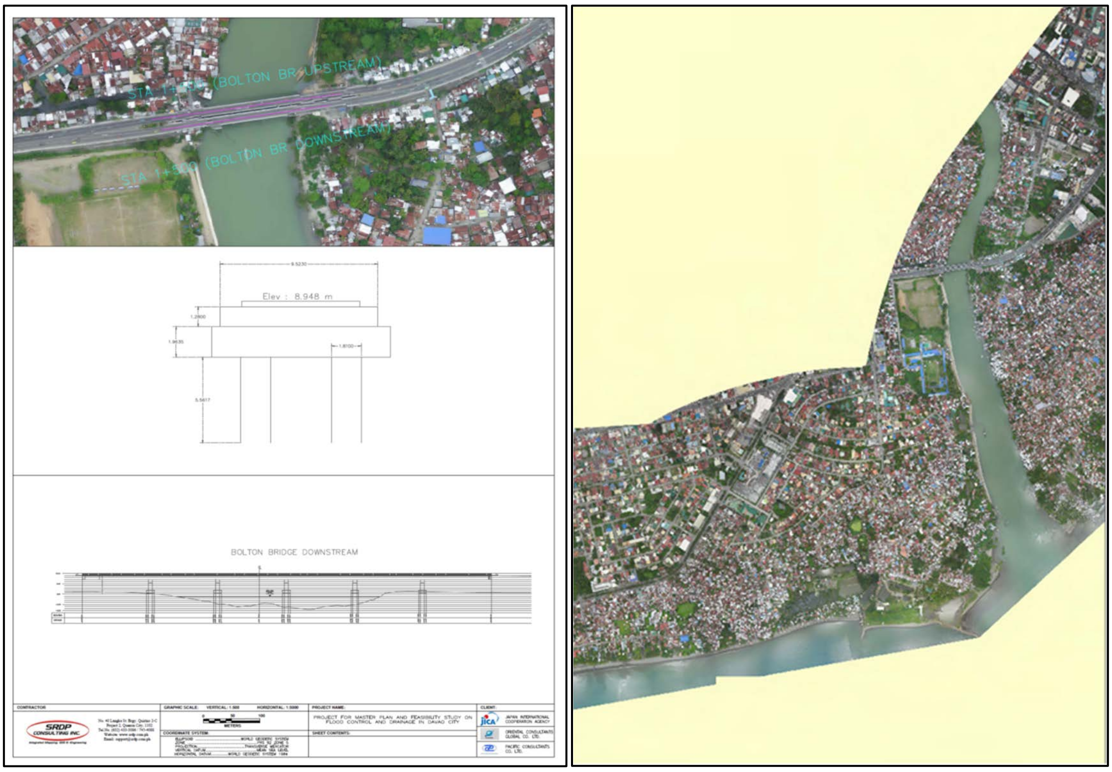
2) River Cross Sections



Source：Project Team

Figure 2.5.16 River Cross Sections

3) Bridge Cross Sections



Source：Project Team

Figure 2.5.17 Bridge Cross Sections

2.5.5 Riverbed Material Survey

(1) Objectives and Items of Survey

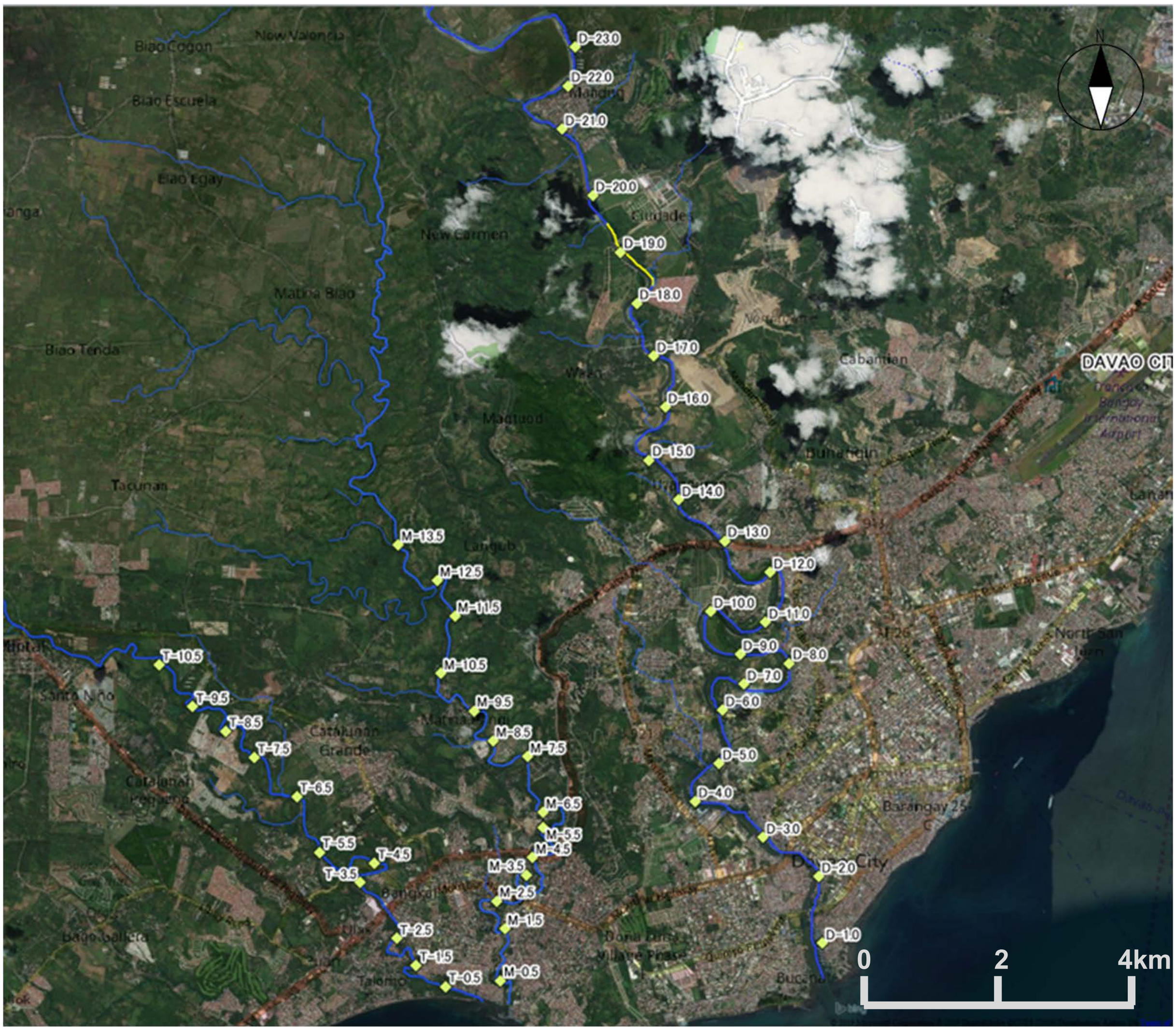
The riverbed material survey was conducted on the following items for providing basic data for riverbed fluctuation analysis and sediment yield study.

- Riverbed material grain size analysis (sieve analysis)
- Specific gravity test

(2) Target Area

The riverbed material sampling was conducted at a pitch of approximately 1 km for the three target rivers. The riverbed material sampling points are as shown below.

- Davao River : 0.0 km to 23.0 km: 24 points
- Matina River : 0.0 km to 13.5 km: 14 points
- Talomo River : 0.0 km to 11.0 km: 11 points



Source: Project Team

Figure 2.5.18 Sampling Point of Riverbed Materials

(3) Activities

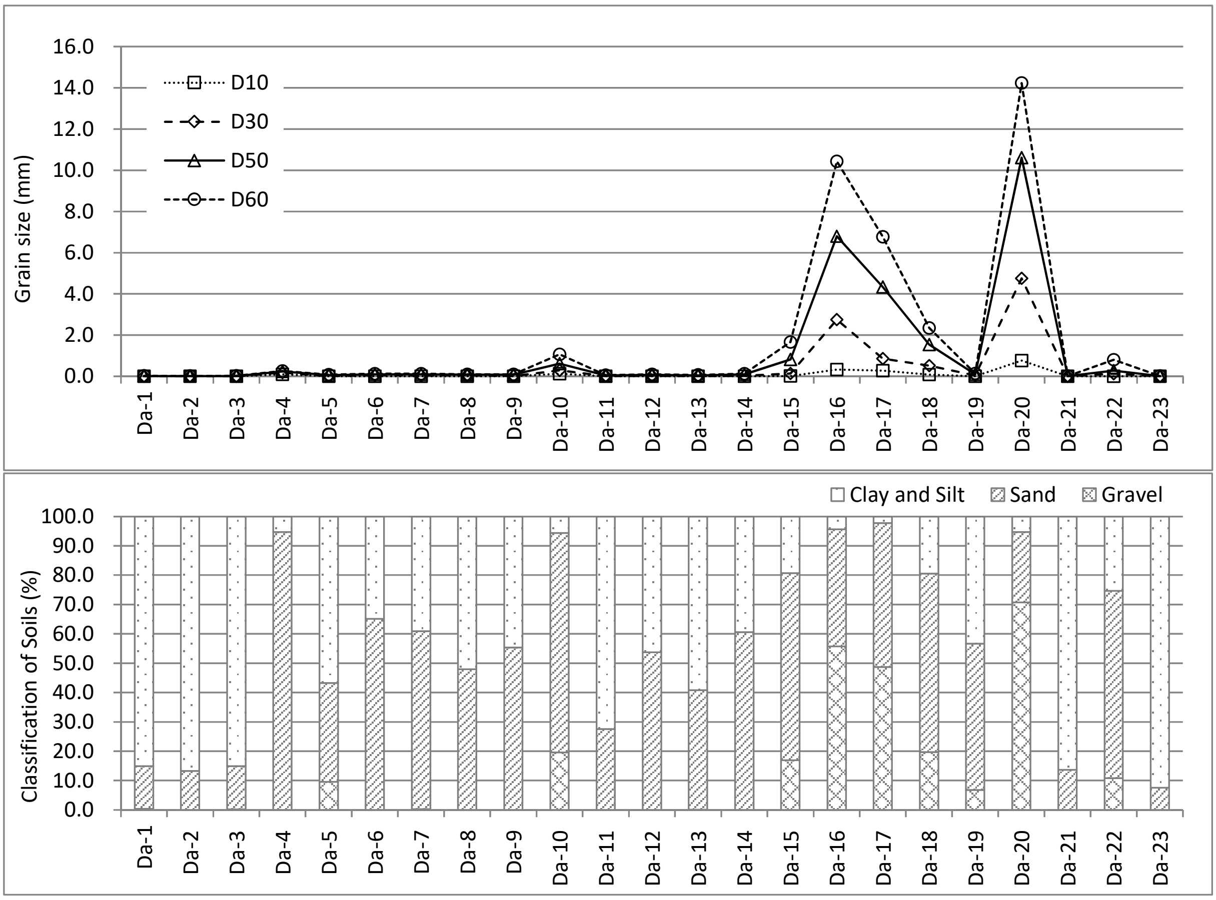
In the riverbed material survey, sampling was conducted at the riverbed surface and 30 cm below from the riverbed surface for each sampling point shown in Figure 2.5.18. Here, since the riverbed material with a grain size of about 10 cm or more is not the application of the indoor sieving test, the diameter and the mass were measured on site.

After drying the sample following the specifications of the American Society for Testing and Materials, the sampled riverbed material was measured its specific gravity using a hydrometer, and grain size distribution at each sampling point resulted from the sieve analysis of the passage of each opening.

(4) Survey Result

The survey result of each river is described below. The riverbed material sampling was conducted at the surface of the riverbed and 30 cm below the surface of the riverbed. The result of combining these samples shall be applied as the basic data of the riverbed fluctuation analysis.

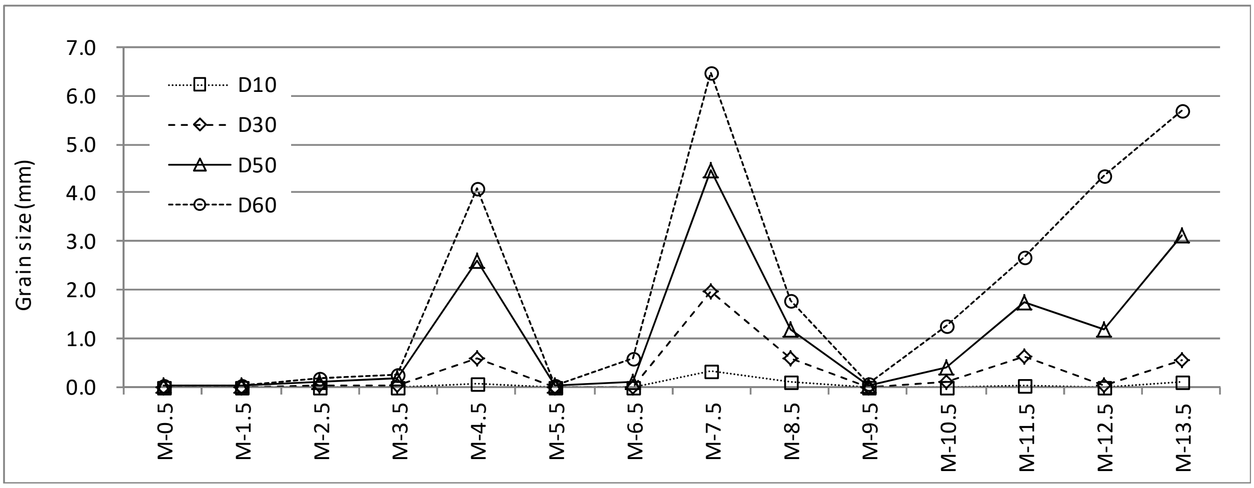
The riverbed material grain size distribution and soil classification ratio in the Davao River is as shown in Figure 2.5.19. Most of the riverbed material consists of clay, silt, and sand up to approximately 15 km from the river mouth. At the upstream section of 15 km from the river mouth, the composition ratio of gravel is increasing. The D50 (the particle size of 50% in suspension; average particle size) is 2 to 10 mm at sections containing a high ratio of gravel, where upstream of approximately 15 km from the river mouth, while the D50 is about 0.1 mm at other section composed of clay, silt, and sand.

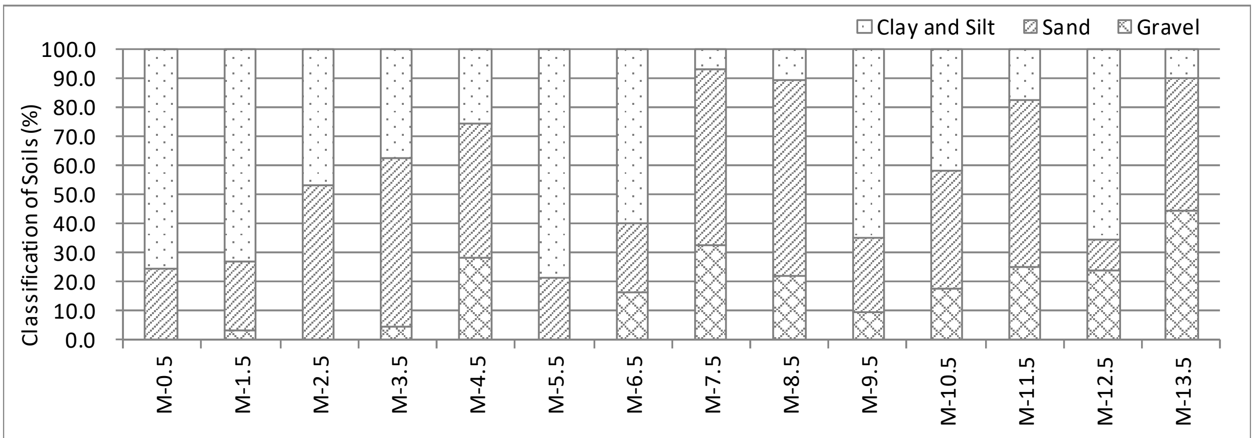


Source: Project Team

Figure 2.5.19 Riverbed Material Grain Size Distribution (up) and Soil Classification (below) in the Davao River

The riverbed material grain size distribution and soil classification ratio in the Matina River is as shown in Figure 2.5.20. Although there is no clear change of composition ratio of riverbed material as there is in the Davao River, the composition ratio of gravel is large around 4.5km from the river mouth and from 7.5km to 8.5km. The composition of the riverbed material shifts from clay and silt to gravel from approximately 5 km from the river mouth, and the grain size increases with the augmentation of gravel in the section from 10 km to upstream. The D50 is 1 to 4 mm at sections consisting a high ratio of gravel from about 10 km upstream from the river mouth, and the D50 is about 0.1 mm at sections composed of clay, silt, and sand on the downstream side.



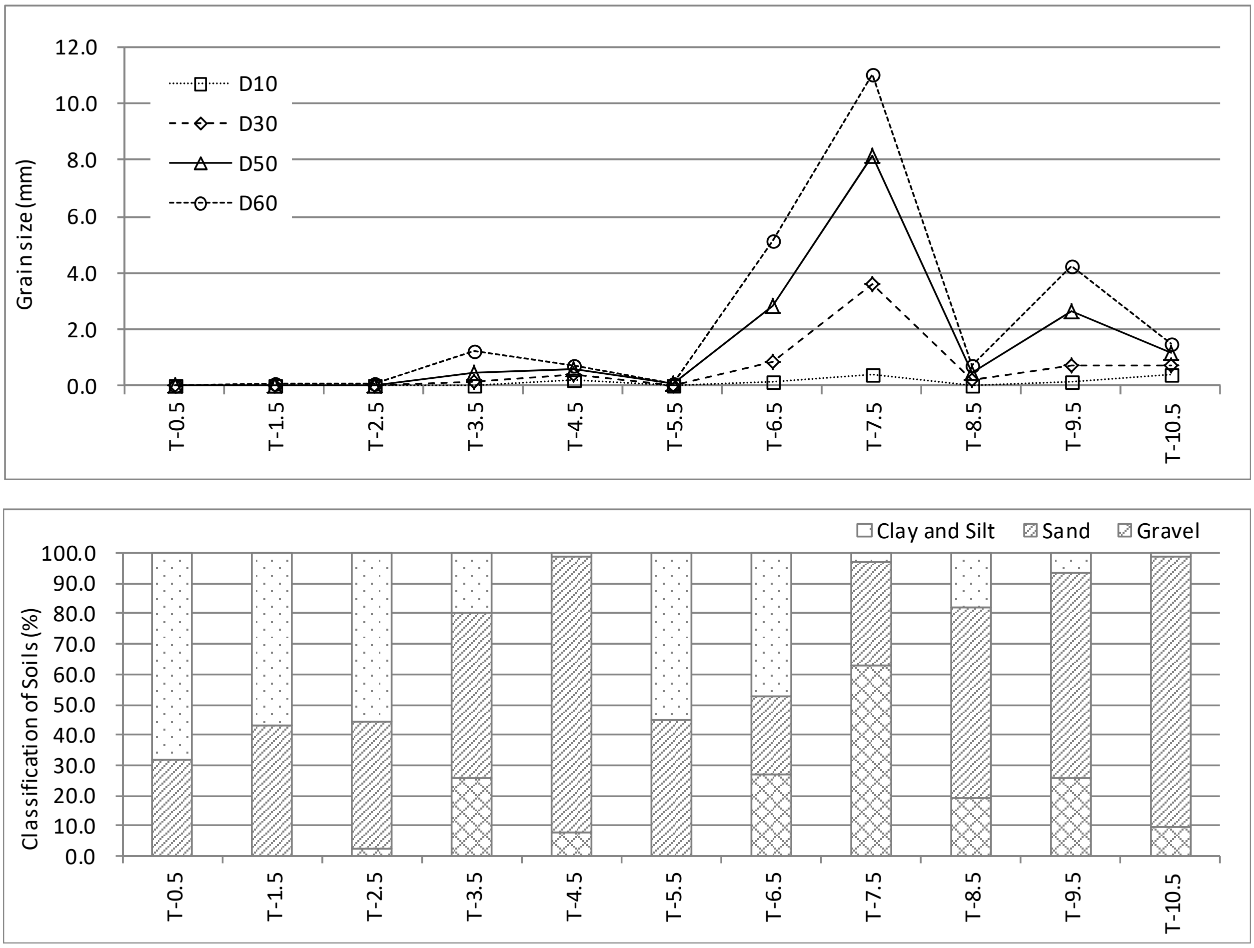


Source: Project Team

Figure 2.5.20 Riverbed Material Grain Size Distribution (up) and Soil Classification (below) in the Matina River

The riverbed material grain size distribution and soil classification ratio in the Talomo River is as shown in Figure 2.5.21. The composition of riverbed material changes around 6 km from the river mouth. Most of the riverbed material at the section downstream of 6 km from the river mouth consists of clay, silt, and sand, which the ratio of sand is higher compared with Davao River and Matina River. At the upstream section of 6 km from the river mouth, the composition ratio of clay and silt drastically decreases and, instead, the ratio of sand and gravel increases.

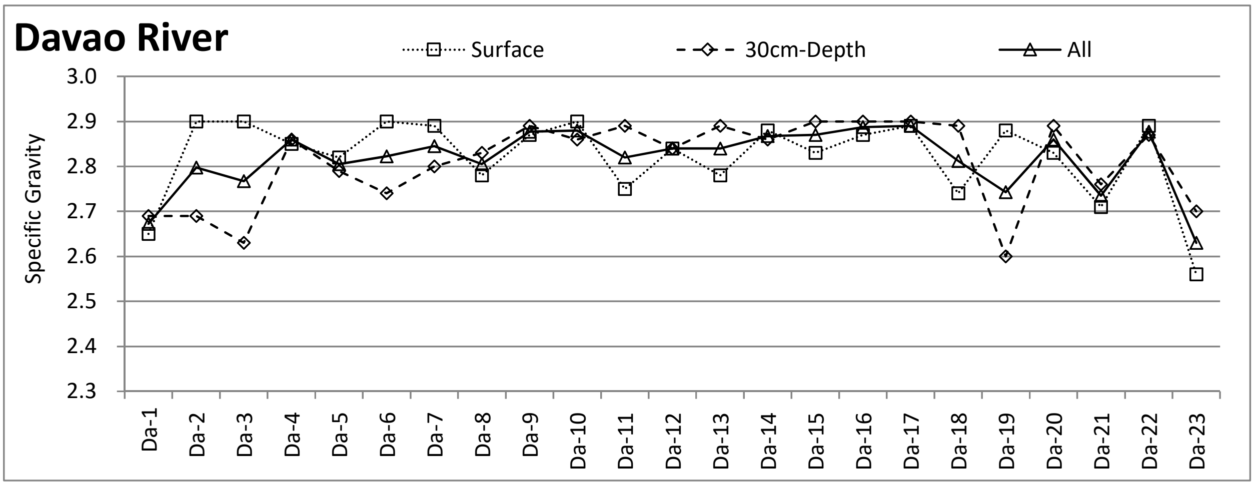
The D50 is 2 to 8 mm at sections consisting a high ratio of gravel from about 6 km upstream from the river mouth, and the D50 is about 0.1 mm at downstream sections composed of clay, silt, and sand.

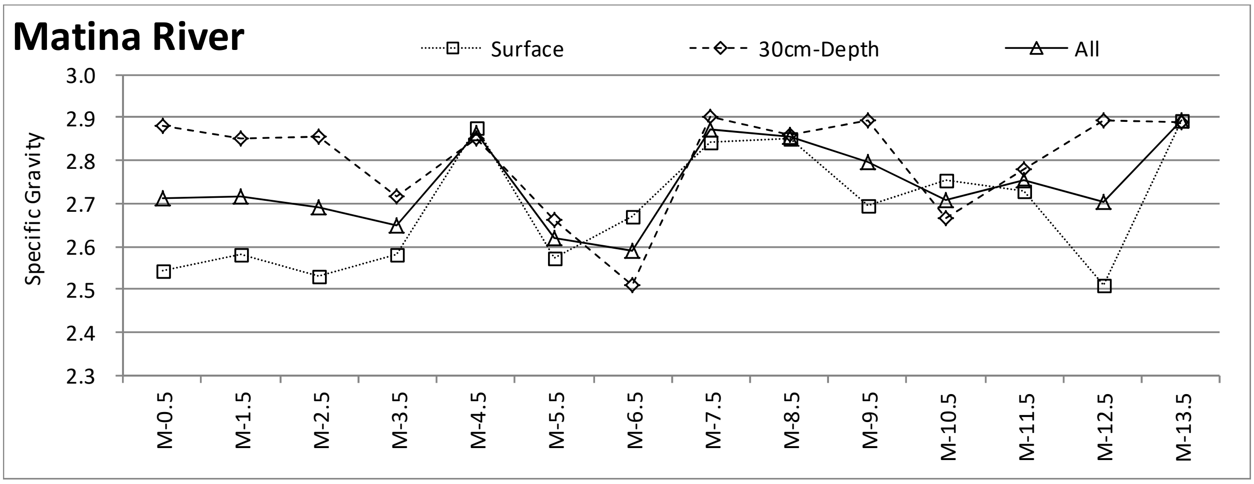


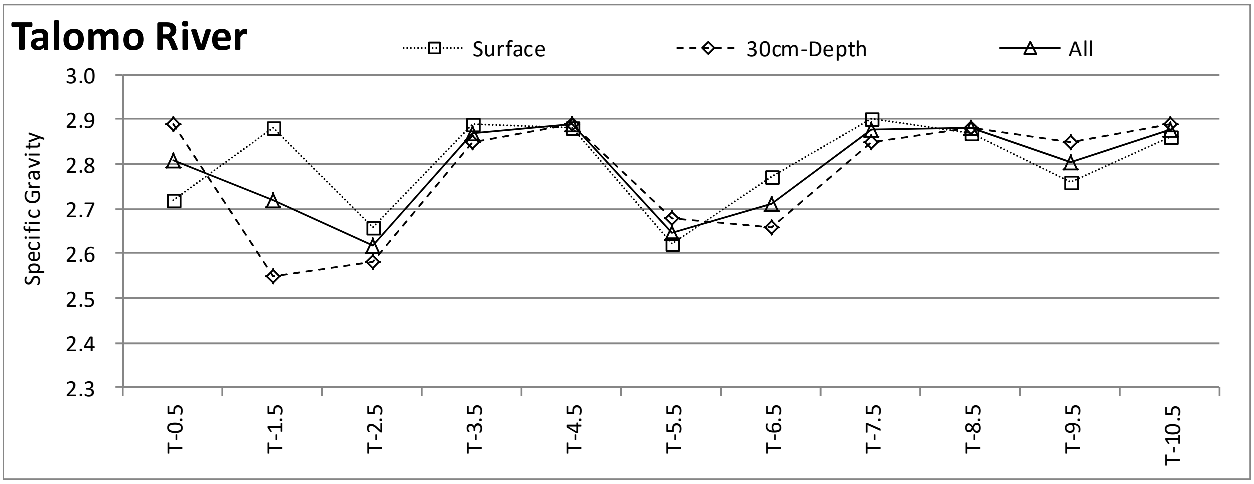
Source: Project Team

Figure 2.5.21 Riverbed Material Grain Size Distribution (up) and Soil Classification (below) in the Talomo River

Figure 2.5.22 shows the results of the specific gravity test. The specific gravity of the material of the Davao River, the Matina River and the Talomo River is about 2.8 (g/cm^3) which is slightly larger than the general value. This is probably because there are many gravel in the rivers due to volcanic activity.







Source: Project Team

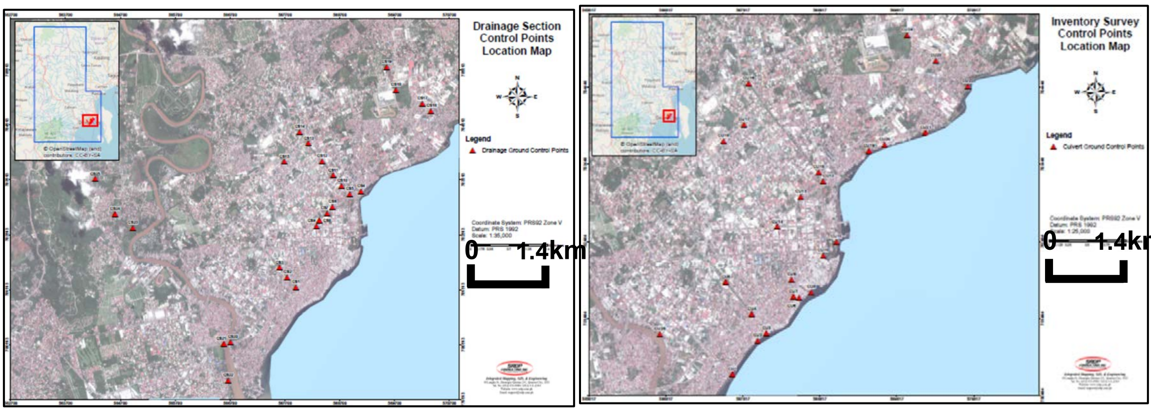
Figure 2.5.22 Specific Gravity (up: Davao River, middle: Matina River, below: Talomo River)

2.5.6 City Drainage Survey

The City Drainage Survey consists of the setting up of drainage cross section points and inventory ground control points (50 points), a drainage cross sectional survey (25 sections) and an inventory survey for manhole/culvert (25 locations) in Poblacion and Agdao Districts, which was carried out. Information of a location map of city drainage survey, survey method and output was as follows.

(1) Setting up of drainage cross section points and inventory ground control points

Before starting the city drainage survey, the setting up of 25 drainage cross section points and 25 inventory ground control points for manhole/culvert locations was carried out by GNSS survey and leveling. The same equipment, survey method and accuracy as explained in (1) Setting up of river cross section point of 2.5.4 River Topographic Survey of this report was applied for the setting up of drainage cross section points and inventory ground control point. Locations of a drainage cross section points and inventory ground control points are as follows.

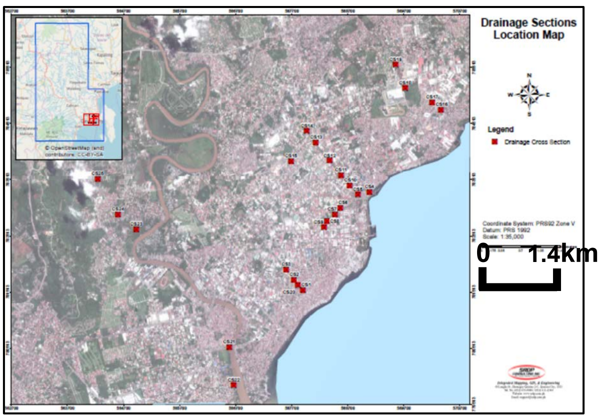


Source：Project Team

Figure 2.5.23 Location Map of Drainage Cross Section Points (Left) and Inventory Ground Control Points (Right)

(2) Drainage cross sectional survey

The drainage cross sectional survey was carried out from 25 drainage cross section points by GNSS Survey and leveling. The same equipment, survey method and accuracy as explained in (3) River cross sectional survey of 2.5.4 River Topographic Survey of this report was applied for Drainage cross sectional survey. Location map of the drainage cross sectional survey and field notes are as follows.

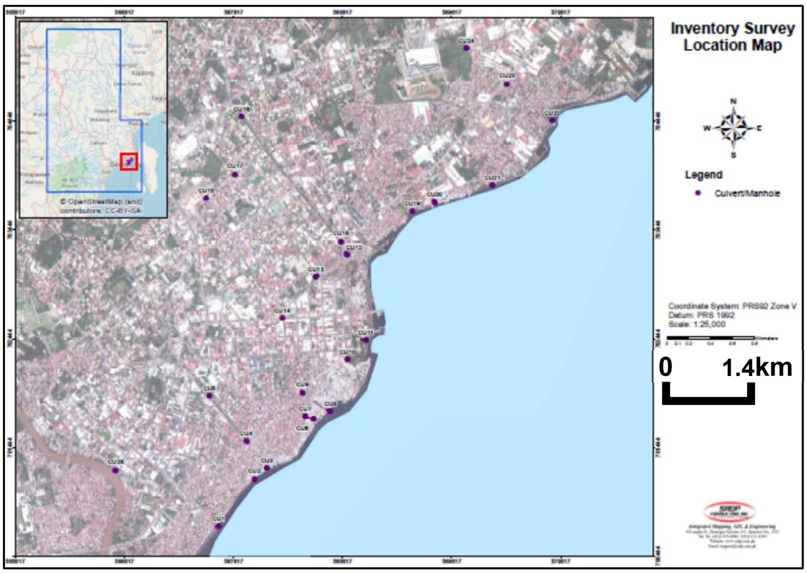


Source：Project Team

Figure 2.5.24 Location Map of Drainage Cross Sectional Survey

(3) Inventory Survey for Manhole/Culvert

Inventory Survey for Manhole/Culvert was carried out from 25 inventory ground control points by GNSS Survey and leveling. The same equipment, survey method and accuracy as explained in (3) River cross sectional survey of 2.5.4 River Topographic Survey of this report was applied for Drainage cross sectional survey. Location map of inventory survey for Manhole/ Culvert and field notes are as follows.



Source：Project Team

Figure 2.5.25 Location Map of Inventory Survey for Manhole/Culvert

(4) Output

1) Drainage cross section

Source：Project Team

Figure 2.5.26 Drainage cross section

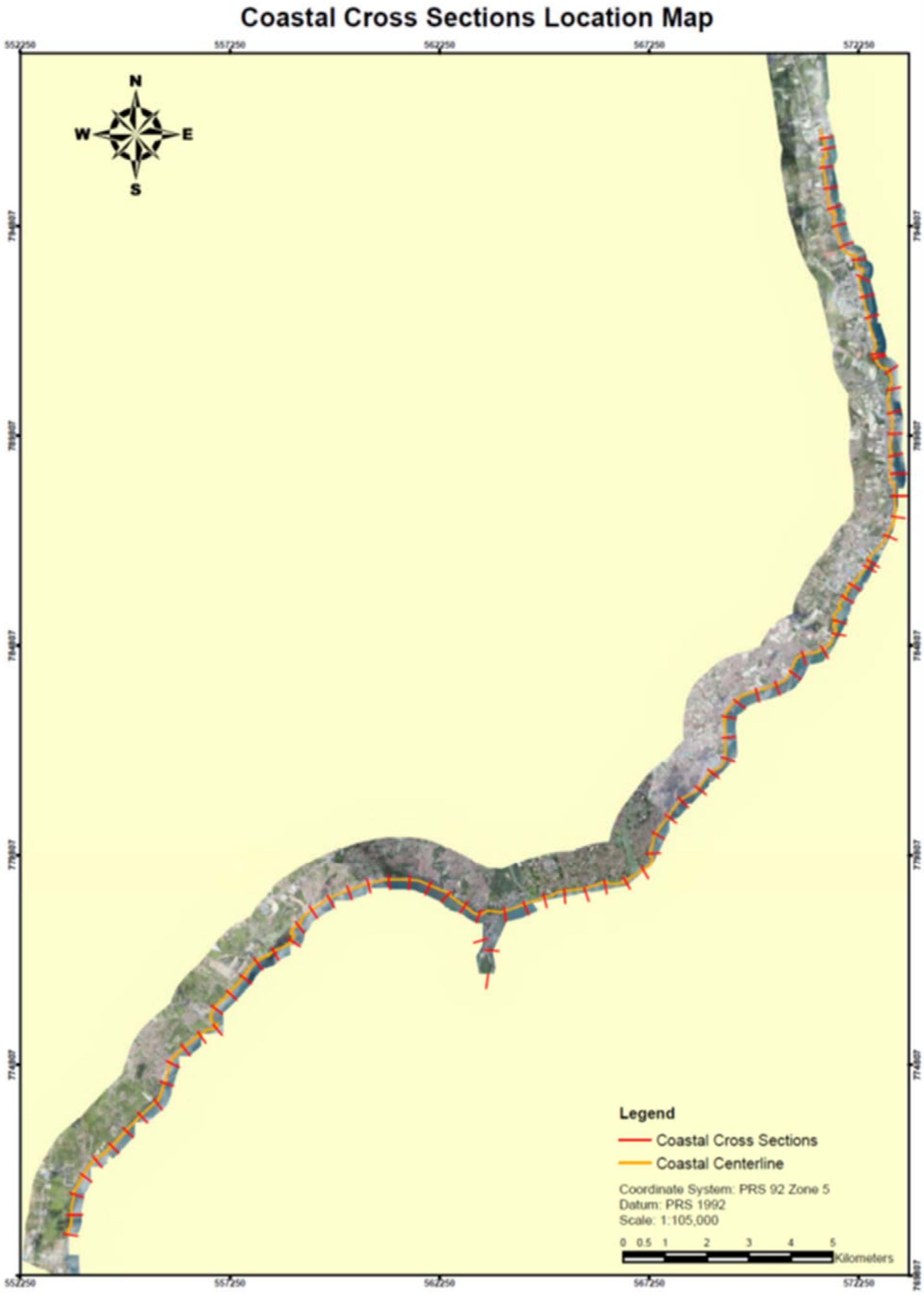
2) Inventory Survey Map for Manhole/Culvert

Source：Project Team

Figure 2.5.27 Inventory Survey Map for Manhole/Culvert

2.5.7 Shoreline Survey

Shoreline Survey was carried out from the South of Davao City to the entry points of the Coastal Road (10 km), the Construction site of Coastal Road to the North of Davao City (12 km) and from the End of Coastal Road to the North of Davao City (18 km). The Shoreline Survey consists of setting up of costal cross section points (84 points), 3D sectional measurement for costal profile sections (40 km), costal cross-sectional survey, UAV survey and photography for seabed soil on high tide spot (84 points) and low tide spots (84 points) on the coastal cross sections. Information of a location map of shoreline survey, survey method and output are as follows.

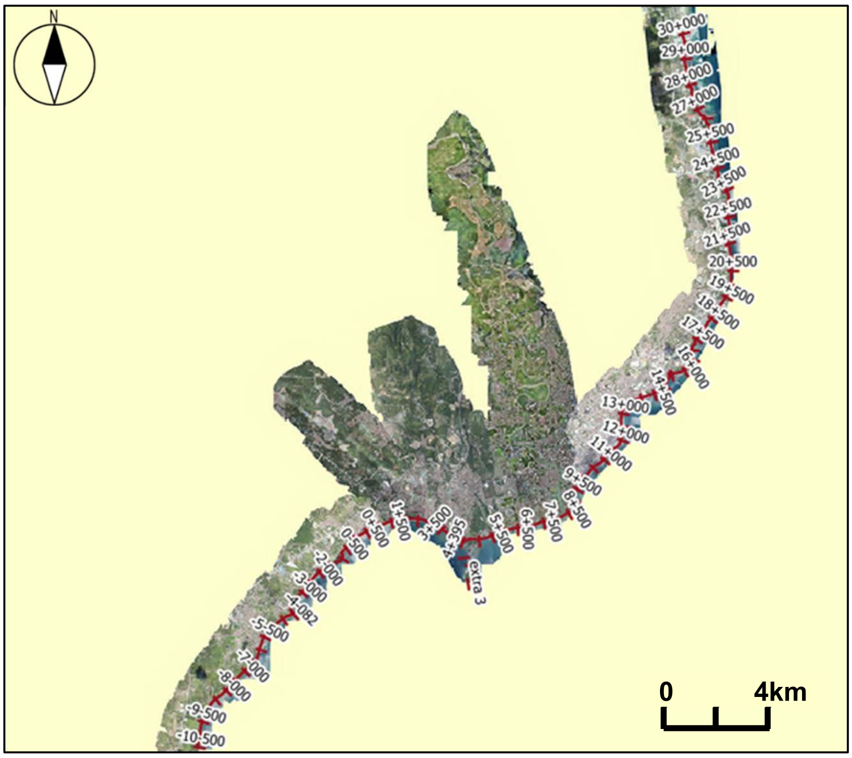


Source：Project Team

Figure 2.5.28 Location Map of Shoreline Survey

(1) Setting up of Coastal Cross Section Points

Before starting the Shoreline Survey, the setting up of 500 m pitch costal cross section points from South of Davao City to the entry points of Coastal Road (21 points), the Construction site of Coastal Road to the North of Davao City (25 points) and from the End of Coastal Road to the North of Davao City (37 points) was carried out by GNSS survey and leveling. The same equipment, survey method and accuracy as explained in (3) River cross sectional survey of 2.5.4 River Topographic Survey of this report was applied for setting up of coastal cross section points. Location of a coastal cross section points is as follows.



Source：Project Team

Figure 2.5.29 Location Map of Costal Cross Section Points

(2) 3D Sectional Measurement for Coastal Profile Sections

3D sectional measurement for coastal profile sections from the South of Davao City to the entry points of Coastal Road (10 km) and the Construction site of Coastal Road to the North of Davao City (12 km) were carried out by GNSS survey and leveling, and from the End of Coastal Road to the North of Davao City (18 km) were carried out by UAV measurement and prepared 3D data of costal profile sections. The same equipment, survey method and accuracy as explained in (3) River cross sectional survey of 2.5.4 River Topographic Survey of this report was applied for 3D sectional measurement for coastal profile sections. Location of a 3D sectional measurement for coastal profile sections is as shown in Figure 2.5.28 Location Map of Shoreline Survey.

(3) Coastal Cross-Sectional Survey

The coastal cross-sectional survey from the South of Davao City to the entry points of Coastal Road (21 sections), the Construction site of Coastal Road to the North of Davao City (25 sections) and from the End of Coastal Road to the North of Davao City (37 sections) were carried out by GNSS survey and leveling. The same equipment, survey method and accuracy as explained in (3) River cross sectional survey of 2.5.4 River Topographic Survey of this report was applied for costal cross-sectional survey. Location of a costal cross-sectional survey is as shown in Figure 2.5.28 Location Map of Shoreline Survey.

(4) UAV Survey

UAV Surveys (aerial survey) were carry out covering 1km width area from the South of Davao City to the entry points of Coastal Road (10km), the Construction site of Coastal Road to the North of Davao City (12km) and from the End of Coastal Road to the North of Davao City (18km). Ground Resolution of Aerial photos by aerial survey was 10cm and covreage area was 40k㎡. Ortho-photos were prepared using coordinates and elevation data of spot points by the Ground Height Survey data (Spot Survey) .

Source：Project Team

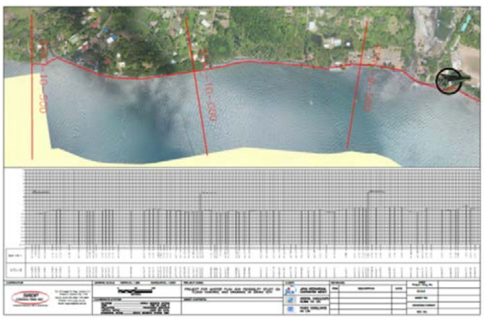
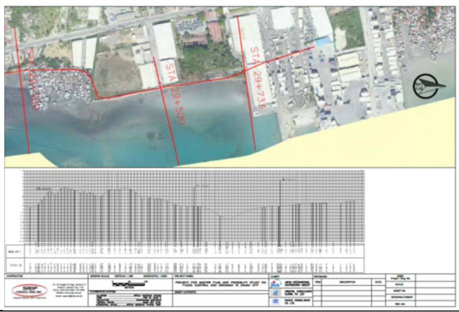
Figure 2.5.30 Area Map of Ortho-photo (Shoreline Survey)

(5) Photography for Seabed Soil on High Tide Spot and Low Tide Spots on the Coastal Cross Sections

Photography for seabed soil on high tide spot (84 points) and low tide spots (84 points) on the 84 coastal cross sections were carried out. The collected photography and field data were edited and compiled into the record sheets.

(6) Output

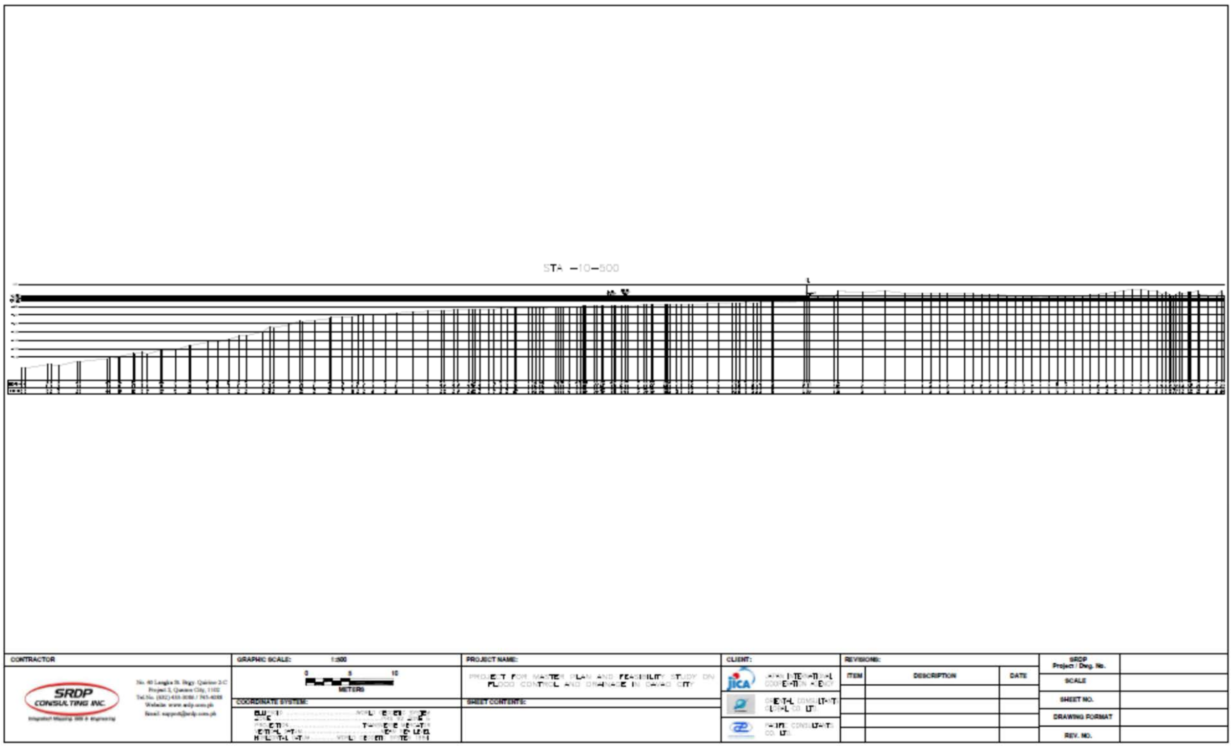
1) 3D sectional measurement for coastal profile sections

Beginning point of costal profile section	3D Costal profile section	Endpoint of costal profile section
		

Source：Project Team

Figure 2.5.31 3D Costal Cross Sections

2) Coastal Cross Sections



Source：Project Team

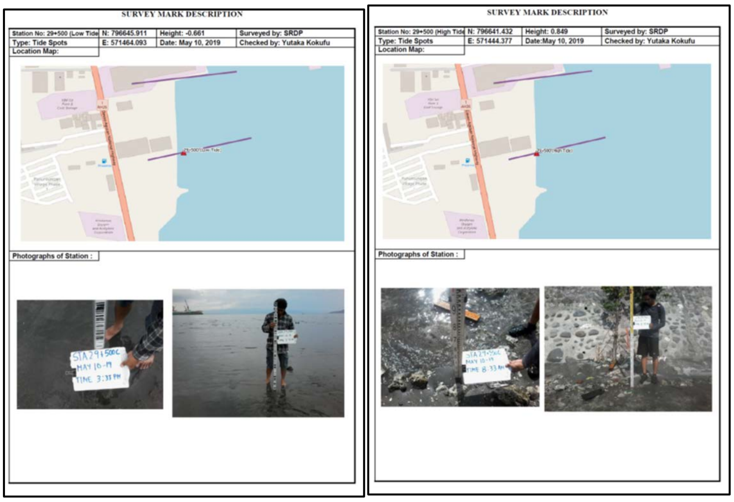
Figure 2.5.32 Costal Cross Sections

3) Orth-photo

Source：Project Team

Figure 2.5.33 Ortho-photo Sample (Shoreline)

4) Photography for Seabed Soil on High Tide Spot and Low Tide Spots

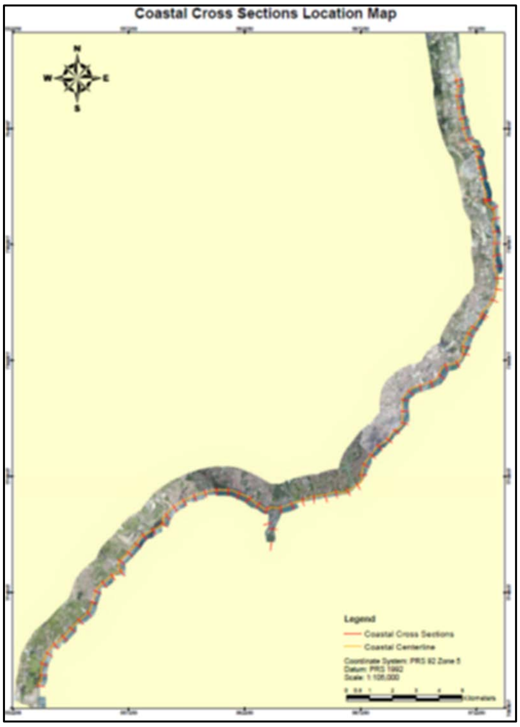


Source：Project Team

Figure 2.5.34 Record Sheets of Photography for Seabed Soil on High Tide Spot and Low Tide Spots

2.5.8 Bathymetric Survey along the Coastal Road and Davao North Coast

Bathymetric Surveys (sounding measurement) from the South of Davao City to the entry points of the Coastal Road (21 sections), Construction site of Coastal Road to the North of Davao City (25 sections) and from the End of Coastal Road to the North of Davao City (37 sections) were carried out from the coastal cross section points to sea along the coastal cross section line by sounding**.** Location Map of Bathymetric Survey is as follows.



Source：Project Team

Figure 2.5.35 Location Map of Bathymetric Survey

(1) Sounding Measurement

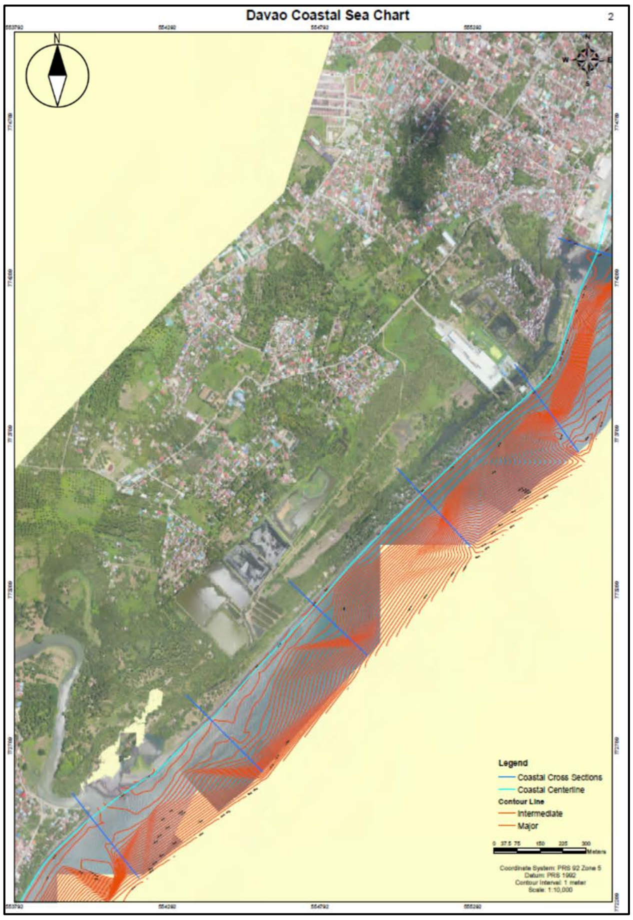
Sounding Measurement was carried out by GNSS receiver and echo sounder. The width of the Sounding Measurement is 250 m from shoreline. The accuracy of position and depth from the coastal cross section point on the coastal section line are as follows.

・Accuracy of coordinates： ±10cm
・Accuracy of depth： ±10cm

The final coastal cross section (84 sections) were prepared using sounding measurement data and the coastal cross section data.

(2) Sea Chart Preparation

Sea chart was prepared at scale of 1/10,000 with 1 m depth line using sounding measurement data, shoreline Survey data and UAV survey data. Total length of sea chart was 40 km of from the South of Davao City to the entry points of Coastal Road (10km), the Construction site of Coastal Road to the North of Davao City (12km) and from the End of Coastal Road to the North of Davao City (18km) and width has covered 250m. The area of the prepared sea chart is 10 km^2.

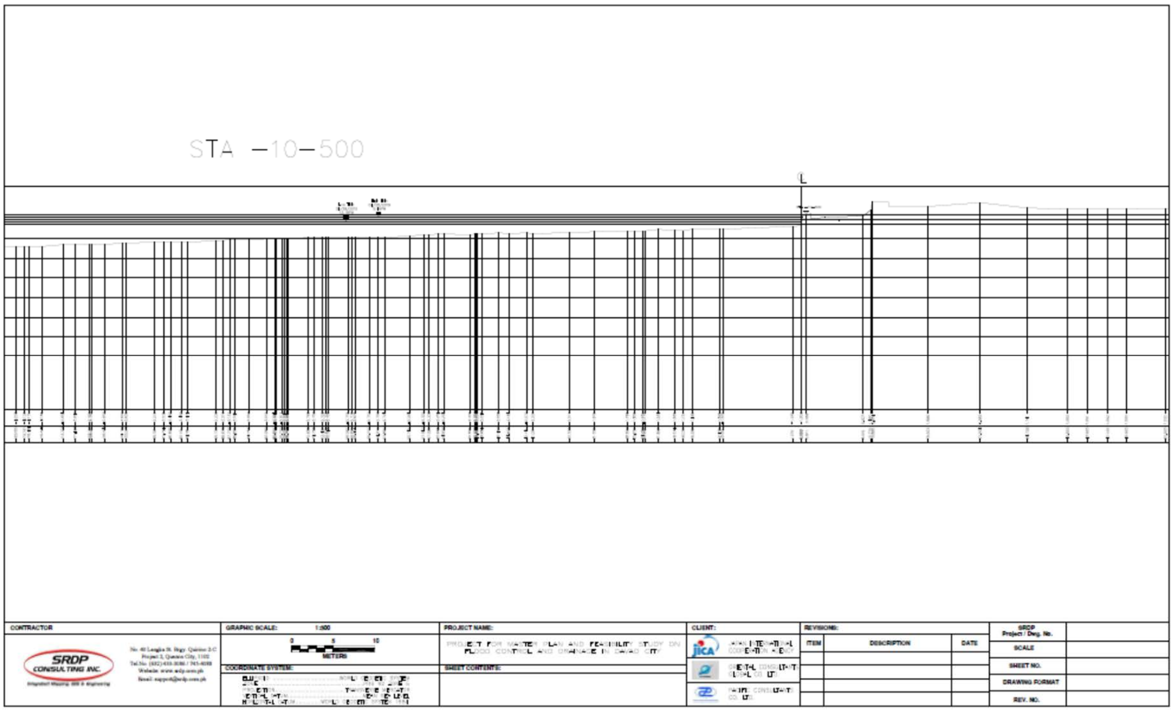


Source：Project Team

Figure 2.5.36 Depth Lines Chart

(3) Output

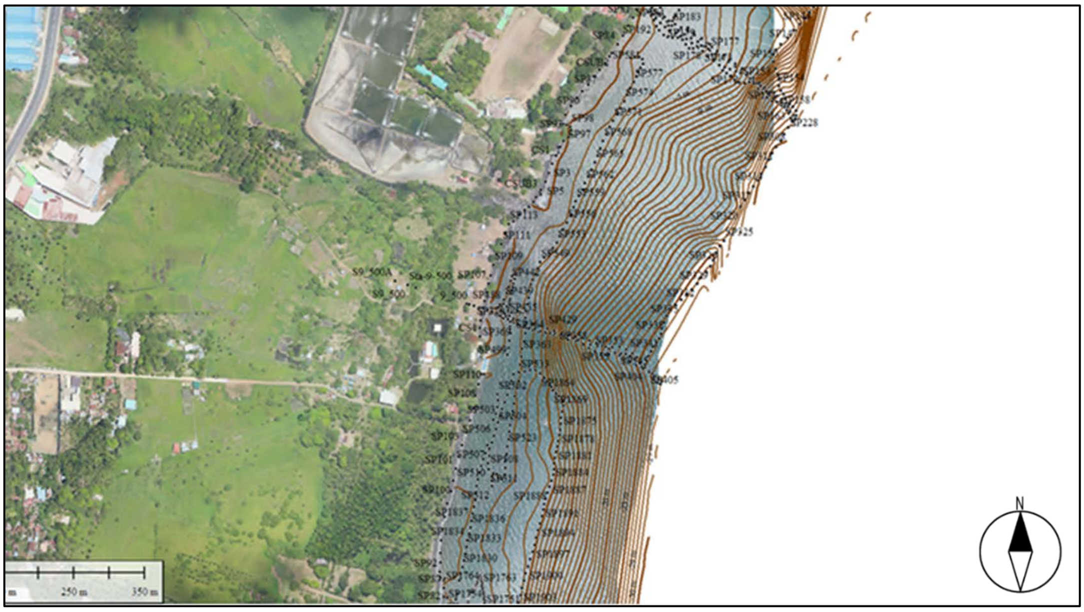
1) Coastal Cross Section



Source：Project Team

Figure 2.5.37 Coastal Cross Section

2) Sea Chart



Source：Project Team

Figure 2.5.38 Sea Chart

2.6 Geological Conditions

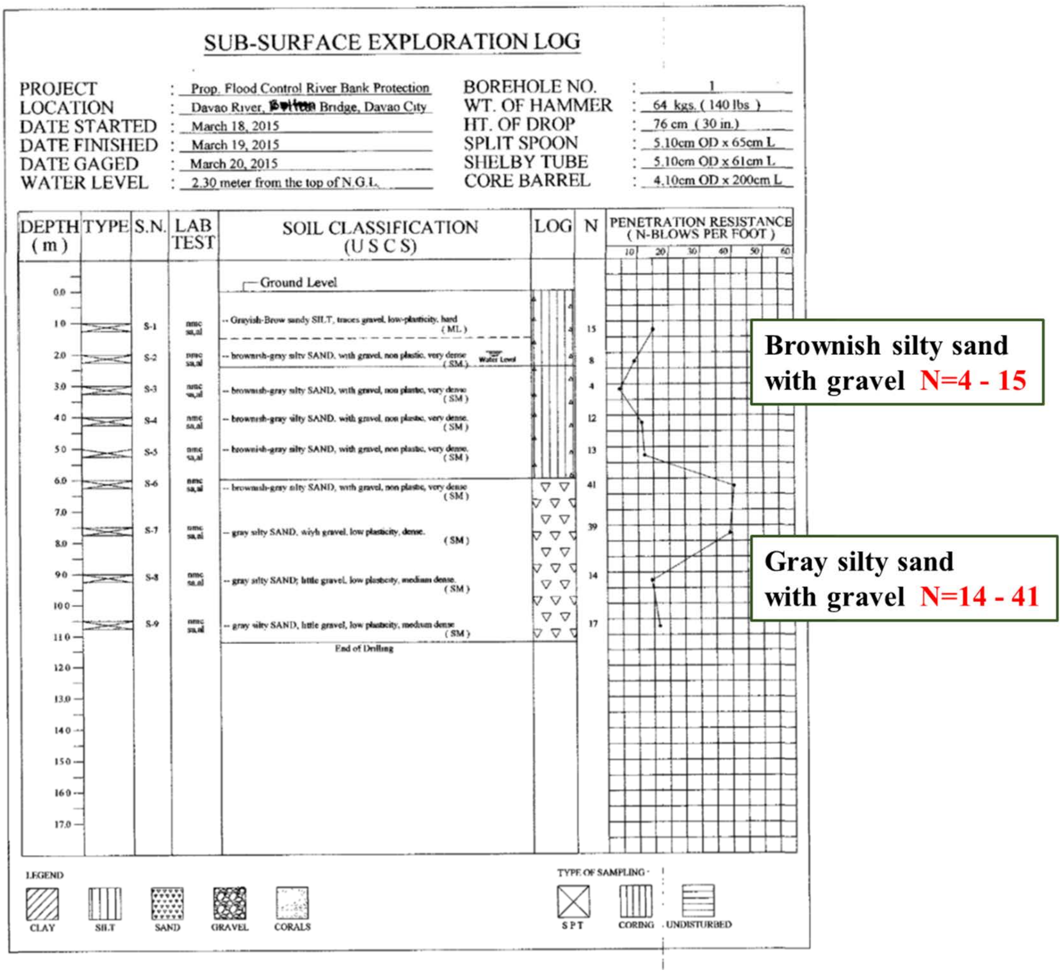
In the target area of this project, road and bridge constructions by DPWH-RO and embankment and revetment constructions by DPWH-DEO have been / are being carried out, geological survey being conducted for those constructions as well. Nevertheless, a geotechnical survey report integrating the survey results (incl. standard penetration test, particle size distribution, liquid / plastic limit test, moisture content test) has only been compiled for a few surveys and that, in most cases, the survey results can only be confirmed through borehole logs and assumed geological sections reflected in the design drawings. There seems to be confusion in the utilization of survey results, as implied by the identical geological sections appearing in the drawings of different sections. This implies that survey results may not be used correctly.

2.6.1 Davao River

Althouth it is difficult to accurately understand the geolocial conditions along the Davao River due to above mentioned confusion of the data, the geological features of the area in general are assumed as follows,

- ✓ Depth of bearing layer (N > 30 for sand, and N > 20 for silt and clay) is, in most sections, less than 10 meters from the ground level. As a exception, there are some data indicating the depth of bearing layer to be at 15 to 25 meters from the ground level only for sections between the river mouth to 3.0 km, in between data with bearing layer at less then 10 meters.
- ✓ The thickness of soft silt / clay layer that exists above the bearing layer is less than 5 meters for most sections. An only exception can be seen at around 1.5 km left bank where the thickness soft silt / clay layer is more than 10 meters due to available data.

Borehole log at around 0+800k (Right bank) is shown as reference. Loose silty sand with an N value of 4 to 13 is found in the surface layer of about 6 m, and a medium to dense silty sand layer with an N value of 14 to 41 is found below about 5 m. Although the same borehole log appears in the design drawing of the revetment at around 2+200k (Right bank), it is considered that the information is representative of around 0+800k judging by the location name on the log sheet, which is Bolton Bridge.

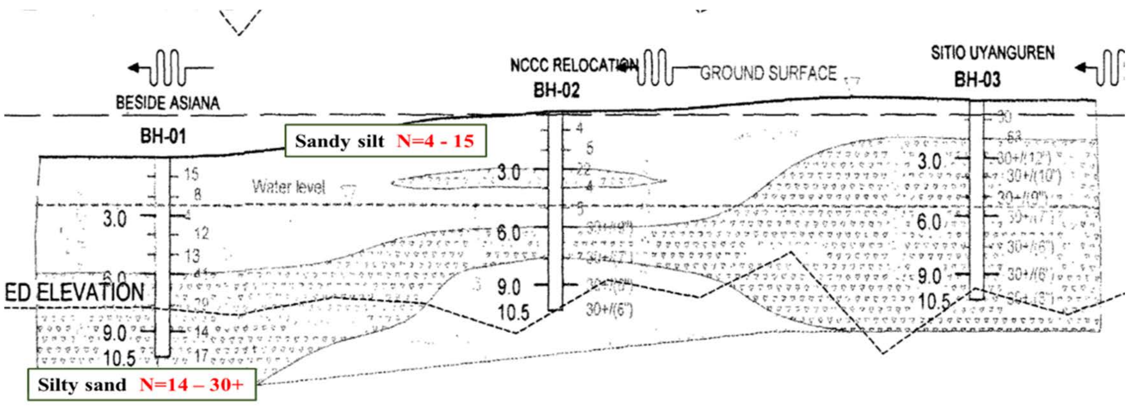


Source：DPWH DEO (annotated by Project Team)

Figure 2.6.1 Geological Conditions along Davao River (around 2+200km)

2.6.2 Talomo River

The assumed geological cross section of 2+700 to 2+900 km (Left bank) of the Talomo River is shown in Figure 2.6.2. A soft to medium sandy silt having an N value of about 4 to 15 is found in the surface layer of 2 to 6 meters, and a medium to dense silty sand having an N value of 14 to 30 or more is found below.

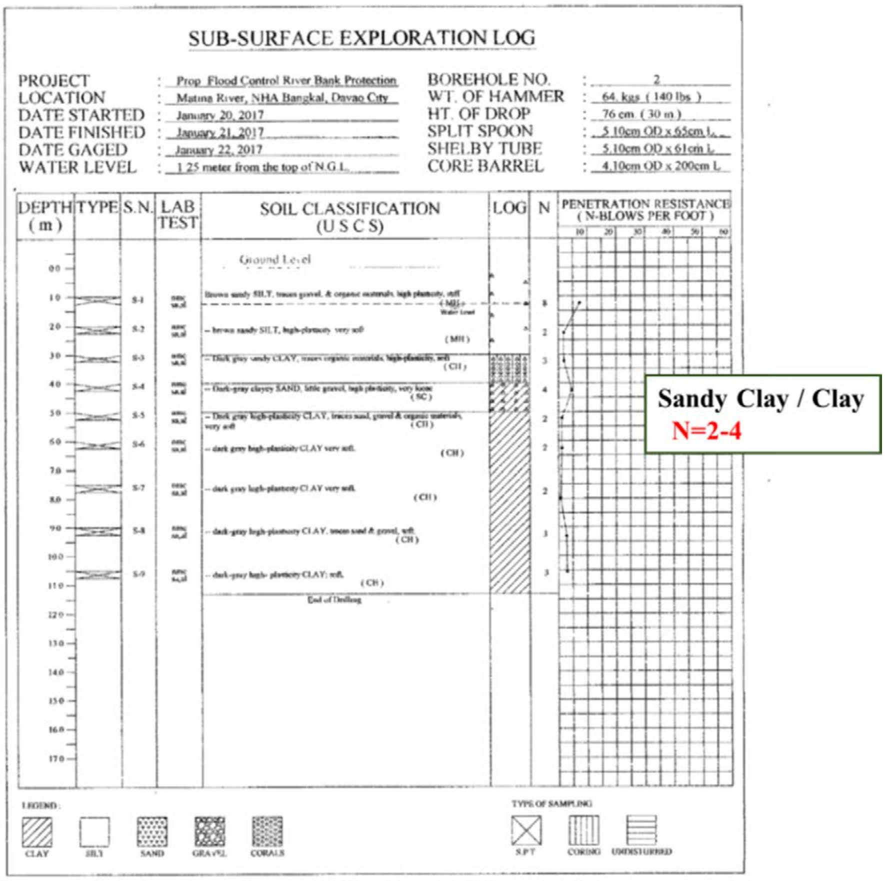


Source：DPWH DEO (annotated by Project Team)

Figure 2.6.2 Geological Conditions along Talomo River (around 2+700 to 2+900km)

2.6.3 Matina River

A soft clay layer with an N value of 2 to 4 can be seen continuously to the bottom of borehole at about 11 m from the ground surface at around 0 +800 km (right bank). Similar geological conditions are assumed in the design documents of upstream section (above 2km), although there seems to be a confusion in the utilization of data, such as identical cross section in different sections.



Source：DPWH DEO (annotated by Project Team)

Figure 2.6.3 Geological Conditions along Matina River (around 0+800 km)

2.6.4 Summary of Current Status of Geological Survey

(1) Existing Geological Survey

Embankment and revetment construction work by DPWH-DEO along the three target rivers are underway and geological surveys are also conducted for those construction work activities. Nevertheless, it was observed that there are confused utilization of data, limited survey points and lack of description in the report about the survey location and geotechnical test results, the last one being for the few cases where a survey report is compiled.

As a consequence, conducting appropriate geological surveys to reflect the results in the design of structure measures is the issue of upmost importance.

(2) Geological Conditions of the Target Area

It is assumed that, for all of three rivers, the subsurface ground consists of around 5 m of soft layer on the top. The thickness of the soft layer can potentially be greater and reach more than 10 m along Matina River, implying that measures against soft ground may potentially be required in the design of structural measures.

2.7 Riverine Flood Analysis

2.7.1 Inundation and Damage of Riverine Flood

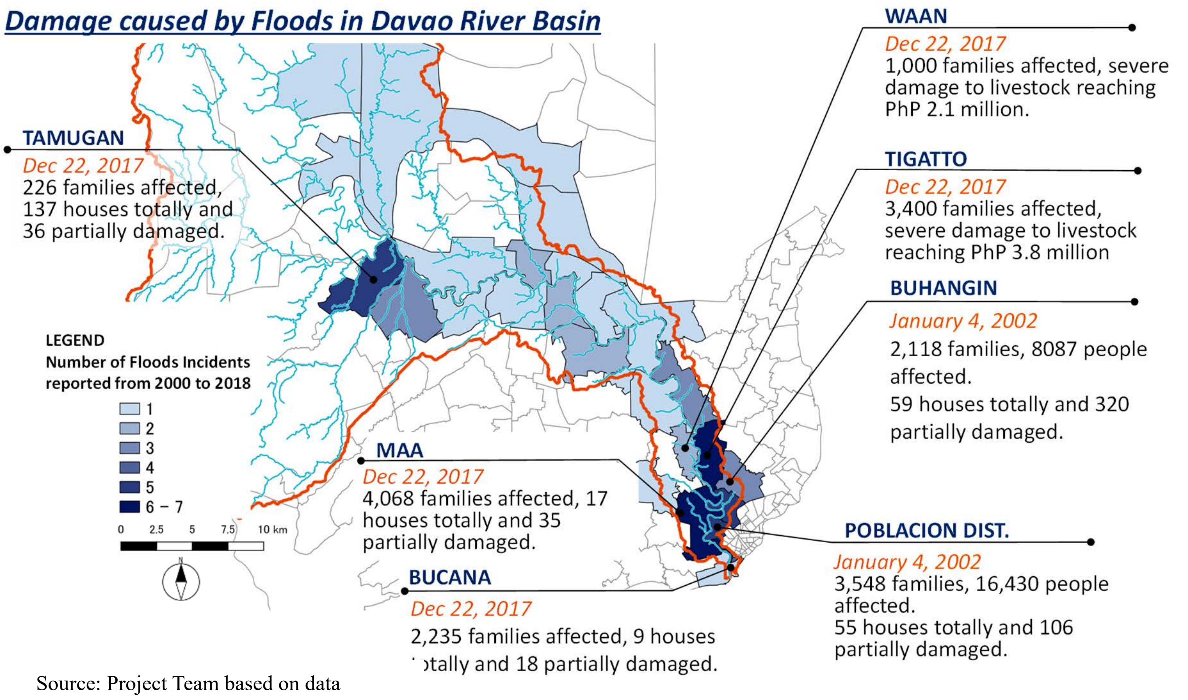
(1) Record of Flood

In Davao River Basin, major floods have been recorded in 2002 and 2017. Major floods were recorded in Talomo River Basin in 2000 and 2002, and in Matina River Basin in 2002 and 2011. In December 2017, Typhoon Vinta caused enormous damage, especially in Davao River. An outline of the damage recorded by the riverine flood of each basin is shown in the following tables and figures.

1) Davao River Basin

Based on flood disaster records for the period 2000 - 2018 provided by CDRRMO in Davao City, the outline of the flood damage caused by the riverine flood of the Davao River basin was organized. Vinta Typhoon of December 2017 affected 21,768 families which corresponds to two-thirds of the total number of affected families (30,503). Although the number of reported incidents is large (30 flood incidents from 2000), the total number of casualties is 7 and the occurrence of floods affecting families is low.

In Davao River Basin, the frequency of flood damage is high in the urbanized downstream area covering the Barangays of Ma-a, Tigatto, BRGY 2 and BRGY 5. Figure 2.7.1 shows the frequency and scale of the damage of floods affecting more than 1000 families since 2000. (Although the number of affected families in Tamugan is less than 1000, damage of December 2017 Flood are shown as an example of damage to the middle reaches). Although if there are some barangays with a number of floods reported in the middle reaches such as Tamugan, flood reports are concentrated in the lower part of the Davao River basin where the urbanized area is located.



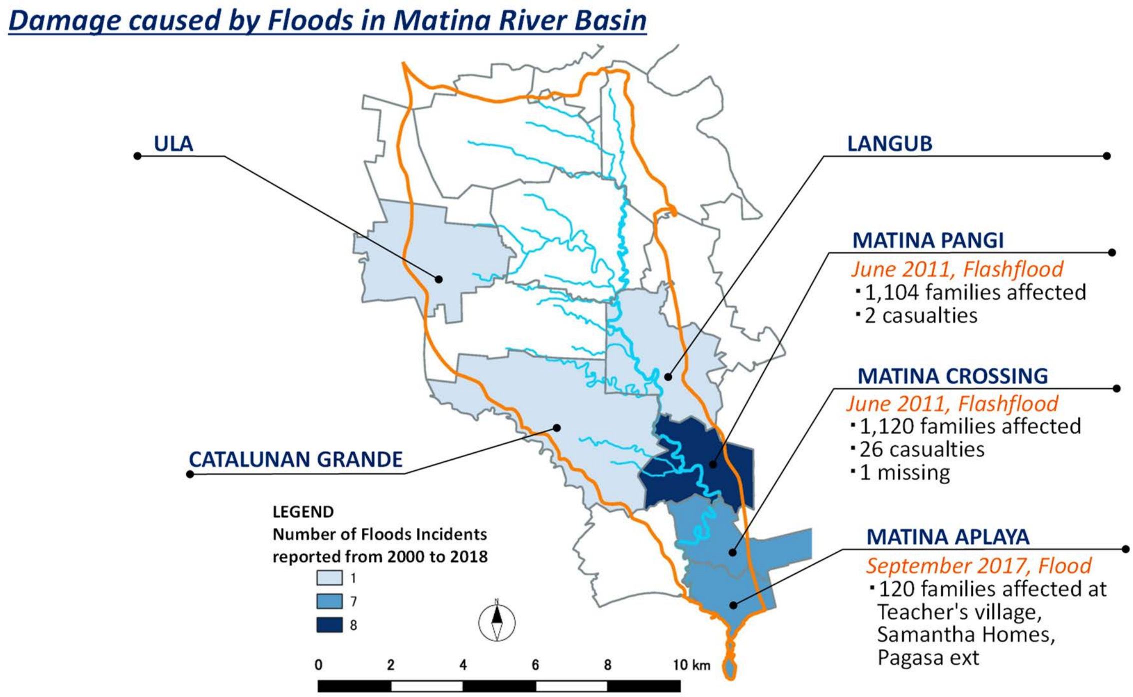
Source: Project Team based on data provided by CDRRMO

Figure 2.7.1 Number of Flood Incidents and Largest Recorded Damage to Barangays in Lower Davao River Basin (2000-2018)

2) Matina River Basin

Similar to the Davao River Basin, the outline of flood damage in the Matina River Basin is summarized based on the 2000-2018 flood disaster records provided by CDRRMO in Davao City. In Matina River, the floods of 2000 and 2011 were the biggest in terms of affected families. Compared to the Basins of Davao River and Talomo River, the number of affected families is small. However, the number of incidents reported in the three Barangays of Matina Pangi, Matina Aplaya and Matina Crossing is large.

Figure 2.7.2 shows the number of flood incidents per barangay frequency and outline of major flood damage since 2000 in the three Barangays of Matina Pangi, Matina Aplaya and Matina Crossing where the number of reported incidents is large. The most destructive flood in the Matina River basin is the flashflood of June 2011 which caused 26 deaths by drowning in Matina Crossing and 2 in Matina pangi (Since the total number of casualties since 2000 is 31, the number of casualties caused by the flood of 2011 represents 90% of the total).



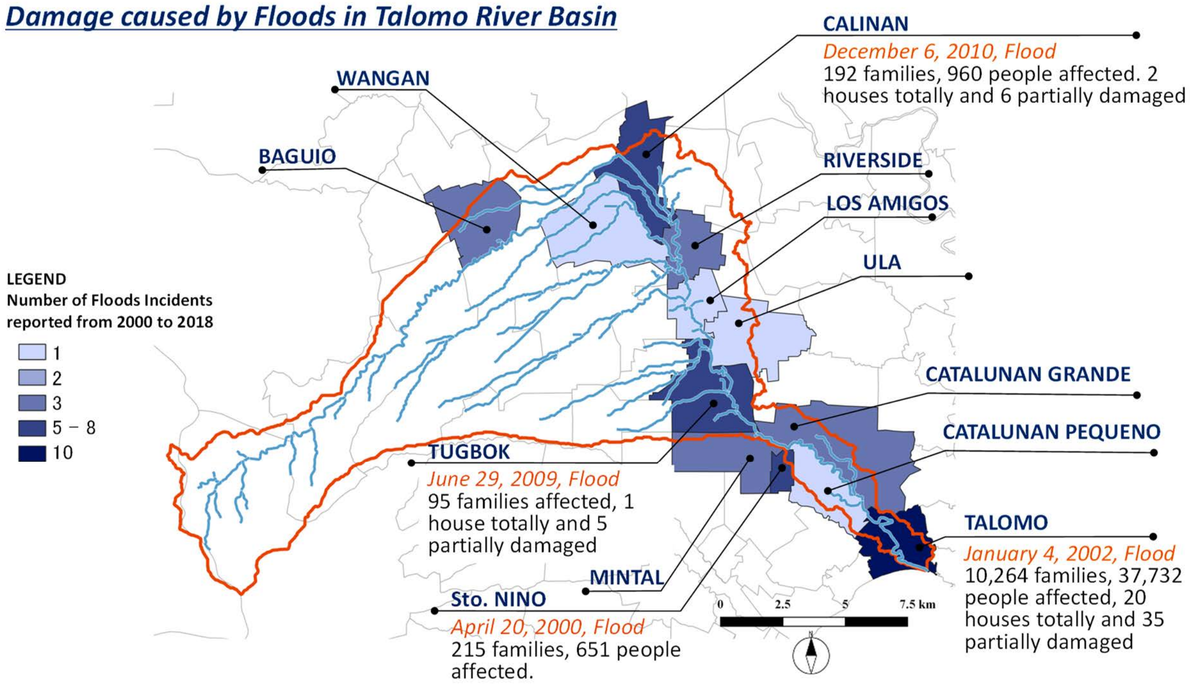
Source: Project Team based on data provided by CDRRMO

Figure 2.7.2 Number of Flood Incidents and Largest Recorded Damage to Barangays in Matina River Basin (2000-2018)

3) Talomo River Basin

Similar to the Basins of Davao River and Matina River, the outline of flood damage in the Talomo River basin is summarized based on the 2000-2018 flood disaster records provided by CDRRMO in Davao City. 32 flood incidents were reported since 2000. From the viewpoint of affected families, the flood of January 2002 is prominent with 10,315 affected families which represents around 60% of the total number of affected families (18,315). Although the number of incidents reported since 2010 is 22 which is equivalent to 70% of the total number of 32 flood incidents, the number of affected families since 2000 is 1,013 which is equivalent to 6% of the total number since 2000.

Figure 2.7.3 shows the number of reported flood incidents since 2000 and the outline of damage of major floods in the barangays with more than five flood reports. In the Talomo River Basin, flood incidents are widely reported not only in the downstream but also in the middle stream. In particularly in in the most downstream Talomo Barangay where the number of flood incidents is the biggest (10) and where the flood of January 2002 affected 10,264 families (around 60% of the total 18,053 affected families since 2000).



Source: Project Team based on data provided by CDRRMO

Figure 2.7.3 Number of Flood Incidents and Largest Recorded Damage to Barangay in Talomo River Basin (2000-2018)

(2) Large-Scale Flood and Characteristic of Flood Damage

1) Flood Damage in Typhoon Vinta in Davao River Basin (December 22, 2017)

The largest flood in recent years in the Davao River basin is the flood caused by the typhoon Vinta in December 2017. Typhoon Vinta passed through the northern part of the basin at a central pressure of 990 hPa and the maximum daily rainfall during the typhoon Vinta was recorded on December 21.

The flood caused by Vinta was a large-scale flood and was nearly the largest flood in the past with a probability of about 40 years (based on the results of the statistical analysis on Water Level and Discharge conducted by the Project Team). The barangays that were heavily damaged are Waan, Tigatto, Maa, Poblacion (district) and Bucana. Especially in the Tigatto area, the existing dike had blocked drainage and the area was flooded for a long time (up to about 2 days according to the interview survey result). According to the data of CDRRMO, the monetary damage to Davao City due to the flood was calculated at about 79 million pesos for agricultural damage, about 9 million pesos for animals/livestock/poultry damage, about 116 million pesos for infrastructure damage, and about 204 million pesos in total when PAGASA recorded 39.4 mm/day at Davao City Station, 112.4 mm/day at Malaybalay Station, and 114.5 mm/day at Tagum Station.

There were no records on affected families and other flood damage for the Basins of Matina River and Talomo River.

2) Flood Damage by Large-Scale Flood on June 29, 2011 in Matina River Basin

The 2011 flood caused serious damage to the lower reaches of the Matina River, with 26 casualties (deaths by drowning) at Matina Crossing. According to interviews with residents, heading-up occurred in the upstream side of the old Matina-Pangi Bridge II, and then the rapid run-off that occurred when the bridge finally ran out could cause great damage downstream. After the flood, the bridge was rebuilt raising it by about 3 m. The rainfall amount recorded by PAGASA at the Station of Davao City was 0.6 mm/day on June 27, 8.0 mm/day on June 28, and 3.8 mm/day on June 29. Since the daily rainfall amount does not reach 10 mm/day, it seems that the rain area was not captured by the Station of Davao City.

The flood affected 2,307 families in Matina River Basin, 497 in Davao River Basin (Ma-a Barangay) and there was not any record for the Talomo River Basin.

3) Flood Damage by Large-Scale Flood on January 4, 2002 in Talomo River Basin

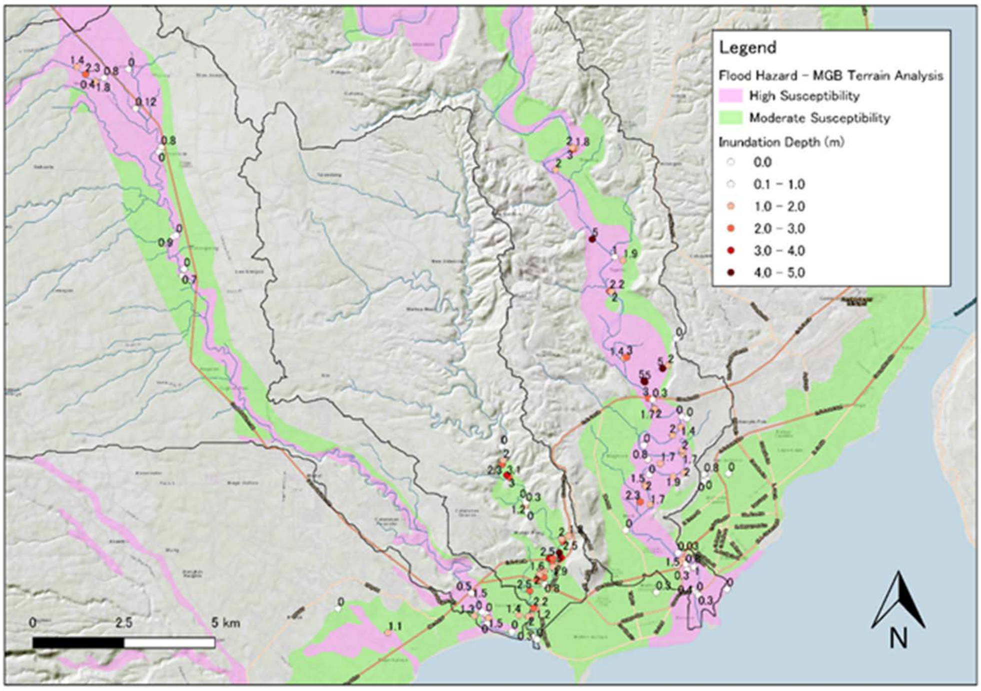
The January 2002 flood caused damage to more than 10,000 families in the most downstream barangay of the Talomo River. The rainfall amount recorded by PAGASA at the Station of Davao City was 5.0 mm/day on January 2, 89.2 mm/day on January 3,and 0.0 mm/day on January 4. The flood affected 5,744 families in Davao River Basin and there was not any record for the Matina River Basin.

(3) Characteristics of Flood and Flood Damage identified by Resident Information

At the coordination meeting held on January 29, 2019, inviting the barangay captains who were suffering from the flood damage by the riverine flood, characteristics of the flood damage were discussed in each basin. Based on the information from barangay captains, flood characteristics, the characteristics of the flood damage and expected measures of each basin are summarized.

(4) Characteristics of Flood and its Damage by Flood Mark Survey Results

Depth and duration of inundation were confirmed by interviews with residents in the three target rivers. Figure 2.7.4 shows the survey results of maximum inundation depth caused by the past floods. As a result, data along the Davao River shows the situation at the time of the typhoon Vinta in 2017 and data along the Matina River indicates the situation at the time of flood in 2011.

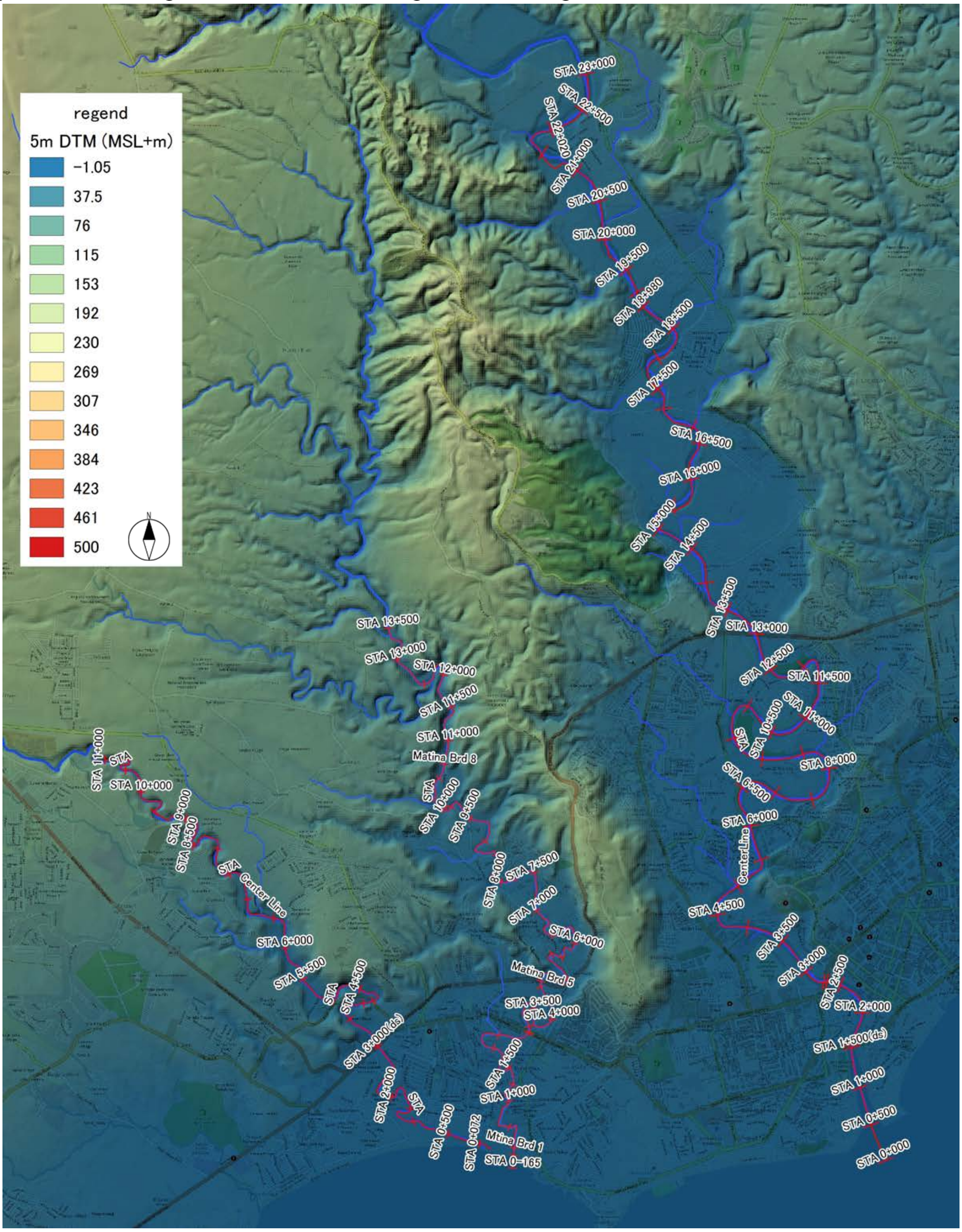


Source: Project Team

Figure 2.7.4 Historical Maximum Inundation Depth by Past Floods as a Result of Flood Mark Survey

2.7.2 Geography of Floodplain

Topographic maps were created based on IFSAR and LiDAR data (hereinafter referred to as the thematic map), and river topographical surveys were conducted. The DEM, which is generated from the thematic map, and the location of the river cross-section survey are shown in Figure 2.7.5. The longitudinal profiles of the target rivers are shown in Figure 2.7.6 to Figure 2.7.8.



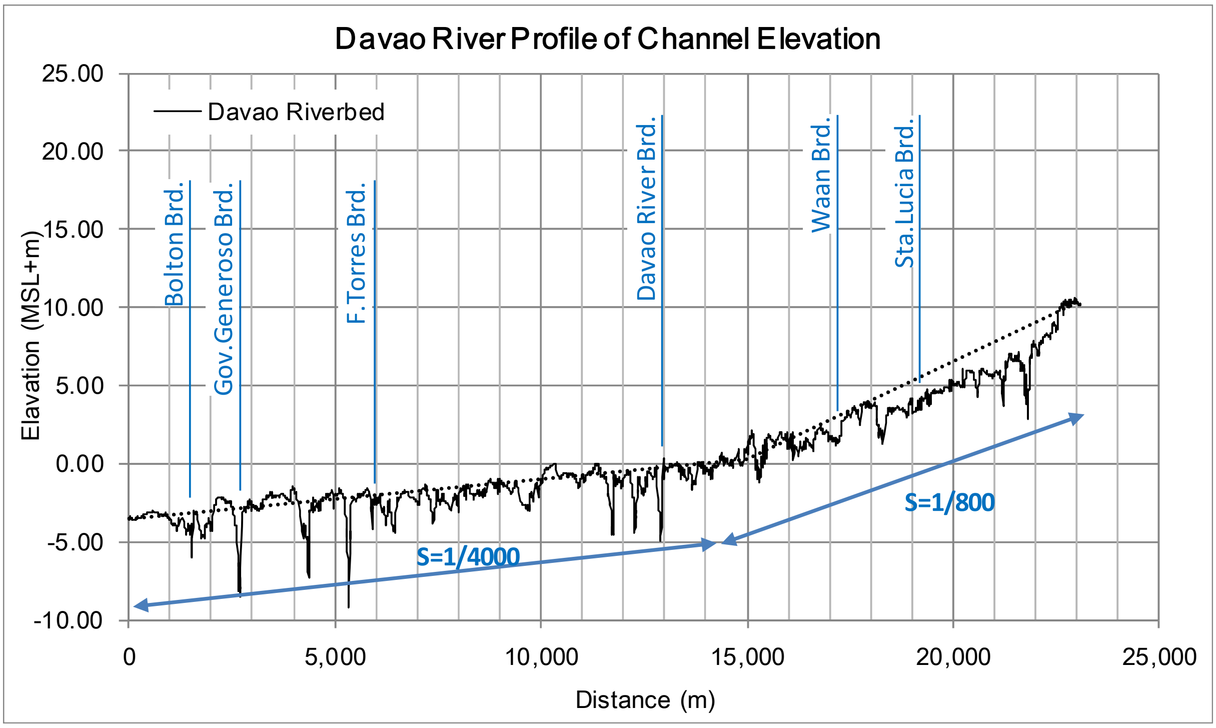
Source: Project Team

Figure 2.7.5 Topographical Map of Flood Plain and Location of River Cross-section Survey

The topographical features from the upstream end of the river cross-section survey to the river mouth in each targeted river for flood analysis are described below.

(1) Davao River

The topography of the upstream end of the river cross-section survey, which is near the exit of the mountainous river, shapes the valley bottom which is considered to be formed by erosion from the river. The riverbed gradient changes around 15 km from the river mouth, and then the river flows down the relatively gentle plain where Davao City is formed and pours into the Davao Gulf. The floodplain upstream of the riverbed gradient transition point forms a valley bottom plain with a width of 1.5 km to 2.0 km along the river, and the flood type is classified as a downflow-type flood. Downstream of the gradient transition point, the flood type should be classified as diffusive-type flood inferred from the topographical gradient. On the other hand, expansion of inundation will be suppressed by hilly land at the left bank side of the section from 3 km to 8 km from the river mouth. In addition, there is a narrow portion of the bottom width of the river valley immediately upstream of the cross point of the Davao City Diversion Road, which is located around 13 km from the river mouth, and it is supposed that flood water would go back to the river here. This return of flooding water to the river could progress the meandering in the section from 6 km to 13 km from the river mouth.

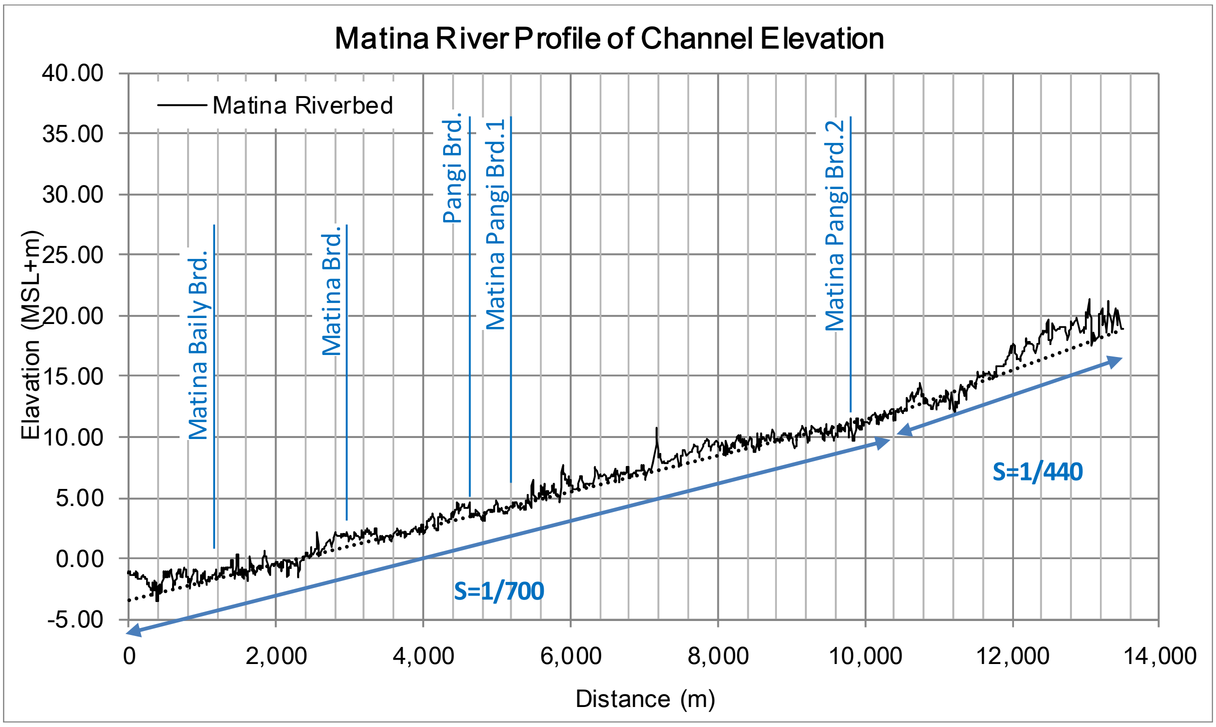


Source: Project Team

Figure 2.7.6 Longitudinal Profile of Davao River

(2) Matina River

The riverbed gradient is relatively steep throughout the study section, and there is a gradient transition around 10 km from the river mouth. The topography upstream from the gradient transition point forms a narrow valley shape, and the downstream is a valley bottom plain with a bottom width of about 500 m to 1 km. An urban area has developed in the depositional plain which is the downstream section of about 4 km from the river mouth. The flood type from the upstream end to the exit to the depositional plain of the river is classified as a downflow-type in which flood water flows along the river. Flooding which occurs near the river mouth should be classified as a diffusive-type flood from the character of the flood plain. Meanwhile, since the riverbed gradient remains steep at around 1/700, the flood water could not expand and will flow down into the river mouth directly although flood water easily spreads in the depositional plain in general.

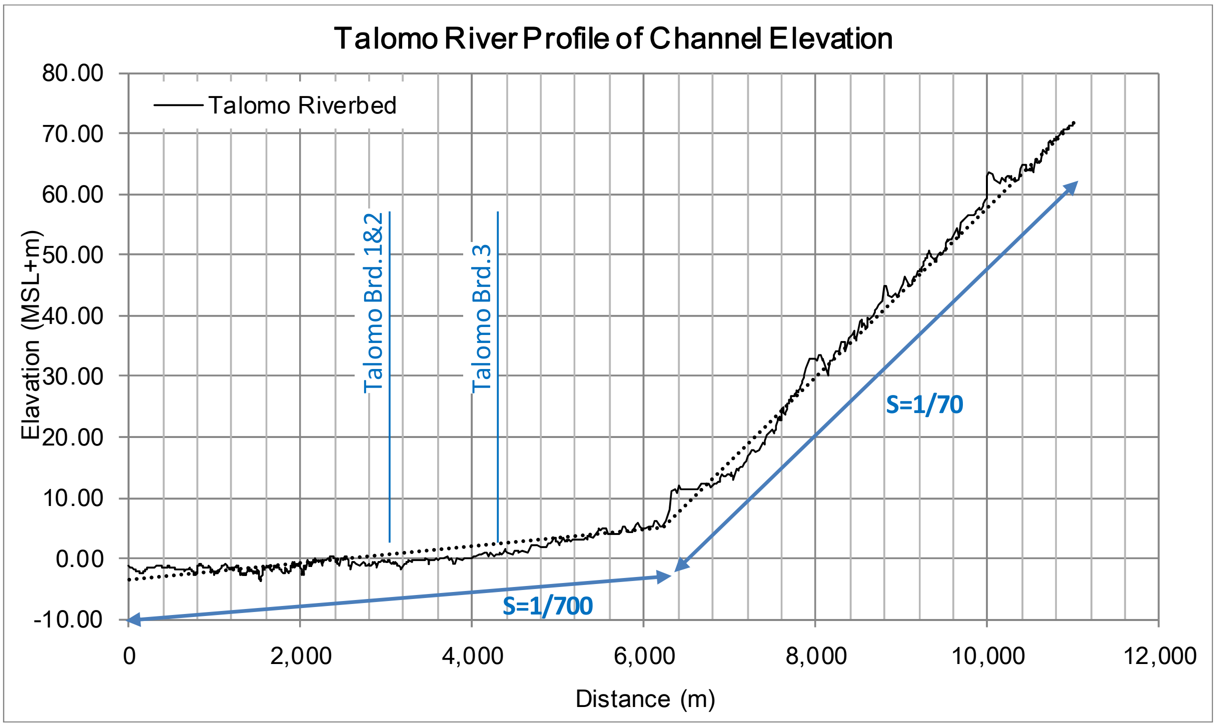


Source: Project Team

Figure 2.7.7 Longitudinal Profile of Matina River

(3) Talomo River

The riverbed gradient suddenly changes about 6.5 km from the river mouth. The topography of the upstream from the gradient transition point forms a narrow valley shape, and the downstream is a valley bottom plain with a bottom width of about 500 m to 1 km. Similar to the Matina River, an urban area has developed in a depositional plain that expands in the downstream section of about 3.5 km from the river mouth. The flood type from the upstream end to about 3.5 km from the river mouth should be classified as a downflow-type flood, and the flood type near the river mouth should be classified as a diffusive-type flood from the character of the flood plain. Meanwhile, since the riverbed gradient still keeps steep of around 1/700, it is likely that the flood water directly flows down into the river mouth.



Source: Project Team

Figure 2.7.8 Longitudinal Profile of Talomo River

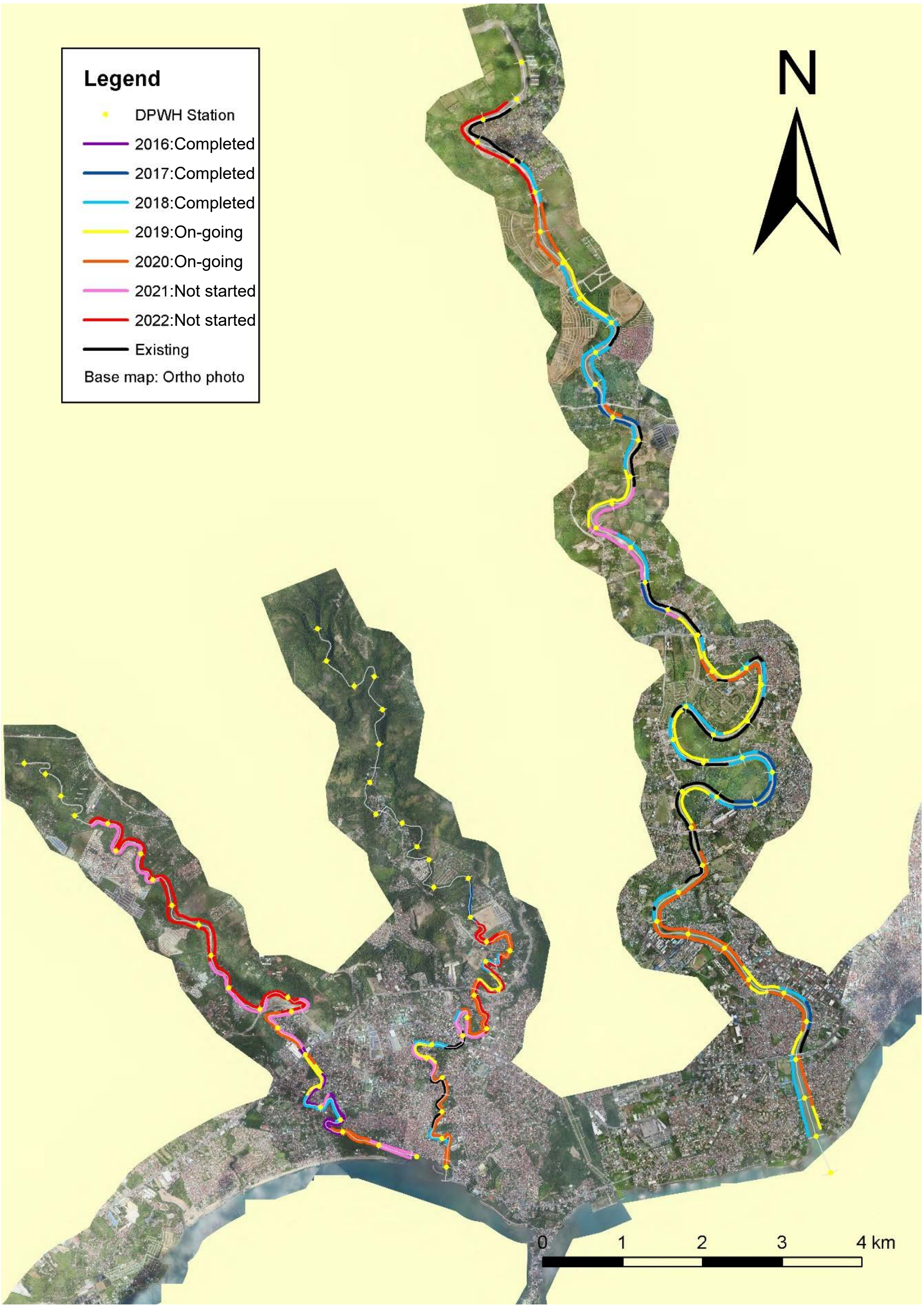
2.7.3 Existing Flood Countermeasures

In the downstream part of the three target rivers, construction of concrete dikes was carried out as a partial flood countermeasure in the past. In addition, from 2017, gabion-made revetments and small dikes are planned to be constructed up until 2022, and DPWH DCDEO I is proceeding with the construction for each section planned for each year as shown in Figure 2.7.9. The section shown as "Existing" in the figure is the section where concrete dikes were constructed in the past.

As for the flood control works for riverine flood by DCDEO I, a total of 10 construction work projects were implemented with a total construction cost of 348 million pesos in 2017. In 2018, a total of 41 construction work projects with a total cost of 1,989 million pesos were implemented. As for the 41 construction work projects, 23 are for Davao River, 4 are for Matina River and 1 is for Talomo River. Most of the construction work projects are the construction of revetments and dikes.

In a plan for 2019, 32 construction work projects are planned in total and the total construction cost is 1,698 million pesos. As for the 32 construction work projects, 17 are for Davao River, 2 are for Matina River and 2 are for Talomo River. Most of the construction work projects are the construction of revetments and dikes.

As a situation of each cross section after the implementation of the flood control measures, the flow capacity of each cross section, which is a result of evaluation at the locations surveyed in this Project, is described in Chapter 2.7.4.



Source: Project Team

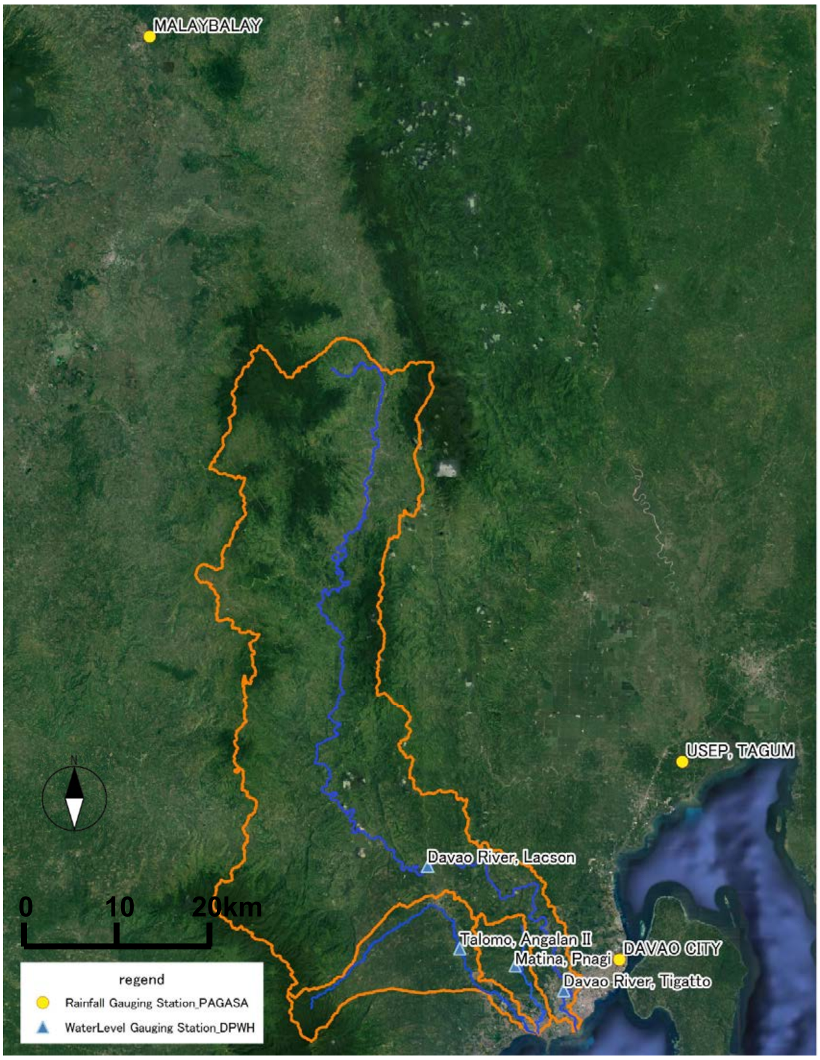
Figure 2.7.9 Existing Flood Countermeasures and Construction Plan of Flood Countermeasures by DPWH DEO I in Target Three Rivers

2.7.4 Basic Analysis

The information and data which is required for conducting the study and analysis regarding riverine flooding have been collected and the hydrological statistical analysis was examined.

(1) Hydro-meteorological Data

The data collection of rainfall data and flow discharge/water level data which shall be the basis of hydrological and hydraulic analysis was conducted. Figure 2.7.10 shows location of hydrological stations. There are three rainfall gauging stations managed by PAGASA into and around the target river basins of this project as shown in Table 2.7.1. Although the published data by PAGASA is daily rainfall data only, hourly data of each gauging station during several past floods and annual maximum rainfall was separately provided by PAGASA.



Source: Project Team

Figure 2.7.10 Location of Rainfall and Water Level Gauging Station

The water level/flow discharge observation situation of the three target rivers is as shown in Table 2.7.2. Although the observation data is a daily average value, the maximum water level/flow discharge data were obtained from DPWH BOD and RO for some of the past floods.

For reference, since Davao City is located in a lower latitude region, flood damages caused by typhoons seldom occur basically, through the city had damaged severely due to the typhoon Vinta. there are only 3 typhoons that passed within 150km from the center of Davao City (see Figure 2.7.11), therefore, it is very difficult to find a relation between typhoon tracks and flood damage. Even so, it can be said that when a typhoon passes on the upper basin of the Davao River, like the Vinta, severe damage will occur by the typhoon.

Table 2.7.1 Rainfall Gauging Station around Target River Basins

STATION	LATITUDE	LONGITUDE	ELEVATION	Period of Observation	collected period	Type of Data
DAVAO CITY	07°07'40.41"N	125°39'17.43"E	17.29m	1961 - 2018	2001 - 2018	Daily Data
TAGUM	07°20'48"N	125°43'30"E	21.70m	2001 - 2017*	2001 - 2017	Daily Data
MALAYBALAY	08°09'04.80"N	125°08'02.04"E	627.00m	1961 - 2018	2001 - 2018	Daily Data

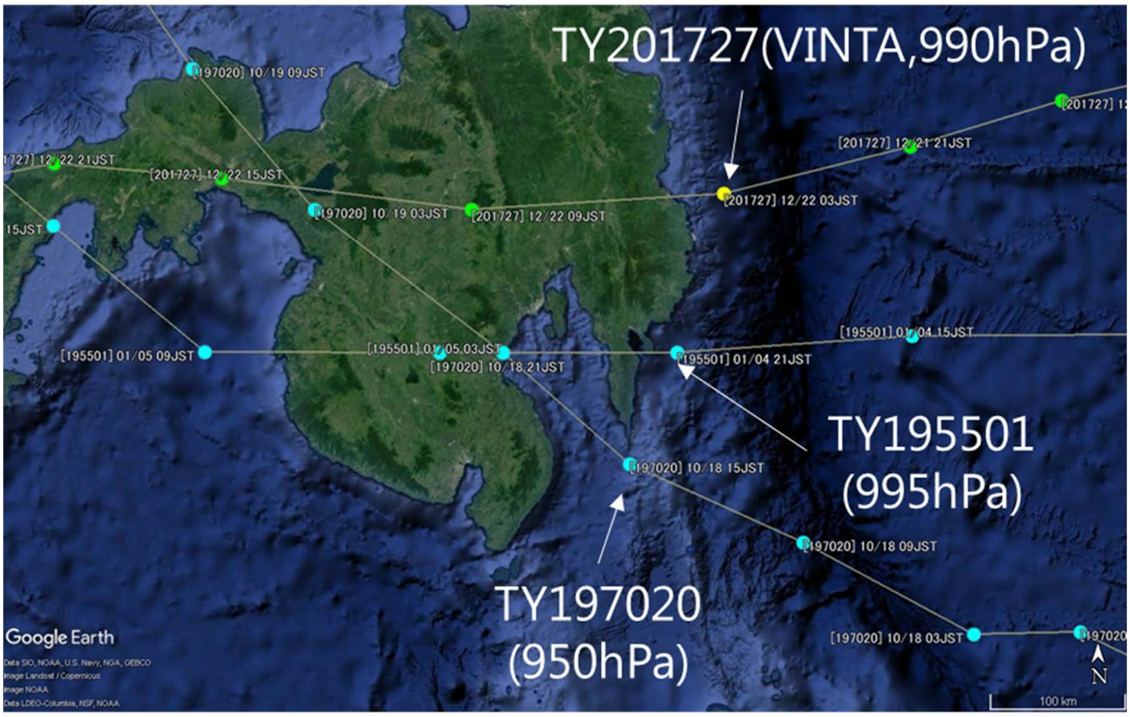
* From 2007 to 2010 of Tagum sta. is missing.

Source: PAGASA

Table 2.7.2 Water Level/Flow Discharge Gauging Station around Target River Basins

River	Gauging Station	Latitude	Longitude	C.A. (km2)	Height (m)	Gauge Type	Period of Observation	Collected period	Observed by	Remarks
Davao	Lacson	07-13'-53"	125-26'-32"	1469	10.502	Staff Gauge	2001 -	2001 - 2017	BRS,DPWH	
	Tigatto	07-05'-38"	125-35'-35"	1683	20.000	Staff Gauge	1984 - 1999	-	BRS,DPWH	old station
Matina	Pangi	07-07'-16"	125-32'-21"	48	5.890	Staff Gauge	1959 - 1970	-	BRS,DPWH	
Talomo	Angalan II (Tugbok)	07-08'-25"	125-28'-40"	165	13.235	Staff Gauge	1986 -	1986 - 2017	BRS,DPWH	

Source: DPWH



Source: Google Earth and Digital Typhoon

Figure 2.7.11 Typhoon Tracks near Davao City

(2) Rainfall Analysis (including Basin Average Rainfall, Statistical Analysis)

1) Daily Rainfall Statistical Analysis (by Thiessen method)

The objects of rainfall analysis are required to have a long term observed record. In terms of this, Davao City, Tagum, and Malaybalay stations are selected as the objects of rainfall analysis in this study. The basin average rainfall is calculated by the Thiessen method using the rainfall data of rainfall gauging stations near the basin, then the annual maximum daily rainfall was picked out. According to the results of a statistical analysis using the annual maximum basin average rainfall from 2001 to 2018 calculated above, the calculated average daily rainfall amount of each return period will be 154 mm/day with 50-year probability and 171 mm/day with 100-year probability.

Upon comparing the Davao River basin average rainfall and damage record caused by flooding, there is an inconsistency in the relation between the magnitude of the flood damage and the basin average rainfall amount. In addition, the basin average rainfall amount of the typhoon Vinta, in which the number of affected families was 21,7768, was only 82.7mm/day and this was evaluated as approximately 3-year probability. (see Table 2.7.3)

Therefore, it can be recognized there is no correlation between the damage situation in past floods and the basin average rainfall calculated by the Thiessen method. As the cause of this, it can be considered that the Thiessen method with applicable gauging stations cannot capture the spatial distribution of basin rainfall in the case of the Davao River basin. Since, all gauging stations which obtain rainfall data in this study are located outside of the basin, and since the Davao River basin which is over 1,700 km2, the basin average rainfall which is calculated by using the rainfall data of these gauging stations, shall be taken the proper complement of spatial distribution.

Table 2.7.3 Basin Average Rainfall and Flooding Damage Record in Past Floods

Date of flood	Average rainfall by PAGASA	Affected population	Affected family	Affected house	Estimated return period
2002/1/4	122.2		18,110		13.1 year
2005/7/25	7.4	140		19	0.1 year
2006/3/5	12.4		1,047		0.1 year
2006/5/5	10.5	5,230			0.1 year
2011/1/17	29.9		1,317		0.3 year
2011/4/5	59.6		889		1.0 year
2011/5/4	51.0		620		0.7 year
2011/7/28	10.7	548		264	0.1 year
2012/12/4	58.5		798		1.0 year
2013/1/20	85.3		7		2.9 year
2013/2/9	27.0		1,075		0.3 year
2013/6/5	16.5		311		0.2 year
2013/7/20	10.0	2,595		10	0.1 year
2014/8/21	12.7	96	146		0.1 year
2016/6/21	47.0	170	20	2	0.6 year
2017/2/23	64.4	1,577		20	1.2 year
2017/12/22	82.7		21,768		2.6 year

Source: CDRMO, OCD/NDRRMC, UN-OCHA

2) Complement of spatial rainfall distribution by GSMaP

In order to capture the spatial rainfall distribution within the basin more accurately, it is thought that using the Global Satellite Mapping of Precipitation (GSMaP) which is developed by synthesizing rainfall data acquired by satellites provided by the Earth Observation Research Center (EORC) of the Japan Aerospace Exploration Agency (JAXA).

As a result of the consideration, the rainfall statistical analysis is executed applying the complemented PAGASA's rainfall since complementing PAGASA's rainfall data by GSMaP indicated certain improvement of inconsistency, especially to the largest scale of floods in the past.

Table 2.7.4 Flooding Damage Situation and Corrected Basin Average Rainfall

Date of flood	Average rainfall by PAGASA	Affected population	Affected family	Affected house	Flooding Date	Corrected Rain data (7day moving ave.)
2002/1/4	122.2	0	18,110	0	2002/1/3	100.1
2005/7/25	7.4	140	0	19	2005/7/23	7.6
2006/3/5	12.4	0	1,047	0	2006/3/8	111.3
2006/5/5	10.5	5,230	0	0	2006/5/2	11.3
2011/1/17	29.9	0	1,317	0	2011/1/16	23.7
2011/4/5	59.6	0	889	0	2011/4/5	60.2
2011/5/4	51.0	0	620	0	2011/5/3	48.7
2011/7/28	10.7	548	0	264	2011/7/25	5.2
2012/12/4	58.5	0	798	0	2012/12/3	35.2
2013/1/20	85.3	0	7	0	2013/1/19	105.7
2013/2/9	27.0	0	1,075	0	2013/2/9	28.5
2013/6/5	16.5	0	311	0	2013/6/5	17.7
2013/7/20	10.0	2,595	0	10	2013/7/22	26.6
2014/8/21	12.7	96	146	0	2014/8/20	22.7
2016/6/21	47.0	170	20	2	2016/6/21	50.7
2017/2/23	64.4	1,577	0	20	2017/2/23	38.2
2017/12/22	82.7	21,767	0	0	2017/12/21	81.9

Source: Project Team

The probable basin average rainfall is calculated through the statistical analysis using the annual maximum rainfall which is calculated utilizing the corrected PAGAS rainfall data.

Even though statistical analysis is performed with various plotting methods, since the sample data is the annual maximum data, the most compatible plotting method which is formulated based on the extreme value theory like Gumbel distribution, Generalized extreme value distribution (GEV), and sqrt-exponential type distribution of maximum shall be applied. As a result of the analysis, regarding the Davao River basin, since there is no probability distribution based on the extreme value theory which has sufficient compatibility and the Standard Least Squares Criterion (SLSC) value is less than 0.04, the probability distribution which has the least SLSC value, that is GEV, is applied. In the Matina River basin, GEV satisfies what SLSC value is less than 004. And, in the Talomo River basin, since Gumbel method and GEV meet the condition, the method which has less SCSL value, that is the Gumbel method, is applied. The SLSC value, correlation coefficient, Jack-knife estimation value, and estimation error of statistical analysis results of each river are shown in Table 2.7.5 to Table 2.7.7.

Table 2.7.5 Result of Basin Average Rainfall Statistical Analysis (Davao River)

Davao River	1-day Basin Mean Rainfall			
	Exp	Gumbel	SqrtEt	Gev
X-COR(99%)	0.973	0.967	0.976	0.979
P-COR(99%)	0.902	0.97	0.964	0.973
SLSC(99%)	0.047	0.056	0.051	0.046
Log Likelyhood	-74.2	-78	-78.5	-78.2
pAIC	152.4	159.9	161	162.4
X-COR(50%)	0.983	0.978	0.982	0.983
P-COR(50%)	0.959	0.957	0.951	0.963
SLSC(50%)	0.051	0.108	0.097	0.068

Davao River	Probability (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	72.5	76.0	77.0	74.2
5-yr	93.3	94.5	100.5	92.4
10-yr	109.0	106.8	117.7	106.3
15-yr	118.2	113.8	127.9	114.9
25-yr	129.8	122.3	141.2	126.4
50-yr	145.5	133.8	159.8	143.3
80-yr	156.2	141.6	173.0	155.7
100-yr	161.2	145.3	179.4	161.9

Davao River	Jackknife Estimate (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	72.5	76.0	76.6	74.0
5-yr	93.3	94.5	100.2	92.9
10-yr	109.0	106.8	117.3	107.3
15-yr	118.2	113.8	127.5	116.1
25-yr	129.8	122.3	140.7	127.5
50-yr	145.5	133.8	159.4	143.6
80-yr	156.2	141.6	172.5	154.8
100-yr	161.2	145.3	178.9	160.2

Davao River	Jackknife Erorr (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	4.0	4.5	4.2	3.0
5-yr	8.4	8.7	4.7	6.6
10-yr	12.5	11.9	5.1	11.5
15-yr	15.1	13.8	5.3	15.1
25-yr	18.3	16.2	5.5	20.7
50-yr	22.7	19.4	5.8	30.4
80-yr	25.7	21.6	6.0	38.5
100-yr	27.1	22.6	6.1	42.9

Source: Project Team

Table 2.7.6 Result of Basin Average Rainfall Statistical Analysis (Matina River)

Matina River	1-day Basin Mean Rainfall			
	Exp	Gumbel	SqrtEt	Gev
X-COR(99%)	0.988	0.969	0.983	0.992
P-COR(99%)	0.988	0.985	0.991	0.994
SLSC(99%)	0.032	0.053	0.053	0.028
Log Likelyhood	-85.2	-88.1	-86.9	-86.8
pAIC	174.3	180.2	177.9	179.5
X-COR(50%)	0.98	0.976	0.981	0.986
P-COR(50%)	0.979	0.978	0.972	0.974
SLSC(50%)	0.05	0.1	0.105	0.05

Matina River	Probability (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	90.5	97.0	94.4	91.9
5-yr	128.7	131.1	124.0	124.4
10-yr	157.7	153.7	145.6	151.3
15-yr	174.6	166.4	158.5	168.7
25-yr	195.9	182.2	175.2	192.8
50-yr	224.8	203.4	198.7	230.3
80-yr	244.4	217.6	215.3	259.3
100-yr	253.7	224.4	223.4	274.2

Matina River	Jackknife Estimate (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	90.5	97.0	93.7	91.5
5-yr	128.7	131.1	123.4	125.3
10-yr	157.7	153.7	145.0	153.5
15-yr	174.6	166.4	157.9	171.5
25-yr	195.9	182.2	174.5	195.9
50-yr	224.8	203.4	198.0	232.3
80-yr	244.4	217.6	214.6	259.1
100-yr	253.7	224.4	222.7	272.4

Matina River	Jackknife Erorr (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	6.8	8.0	7.2	7.7
5-yr	15.6	16.2	12.8	14.0
10-yr	23.1	22.1	17.5	21.2
15-yr	27.6	25.4	20.5	27.2
25-yr	33.3	29.6	24.3	37.3
50-yr	41.1	35.3	30.0	56.6
80-yr	46.4	39.1	34.1	74.1
100-yr	48.9	41.0	36.1	83.9

Source: Project Team

Table 2.7.7 Result of Basin Average Rainfall Statistical Analysis (Talomo River)

Talomo River	1-day Basin Mean Rainfall			
	Exp	Gumbel	SqrtEt	Gev
X-COR(99%)	0.976	0.989	0.986	0.989
P-COR(99%)	0.976	0.991	0.992	0.992
SLSC(99%)	0.043	0.028	0.043	0.029
Log Likelyhood	-75.1	-78.5	-78.9	-78.5
pAIC	154.2	161.1	161.8	163
X-COR(50%)	0.969	0.974	0.969	0.973
P-COR(50%)	0.969	0.967	0.97	0.966
SLSC(50%)	0.062	0.05	0.083	0.051

Talomo River	Probability (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	73.7	77.4	78.3	77.1
5-yr	95.5	96.9	102.1	96.6
10-yr	112.1	109.8	119.4	109.8
15-yr	121.8	117.1	129.7	117.3
25-yr	134.0	126.1	143.0	126.8
50-yr	150.5	138.2	161.7	139.6
80-yr	161.7	146.4	175.0	148.3
100-yr	167.1	150.3	181.4	152.5

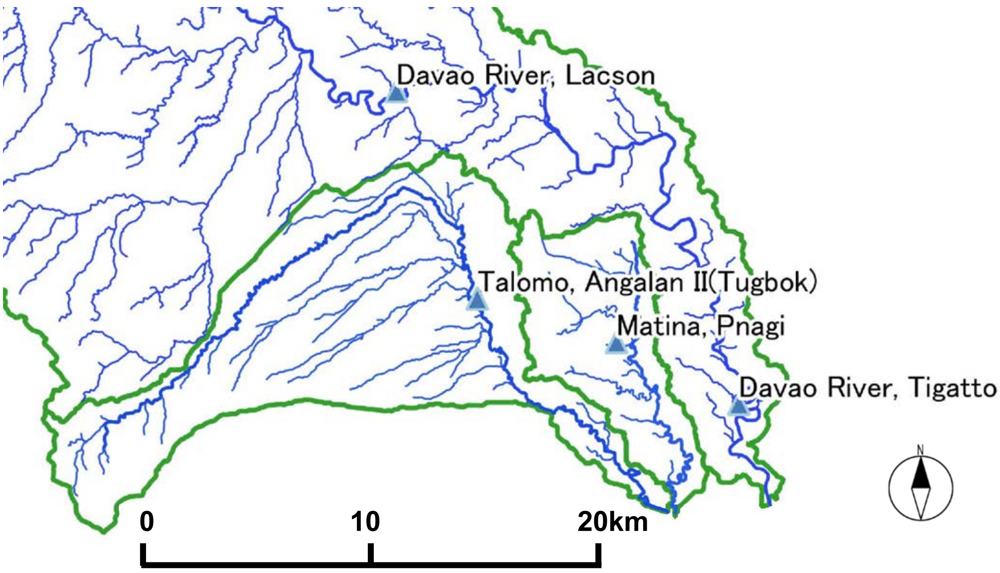
Talomo River	Jackknife Estimate (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	73.7	77.4	78.0	77.0
5-yr	95.5	96.9	101.7	96.9
10-yr	112.1	109.8	119.0	110.3
15-yr	121.8	117.1	129.3	117.8
25-yr	134.0	126.1	142.6	127.1
50-yr	150.5	138.2	161.3	139.4
80-yr	161.7	146.4	174.5	147.4
100-yr	167.1	150.3	181.0	151.1

Talomo River	Jackknife Erorr (mm)			
	Exp	Gumbel	SqrtEt	Gev
2-yr	4.2	4.6	4.1	5.6
5-yr	6.8	7.0	4.6	7.7
10-yr	9.3	9.0	5.0	9.1
15-yr	10.9	10.1	5.1	10.2
25-yr	12.9	11.6	5.4	12.2
50-yr	15.7	13.6	5.7	16.2
80-yr	17.6	15.0	5.9	19.9
100-yr	18.5	15.7	6.0	21.9

Source: Project Team

(3) Water Level, Runoff Analysis (including Statistical Analysis)

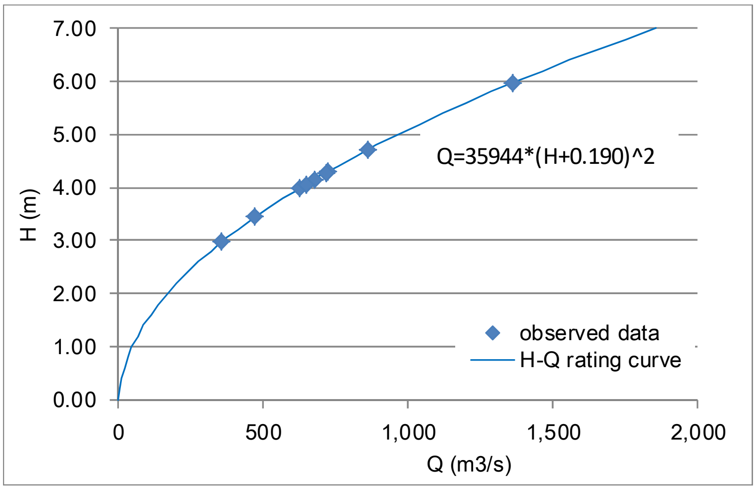
Figure 2.7.12 shows the locations of the water level/flow discharge stations in the target river basins. As shown in Table 2.7.2, the data observed at Lacson station, which has been on the Davao River for 17 years, and the data at Angaran II station, which has been on the Talomo River for 32 years is provided by DPWH.



Source: Project Team

Figure 2.7.12 Location of Water Level / Flow Discharge Gauging Stations in Target River Basins

The annual maximum flow discharge from 2001 to 2017 observed at Lacson gauging station is shown in Figure 2.7.13. Here, though both water level data and flow discharge data are available from 2001 to 2009, only water level data is available after 2010. Therefore, the flow discharge data after 2010 is calculated data using the HQ relation by observed data until 2009. By the way, the highest water level during typhoon Vinta was 5.0 m in the DPWH record, however, this value is the upper limit of water gauge at Lacson gauging station and the actual highest water level exceeded this upper limit. Therefore, the gauge keeper was interviewed, and the result was that the actual highest water level was 6.4 m.



year	Discharge (liters/sec)	Gage height (EL+m)	(Q)^0.5	calc.Q (liters/sec)
2001/3/28	726,000	4.30	852.056	724,579
2002/1/4	1,360,200	5.98	1166.276	1,368,276
2003/12/22	627,100	3.98	791.896	624,974
2004/9/26	864,000	4.70	929.516	859,437
2005/6/18	355,600	2.98	596.322	361,157
2006/3/9	678,500	4.15	823.711	676,973
2007/1/9	719,600	4.28	848.292	718,138
2008/7/4	651,000	4.06	806.846	649,185
2009/1/15	474,300	3.44	688.694	473,584
2010/9/13		4.22		698,988
2011/6/15		3.76		560,766
2012/12/16		4.20		692,662
2013/2/19		4.50		790,570
2014/12/29		3.10		389,019
2015/8/1		3.60		516,255
2016/6/25		3.50		489,370
2017/12/22		6.40		1,560,903

Source: Project Team

Figure 2.7.13 H-Q Relation at Lacson Gauging Station

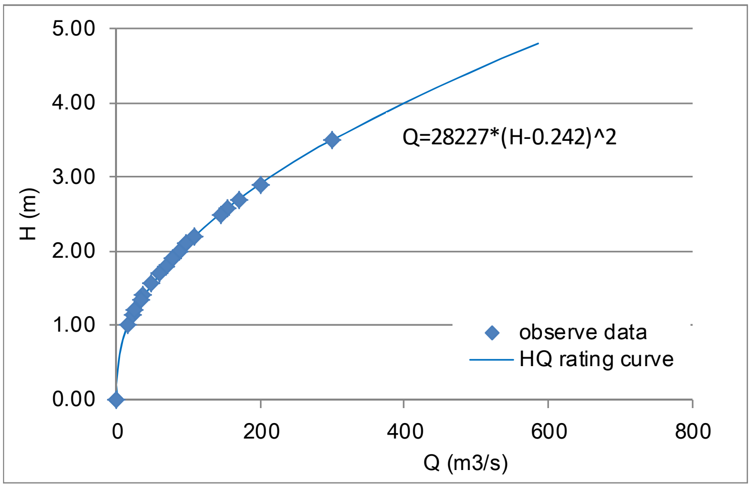
Table 2.7.8 Probable Water level/Flow Discharge at Lacson Gauging Station on Davao River

return period	gauge height (m)	flow discharge (m3/s)
2	4.00	627
5	4.80	887
10	5.37	1,099
25	6.11	1,415
30	6.25	1,484
Vinta	**6.40**	**1,561**
50	6.65	1,686
80	7.01	1,886
100	7.18	1,985
200	7.69	2,310

Source: Project Team

Similar to the Davao River, the statistical analysis was performed on the Talomo River (Angalan II (Tugbok) Gauging station) using the annual water level/flow discharge. The result is shown in Table 2.7.9.

According to the analysis result, the flood scale of typhoon Vinta at Angalan II (Tugbok) Gauging station was evaluated at less than a 2-year flood. This means that the rainfall amount in the Talomo River basin during the time of typhoon Vinta was relatively less. On the other hand, the past highest water level during the data collection period (1986-2017) was recorded at the flood at the end of June 2009. This flood scale is evaluated as an approximately 80-year probability.



year	Discharge (liters/sec)	Gage height (EL+m)	(Q)^0.5	calc.Q (liters/sec)
1986/3/10	78,000	1.90	279.28	77,579
1987/2/5	69,000	1.80	262.68	68,502
1988/8/17	37,000	1.40	192.35	37,840
1989/2/27	78,000	1.90	279.28	77,579
1990/11/9	16,400	1.00	128.06	16,211
1991/6/29	87,000	2.00	294.96	87,220
1992/1/1	-	-	-	-
1993/3/1	48,200	1.56	219.54	49,021
1994/9/16	23,120	1.14	152.05	22,753
1995/8/15	78,000	1.9	279.28	77,579
1996/1/1	-	-	-	-
1997/12/18	26,000	1.20	161.25	25,896
1998/1/6	33,700	1.34	183.58	34,020
1999/12/12	157,000	2.58	396.23	154,274
2000/2/16	205,000	2.90	452.77	199,398
2001/1/1	87,000	2.00	294.96	87,220
2002/1/4	175,000	2.70	418.33	170,518
2003/12/22	97,000	2.10	311.45	97,426
2004/5/9	108,000	2.20	328.63	108,197
2005/1/24	60,000	1.70	244.95	59,990
2006/3/5	108,000	2.20	328.63	108,197
2007/12/11	97,000	2.10	311.45	97,426
2008/3/10	145,000	2.50	380.79	143,896
2009/6/29	285,500	3.50	534.32	299,588
2010/12/6	78,000	1.90	279.28	77,579
2011/4/21		2.10		97,426
2012/2/12		2.80		184,676
2013/6/5		3.00		214,685
2014/1/11		2.51		145,173
2015/6/25		1.36		35,271
2016/5/23		1.28		30,403
2017/2/16		2.26		114,930

Source: Project Team

Figure 2.7.14 H-Q Relation at Angalan II (Tugbok) Gauging Station

Table 2.7.9 Statistical Analysis of Water level/Flow discharge at Tugbok Gauging Station

return period	gauge height (m)	flow discharge (m3/s)
Vinta	1.26	29
2	1.98	89
5	2.54	148
10	2.86	187
15	3.02	209
20	3.12	225
25	3.19	236
30	3.25	246
50	3.40	273
Historical MAX	3.50	300
80	3.53	298
100	3.58	309
200	3.73	346

Source: Project Team

Regarding the Matina River, there is no available water level/flow discharge data for statistical analysis. Even so, DEO has reviewed "the Davao City Urban Drainage and Flood Control Project (1998)" cooperating with DPWH in response to the June 2011 flood. In this study, the probable flow discharges have been calculated by the runoff analysis using probable rainfall (See Table 2.7.10). In this study, the probable flow discharge was considered by three methods (Specific Discharge for regions in the Philippines (Creager's Formula), Rational Formula, and the Unit Hydrograph method with the HEC-

HMS), then the probable flow discharge which was calculated by the Unit Hydrograph method was applied. Also, this report shows that a comprehensive assessment could not be carried out on the entire river basin, including the 29 June 2011 flood because of the limitation of available data/information, therefore, in order to consider flood control countermeasures, that flood was assumed a 50-year flood.

Table 2.7.10 Probable Flow Discharge of Matina River

return period	gauge height (m)	flow discharge (m3/s)
2	-	325.8
5	-	446.0
10	-	504.5
25	-	586.1
30	-	-
50(Historical MAX?)	-	623.5
80	-	-
100	-	658.5
200	-	-

Source: Review and Assessment of Flood Control Master Plan for Davao City

2.7.5 River Flow Capacity Evaluation

The current river flow capacity is evaluated to obtain basic data for master plan formulation.

River flow capacity evaluation shall calculate the flow discharge equivalent to the evaluation height in each cross-section after figuring out the relationship between flow discharge and water level (H-Q relationship) by one-dimensional non-uniform flow calculation. The considering conditions are shown below.

(1) Cross-section data

The river cross-section data used for calculation applies the river topographic survey results obtained are shown in Table 2.7.11.

Table 2.7.11 River Survey Output for Flow Capacity Evaluation

River	River Station of calculate reach	Reach length (km)	Number of Cross-section	Survey date
Davao	sta.0+000 ~ sta.23+000	23.09	52	Apr.2019
Matina	sta.0-165 ~ sta.13+500	13.68	37	Mar.2019
Talomo	sta.0+072 ~ sta.11+000	10.84	25	Feb.2019

Source: Project Team

(2) Manning's n value

The roughness coefficient sets Manning's n value according to the characteristics of the river channel, such as a natural river, remodeled river, floodplain, etc. Manning's n value is determined so that the hydraulic simulation model can reappear flooding conditions of typhoon Vinta. The hydraulic simulation model is described in section 2.7.6 Hydrological and Hydraulic Model.

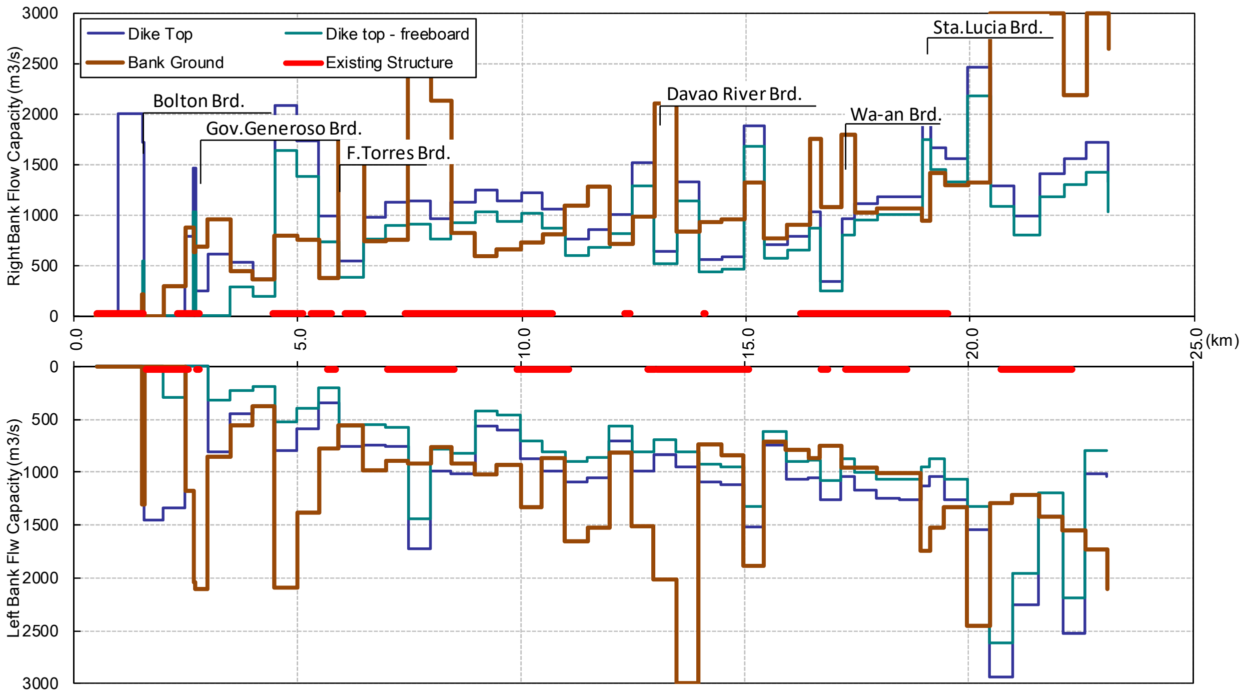
(3) Boundary condition of downstream end

The boundary condition of the downstream end is the water level given as the initial condition at the downstream end of the calculation section, in the case of a river which has a gently sloping riverbed it greatly affects the flow capacity calculation. Since the downstream end of the calculation section of the target rivers in this study is the river mouth, the tide level of the river mouth will be given as the boundary condition of the downstream end. Here, since generally storm surges and floods are handled as independent events, the tide level applied for flow capacity calculation is to be the average high tide level (MHHW). At the stage of the Progress Report, with considering section 2.10 Coastal Disaster Analysis the downstream end is set as MSL+0.981m.

(4) Influence of bridges

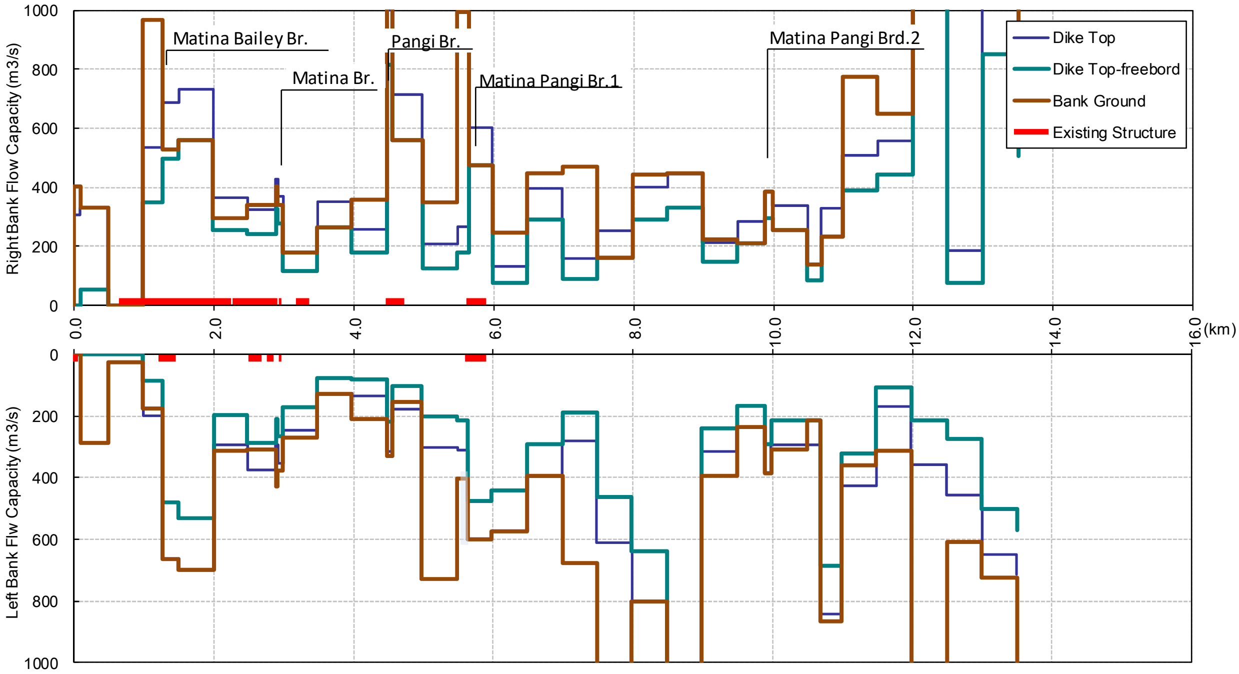
In order to properly consider the rise in water level caused by bridges, surveying of the bridge cross-sections is carried out in the river topographic survey. In this study, the energy loss due to the contraction/expansion at points immediately upstream and downstream of the bridge and the loss due to obstacles such as bridge piers are considered.

The result of the flow capacity calculation which was conducted based on the condition described above is shown in Figure 2.7.15 to Figure 2.7.17.



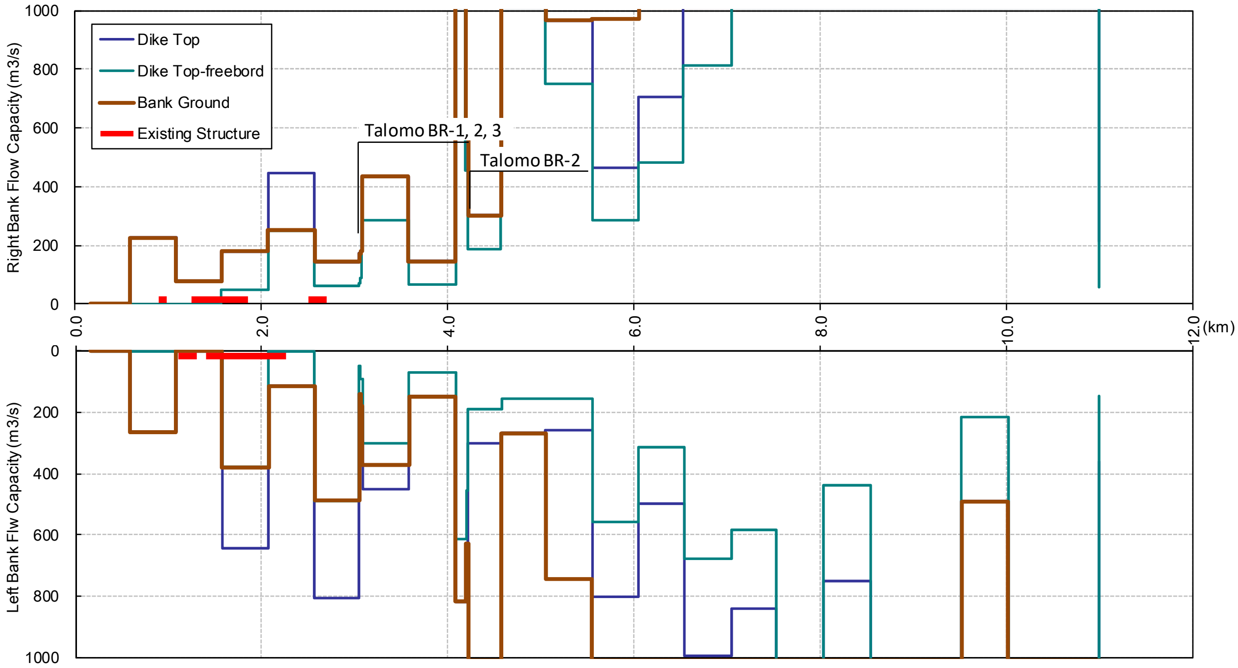
Source: Project Team

Figure 2.7.15 Flow Capacity of the Davao River



Source: Project Team

Figure 2.7.16 Flow Capacity of the Matina River



Source: Project Team

Figure 2.7.17 Flow Capacity of the Talomo River

2.7.6 Hydrological and Hydraulic Model

Since the strengthening DPWH official's capacity to formulate a flood control master plan is listed as one of the outputs of this project, DPWH officials will examine runoff analysis by themselves in OJT. Therefore, the Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) shall be applied for the runoff analysis of this project from the viewpoint of the software which has achievement in the Philippines, and is being provided free of charge, and naturally also has the proper function for runoff analysis.

(1) Rainfall and Runoff Model

The runoff analysis model of HEC-HMS has incorporated a basin model and a river model. The basin model consists of: runoff-volume models, which are to calculate the amount of loss due to infiltration and evapotranspiration; the direct-runoff models, which are to calculate the runoff directly from the effective rainfall; and the base-flow models, which are corresponding to the groundwater runoff. In this project, considering the available hydrologic data of the selected rivers, specific events of runoff analysis, and the applicable status in the Philippines so far, these models, which are indicated in the table below, are applied for each phenomenon.

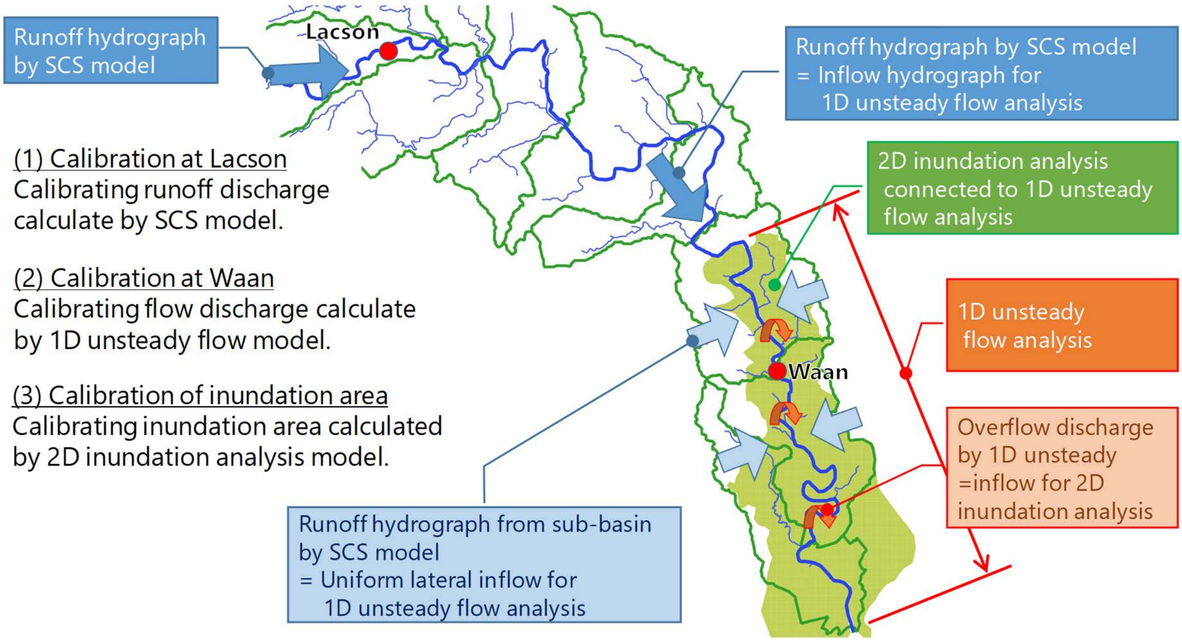
Table 2.7.12 Applied Models of HEC-HMS

Basin model	Loss model	SCS Curve Number model
	Direct runoff model	SCS unit hydrograph model
	Base-flow model	Exponential recession model
River model		Lag-time model

Source: Project Team

(2) Hydraulic Model (Flood model)

The hydraulic analysis model for the Davao River is as shown in Figure 2.7.18, the target section of river improvement, for which the river topographic survey was carried out in this project, is modeled as an unsteady flow model for considering the storage function of the channel itself. This section is also connected to the 2D flood plain model for flood analysis.



Source: JICA Project Team

Figure 2.7.18 Summary of Hydraulic Analysis Model for Davao River

(3) Verification of the Hydraulic Model

It is desirable that the coefficients of the runoff analysis model are verified by hourly rainfall-discharge datasets. For the Davao River, the selected flood is the flood of Dec.22 2017 (Typhoon Vinta) and verification points are set as Wa-an Bridge gauging station and Lacson gauging station.

Lacson gauging station has daily data only but the data before and after the peak of object flood can be obtained separately. This makes it be possible to verify the coefficients of the runoff model. The arrangements result of SCS CN and lag-time by the typhoon Vinta is shown in Table 2.7.13 and Table 2.7.14.

Table 2.7.13 Applied SCS CN

Landcover	Hydrologic Soil Group				referring CN category *
	A	B	C	D	
Annual Crop	70	79	84	88	Row Crops, contured, Poor
Brush/Shrubs	57	73	82	86	Woods-grass combination, Poor
Built-up	61	75	83	87	Residential districts by average lotsize 1/4 acre
Closed Forest	36	60	73	79	Woods, Fair
Grassland	76	85	90	93	Fallow, Crop residue cover
Inland Water	100	100	100	100	
Open Forest	45	66	77	83	Woods, Poor
Open/Barren	77	86	91	94	Fallow, Bare soil
Perennial Crop	39	61	74	80	Pasture, grassland, or range, Good

* "National Engineering Hnadbook by Natural Resources Conservation Service", USDA

Source: JICA Project Team

Table 2.7.14 Applied Runoff Model Coefficients on Davao River Basin

No.	Name	Area (km2)	Initial Ab-straction (mm)	potential maxmum retention (S)	Curve Number	Imper-vious (%)	No.	Name	Area (km2)	Initial Ab-straction (mm)	potential maxmum retention (S)	Curve Number	Imper-vious (%)
1	D-B1	28.47	47.19	235.97	51.8	0.0	28	D-B21	19.33	14.89	74.44	77.3	0.0
2	D-B2	8.88	25.14	125.70	66.9	0.0	29	D-B22-1	35.50	38.59	192.93	56.8	0.0
3	D-B3	16.89	25.25	126.23	66.8	0.0	30	D-B22-2	27.05	33.48	167.41	60.3	0.0
4	D-B4	29.98	48.08	240.42	51.4	0.0	31	D-B22-3	17.77	25.24	126.19	66.8	0.0
5	D-B5	18.55	25.50	127.52	66.6	0.0	32	D-B23	28.79	25.60	127.99	66.5	0.0
6	D-B6	34.87	23.97	119.86	67.9	0.0	33	D-B24	50.67	26.65	133.23	65.6	0.0
7	D-B7	7.83	22.39	111.94	69.4	0.0	34	D-B25-1	71.03	18.20	91.01	73.6	0.0
8	D-B8-1	36.44	85.15	425.77	37.4	0.0	35	D-B25-2	12.45	16.92	84.59	75.0	0.0
9	D-B8-2	43.68	35.70	178.49	58.7	0.0	36	D-B26-1	36.51	29.00	145.00	63.7	0.0
10	D-B9	20.04	38.28	191.38	57.0	0.0	37	D-B26-2	42.58	50.25	251.25	50.3	0.0
11	D-B10	27.17	22.66	113.31	69.2	0.0	38	D-B26-3	54.61	34.74	173.71	59.4	0.0
12	D-B11	30.46	20.17	100.84	71.6	0.0	39	D-B26-4	29.70	56.75	283.77	47.2	0.0
13	D-B12	75.29	34.06	170.29	59.9	0.0	40	D-B26-5	21.52	39.40	196.99	56.3	0.0
14	D-B13	18.63	42.91	214.56	54.2	0.0	41	D-B26-6	31.82	42.03	210.14	54.7	0.0
15	D-B14	38.93	29.39	146.95	63.4	0.0	42	D-B26-7	20.78	27.82	139.08	64.6	0.0
16	D-B15-1	59.97	38.10	190.52	57.1	0.0	43	D-B27-1	101.95	47.99	239.96	51.4	0.0
17	D-B15-2	34.77	39.60	198.01	56.2	0.0	44	D-B27-2	46.69	24.45	122.25	67.5	0.0
18	D-B15-3	47.49	29.04	145.21	63.6	0.0	45	D-B28	21.91	27.54	137.72	64.8	0.0
19	D-B15-4	46.56	31.70	158.52	61.6	0.0	46	D-B29	50.71	23.92	119.58	68.0	0.0
20	D-B16	15.92	31.49	157.46	61.7	0.0	47	D-B30	26.83	27.01	135.06	65.3	0.0
21	D-B17	13.32	35.10	175.52	59.1	0.0	48	D-B31	33.46	25.24	126.21	66.8	0.0
22	D-B18	5.90	34.87	174.37	59.3	0.0	49	D-B32	23.86	22.77	113.84	69.1	0.0
23	D-B19-1	28.47	16.99	84.96	74.9	0.0	50	D-B33	28.25	21.50	107.50	70.3	0.0
24	D-B19-2	16.11	24.36	121.80	67.6	0.0	51	D-B34	30.87	18.44	92.19	73.4	0.0
25	D-B19-3	36.52	29.62	148.12	63.2	0.0	52	D-B35	24.94	11.91	59.56	81.0	0.0
26	D-B19-4	25.74	31.40	157.01	61.8	0.0	53	D-B36	21.98	9.94	49.70	83.6	0.0
27	D-B20	74.99	27.70	138.49	64.7	0.0	54	D-B37	12.14	10.75	53.73	82.5	0.0

Source: JICA Project Team

Based on the result of the verification at Lacson gauging station, it is examined that verification of coefficients of the runoff model and Manning's n value of the river channel. Here, the arrangement of coefficients is carried out with making sure the flood simulation result and the actual flooding condition, which is based on the interview and flood mark survey examined in this project, are the same.

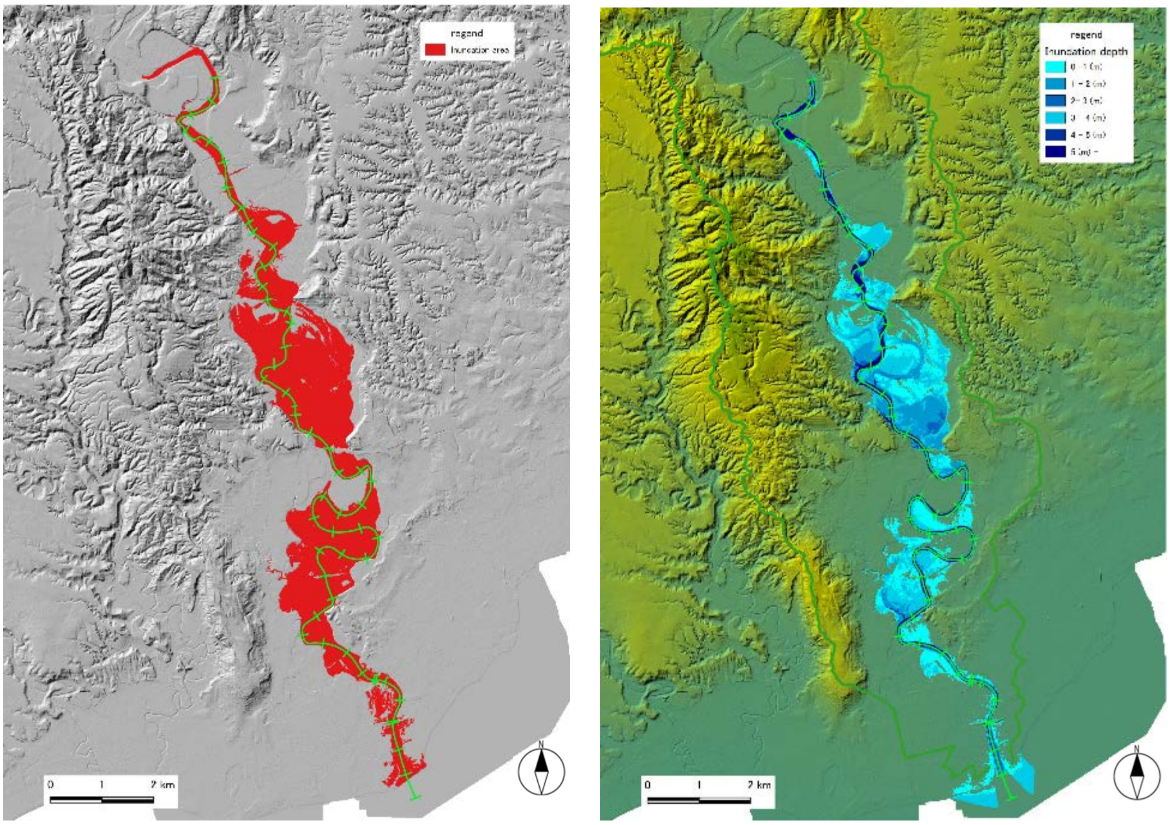
In order to estimate the flooding area, the longitudinal profile of the flooding level was made utilizing the interview and flood mark survey results at bridge points where more accurate results could be obtained. Then, utilizing the longitudinal profile and DTM, generating diffusion of floodwater (see Figure 2.7.19).

The simulation condition of typhoon Vinta by the hydraulic model is indicated in the table below. As a result of the flooding simulation with the conditions indicated in the table, it can reproduce the flood area which is almost the same as it was created by typhoon Vinta.

Table 2.7.15 Condition of Flood Analysis

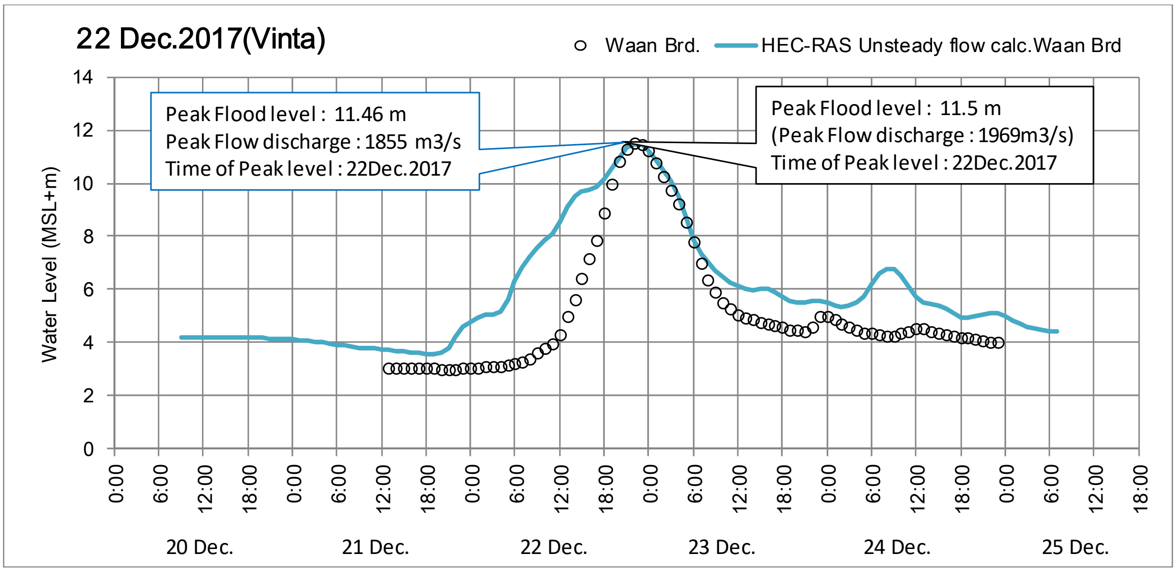
Item	Applied calculation method / value	Note
River water level calculation	1D unsteady	Actual data is applied for boundary condition
Floodwater calculation	2D unsteady	
Calculation mesh size	50m	Generated by 5m size of DTM
Roughness coefficient of flood plan	0.06	

Source: JICA Project Team



Source: JICA Project Team

Figure 2.7.19 Estimated Flood Area by Typhoon Vinta based on Interview and Flood-mark Survey (Left) and Hydraulic Simulation (Right)



Source: JICA Project Team

Figure 2.7.20 Simulation Result of 1D unsteady model (Wa-an Bridge)

Regarding the Matina River and the Talomo River, since there is no available hydrological data for hydraulic model verification, the coefficients on the model for the Davao River basin are applied mutatis mutandis. Here, the storage function of the river channel is not considered in the runoff model because of the size and shape of its basin.

2.7.7 Probable Flood Hydrograph (Riverine flood)

(1) Summary of Probable Rainfall and Discharge

Table 2.7.16 shows the summary of probable rainfall and peak discharge of each target river. Probable flood hydrograph and probable peak discharge were calculated with the verified runoff model, which was described in section 2.7.6. The model hyetographs for each probability, which will be described later, were created with each probable rainfall amount.

Table 2.7.16 Summary of Probable Rainfall and Discharge

T (yrs)	Davao			Matina			Talomo		
	Probable Rainfall (mm/24hr)	+ Climate Change (mm/24hr)	Probable Discharge (m3/s)	Probable Rainfall (mm/24hr)	+ Climate Change (mm/24hr)	Probable Discharge (m3/s)	Probable Rainfall (mm/24hr)	+ Climate Change (mm/24hr)	Probable Discharge (m3/s)
	GEV	110%	Wa-an Br.	RIDF	110%	MatinaPangi Br.	RIDF	110%	Mintal
2	84.50	92.95	821	77.18	84.90	113	69.06	75.96	82
5	105.50	116.05	1387	100.65	110.72	190	90.06	99.07	178
10	119.80	131.78	1831	115.66	127.23	246	103.49	113.84	259
25	138.00	151.80	2439	134.61	148.07	320	120.45	132.49	376
50	151.10	166.21	2904	148.26	163.09	377	132.66	145.93	474
100	163.60	179.96	3367	162.31	178.54	435	145.23	159.75	577

Source: JICA Project Team

(2) Model Hyetograph

Model hyetographs are made by expanding several actual flood patterns up to its amount which would be the same as the design amount which is calculated by statistical analysis.

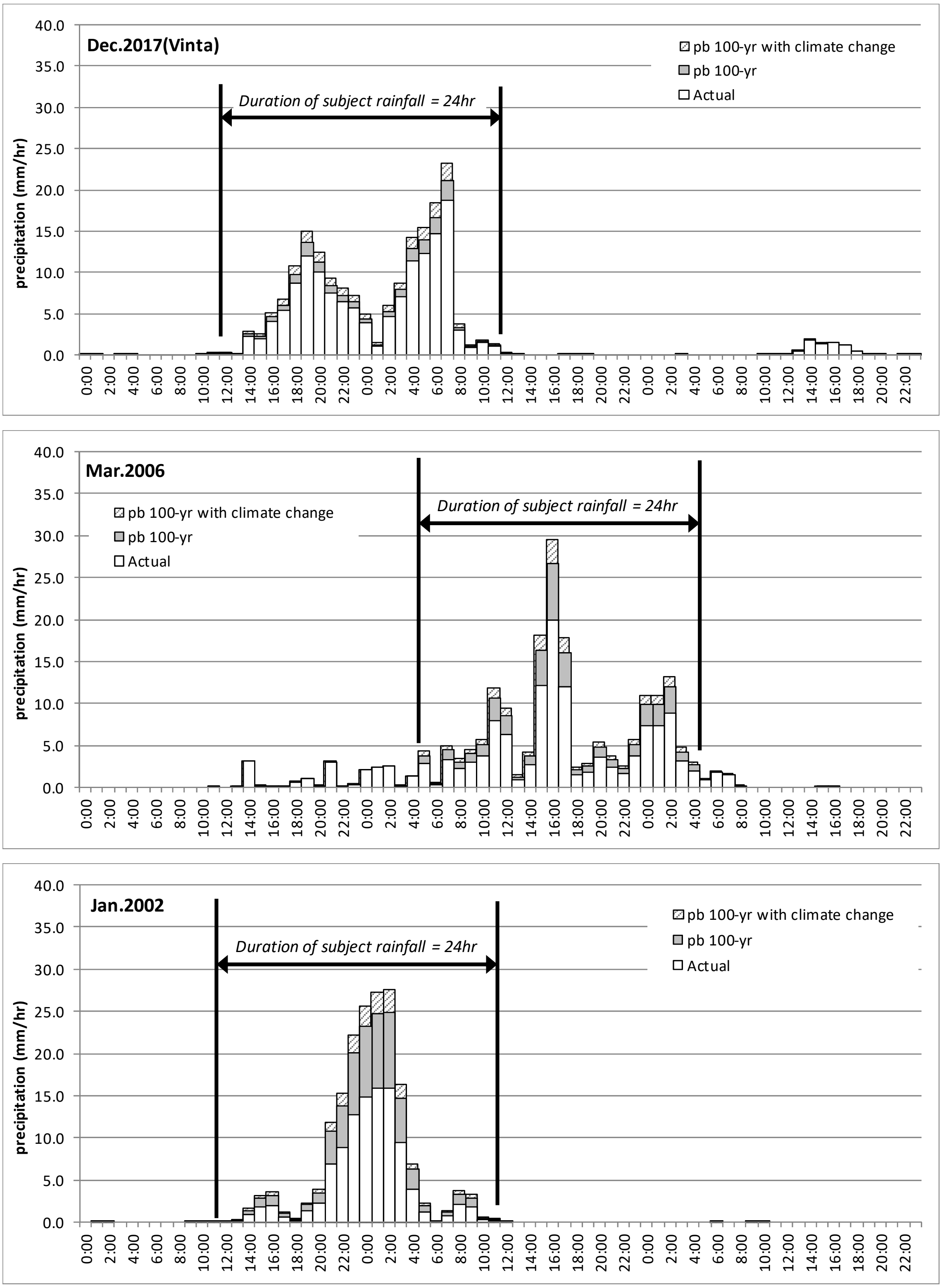
The design flood patterns are selected among the past floods after 2001, which are able to be complemented utilizing GSMaP based on the daily rainfall data. Since most of the selected floods' rainfall continue time is less than 24 hours, the object time for expansion is determined as 24 hours.

In order to prevent rain after expansion from becoming unrealistic, the design rainfall patterns were selected from three floods which are comparatively large on the probable scale flood. The design rainfall amount is increased by 10% considering the climate change effect which is described in Section 2.7.9.

Table 2.7.17 Summary of Design Flood Patterns of Davao River

Typical Rainfall Pattern	Rainfall (mm/24hr)	Expand coefficient	Note
Dec.2017 (Vinta)	145.1	1.24	100-yr rainfall amount = 163.60 (mm/24hr)*110% = 179.96 (mm/24hr)
Mar.2006	121.8	1.48	
Jan.2002	104.4	1.72	

Source: JICA Project Team

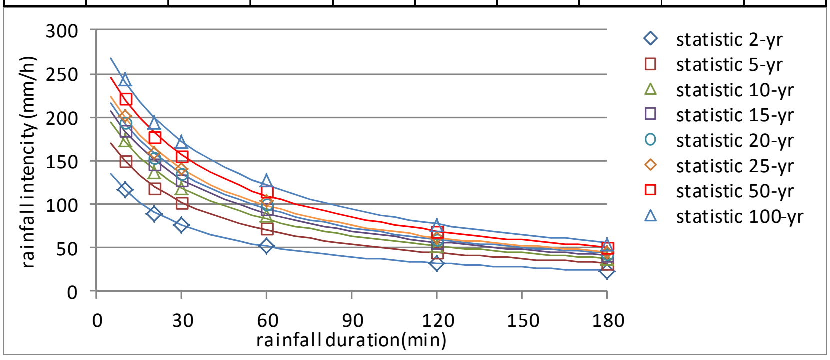


Source: JICA Project Team

Figure 2.7.21 Design Flood Patterns of Davao River

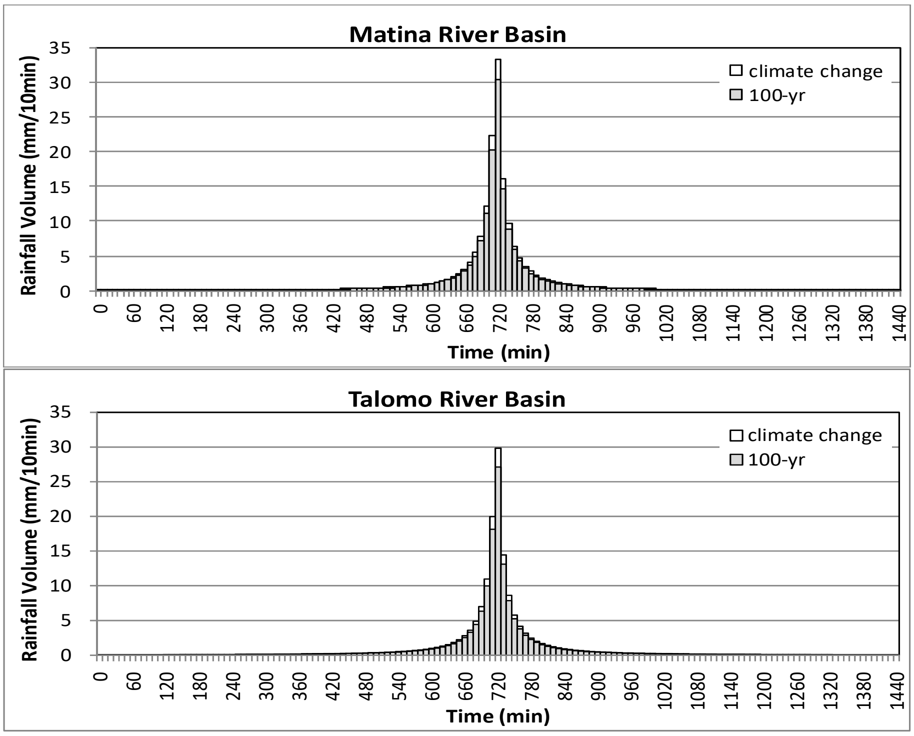
Regarding the Matina River and the Talomo River, the design flood pattern is made by the Alternating Block method utilizing RIDF of the Davao City gauging station due to their river basin scales. The 10% increase because of climate change is also considered, like the Davao River case.

T	10	20	30	1	2	3	6	12	24
(yrs)	min	min	min	hr	hr	hr	hr	hr	hr
2	117.0	90.0	76.4	53.2	32.6	23.9	13.4	7.2	3.8
5	150.6	117.9	102.0	73.2	44.4	32.1	18.1	9.6	5.0
10	172.8	136.2	118.8	86.5	52.3	37.6	21.3	11.2	5.9
15	185.4	146.7	128.4	94.0	56.7	40.7	23.0	12.1	6.3
20	194.4	153.9	135.2	99.3	59.8	42.9	24.3	12.7	6.6
25	201.0	159.6	140.2	103.3	62.1	44.5	25.2	13.2	6.9
50	222.0	177.0	156.2	115.8	69.5	49.7	28.1	14.7	7.7
100	243.0	194.1	171.8	128.1	76.8	54.7	31.1	16.2	8.4



Source: JICA Project Team made based on PAGASA data

Figure 2.7.22 Rainfall Intensity Duration Curve at Davao City Gauging Station

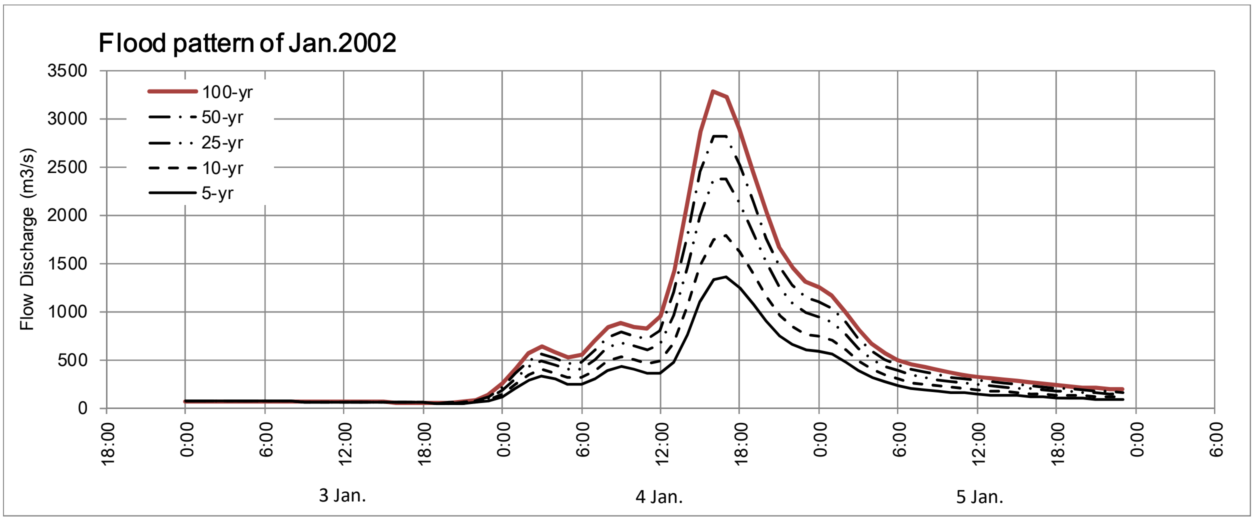


Source: JICA Project

Figure 2.7.23 Design Flood Patterns (above: Matina River, below: Talomo River)

(3) Basic Discharge

Regarding the Davao River, runoff analysis was examined with each design flood pattern whose rainfall amount was expanded up to the 100-yr scale (179.96mm/24hr). As a result of the analysis, the peak flow discharge of a 100-yr flood scale at Waan Bridge is 3,367(m^3/s), which is that of the pattern of 2002. The hydrograph of the pattern of 2002 for each probable scale is shown in Figure 2.7.24.

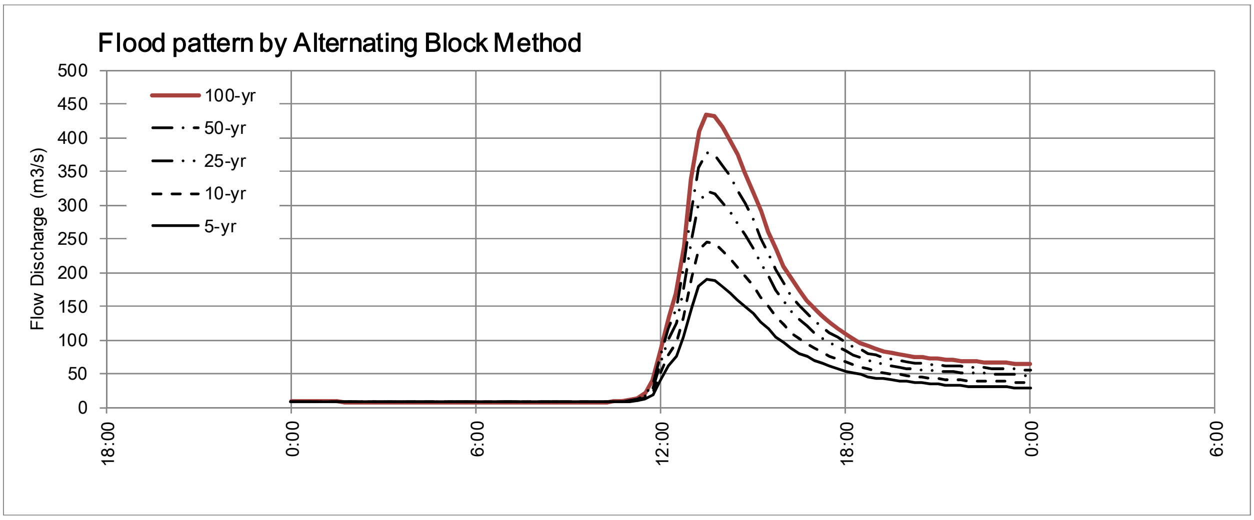


Source: JICA Project

Figure 2.7.24 Hydrograph of Each Probable Scale of Davao River

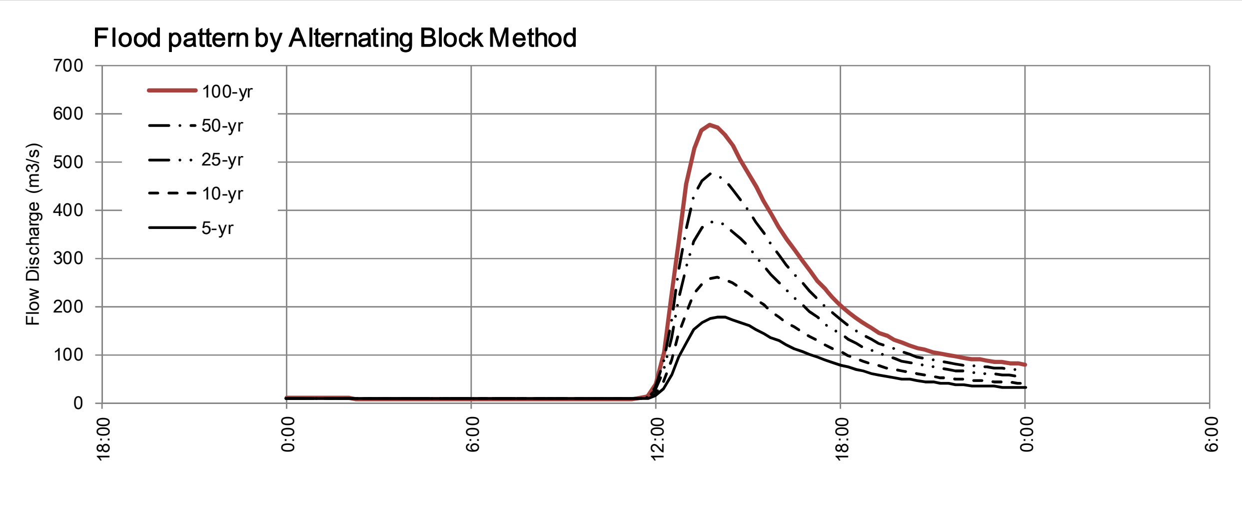
The above hydrograph is the value at Waan Bridge (Tigatto gauging station), which is the control point of the Davao River. In the Davao River, several tributaries with a catchment area of less than about 10 km^2 flow into the downstream of the Waan Bridge. Since the peak flow of the tributary occurs before the main river, the inflow from the tributary has almost no effect on the peak flow of the main river downstream of the Waan Bridge. Therefore, the peak discharge from the downstream of the Waan Bridge to the river mouth is almost the same as the peak discharge of the Waan Bridge.

Same as the Davao River, the hydrograph of each probable scale of the Matina River and the Talomo River is shown in Figure 2.7.25 and Figure 2.7.26. The peak flow discharge of the 100-yr flood scale is calculated as 435(m^3/s) on the Matina River and 577(m^3/s) on the Talomo River respectively.



Source: JICA Project

Figure 2.7.25 Hydrograph of Each Probable Scale of Matina River



Source: JICA Project

Figure 2.7.26 Hydrograph of Each Probable Scale of Talomo River

The above hydrographs of the Matina and Talomo Rivers are the values at the control points of Angalan II (Tugbok) and Matina Pangi Bridge (Pangi), respectively. The area of river basins of the Matina and Talomo Rivers are not so large, and flow hydrographs of discharge from tributaries and residual basins downstream of the control points affect the peak discharge of the main river, so the peak discharges downstream of the reference points are larger than those of the reference points. At the river mouths of the Matina and Talomo rivers, the peak discharges in 100-year probable rainfall are estimated at 550 (m^3/s) for the Matina River and 690 (m^3/s) for the Talomo River.

2.7.8 Flood Simulation and Flood Risk Analysis

Flood simulation is executed for the river section which is the object for river improvement in this project. For the upper section of the Davao River, the flood simulation is also examined, and the delineated estimated flood-prone areas identified to prevent an increase in flood risk with future development.

(1) Flood Simulation

1) Object River Section

The selected sections are the indicated sections in Table 2.7.18 which were carried out in the river topographic survey in this project.

Table 2.7.18 Object Section for Flood Simulation

River	River Station of calculate reach	Reach length (km)	Number of Cross-section	Survey date
Davao	sta.0+000 ~ sta.23+000	23.09	52	Apr.2019
Matina	sta.0-165 ~ sta.13+500	13.68	37	Mar.2019
Talomo	sta.0+072 ~ sta.11+000	10.84	25	Feb.2019

Source: JICA Project

2) Object Flow Discharge

Since the M/P targets the 100-year flood scale, 5 cases were examined: 5-year, 10-year, 25-year, 50-year, and 100-year scale of floods are considered. 1D unsteady flow analysis is executed with inflow from the upstream end of the object section and from sub-basins along the section, which calculated by the rainfall-runoff model, then the overflow volume is simulated on the flood plain by 2D unsteady analysis.

3) Coefficient of Roughness

The coefficient of roughness applied for the 1D unsteady analysis of the river water level is set as the value of 0.030 - 0.036 for ensuring reproducibility which has been determined by verification of the runoff model. The general value of flood plain, 0.06 is applied for 2D unsteady flood analysis.

4) Water level at River mouth

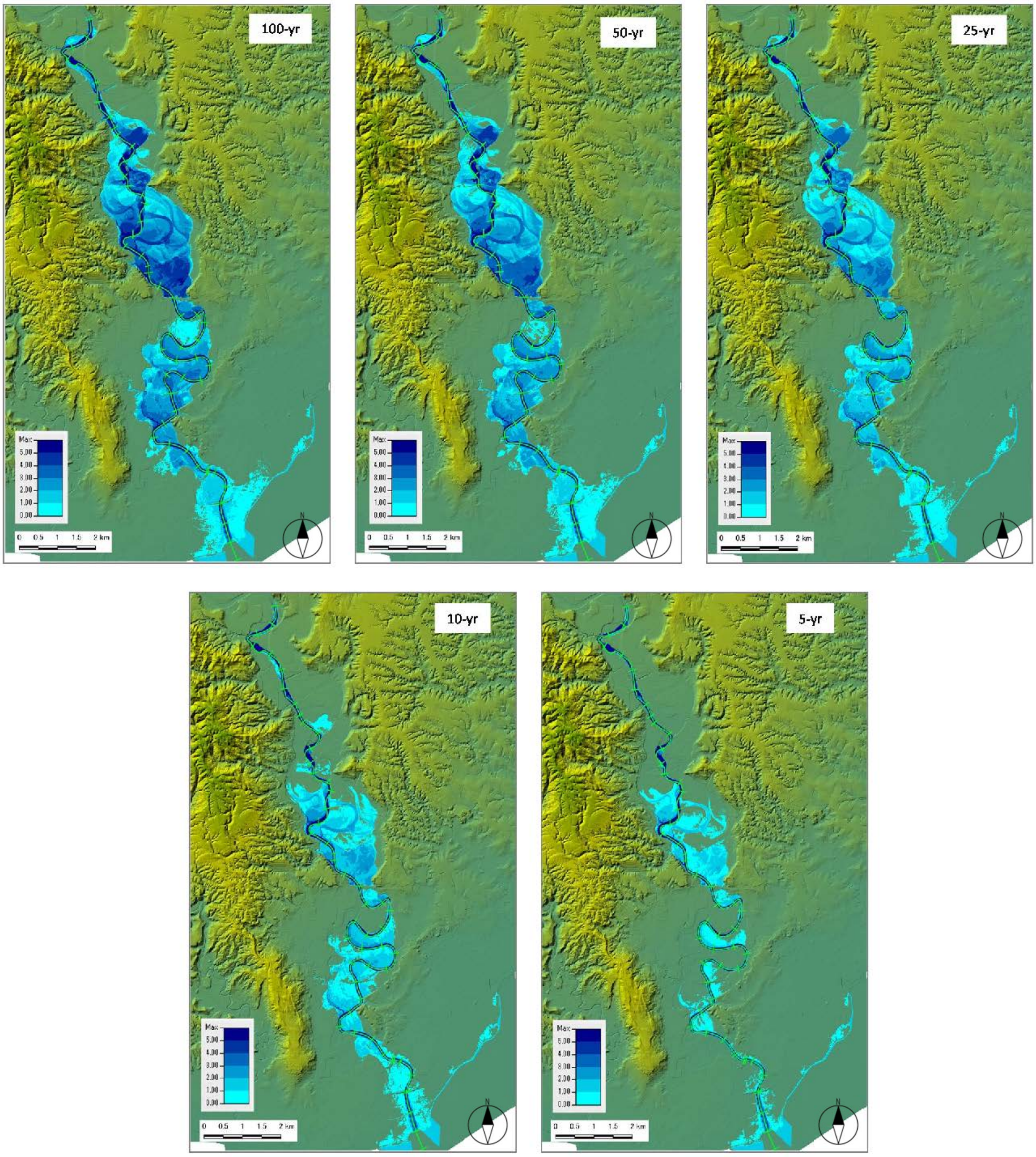
Since it is hard to logically determine an estimated tide level variation at the river mouth, the river mouth water level as the boundary condition of the simulation is set as the MHHWL, adding the climate change effect (MSL+0.981m).

5) Flood Analysis Result

The flood analysis result for each probability is shown in Figure 2.7.27 to Figure 2.7.29.

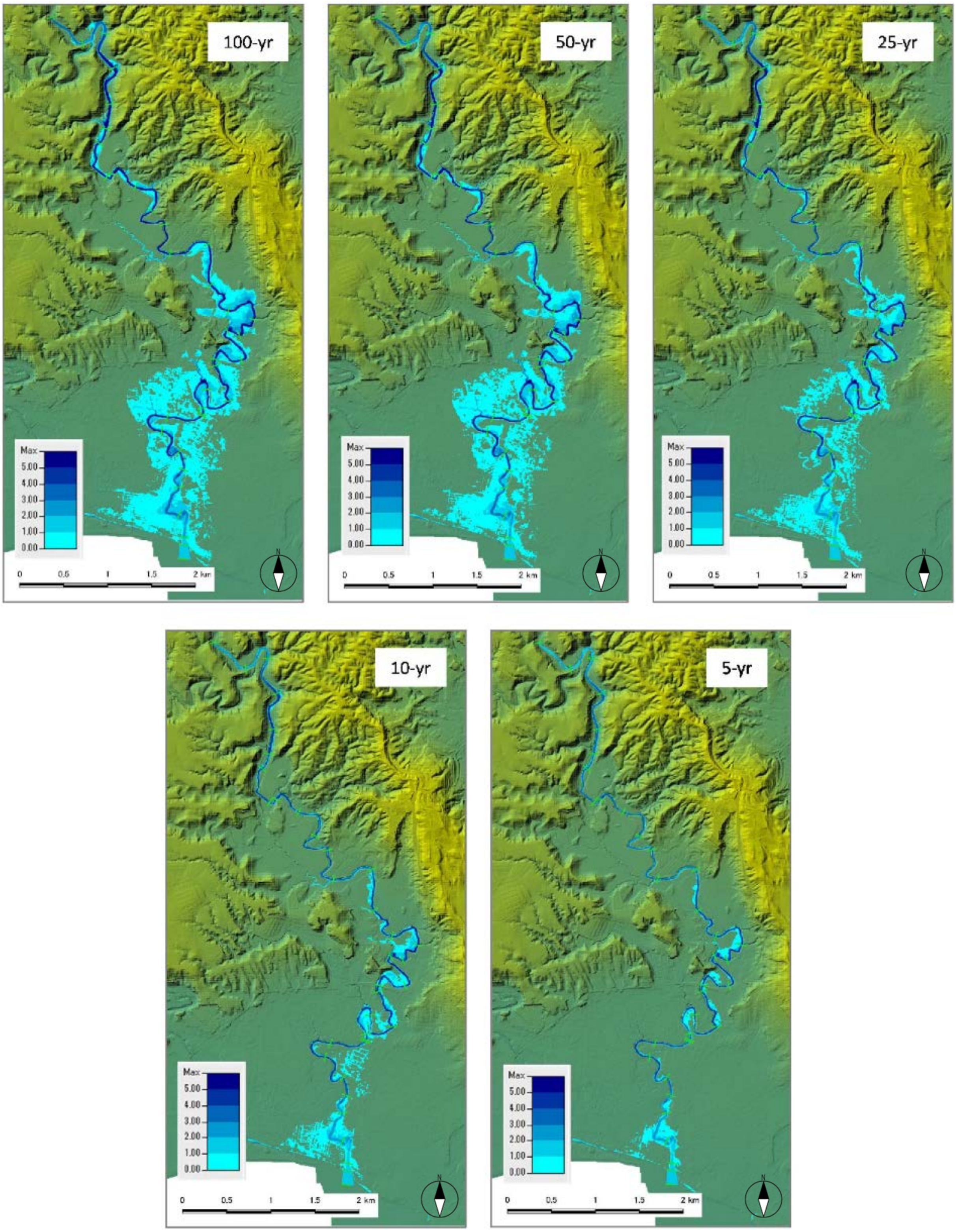
According to the simulation result, it could be said that there is a higher risk at the upstream section of Crocodile Park. In addition to the Jade Valley where there is a residential area in the lower land and is a flood-prone area, since the flooding estimated area includes multiple blocks which have the plan of development hereafter, flood control would be an essential matter.

Regarding the Matina River and the Talomo River, the existing residential area would be inundated by a flood of a 10 to 25-year scale. Thus, it is desirable to eliminate the possible flood damage.



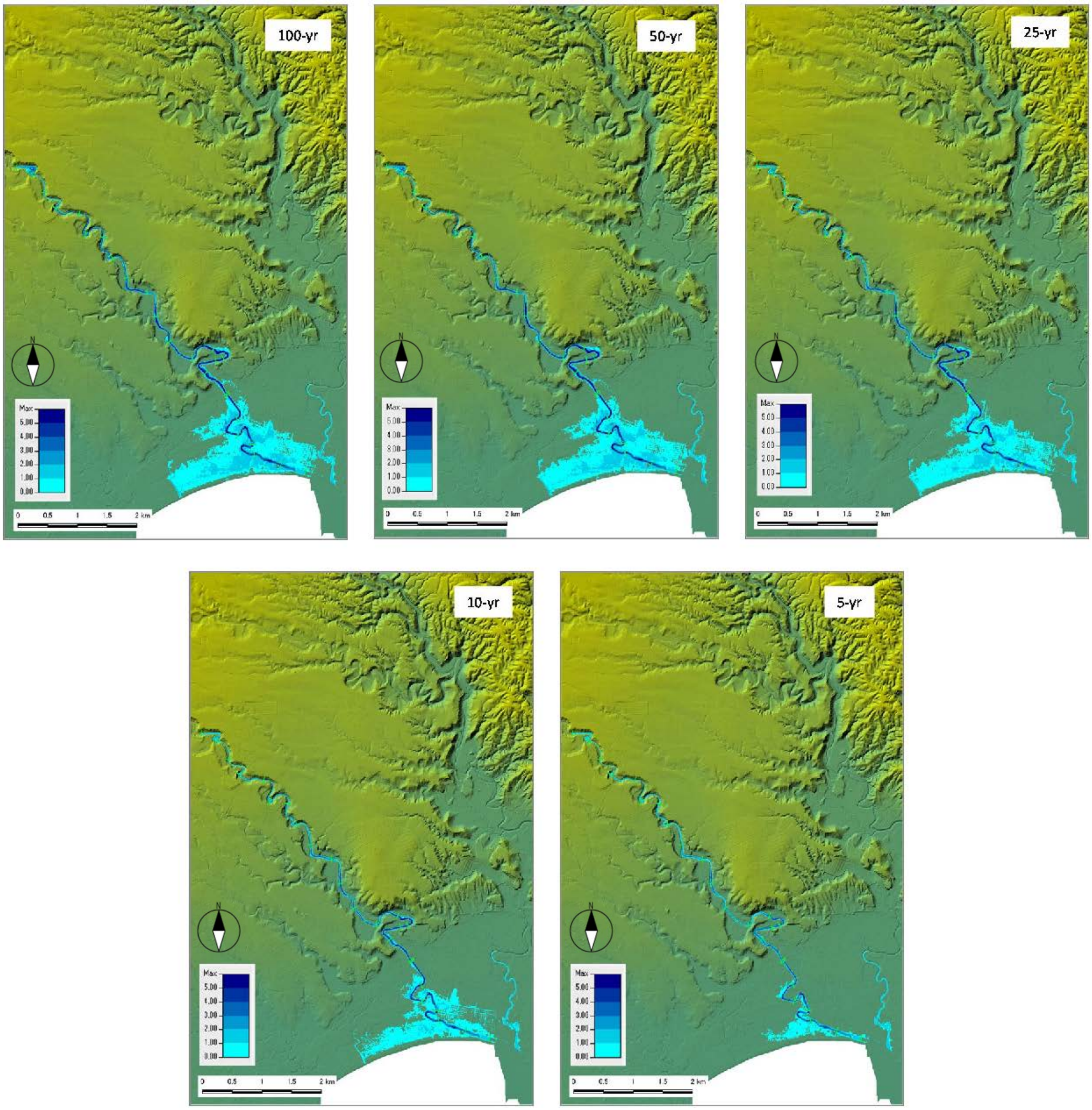
Source: JICA Project

Figure 2.7.27 Probable Flood Analysis Result of Davao River



Source: JICA Project

Figure 2.7.28 Probable Flood Analysis Result of Matina River

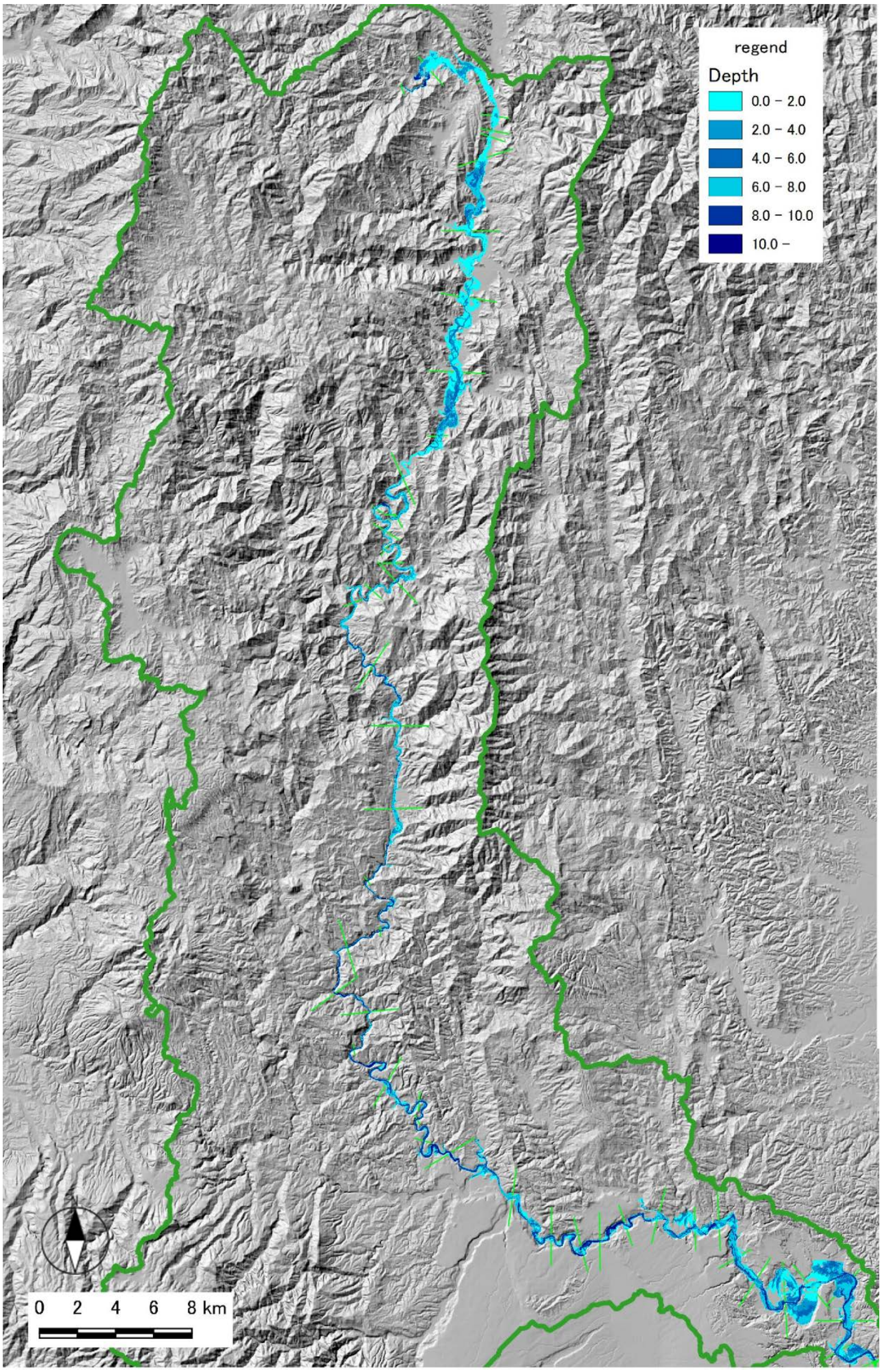


Source: JICA Project

Figure 2.7.29 Probable Flood Analysis Result of Talomo River

(2) Flood Risk at Upper basin of the Davao River

At the moment, there is no large-scale development plan on the upper basin of the Davao River, but even so it is desirable to prevent flood risk in the future by designating the riverine flood-prone area as a conservation area beforehand. From this perspective, the delineation of the estimated inundation area was done in the upper basin. The estimated inundation area by 100-yr flood is indicated in the Figure 2.7.30. According to the flood analysis result, the section from the upstream end to the point of about 25km forms the valley bottom plain and riverine flooding is expected in this plain. Therefore, it is judged that development activities should be suppressed. The delineation of a conservation area is described in Chapter 3.



Source: JICA Project

Figure 2.7.30 Estimated Inundation Area in Upper Basin of Davao River (100-yr Flood)

2.7.9 Climate Change Impact Analysis

Since the Philippines is an island country and furthermore its coastal areas are densely populated and urbanized, it is a concern that especially high sea-level rise caused by climate change shall provoke a severe impact. Upon the climate change risk, the Philippine government enacted the Republic Act (R.A.) No. 9729 otherwise known as the Climate Change Act of 2009. This allowed the mainstreaming of climate change into government formulation of policies and the creation of the Climate Change Commission (CCC) which is tasked to coordinate, formulate, monitor and evaluate programs and actions on climate change. Also, the National Framework Strategy and Program on Climate Change (NFSCC, 2010-2022) and National Climate Change Action Plan (NCCAP, 2011-2028) were established to build up more climate risk-resilient Philippines.

The Philippine Development Plan (2017-2022) which is the first medium-term plan anchored on Ambisyon Natin 2040 states strategies in several sectors for climate change impacts. In the sector of disaster risk deduction, strategies such as completion and updating of flood control and drainage master plans and development, preparation of hazard maps, strengthening of the flood management capabilities and coordination among concerned agencies, upgrading of engineering standards for the design and O&M of flood control works and ensuring resilient infrastructure facilities are listed. The approaches on climate change in the Philippines will be organized and the reflection of the impacts of climate change in flood M/P will be considered in this chapter.

(1) Existing Study and Analysis for Climate Change Impact

Over the past 65 years (1951-2015), the annual mean temperature in the Philippines has increased by 0.68°C. Likewise, the annual maximum temperature has risen by 0.33°C and annual minimum temperature has increased by 0.98°C, and the temperature is expected to rise more in future. Increasing trends in annual and seasonal rainfall were found to be associated with an increment of extreme rainfall events. Nevertheless, the multi-model central estimate of projected changes in rainfall could be within the natural rainfall variations, except for the reduction in the central Mindanao. The sea level in certain parts of the Philippines has risen by nearly double the global average rate in the period of 1993-2015.

In the Philippines, regional climate models such as the Providing Regional Climates for Impact Studies (PRECIS), which is developed at the Hardley Centre in the United Kingdom, are utilized to provide realistic and spatially detailed quantities at local scale (25 km resolution). DOST-PAGASA projected the impacts with the models as shown in Table 2.7.19.

Table 2.7.19 Impact Projection by PAGASA

Contents of Impacts Projection
• Mean annual temperature over the country could increase by 0.9-1.9°C (RCP4.5) to 1.2-2.3°C (RCP8.5) by around 2050, and 1.3-2.5°C (RCP4.5) to 2.5-4.1°C (RCP8.5) by around 2080.
• Considering the models' assumption underlying RCP8.5 scenario, the driest possible rainfall change* could reach beyond 40% reduction in many areas.
• The wettest possible change**, on the other hand, could exceed a 40% increase in rainfall.
• The rainfall projection of median case*** tends to decrease over the most part of the Philippines through a season.
• More specifically, seasonal rainfall during December-February could increase by approximately 20% in wettest possible case and rainfall of September-November could decrease by about 40% in driest possible case in central Mindanao.
• Projections show that the frequency of tropical cyclones that affect the Philippines will decrease or stay with the current observed trends. The intensity, however, will increase in the future.
• Global mean sea level is projected to be up to 0.5m (RCP4.5) and 0.7m higher (RCP8.5) by 2100. This range will be almost the same in the Philippines.

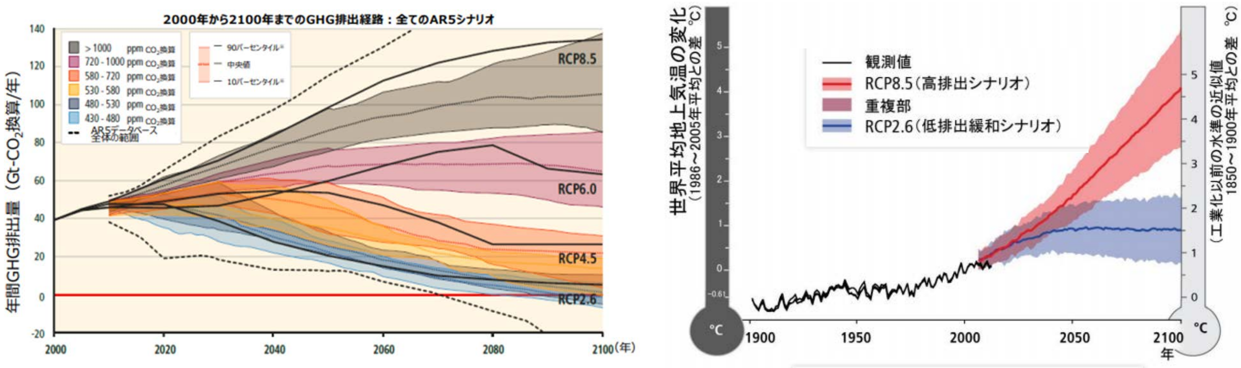
*the 10th percentile of the models' projections
**the 90th percentile of the models' projections
***the 50th percentile of the models' projections
Source: DOST-PAGASA, Observed Climate Trends and Projected Climate Change in the Philippines

The projection of climate change impacts is based on the Representative Concentration Pathways (RCP) which is a greenhouse gas concentration trajectory adopted by the IPCC for its AR5 in 2014. Four RCPs shown in Table 2.7.20 are labelled after a possible range of radiative forcing values in the year 2100. Figure 2.7.31 shows the change in GHG emission and mean temperature depending on the scenarios. DOST –PAGASA in the Philippines selects RCP4.5 and RCP8.5 out of four scenarios to project the climate change impact.

Table 2.7.20 Contents of RCPs

RCP	GHG Concentration in 2100 (measured in CO_2-equivalents)	Change in Concertation
RCP 2.6	Low stabilization scenario Peak at 490ppm before 2100 and decrease	Decrease after peak
RCP 4.5	Medium stabilization scenario Approx. 650ppm (stable after 2100)	Stabilization
RCP 6.0	High stabilization scenario Approx. 850ppm (stable after 2100)	Stabilization
RCP 8.5	Highest GHG emission scenario Exceed 1,370ppm	Continuous increase

Source: Ministry of the Environment, Japan - IPCC Report Communicator



Source: Ministry of the Environment, Japan - IPCC Report Communicator

Figure 2.7.31 Change in GHG Emissions and Mean Temperature

(2) Projection of Impact in the Target Area

1) Mean Temperature

Table 2.7.21 shows the changes in projected mean temperature over the three provinces which cover the target basins in the mid-21st century (2036-2065). It is projected that the annual mean temperature could increase by 1.2-1.3°C in RCP4.5 (assuming the moderate emission scenario) and 1.6-1.7°C in RCP8.5 (assuming the high emission scenario) respectively.

Table 2.7.21 Changes in Projected Mean Temperature

Projected Mean Temperature (2036-2065)											
Scenario	Province	DJF		MAM		JJA		SON		Average	
		Change	Projected value	Change	Projected value	Change	Projected value	Change	Projected value	Change	Projected value
Moderate Emission (RCP4.5)	Davao del Sur	1.2	28.1	1.2	29.0	1.2	28.1	1.2	28.3	1.2	28.4
	Davao del Norte	1.2	27.9	1.2	29.0	1.2	28.6	1.2	28.6	1.2	28.5
	Bukidnon	1.3	26.4	1.3	27.8	1.2	27.0	1.2	26.9	1.3	27.0
High Emission (RCP8.5)	Davao del Sur	1.6	28.5	1.7	29.5	1.6	28.5	1.6	28.7	1.6	28.8
	Davao del Norte	1.6	28.3	1.7	29.5	1.6	29.0	1.6	29.0	1.6	29.0
	Bukidnon	1.7	26.8	1.8	28.3	1.6	27.4	1.6	27.3	1.7	27.5

*DJF: December to February, MAM: March to May, JJA: June-August, SON: September to November

Source: DOST-PAGASA, Observed Climate Trends and Projected Climate Change in the Philippines

2) Rainfall

Changes in projected rainfall of the three provinces in the mid-21st century (2036-2065) are shown in Table 2.7.22. It is expected that the annual total rainfall could decrease by as much as 97.4-297.7mm for the RCP4.5 and 18.4-136.5mm for the RCP8.5 compared to the rainfall observed from 1971 to 2000. In addition, the three months rainfall is expected to be on a downward trend throughout the year in RCP4.5. Especially, it shows a large decrease in 14.5-26.5% in the period from September to November.

Even in RCP8.5, only Davao del Sur province is expected to increase by 2.1-4.4% in the period from March to August, and all other area and period show a downward trend.

In terms of typhoons, the frequency of occurrence decreases in areas where typhoons frequently pass, although it is predicted that the intensity will be stronger.

Table 2.7.22 Changes in Projected Rainfall

Projected Total Rainfall (2036-65)											
Scenario	Province	DJF		MAM		JJA		SON		Annual Total	
		Percent change	Projected value	Percent change	Projected value	Percent change	Projected value	Percent change	Projected value	Percent change	Projected value
Moderate Emission (RCP4.5)	Davao del Sur	-3.6	277.9	-4.1	332.9	-1.8	485.3	-14.5	378.1	-6.2	1474.2
	Davao del Norte	-3.3	616.1	-4.6	473.4	-9.4	485.1	-20.4	442.8	-9.3	2017.4
	Bukidnon	-3.2	319.2	-9.7	303.1	-16.3	547.4	-26.5	411.2	-15.8	1580.9
High Emission (RCP8.5)	Davao del Sur	-0.9	285.6	2.1	354.2	4.4	515.6	-10.1	397.8	-1.2	1553.2
	Davao del Norte	-2.1	623.6	-2.4	484.5	-2.8	520.4	-11.0	495.2	-4.6	2123.7
	Bukidnon	-7.4	305.3	-6.7	313.1	-4.4	625.1	-10.9	498.6	-7.3	1742.1

*DJF: December to February, MAM: March to May, JJA: June-August, SON: September to November
Source: DOST-PAGASA, Observed Climate Trends and Projected Climate Change in the Philippines

3) Short-Term Rainfall Intensity

In the present project, PAGASA provided the bias-corrected annual maximum daily rainfall for the RCM output using the observed data at Davao station, which is not opened to the public. Although the data had been bias-corrected, there were still some outliers in the data. The outliers have been excluded for further statistical analysis by rejection test for extreme value.

The probable rainfall for annual maximum daily rainfall has been estimated for the bias-corrected data for each of maximum 11 RCM outputs. The ensemble mean value is presented in Table 2.7.23. Table 2.7.24 shows the ratio of the estimated future probable rainfall for annual maximum daily rainfall and the calculated value for the past climate condition (1971-2000).

Table 2.7.23 Estimated Probable Rainfall for Annual Maximum Daily Rainfall

	Probable Rainfall (mm/day)										
Return Period (year)	**2**	**3**	**5**	**10**	**20**	**30**	**50**	**80**	**100**	**150**	**200**
Observed 1971-2000	99.0	112.4	127.3	146.1	164.1	174.4	187.3	199.2	204.8	215.0	222.2
Historical 1971-2000	95.1	108.0	122.3	140.3	157.6	167.5	179.9	191.3	196.7	206.5	213.4
RCP45 2036-2065	91.7	107.7	125.5	147.9	169.4	181.7	197.2	211.3	218.0	230.1	238.7
RCP45 2070-2099	92.4	108.3	125.9	148.1	169.3	181.6	196.9	210.9	217.5	229.5	238.0
RCP85 2036-2065	94.3	108.7	124.9	145.1	164.5	175.7	189.6	202.4	208.5	219.5	227.3
RCP85 2070-2099	97.0	112.4	129.6	151.1	171.8	183.8	198.7	212.3	218.7	230.4	238.7

Source: Project Team based on the data provided by DOST-PAGASA

Table 2.7.24 Ratio of Estimated Future Probable Rainfall for Annual Maximum Daily Rainfall and Calculated Value for Past Climate Condition

	Probable Rainfall (mm/day)										
Return Period (year)	2	3	5	10	20	30	50	80	100	150	200
Historical 1971-2000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RCP45 2036-2065	0.96	1.00	1.03	1.05	1.07	1.08	1.10	1.10	1.11	1.11	1.12
RCP45 2070-2099	0.97	1.00	1.03	1.06	1.07	1.08	1.09	1.10	1.11	1.11	1.12
RCP85 2036-2065	0.99	1.01	1.02	1.03	1.04	1.05	1.05	1.06	1.06	1.06	1.06
RCP85 2070-2099	1.02	1.04	1.06	1.08	1.09	1.10	1.10	1.11	1.11	1.12	1.12

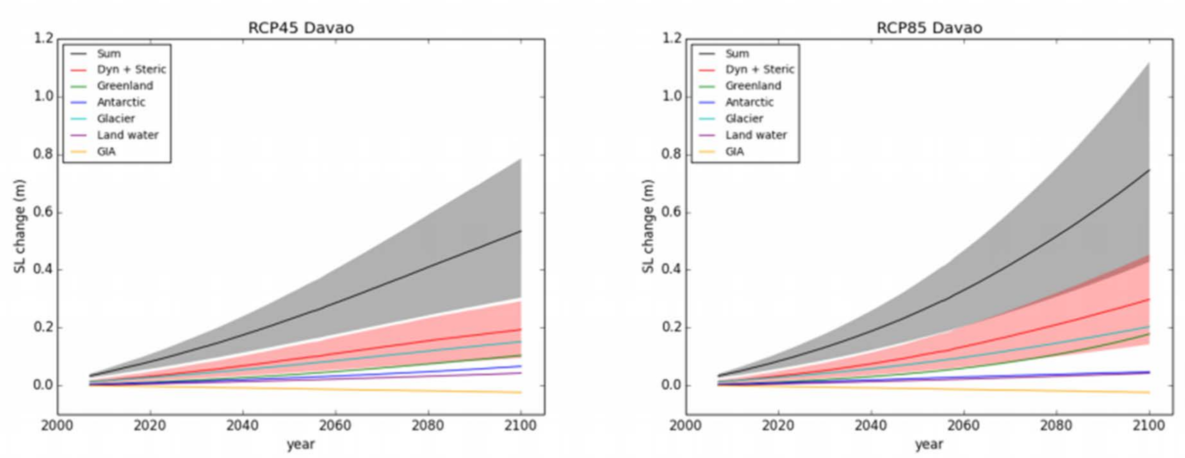
Source: Project Team based on the data provided by DOST-PAGASA

The estimated probable rainfall for the future tends to increase. The higher for the extreme event with longer return period, the larger increasing rate is. The increasing rate against for both the middle (2036-2065) and the end (2070-2100) of the 21 century for 100 year return period and 2 year return period are about 10% and zero, respectively, for both RCP4.5 and RCP8.5 scenarios.

4) Mean Sea Level

As shown in Figure 2.7.32, sea level rise in Davao will continue in both moderate (RCP4.5) and high (RCP8.5) emission scenarios. The increase is expected to be almost the same, approximately 0.2m by the mid-21st century. The trend for RCP4.5 will continue to be linear up to 0.5m by the end of the 21st century, while the sea level rises by approximately 0.7m for RCP8.5.

The mean sea level rise will be taken further consideration by referring to the result assessment in Section 2.10.



Source: Met Office, Projections of mean sea level change for the Philippines

Figure 2.7.32 Changes in Mean Sea Level

(3) Adopted Estimation of Impact in the Project

Considering the project target year for planning (may set to 2045) and development period of the facilities which will be constructed by the target year, the adopted period for the climate change projection should be 2036-2065.

In this Project, it is proposed that the conditions of climate changes in 2036-2065 are assumed based on the moderate emission scenario (RCP4.5) in the PAGASA's Study as follows:

- ✓ Mean Temperature: is assumed to increase by 1.2 degrees compared to the condition in 2000.
- ✓ Rainfall: is projected to decrease, however, the rainfall intensity in the heavy rainfall event tends

to increase. It is assumed that the probable rainfall for annual maximum daily rainfall increases by 10% from the climate condition in 2019.

- ✓ Mean sea level: is assumed to be 0.2m higher than the level in 2000, and 0.1m higher than the level in 2019.

2.7.10 Major Issues on Riverine Flood

The major issues on riverine flood have been identified, on the basis of field reconnaissance, flood mark survey, hydrological and hydraulics analysis, interviews to stakeholders and workshops, as shown below.

(1) Improvement of Present Situation of Implementation of Flood Control Measures with Different Design Levels

In the target 3 rivers, construction of dike and revetments was carried out in some sections in the past as a partial flood countermeasure, and large-scale dike and revetment construction works by DPWH's district engineering offices has been underway since 2017. In these construction works, the standard elevation has been set for each construction section, and then the longitudinal continuity of the dike height cannot be secured. It is required to implement the flood control measures using unified standard elevation and design conditions.

(2) Increase in Insufficient Flow Capacity for Large Scale Runoff

Present flow capacities of target 3 rivers are about 2 year scale flood or less and are not enough capacity for severer extreme flood events. It is required to increase the insufficient capacity for large scale runoff.

(3) Recovery of Decreasing Natural Retarding Function

Downstream area of the target 3 rivers has been highly urbanized. Due to the development of low-lying area along the rivers, as well as development of swamp and depression area in the basins, the natural retarding function tends to decline in the basins. It is necessary to preserve natural retarding function and to secure and enhance the retarding function by installing artificial storage facilities.

(4) Planning of Measures Harmonizing with Development along the River and in the Surrounding area, with the Viewpoint of Urban Planning

The downstream area of the target 3 rivers has been highly urbanized. Davao City is engaged in activities such as granting development permits on the condition that raising the land is a prerequisite for development in flood-prone areas. Though, it may cause that raising some of the land will lead to poor drainage and reduced retarding function in other areas, and increasing the risk of flooding. On the other hand, it is also possible to take measures against floods and promote the development of new land, such as implementing cut-off works for the meandering part of the river and utilizing the old river channel after the implementation as a relocation site. It is required to take measures in harmony with the development plan of the Davao City as well as from the viewpoint of flood risk reduction.

(5) Consideration in Possible Increase in Runoff by Land use and Climate Change

The JICA-supported infrastructure development plan for the Davao City in 2018 set 2045 as the target year, and created a future land use map as of 2045. It is expected that the runoff coefficient will increase due to urbanization in the downstream section that is target protected area of the target 3 rivers. In addition, as shown in Section 2.7.9, due to the effects of climate change, it is also expected that rainfall intensity will increase by about 10% from the current climate in the middle of the 21st century (2036-2065).

Runoff will be assumed to increase due to such changes in land use and the effects of climate change, therefore, it is required to formulate appropriate plan based on these conditions. Structural measures should be examined using the design flood discharges set based on these expected changes.

(6) Control of Development in Flood Risk Area

Area along the target 3 rivers faces the pressure of urbanization despite the high flood risk. In the land use plan of the Davao City, the plan based on the flood risk has been proposed for the flood risk area, and the development permit is also examined based on the flood risk. Though, it has possibility that the flood risk area under the planning conditions considering changes in land use and climate change in this M/P will differ from the existing flood risk area, and also that future flood risks will change due to the gradual implementation of flood control measures. It is necessary to identify the flood risk area and create a flood risk map (update the existing flood risk map) under the planning conditions of this M/P, and make it known to residents. In addition, development regulations and land use regulations are needed in identified flood risk areas and areas where countermeasures are expected to be implemented.

(7) Sharing Information related to Flood

In the target 3 rivers, floods occur almost every year, including small ones. In Davao City, DCDRRMO is distributing flood-related information to residents (barangays) in cooperation with PAGASA's Davao River Flood Forecasting and Warning Center, but the number of observatories is not enough and the accuracy is not adequate. In addition, although flood hazard maps have been created, they have been created by multiple organizations using different methods and accuracy, and then, those maps are not fully utilized whereas they are distributed to the barangay office. It is required to improve and update flood-related information and strengthen the information provision and sharing system.

(8) Consideration in Artificial Factors such as Cutting Trees, Improper Waste Disposal and Informal Settlement

In recent years, deforestation associated with development has been regarded as a problem in the target basin, and illegal dumping into rivers and illegal residence along rivers are recognized as factors that increase flood risk. It is necessary to consider countermeasures that take these artificial factors into consideration.

(9) Enhancement of Flood Control Planning Capacity

It has cases that the dike and revetment have been planned and constructed for each construction section under different design conditions and design discharge, causing inconsistent dike alignment and different crown height of the dike. The capacity to formulate integrated flood control plan is inadequate and it is considered necessary to enhance the planning capacity.

(10) Better Operation and Maintenance Activities

It can be seen some situations where maintenance activities such as patrols to grasp the need for repair or repair of structures are not sufficiently carried out. For example, a state such as partial subsidence of the gabion dike, depression of the soil on the back surface of the dike due to suction, or partial collapse of the front part of the gabion dike has been left unattended for a long period of time. Maintenance activities need to be improved.

(11) Better Coordination for Project Implementation including Land Acquisition and Resettlement

In the Philippines, there is no permanent supervisory body related to the relocation, and basically the executing agency (DPWH in this Project) and local governments (Davao City and Barangay) play a central role. In addition, the National Housing Authority is involved in housing development, and presidential agencies and others are involved in the relocation of informal settlers and the recovery of livelihoods. In the projects of the target 3 rivers, land acquisition and relocation are expected to be important issues in implementation, and it is required to coordinate related organizations for securing project implementation including the development of relocation sites.

2.8 Sediment Production and Sediment Yield in the Basin

2.8.1 General

For conducting appropriate operation and maintenance, and for controlling a flood occurrence in a watershed, it is necessary to estimate sediment yield. The lack of certain functions as flood control structures, such as revetment, due to riverbed fluctuation has not been reported so far by DPWH RO XI or DEO who are in charge of maintaining these structures. Even so, it can be seen that the base of some bridge piers which are located at the downstream section of the Davao River have been exposed. That is because the riverbed material which consists of fine grain size sand at the downstream section easily fluctuates due to the supply of sediment discharge from upstream. In addition, river mouth blocking could become a concern if the river training works allowed an increase in sediment discharge even though regular dredging works is conducted. For formulating M/P, it is important considering matters related to sediment yield and sediment discharge.

2.8.2 Past Study of Sediment Production

A past study conducted by Tan and Guanzon shows the average sediment load of the Davao Gulf at 5.3 kg/s in 2003 (Villanoy, 2009)[4]. According to DPWH RO-XI records, the estimated maximum sediment transported by Davao River is about 70 kg/s from 2001 to 2004, with the average at 10kg/s.

In the past, DPWH RO-XI has conducted an observation of sediment discharge amount for rivers flowing through Davao city, and the Davao River and the Talomo River among the three target rivers of this project were included in that observation. Table 2.8.2 shows the survey results from 2000 to 2003. Based on the observation results, Figure 2.8.1 shows the relationship between the flow discharge (Q) and the sediment discharge (Qs). Here, the specific gravity of the sediment is to be to 2.8 (g/cm3) according to the result of the riverbed material survey. Table 2.8.1 shows the Q-Qs function estimated from sediment discharge amount observation results.

Table 2.8.1 Q-Qs Function Estimated by the Sediment Discharge Observation

River name	Sediment discharge
Davao River	$Qs = 4.765E\text{-}07Q^{1.9705}$
Talomo River	$Qs = 5.418E\text{-}07Q^{1.8303}$

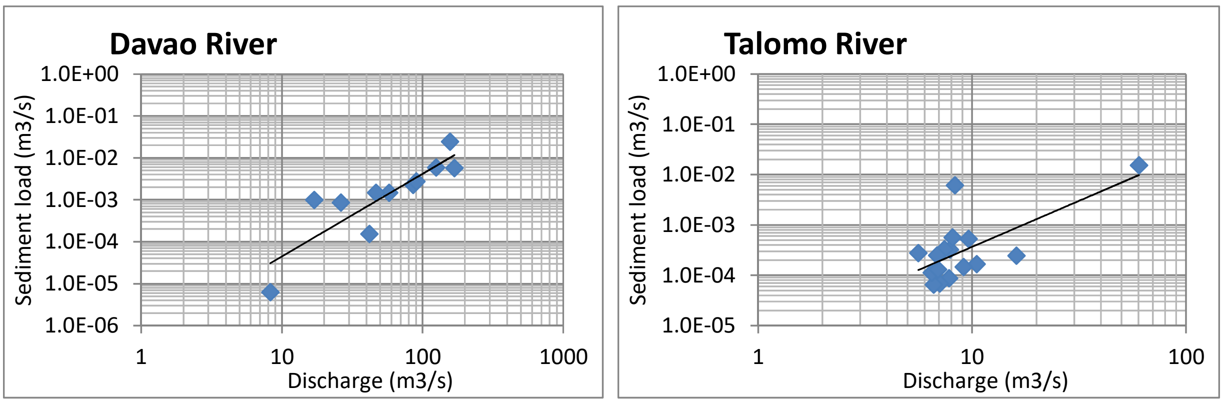
Source: Project Team

4 Orient Integrate Development Consultants, INC., "Formulation of Davao River Basin Management and Development Plan", Feb.2015

Table 2.8.2 Result of Sediment Discharge Observation

Date	River	Location	Discharge measurement (m3/s)	Wt. of Sample (g)	Wt. of Sediment (g)	Consentration by Weight (ppm)
2000/01/11	Talomo	Talomo	7.80	385	0.012	31.169
2001/06/27	Talomo	Tugbak	9.62	247	0.038	153.846
2001/07/18	Davao	Lacson	156.43	254	0.110	433.071
2001/08/08	Davao	Lacson	16.97	253	0.041	162.055
2001/08/08	Talomo	Tugbak	7.87	253	0.029	114.625
2001/09/04	Davao	Lacson	41.94	388	0.004	10.309
2001/09/04	Talomo	Tugbak	5.61	377	0.052	137.931
2001/10/07	Talomo	Tugbak	7.06	476	0.013	27.311
2001/10/11	Davao	Lacson	8.31	476	0.001	2.101
2001/11/07	Davao	Calinan	57.78	474	0.034	71.730
2001/11/07	Talomo	Tugbak	8.31	477	0.981	2056.604
2002/02/20	Talomo	Marilog	60.21	475	0.340	715.789
2002/02/20	Talomo	Marilog	16.15	472	0.020	42.373
2002/03/13	Talomo	Marilog	6.61	474	0.013	27.426
2002/07/12	Talomo	Tugbak	6.47	474	0.023	48.523
2002/08/29	Talomo	Tugbak	10.51	472	0.021	44.492
2002/08/30	Davao	Lacson	125.01	474	0.063	132.911
2002/09/24	Davao	Lacson	168.33	474	0.045	94.937
2002/09/24	Talomo	Tugbak	6.92	478	0.025	52.301
2002/10/16	Davao	Lacson	85.75	473	0.035	73.996
2002/10/16	Talomo	Tugbak	8.10	472	0.092	194.915
2002/11/20	Davao	Lacson	90.28	472	0.040	84.746
2002/11/20	Talomo	Tugbak	7.43	469	0.058	123.667
2002/12/23	Davao	Lacson	46.70	473	0.042	88.795
2002/12/23	Talomo	Tugbak	6.88	473	0.048	101.480
2003/04/25	Davao	Lacson	26.22	472	0.043	91.102
2003/04/25	Talomo	Tugbak	9.14	473	0.021	44.397

Source: DPWH RO-XI



Source: Project Team

Figure 2.8.1 Estimating Relationship of Q-Qs

Regarding the Davao River and the Talomo River, the sediment discharge estimation was conducted using Q-Qs function which obtained by the result of observation. That results in the annual estimated sediment discharge from 2002 to 2009, and the annual average sediment discharge during that period which is shown in Table 2.8.3. Here, annual sediment discharge is calculated as an accumulation of daily sediment load by Q-Qs function.

Table 2.8.3 Q-Qs Function Estimated by the Sediment Discharge Observation

year	Flow volume (mil.m3/yr)		Sedimentload (ton/yr)	
	Davao	Talomo	Davao	Talomo
2002	3,323	283	732,172	34,305
2003	3,095	321	532,313	39,476
2004	2,927	272	478,423	28,895
2005	2,116	259	210,825	25,379
2006	2,565	260	391,174	31,261
2007	2,439	225	337,083	21,797
2008	3,144	260	593,785	29,379
2009	3,624	308	658,303	42,248
average	2,904	274	491,760	31,593

Source: Project Team

As a reference, commercial extracted sand and gravel volume in 2018 is summarized based on the City Environment and Natural Resources Office (CENRO) of Davao. One of the reasons why there is a difference between the approved extracted volume and the actual extracted volume is that some permittees have not taken out riverbed material as much as the volume permitted, in addition to the minimum permission volume is 10,000m3/year.

One of the requirements to be able to get a permit from CENRO is a certification from DPWH and DEO allowing the permittees to extract riverbed material provided that there is no flood control structure affected by the riverbed material extraction works in the area where they plan to extract it. Therefore, the permittees are required to submit an assessment report authored by a mining engineer. The assessment report shall include the study of the available resource materials volume in which the river and flood control structures would be sustained even though the expected volume of riverbed materials is extracted.

Table 2.8.4 Commercial Extracted Sand and Gravel Volume in 2018

River Name	Number of Permittee	Approved Volume (m^3)	Extracted Volume (m^3)	Extracted Volume (ton)
Davao River	61	596,200	267,109	747,905
Matina River	4	40,000	2,691	7,535
Talomo River	1	10,000	8,828	24,718

Source: CENRO

In the assessment report, available material resource volume is calculated by the formula below.

$$v = A \times T$$

Where v=material volume, A=area under application, T=thickness of deposits. The thickness of deposits on the riverbed is estimated by a mining engineer through conducting a site survey.

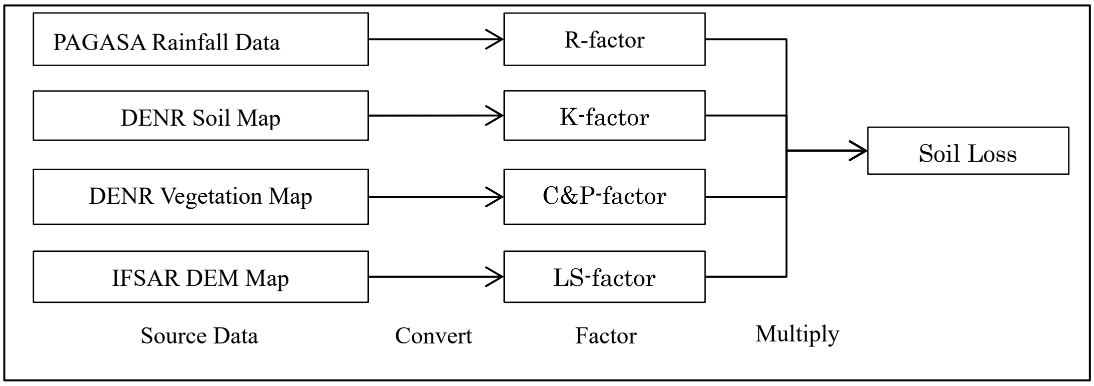
2.8.3 Estimation of Sediment Production and Sediment Yield

(1) Estimation of Sediment Yield by USLE Model

In this study, the erosive quantity of sediment is calculated by using the Universal Soil Loss Equation (USLE). The USLE is an experimental equation used for the estimation of erosion in vast and comparatively flat lands. The calculated values will generally be most accurate for medium-texture soil, slopes lengths of less than 122 m, gradients of 3% to 18%, and consistent cropping and management systems that have been represented in the erosion plot studies. The Universal Soil Loss Equation is shown in the following equation.

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

Where; A=annual soil loss in ton/ha/year, R=rainfall erodibility factor, K=soil erodibility factor, LS=topographic factor, C=cover or crop management factor, P=conservation practice factor. Figure 2.8.2 shows the working procedures when calculating the sediment loss with USLE.



Source: Project Team

Figure 2.8.2 Working Steps for Each Factor and Soil Loss Estimation

1) Rainfall Erodibility Factor (R)

The contribution of the erosive precipitation is represented by the rainfall erodibility factor (R). The R factor corresponds to the kinetic energy (E) of the rainfall multiplied by the maximum intensity of the 30 minute rain according to the original approach of USLE. Even so, in this study, the following equation was adopted to estimate the R factor, considering the available data with referring David[5].

$$R = a \cdot \sum_{i=1}^{n} DP_i^m$$

Where, DPi=daily rainfall with more than 25mm, i=counter for the day of the year, a, m=empirical coefficients (a=0.002, m=2).

Precipitation records from 2001 to 2018 at three PAGASA stations nearby the basins are used for R factor calculation. Daily rainfall data of basin average are applied to Davao River Basin and data at PAGASA Davao City Station are employed in Matina and Talomo River Catchment. Each R factor is estimated to 71.56 for Davao River Basin and 113.11 for the rest of two basins respectively.

---

5 Soil and Water Conservation Planning: Issues and Recommendations, David, W.P, Journal of Philippine Development, No.26, Vol.XV, No.1, 1988.

2) Soil Erodibility Factor (K)

The erodibility of the soil is the susceptibility to erosion, which is the reciprocal of its resistance to erosion. In this study, K factor was assigned based on the soil map provided by DENR. The K value shown in Table 2.8.5 is employed for each soil type. The calculated K factor for the entire study area is shown in Figure 2.8.3.

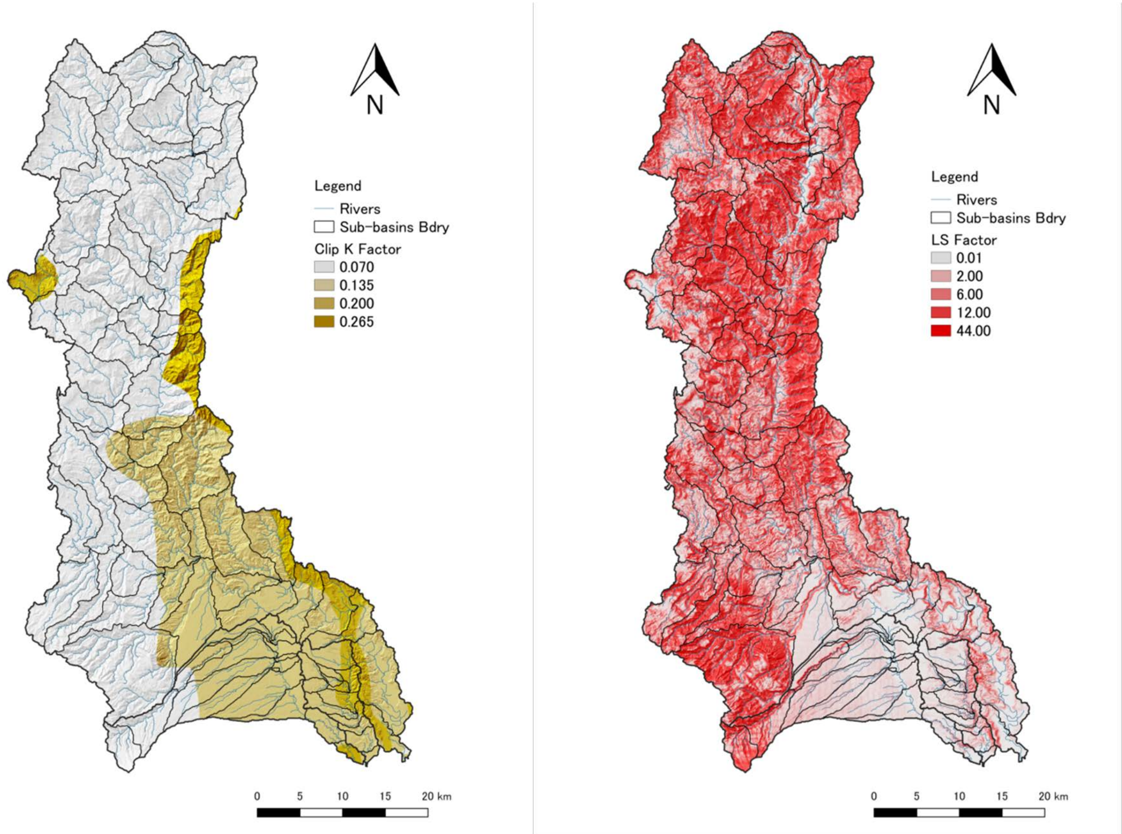
Table 2.8.5 Soil Erodibility Factor Applied for Each Soil Type

Soil Type	DENR Classification	K value applied
Loamy Fine Sand	Mountain Soil (undifferentiated)	0.070
Sandy Loam	Camasan Sandy clay loam	0.265
Loam	-	0.368
Silt Loam	-	0.420
Clay Loam	La Castellana clay loam, Minta clay loam	0.253
Silty Clay Loam	San manuel silty clayloam	0.315
Silty Clay	-	0.230
Sand Clay	-	0.145
Clay	Mtina Clay, Tugbok Clay	0.183

Source: David, W.P.: Soil and Water Conservation Planning: Issues and Recommendations, Journal of Philippine Development, No.26, Vol.XV, No.1, 1988.

3) Topographic Factor (LS)

The topographic factor is a combination of two factors, L and S, where L is the slope length factor, representing the effect of slope length on erosion and S is the slope steepness, representing the effect of slope steepness on erosion. In the study, LS factor is produced using a computer algorithm (Desmet & Govers, 1996) which is an extension of QGIS software. This method is based on the use of Digital Elevation Model (DEM) with a 90m resolution produced from Interferometric Synthetic Aperture Radar (IFSAR) data. Figure 2.8.3 shows the spatial distribution of estimated LS factor.



Source: Project Team

Figure 2.8.3 Soil Erodibility Factor (K) and Topographic Factor (LS)

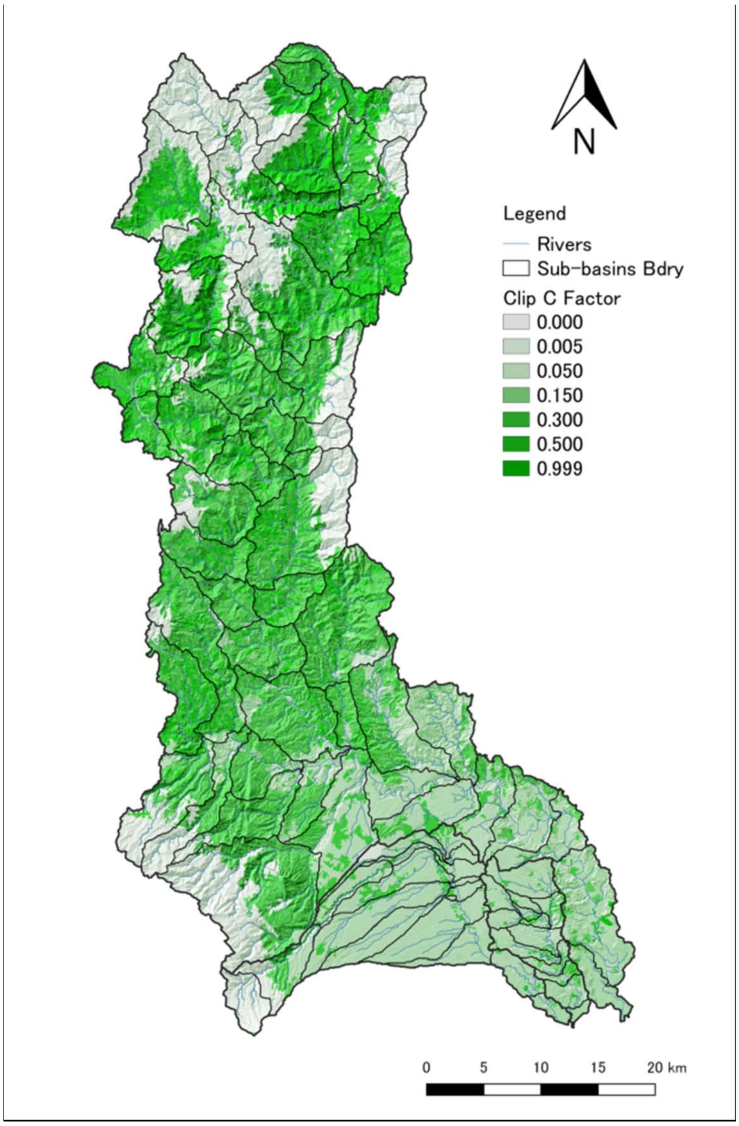
4) Cover/Crop Management Factor (C)

The C factor is introduced to reflect the influence of land cover on the erosion rate. The C factor ranges from near 0 for higher density of vegetation to 1 for barren land. From the land cover data by DENR, the coefficients shown in Table 2.8.6 are adopted according to its classification.

Table 2.8.6 Cover/Crop Management Factor

Land Cover	NAMRIA Category	C Factor
Annual Crop	Other land, cultivated, annual crop	0.300
Barren	Other land, natural, barren land	1.000
Built-up Area	Other land, built-up area	0.100
Fallow	Other wooden land, fallow	0.300
Forest	Open forest, broadleaved	0.005
	Closed forest, broadleaved	
	Closed forest, mixed	
	Bamboo/palm formation	
Grassland	Other land, natural grassland	0.500
Mixed Vegetation	Other wooden land, wooden grassland	0.050
	Other land, cultivated, perennial crop	
Shrubs	Other wooden land, shrubs	0.150
Water Area	Inland water	0.000
	Other land, fishpond	
Wet Area	Mangrove forest	0.000

Source: David, W.P.: Soil and Water Conservation Planning: Issues and Recommendations, Journal of Philippine Development, No.26, Vol.XV, No.1, 1988.



Source: Project Team

Figure 2.8.4 Cover/Crop Management Factor (C)

5) Conservation Practice Factor (P)

The P factor represents erosion reducing measures such as terraces or ridging/contouring. With no erosion-control practice, P = 1.0. In this study, P is assumed as 1.0, considering lacking of soil conservation practices within the basin.

(2) Estimated Sediment Yield

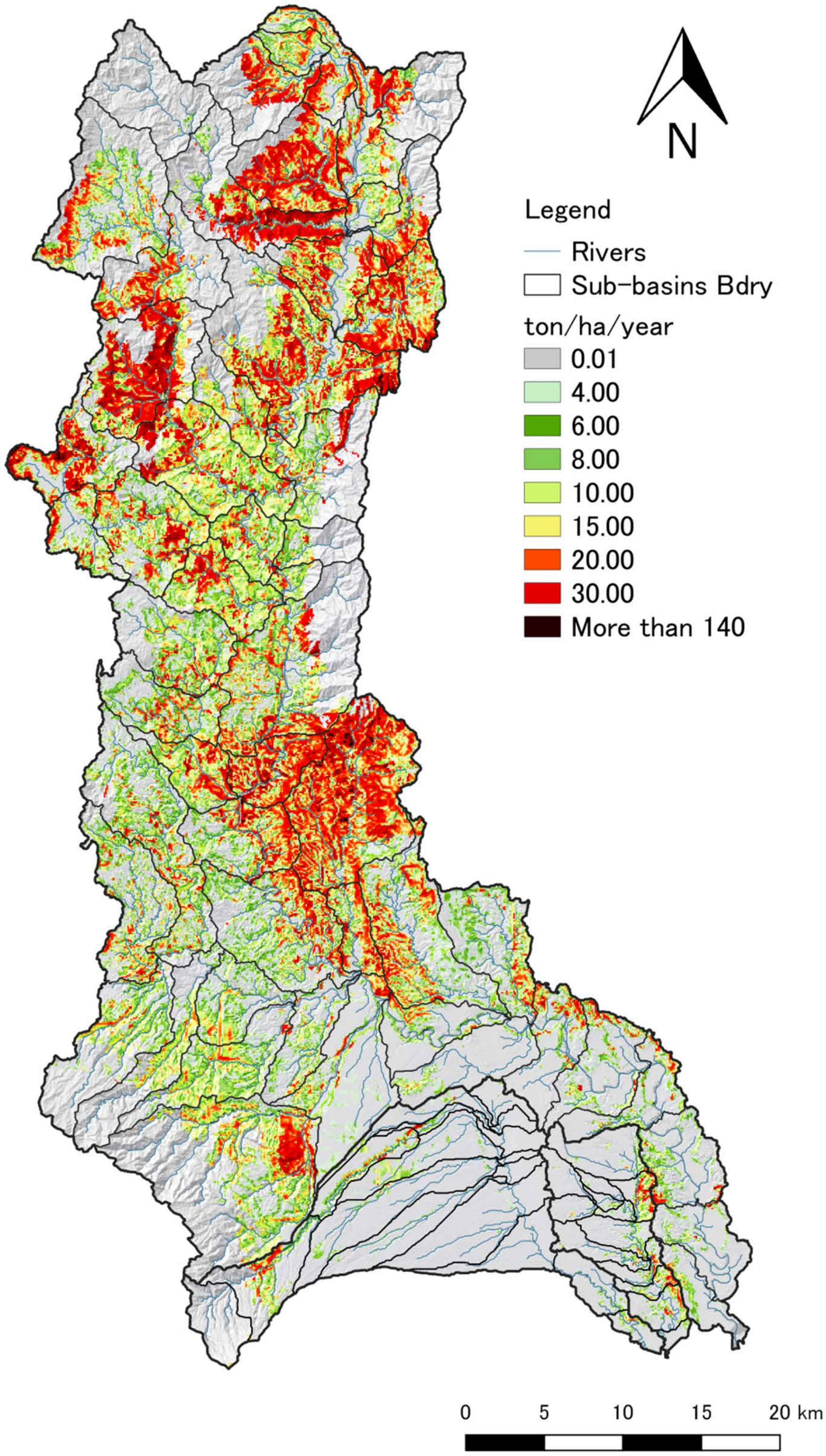
The estimated sediment yield in the entire study basins under the existing condition is 1,781.63 thousand tons per year. Table 2.8.7 shows the sediment yield by sub-basins in each target basin.

Table 2.8.7 Estimated Sediment Yield by Sub-Basin

Basin	SB ID	Area(km²)	Sediment Yield	
			ton/ha/year	thousand ton/year
Davao	D-B1	28.5	8.56	24.37
	D-B2	8.9	9.83	8.73
	D-B3	16.9	11.28	19.05
	D-B4	30.0	7.19	21.54
	D-B5	18.5	9.79	18.15
	D-B6	34.9	18.81	65.58
	D-B7	7.8	8.74	6.84
	D-B8-1	36.4	0.10	0.36
	D-B8-2	43.7	14.48	63.24
	D-B9	20.0	9.30	18.63
	D-B10	27.2	14.02	38.09
	D-B11	30.5	19.04	57.99
	D-B12	75.3	14.10	106.14
	D-B13	18.6	8.18	15.24
	D-B14	38.9	8.28	32.22
	D-B15-1	60.0	6.26	37.56
	D-B15-2	34.8	7.44	25.87
	D-B15-3	47.5	20.33	96.53
	D-B15-4	46.6	15.07	70.17
	D-B16	15.9	11.27	17.95
	D-B17	13.3	4.56	6.07
	D-B18	5.9	8.02	4.74
	D-B19-1	28.5	20.52	58.42
	D-B19-2	16.1	10.20	16.43
	D-B19-3	36.5	11.53	42.08
	D-B19-4	25.7	13.59	34.97
	D-B20	75.0	8.84	66.32
	D-B21	19.3	27.78	53.68
	D-B22-1	35.5	6.86	24.35
	D-B22-2	27.0	7.87	21.27
	D-B22-3	17.8	14.39	25.56
	D-B24	28.8	13.46	38.75
	D-B25	50.7	9.35	47.37
	D-B26-1	71.0	24.94	177.11
	D-B26-2	12.4	16.16	20.11
	D-B27-1	36.5	7.02	25.63
	D-B27-2	42.6	4.14	17.65
	D-B27-3	54.6	6.95	37.94
	D-B27-4	29.7	3.45	10.25
	D-B27-5	21.5	6.05	13.03
	D-B27-6	31.8	6.59	20.97
	D-B27-7	20.8	4.71	9.79
	D-B28-1	101.9	5.76	58.75
	D-B28-2	46.7	3.93	18.33
	D-B29	21.9	3.68	8.05

Basin	SB ID	Area(km²)	Sediment Yield	
			ton/ha/year	thousand ton/year
Davao	D-B30	50.7	9.82	49.80
	D-B31	26.8	1.67	4.49
	D-B32	33.5	5.66	18.94
	D-B33	23.9	4.92	11.75
	D-B34	28.2	3.70	10.46
	D-B35	19.4	3.48	6.76
	Downstream	47.3	2.77	13.09
	River mouth	12.9	2.39	3.07
	Davao River Catchment	1755.0	9.56	1720.25
Talomo	TSB-1	14.9	0.14	0.21
	TSB-2	20.5	4.73	9.69
	TSB-3	11.7	4.34	5.07
	TSB-4	19.4	3.01	5.84
	TSB-5	28.8	1.84	5.29
	TSB-6	18.7	1.71	3.21
	TSB-7	9.7	1.83	1.77
	TSB-8	14.8	0.98	1.44
	TSB-9	29.3	1.27	3.73
	TSB-10	3.5	4.87	1.70
	TSB-11	5.2	0.65	0.34
	TSB-12	2.7	0.28	0.08
	TSB-13	5.5	0.35	0.20
	TSB-14	3.1	0.85	0.26
	TSB-15	1.2	0.76	0.09
	TSB-16	10.6	1.23	1.30
	TSB-17	4.6	2.21	1.02
	Talomo River Catchment	204.2	1.83	41.23
Matina	MSB-1	15.0	1.31	1.97
	MSB-2	5.6	0.58	0.32
	MSB-3	5.2	9.37	4.90
	MSB-4	2.5	1.32	0.33
	MSB-5	1.6	2.40	0.39
	MSB-6	4.2	1.14	0.48
	MSB-7	1.9	2.83	0.55
	MSB-8	8.2	2.57	2.10
	MSB-9	7.7	1.74	1.35
	MSB-10	4.8	3.53	1.70
	MSB-11	3.6	6.65	2.39
	MSB-12	7.7	4.50	3.45
	MSB-13	1.9	1.18	0.23
	Matina River Catchment	70.0	3.01	20.14
	Study Area	2029.2	6.95	1781.63

Source: Project Team



Source: Project Team

Figure 2.8.5 Estimated Sediment Yield

2.8.4 Riverbed Changes

(1) Consideration of Riverbed Changes

1) Current Condition of River mouth Deposition

Temporal variation of the river mouth of target rivers are supposed by aerial photos. As shown in Figure 2.8.6, there is no significant extension trend of the delta of the Davao River. Conversely, regarding the Matina River and the Talomo River, it is recognized that these river mouth delta has extended comparing with 2000.

Source: Project Team

Figure 2.8.6 River mouth Aerial Photo of Davao River by time

Source: Project Team

Figure 2.8.7 River mouth Aerial Photo of Matina River and Talomo River by time

2) Channel bed Dredging at River mouth

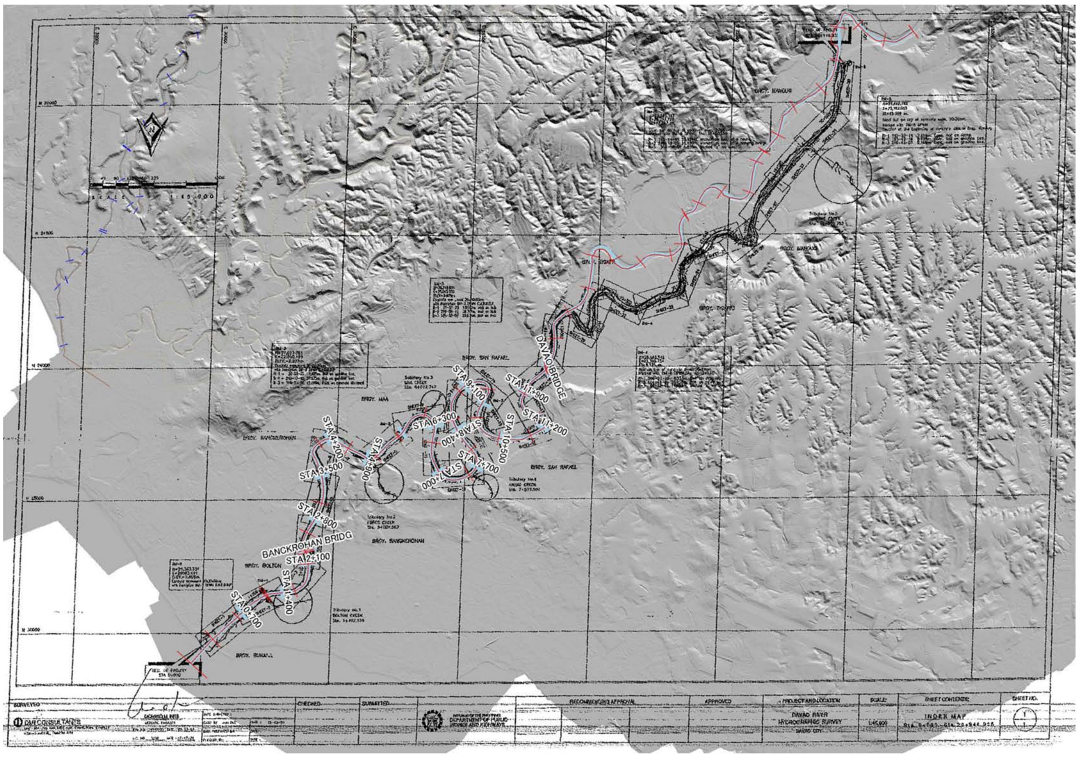
Riverbed excavation or dredging is one of the alternatives for improving the flow capacity. However, excavation works at river mouth is affected by tide and drifting sand and could be inferior to the economical aspect. In addition, since deep excavation causes burying of the dredging parts, it is difficult to maintain the design channel shape. Therefore, considering the design tide level, the proper design channel shape is determined in this project. The design channel shape at the river mouth part will be described in Chapter 3.

3) Necessity of Excavation/Dredging Works at River mouth Channel

As written above, the improvement effect of excavation/dredging at the river mouth is limited, but even so the river bed aggradation trend at the river mouth portion is indicated regarding the Matina River and the Talomo River, therefore, the proper dredging works would be required to maintain river flow capacity. Thus, it should be continued that the river topographical survey and sediment discharge monitoring, and also should make great effort to figure out the inflow and outflow amount of sediment discharge.

4) Channel variation by Comparison of River Topographical Survey

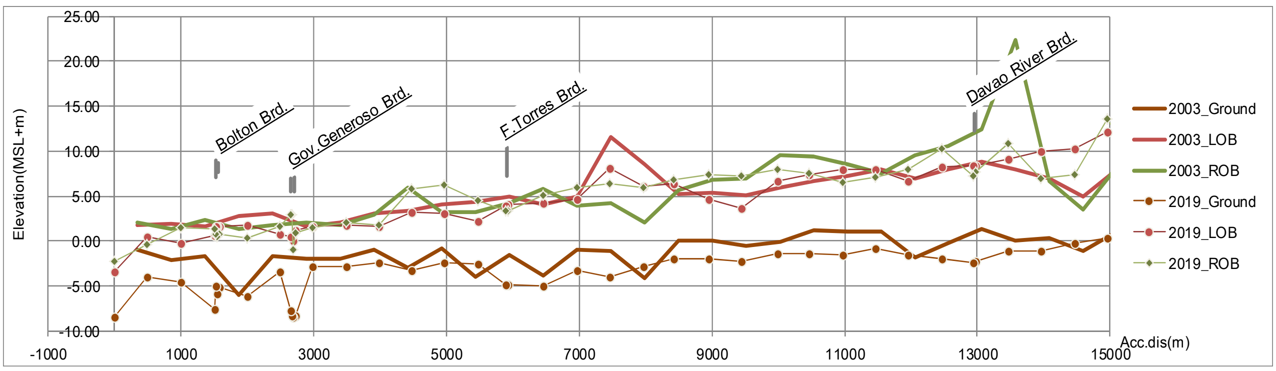
For considering the channel variation over time, in the case of the Davao River, there is an available past river survey result, 2003 survey result. When overlaying the 2003 survey result on the thematic map which was created in this project, these have a significant difference of river alignment in the section of upstream from the Davao River Bridge (see Figure 2.8.8), therefore, a comparison study is targeted the section of the downstream of the Davao River Bridge.



Source: Project Team

Figure 2.8.8 2003 River Survey Result of Davao River

The longitudinal profile of the downstream section from the Davao Bridge is shown in Figure 2.8.9. According to this, a river bed degradation is significant from 8.5 km to 14 km and the depth of degradation is 2 to 2.5 m. However, since a larger-scale flood occurred in 2002, it is assumed that the river bed condition of 2003 survey was temporary change caused by that flood. The local scours around the bridges also are found in the survey of this project. Although the storage of continuous river survey data of the Davao River in the future is required to understand the change of riverbed, from the viewpoint of available data at the moment, the riverbed trends degrading and that trend is significant around bridges.



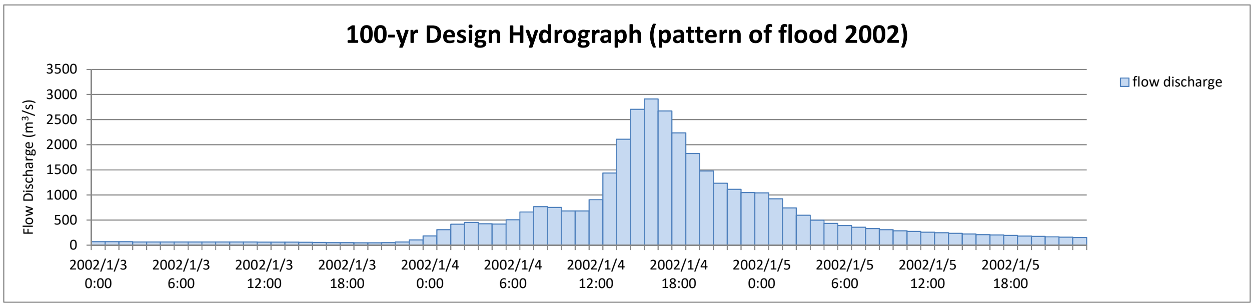
Source: Project Team

Figure 2.8.9 Comparison of Longitudinal Profile of Davao River

(2) Riverbed Change Analysis

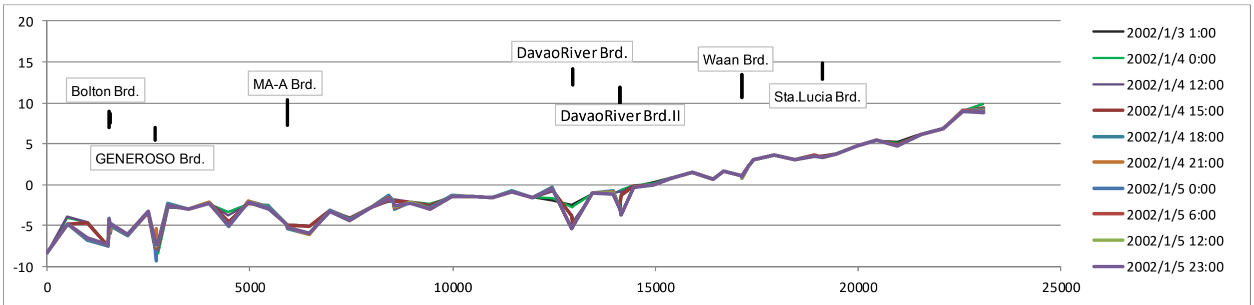
Using the result of the riverbed material survey, the sediment transportation analysis model is created to study the riverbed changes. The HEC-RAS 1D hydraulic model, which is the same model as the flood simulation, is applied to the analysis. The inflow sediment discharge at the upstream end is estimated by the flow discharge (Q) - sediment discharge (Qs) function which determined in Section 2.8.2 Past Study of Sediment Production. Flow discharge condition and the other boundary conditions are the same as those in the flood analysis.

As a result of the sediment transportation analysis, it is recognized that scours occurred around the bridge parts and those started immediately after the peak of the hydrograph. For example, since the local scour at the Davao River Bridge was also found at the site survey, the countermeasure against scour should be considered if reconstruction of the bridge through the river improvement works. While, there is no significant scour/degradation at the other portion. Therefore, it is expected that the riverbed would be maintained against even the design scale flood.



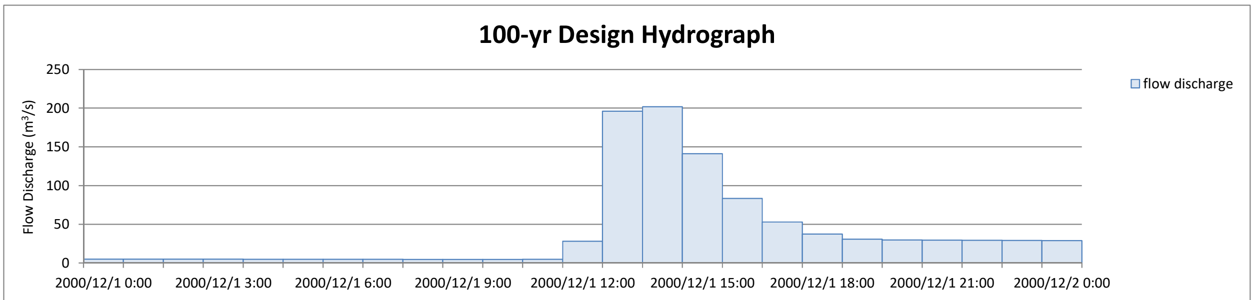
Source: Project Team

Figure 2.8.10 Object Hydrograph for Riverbed Change Analysis (Davao River)



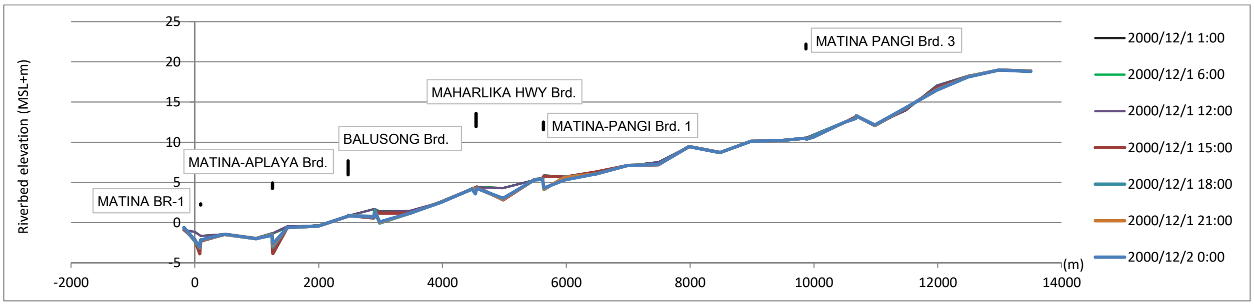
Source: Project Team

Figure 2.8.11 Analysis Result of Riverbed Analysis (Davao River)



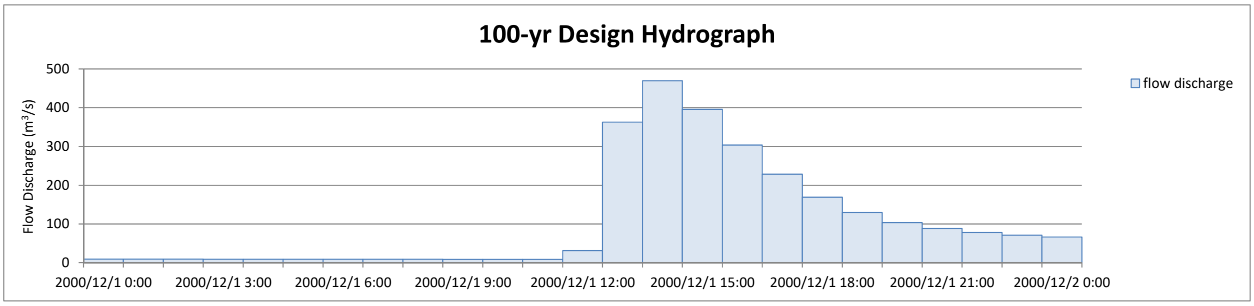
Source: Project Team

Figure 2.8.12 Object Hydrograph for Riverbed Change Analysis (Matina River)



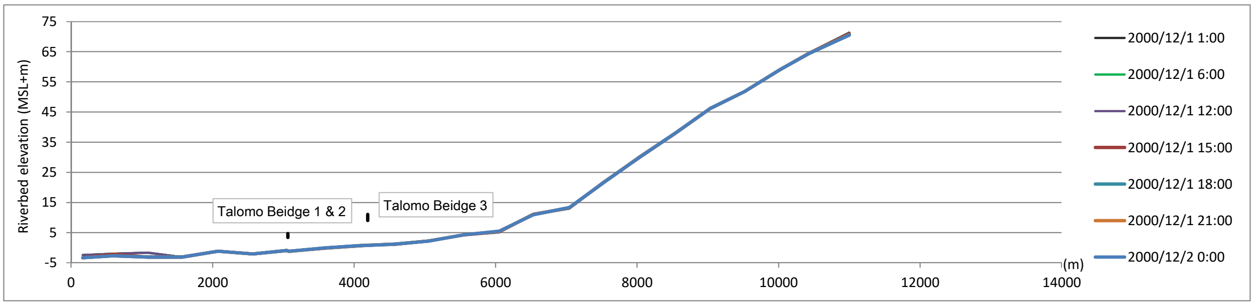
Source: Project Team

Figure 2.8.13 Analysis Result of Riverbed Analysis (Matina River)



Source: Project Team

Figure 2.8.14 Object Hydrograph for Riverbed Change Analysis (Talomo River)



Source: Project Team

Figure 2.8.15 Analysis Result of Riverbed Analysis (Talomo River)

This riverbed change analysis is what based on the Q-Qs function which is estimated by the available data at the moment, and the verification of the analysis could not be executed by river survey results over time. Therefore, it has to say that the analysis result is insufficient to figure out long term riverbed change. Thus, in order to increase the accuracy of the analysis, it is highly recommended that continuous sediment discharge monitoring including flood time, and regular river survey be conducted.

2.9 Inland Flood Analysis

2.9.1 Inland Flood and Damage

Frequent inland flooding still exists in Davao City, although a lot of efforts have been made in the past to alleviate the problem.

According to the information provided by DPWH and the Davao City City Engineering Office (DCCEO), though the depth of inundation is less than 0.5m and the duration for many of the frequent floods is a few hours at maximum, it affects traffic conditions and economic activities, and thus requires improvement for securing proper urban function. For example, the frequent inundation to the La Verna area disrupts traffic on the access road to the airport in Davao City, which therefore needs urgent improvement.

2.9.2 History of Storm Water Drainage Improvement

(1) Storm Water Drainage Improvement

In Davao City, the storm water drainage system has been improved on the basis of the storm water drainage master plan prepared in 1982 (M/P1982). Table 2.9.1 briefs the history of storm water drainage improvement in Davao City.

Table 2.9.1 Brief History of Storm Water Drainage Improvement in Davao City

Year	Outline
1982	Preparation of Storm Water Drainage master Plan (M/P1982) which mainly targeted main drainages in Davao City under World Bank funded project for the Regional Cities Development Project (RCDP) Target Drainage Area: • Roxas Drainage Main • Agdao Drainage Main (Agdao and Dacudao) • Jerome Drainage Main (Lanang) • Insular Creek (Mamay Creek) Target Safety Level for drainage channel : 2 year return period
1980s	Implementation of the M/P1982 under RCDP
1998	Preparation of Storm Drainage Master Plan for Davao City (M/P1998) including Detail design for 25 priority projects and Preparation of master plan for 6 drainage areas which were not covered by M/P 1982 Target Drainage Area: • Lizada • Dumoy • Matina Aplaya • Ma-a • Buhangin Proper (Upper catchment of Insular Creek) • Panacan (Only for the area which directly drains to the sea) Target Safety Level for drainage channel: 25 year return period for main drainage and 10 year return period for lateral drainage are explored to apply. Hoverer, 2 year return period was actually adopted for many cases flowing M/P 1982.
2000	Implementation of rehabilitation of 20 drainage channels (Project Cost 0.118Billion Php)
2001	Study of main drainage system by Task Force Drainage Target Drainage Area: • Agdao Drainage Main (For improvement of Obrero area) • Jerome Drainage Main (Lanang) • Insular Creek (Mamay Creek) • Sasa Creek • Pagamican Creek (Part of Panacan river basin)
2004	Implementation of 18 storm water drainage improvement projects（Project Cost 0.250Billion Php）
2016 -	Implementation of storm water drainage improvement projects by DPWH-DEO Average Annual Investment in 2016-2020: 0.46Billion Php

Source: Project Team

(2) Sewerage System

The development of sewerage system in the central part of Davao City has been proposed for long time, it has not yet been implemented, however. On the basis of the Infrastructure development plan for Davao City in 2018 supported by JICA, the necessity of the sewerage system was reconfirmed. To promote the development of the sewerage system, JICA conducted the data collection survey in 2019. In the study, the separate sewerage system, which deals with storm water and sewerage separately, in the central part of Davao City was recommended in principle.

2.9.3 Drainage Inventory

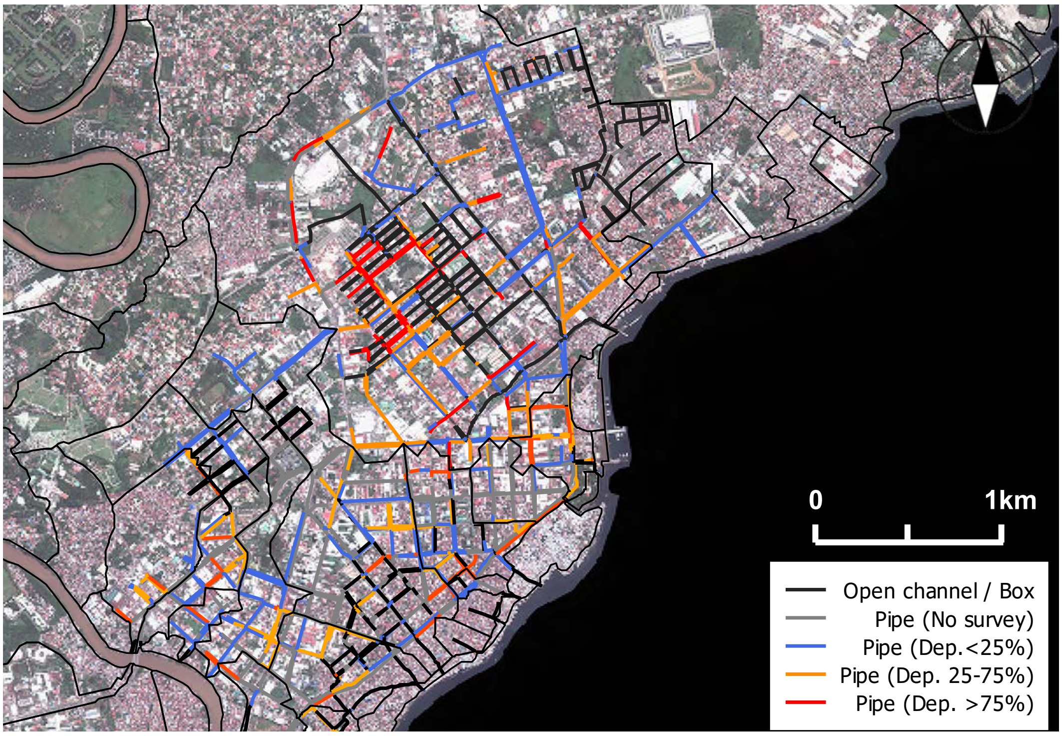
DPWH-RO in coordination with DCCEO has been made effort on preparing the drainage inventory, in accordance with the recommendation provided in M/P1998. In the present project, the additional information was obtained by the drainage inventory, which includes manhole survey and cross-sectional survey of channel for Poblacion and Agdao areas. The drainage network model data for the Poblacion and Agdao areas have been almost completed. The data for the additional survey have not yet been processed for preparing the drainage network model data. It will be completed by the end of Phase 3.

As for the drainage network model data for the Poblacion and Agdao areas, the total numbers of node and link are 1415 and 1741, respectively. The total length of the links is 131.1km: open channel 22.8%, closed conduit 6.9% and pipe 70.3%.

The sediment deposition was observed in about 70% of all pipes. Among the observed pipes, the percentage of the sedimentation in the pipes is as follows.

- Ratio of Deposition - Less than 25% : 33.1% in the total surveyed pipe length
- Ratio of Deposition - 25-75% : 47.9% in the total surveyed pipe length
- Ratio of Deposition - More than 75% : 19/0% in the total surveyed pipe length

The special distribution of sedimentation in the pipes is presented in Figure 2.9.1.



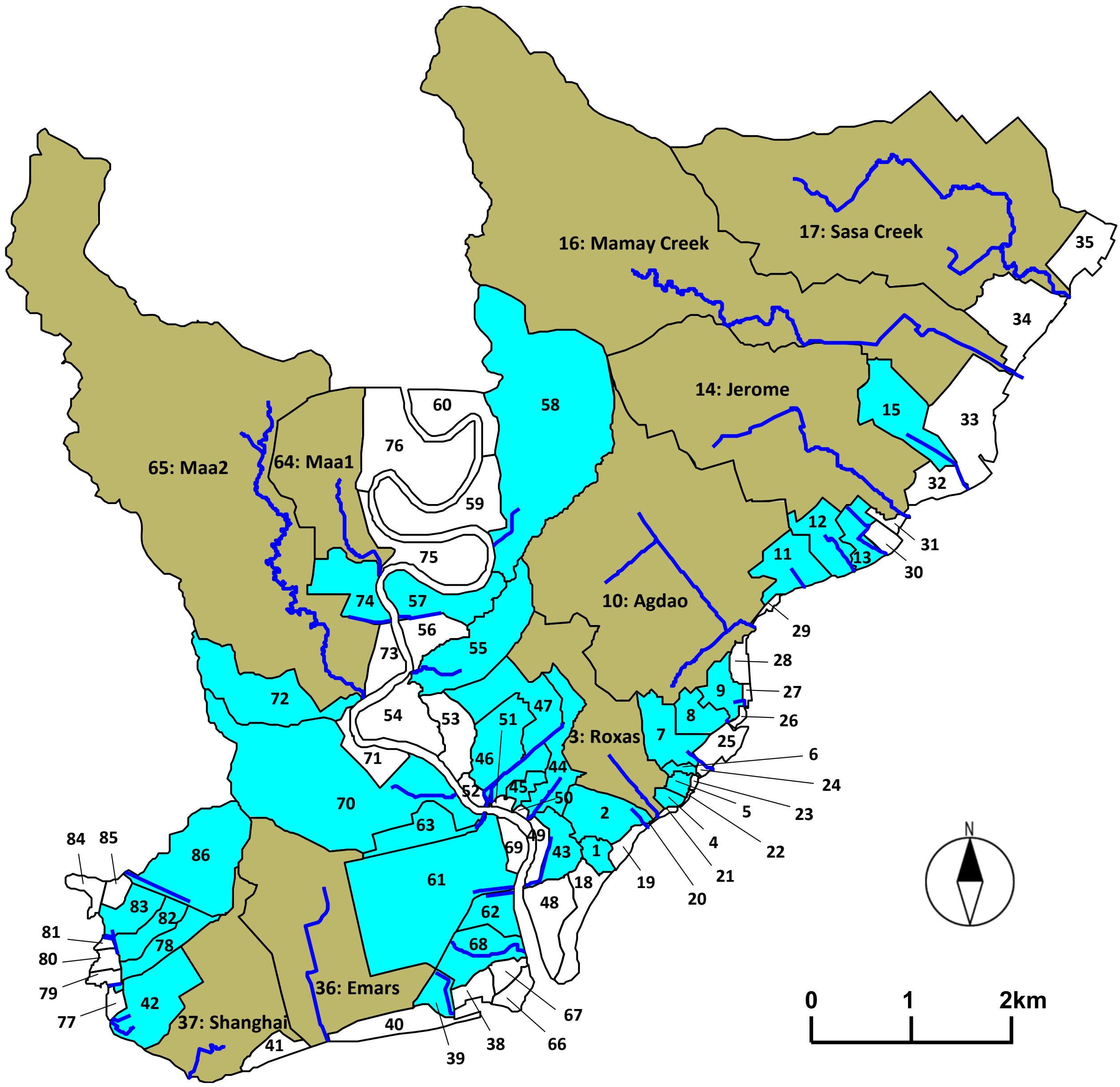
Source: Project Team

Figure 2.9.1 Spatial Distribution of Sedimentation in Pipes

2.9.4 Drainage System

(1) Delineation of Drainage Area

By referring to the results of the drainage inventory survey, topographic condition by the Lidar and road network, the boundary of the drainage area was delineated for the area surrounding the downstream reach of Davao River, which is bounded from the Sasa Creek area at the east end to the left bank area of the lower Matina River at the west end. The delineated drainage boundaries are presented in Figure 2.9.2. The list of drainage areas is shown in Table 2.9.2.



Remarks: The number shown in the figure corresponds to SN in Table 2.9.2.

Source: Project Team

Figure 2.9.2 Delineated Drainage Area Boundaries

Table 2.9.2 List of Drainage Areas

SN	Name	Flow To	Area (ha)	Average slope (%)	Percent of urban type land use (%)	Category
1	**Bucana**	Davao Gulf	9.81	0.192	100	**S**
2	**Mabini**	Davao Gulf	35.61	0.171	88	**S**
3	**Roxas**	Davao Gulf	139.19	0.601	86	**M**
4	**Jacinto**	Davao Gulf	4.71	0.203	98	**S**
5	**Fatima**	Davao Gulf	5.23	0.314	99	**S**
6	**Suzao**	Davao Gulf	3.68	0.285	99	**S**
7	**Ponce**	Davao Gulf	32.01	0.121	78	**S**
8	**Magsaysay**	Davao Gulf	18.87	0.261	100	**S**
9	**StAna**	Davao Gulf	18.53	0.460	92	**S**
10	**Agdao**	Davao Gulf	514.45	1.605	88	**M**
11	**Gotamco**	Davao Gulf	33.51	0.229	95	**S**
12	**Technotrade**	Davao Gulf	29.47	0.133	96	**S**
13	**Nagsil**	Davao Gulf	19.92	0.097	98	**S**
14	**Jerome**	Davao Gulf	421.24	2.515	86	**M**
15	**SouthBay**	Davao Gulf	52.32	1.892	99	**S**
16	**Mamay Creek**	Davao Gulf	891.27	11.036	63	**M**
17	**Sasa Creek**	Davao Gulf	596.86	4.850	66	**M**
18	DG01	Davao Gulf	27.12	0.394	100	T
19	DG02	Davao Gulf	7.38	0.654	99	T
20	DG03	Davao Gulf	0.48	0.682	100	T
21	DG04	Davao Gulf	1.13	0.682	100	T
22	DG05	Davao Gulf	0.74	1.260	100	T
23	DG06	Davao Gulf	1.09	0.675	100	T
24	DG07	Davao Gulf	1.67	0.359	97	T
25	DG08	Davao Gulf	14.47	0.174	98	T
26	DG09	Davao Gulf	1.80	0.415	13	T
27	DG10	Davao Gulf	1.84	1.053	74	T
28	DG11	Davao Gulf	7.83	0.720	67	T
29	DG12	Davao Gulf	2.06	0.278	100	T
30	DG13	Davao Gulf	7.93	0.588	100	T
31	DG14	Davao Gulf	4.68	0.368	100	T
32	DG15	Davao Gulf	18.77	0.466	89	T
33	DG16	Davao Gulf	70.66	0.569	65	T
34	DG17	Davao Gulf	56.77	1.220	96	T
35	DG18	Davao Gulf	29.59	0.743	98	T
36	**Emars**	Davao Gulf	241.84	3.220	76	**M**
37	**Shanghai**	Davao Gulf	160.39	1.121	65	**M**
38	DG51	Davao Gulf	11.17	0.257	94	T
39	**DG52**	Davao Gulf	13.17	0.460	90	**S**
40	DG53	Davao Gulf	27.78	0.715	95	T
41	DG54	Davao Gulf	13.61	0.790	77	T
42	DG55	Davao Gulf	54.73	0.564	87	**S**
43	**Bolton L**	Davao RIver	23.52	0.396	82	**S**
44	**Anda**	Davao RIver	37.70	0.279	85	**S**
45	**Pelayo**	Davao RIver	8.42	0.495	98	**S**
46	**Quirino L A**	Davao River	42.30	2.431	88	**S**
47	**Quirino L B**	Davao River	63.69	2.252	79	**S**
48	DL01	Davao River	33.12	0.298	98	T
49	DL02	Davao River	8.85	0.885	80	T
50	DL03	Davao River	1.41	1.096	100	T
51	DL04	Davao River	2.56	1.242	100	T
52	DL05	Davao River	5.57	2.258	98	T
53	DL06	Davao River	28.84	7.206	64	T
54	DL07	Davao River	42.41	8.097	75	T
55	**DL08**	Davao River	72.38	6.420	69	**S**
56	DL09	Davao River	22.49	5.394	85	T
57	**DL10**	Davao River	40.71	3.907	70	**S**
58	**DL11**	Davao River	263.17	5.249	99	**S**
59	DL12	Davao River	56.55	2.270	38	T
60	DL13	Davao River	35.76	5.674	67	T
61	**Bolton R A**	Davao RIver	173.02	0.475	90	**S**
62	**Bolton R B**	Davao River	20.33	0.501	40	**S**
63	**Quirino R**	Davao River	28.87	1.067	83	**S**
64	**Maa 1**	Davao River	141.30	1.753	72	**M**
65	**Maa 2**	Davao River	902.68	16.378	39	**M**
66	DR01	Davao River	10.40	0.092	82	T
67	DR02	Davao River	8.94	0.058	94	T
68	**DR03**	Davao River	34.33	0.260	95	**S**
69	DR04	Davao River	11.70	0.568	100	T
70	**DR05**	Davao River	218.29	7.169	57	**S**
71	DR06	Davao River	20.85	1.812	75	T
72	**DR07**	Davao River	70.89	13.744	33	**S**
73	DR08	Davao River	18.93	1.133	76	T
74	**DR09**	Davao River	38.96	1.869	60	**S**
75	DR10	Davao River	45.65	1.658	30	T
76	DR11	Davao River	89.37	3.292	36	T
77	ML01	Matina River	5.34	1.501	32	T
78	ML02	Matina River	24.08	0.716	98	**S**
79	ML03	Matina River	5.16	0.483	68	T
80	ML04	Matina River	5.43	1.055	98	T
81	ML05	Matina River	2.11	1.860	21	T
82	**ML06**	Matina River	20.53	0.556	99	**S**
83	**ML07**	Matina River	22.05	0.943	77	**S**
84	ML08	Matina River	9.08	2.589	48	T
85	ML09	Matina River	7.49	1.430	99	T
86	**ML10**	Matina River	87.69	8.365	86	**S**

Source: Project Team

Remarks: "Percent of urban type land use" is the share of residential, commercial, industrial, mixed use, road against total drainage area in 2017

Category: M=Main Drainage Area, S=Secondary Drainage Area, T＝Tertially Drainage Area

(2) Category of Drainage Area and Channel

The delineated drainage areas have different magnitude of area and channels. The category of the drainage area is proposed as follows.

- Main Drainage Area
  Drainage area which was studied as main drainage area in M/P 1982 or M/P1998
- Secondary Drainage Area
  Except main drainage area, the drainage area which has clear drainage channel that reaches to the outlet of the drainage area such as outfall
- Tertially Drainage Area
  Other residual drainage areas besides the main and secondary drainage areas

In M/P1982, the drainage channel was categorized into the following two; Main drainage – principle drainage channel which drains the most of runoff in the drainage area and reaches to the outlet of the drainage area with more than about 50ha in area, and Lateral drainage – other drainage channels. In the present study, the drainage channels are proposed to be categorized as follows.

- Main Drainage Channel
  In main drainage area, principle drainage channel which drains the most of runoff in the drainage area and reaches to the outlet of the drainage area
- Secondary Main Drainage Channel
  In secondary drainage area, principle drainage channel which drains the most of runoff in the drainage area and reaches to the outlet of the drainage area
- Lateral Drainage Channel
  Other drainage channels

2.9.5 Rainfall Analysis

(1) Probable Rainfall

In Davao City, there is only one meteorological station, Davao station by PAGASA, which has enough rainfall data to discuss short term rainfall intensity. In the present study, the statistical data for short term rainfall intensity at Davao station were obtained from PAGASA. The latest data are shown in Table 2.9.3, which are based on the observed data in 61 years from 1951 to 2012.

Table 2.9.3 Statistical Data on Short Term Rainfall Intensity at Davao Station

T (yrs)	10 mins	20 mins	30 mins	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
2	19.5	30.0	38.2	53.2	65.2	71.6	80.3	85.8	91.4
5	25.1	39.3	51.0	73.2	88.8	96.4	108.7	114.9	121.1
10	28.8	45.4	59.4	86.5	104.5	112.8	127.5	134.1	140.7
15	30.9	48.9	64.2	94.0	113.3	122.1	138.1	145.0	151.8
20	32.4	51.3	67.6	99.3	119.5	128.6	145.5	152.6	159.5
25	33.5	53.2	70.1	103.3	124.2	133.6	151.2	158.5	165.5
50	37.0	59.0	78.1	115.8	138.9	149.0	168.8	176.5	183.9
100	40.5	64.7	85.9	128.1	153.5	164.2	186.3	194.4	202.1

Source: PAGASA

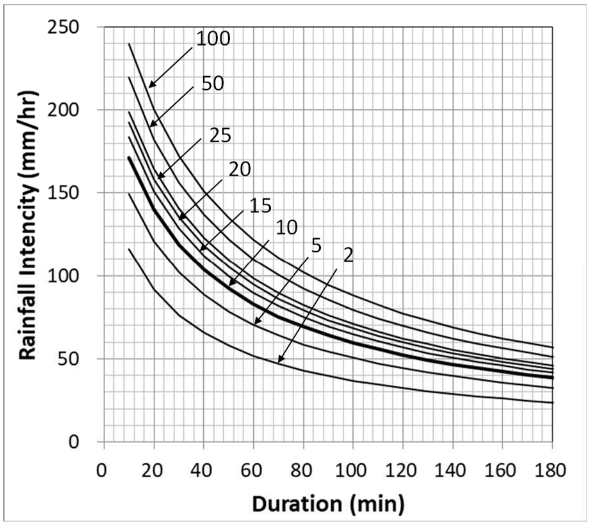
(2) Rainfall Intensity Duration Curve

The probable rainfall shown in Table 2.9.3 is approximated by the following Cleaveland type equation.

$$r(mm/hr) = \frac{a}{(t^n + b)}$$

where a, b, n = coefficient and t = duration of rainfall (min).

The best fitted coefficients were determined in order to minimize the root mean square error. Figure 2.9.3 shows the best fitted approximation curves. The correlation coefficients are more than 0.999.



Davao Station
provided by PAGASA
(based on 61 years data
: 1951-2012)

$$r\ (mm/hr) = \frac{a}{(t^n + b)}$$

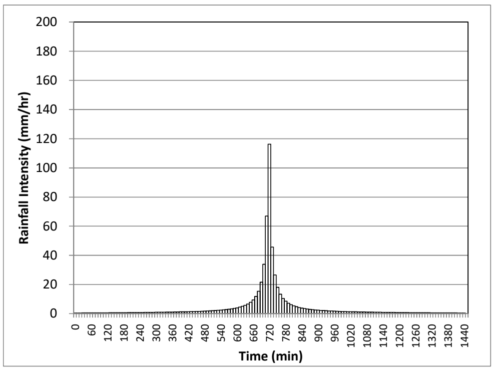
T	a	b	n	r
yr				
2	2920.67	17.260	0.895	0.9998
5	4783.01	23.593	0.926	0.9996
10	6179.89	27.341	0.942	0.9995
15	7013.70	29.297	0.949	0.9994
20	7614.52	30.601	0.954	0.9994
25	8086.05	31.570	0.958	0.9993
50	9581.49	34.372	0.968	0.9992
100	11121.43	36.900	0.976	0.9992

Source: Project Team

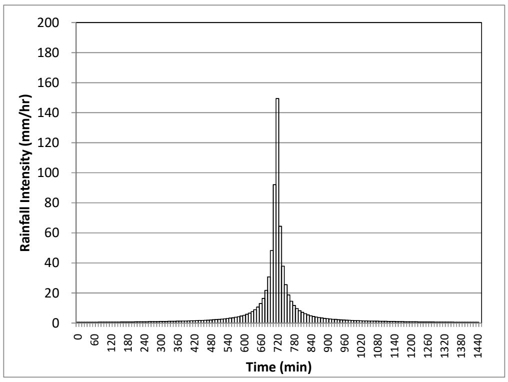
Figure 2.9.3 Rainfall Intensity Duration Curves

(3) Model Hyetograph

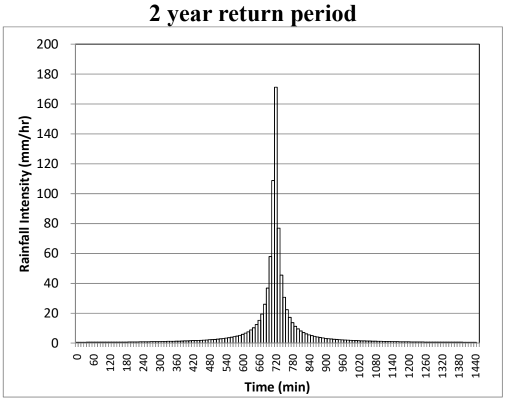
For the discussion on storm water drainage planning, the model hyetograph with a center concentrated type was prepared on the basis of the rainfall intensity duration curves. The model hyetographs for the extreme event with 2, 5, 10 and 25 year return period are presented in Figure 2.9.4.



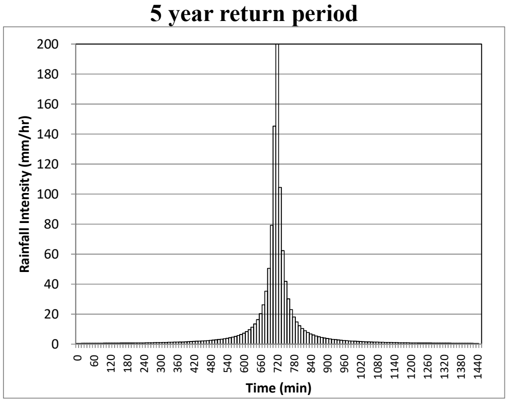
2 year return period



5 year return period



10 year return period



25 year return period

Source: Project Team

Figure 2.9.4 Model Hyetograph

2.9.6 Runoff Analysis and Inundation Simulation

(1) General

In the present project, the macro model for analyzing main drainage channel and the micro model for examining hydraulic behavior of drainage network are introduced, as shown in Table 2.9.4. All models introduced are well-known and used worldwide. They are basically free software or relatively inexpensive commercial software.

Table 2.9.4 Hydrological and Hydraulic Models introduced in the Present Study

	Item	Model	Target Area
Macro Model	1. Inundation analysis due to overflow from main drainage channels 2. Evaluation of design flood discharge along main drainage	HEC-HMS HEC-RAS	Roxas drainage area Agdao drainage area Jerome drainage area Mamay Creek drainage area Sasa Creek drainage area Emars drainage area Shanghai drainage area Maa1 drainage area Maa2 drainage area
Micro Model	Analysis of drainage network including both main and lateral drainage channels	SWMM (Flo2D may be introduced for 2D inundation analysis, which can be used with SWMM)	Poblacion area Agdao area (Matina area) (The area in which the detail drainage network model data exist)

Source: Project Team
SWMM Storm Water Management Model[6]
HEC-RAS: Hydrological Engineering Center River Analysis System[7]
HEC-HMS: Hydrological Engineering Center Hydrological Analysis System[8]

For all analysis, the constant runoff coefficient model is adopted for the loss model in rainfall-runoff modelling, by referring to M/P1982 and M/P 1998.

(2) Runoff Coefficient

The land use map in 2017 has been prepared in the Infrastructure development plan for Davao City in 2018 supported by JICA. In the present study, the land use map in 2017 is used as the existing land use condition. The runoff coefficients by respective land use category shown in Table 2.9.5 were adopted in the present study, by referring to DGCS and M/P1998.

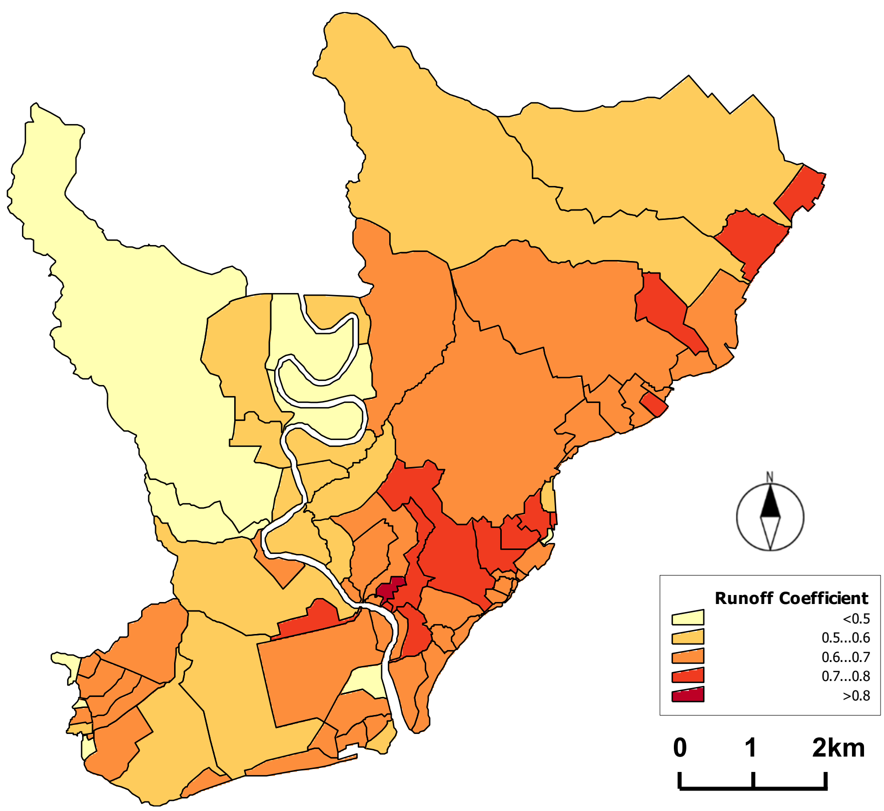
The spatially averaged runoff coefficient for respective drainage area is calculated using the values in Table 2.9.5, which is presented in Figure 2.9.5.

6 Free software for 1-dimensional drainage network flow model developed by US-EPA（US Environmental Protection Agency
7 Free software for 1D and 2D river flow and flood modelling developed by US-ACE（US Army Corps of Engineers）
8 Free software for rainfall-runoff modelling developed by US-ACE（US Army Corps of Engineers）

Table 2.9.5　Runoff Coefficient by Land Use Category

Land Use Category	Adopted Runoff Coefficient in the Present Study	Recommended Value in DGCS	M/P1998
Residential	0.60	High density 0.50 – 0.75 Low density 0.30 - 0.55	General 0.50 – 0.75 Protected 0.30 - 0.65
Commercial	0.80	0.70 - 0.95 (Business district)	General 0.70 – 0.95 Protected 0.75 - 0.85
Industrial	0.80	Light industry 0.50 - 0.80 Heavy industry 0.60 – 0.90	General 0.70 – 0.90 Protected 0.70 - 0.75
Mixed Use	0.70		
Institutional	Density of building more than 40% 0.65 20-40% 0.40 less than 20% 0.25		General 0.65 Special 0.25 Protected 0.60
Agricultural	0.40	0.30 -0.50	
Bushland	0.40		
Forest	0.40	0.30 – 0.50	
Park / Recreational	0.25	0.20 – 0.30	
Open Space	0.25	0.20 – 0.30	0.10
Cemetery	0.25	0.20 – 0.30	
Road	0.90	0.90 -1.00 (Paved)	0.70 – 0.95 (Paved)
Utility	0.30		0.30
Special Use	0.30		
Tourism Development Zone	0.30		0.25
Fish Pond	0.75	0.70 – 0.80 (Flooded)	
Mangrove	0.75	0.70 – 0.80 (Flooded)	
Water Body	1.00		

Source: Project Team, DGCS, M/P1998



Source: Project Team

Figure 2.9.5　Runoff Coefficient by Drainage Area (Existing Condition)

(3) Macro Model

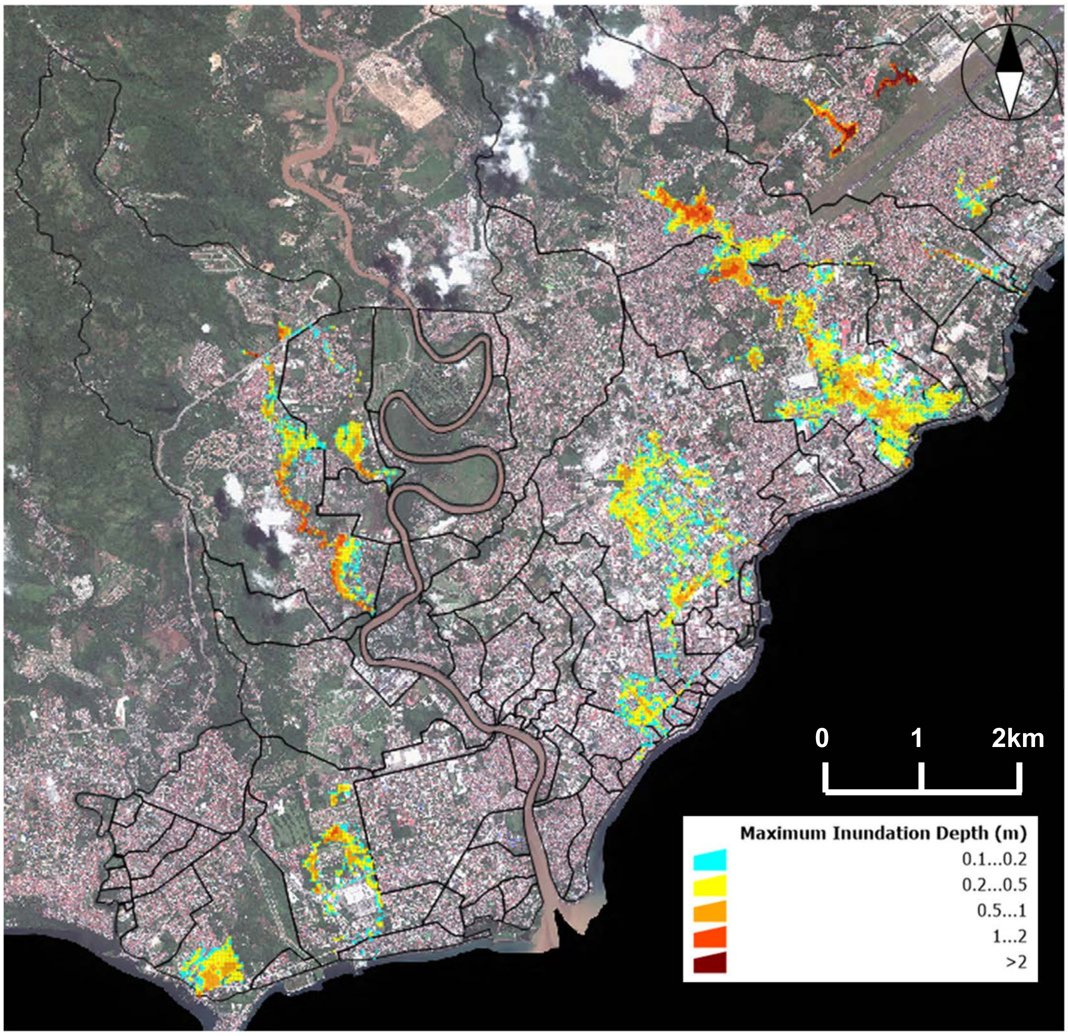
The entire part of the main drainage area has been sub-divided to some sub-catchment areas, then the runoff from each of the sub-catchment area is modelled. As for the rainfall-runoff model for the sub-catchment, the constant runoff coefficient model for loss model and SCS unit hydrograph method for hydrograph have been employed. The delay time for the SCS unit hydrograph method, T_L is estimated as $T_L=0.6T_c$, using the time of concentration, T_c.

The following equation for estimating the time of concentration is adopted, by referring DGCS.

$$T_c = t_0 + t_g + t_d$$

where T_c = time of concentration, t_0=inlet time by overland, t_g=time for flow in gutter or curb, and td=tie for flow in channel. In the present project, it was approximated that t_g was included in t_d.

As the hydraulic model, 1D and 2D coupling flood simulation model by employing HEC-RAS has been employed. The hydraulic behavior in the main drainage channel is analyzed by 1D unsteady flow model and the overflow from the main drainage channel is simulated by plane 2D model. An example of the simulated inundation condition is shown in Figure 2.9.6. The detail for each drainage area is presented in Section 3.7.



25 year return period (Climate change considered, Future land use condition)

Source: Project Team

Figure 2.9.6 Example of Simulated Inundation due to Overflow from Main Drainage Channel

Using the same model, the basic design flood discharge has been set by assuming that there is no overflow from the main drainage channel. The basic design flood discharge for each of the main drainage area is presented in Section 3.7.

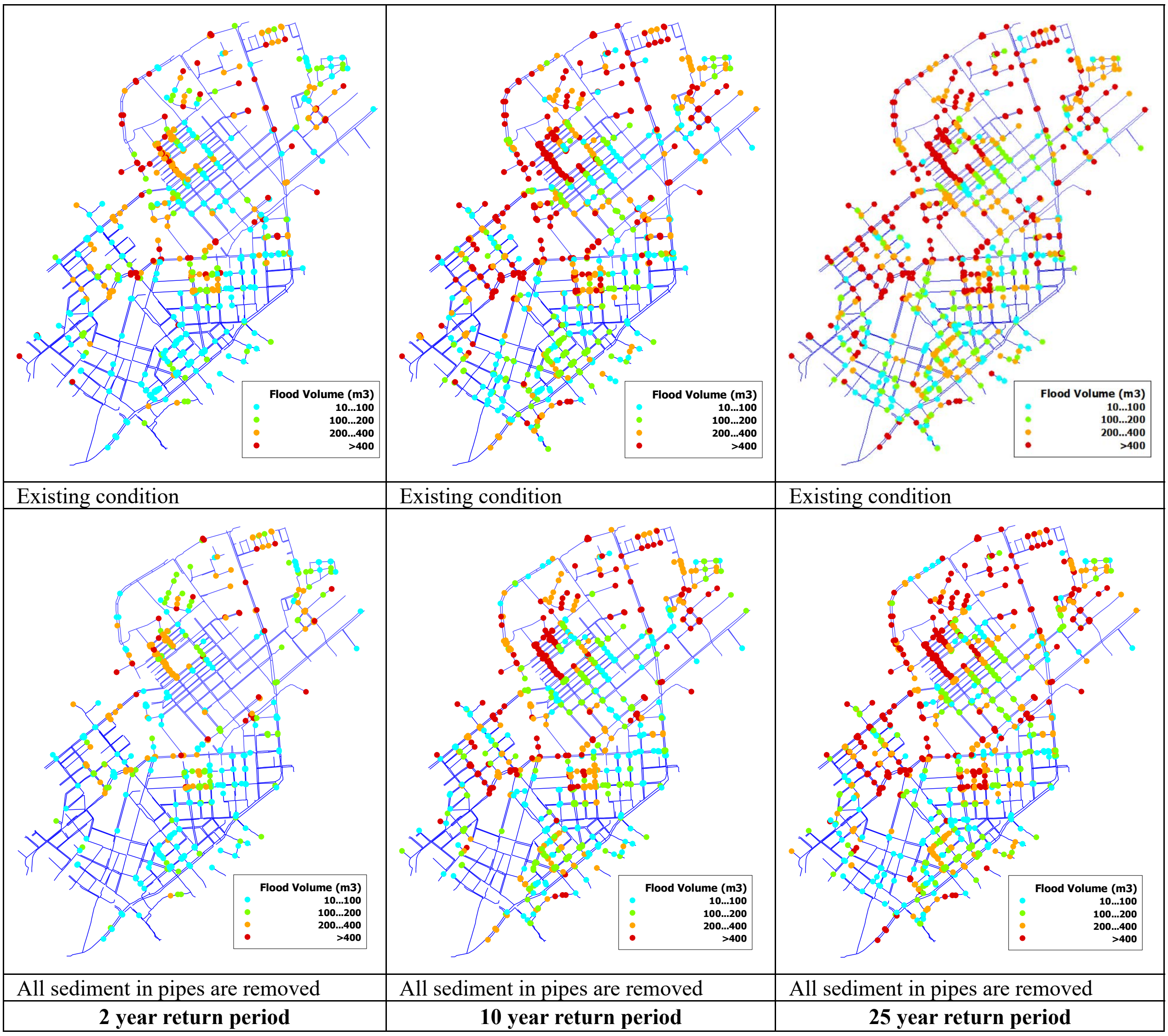
(4) Micro Model

The drainage network model data shown in Section 2.9.3 are inputted to SWMM, then 1D drainage network analysis is conducted. As for the rainfall-runoff model for sub-catchment, the constant runoff coefficient model for loss model and built-in model in SWMM for estimation of hydrograph are employed.

As examples of the simulated results, the results of the following two cases with the climate change considered and with the future land use condition applied.

- Case 1: Existing condition
- Case 2: All sediment in pipes are removed

The spatial distribution of the simulated flood volume for the extreme event with 2, 10 and 25 years return periods is shown in Figure 2.9.7.



Source: Project Team

Figure 2.9.7 Simulated Flood Volume by SWMM

As shown in Table 2.9.6, if all sediment in the pipes is removed, the total flood volume would decrease with about 30% for an extreme event with a 2 year return period. However, for more severe extreme events, the rate of decrease in flood volume is reduced and the flood volume tends to be determined by the original discharge capacity of drainage channels.

Table 2.9.6 Total Flood Volume

Case	2 year return period	10 year return period	25 year return period
1: Existing condition	0.125	0.293	0.392
2: All sediment in pipes are removed	0.083	0.237	0.329

Source: Project Team
Unit: MCM

2.9.7 Major Issues

The major issues on storm water drainage have been identified, on the basis of field reconnaissance, drainage inventory, hydrological and hydraulics analysis, interviews to stakeholders and workshops, as shown below.

(1) Increase in Insufficient Drainage Capacity for Large Scale Runoff

Many drainage channels have been improved to secure enough capacity against the extreme events with 2 year return period, following the concept of M/P1982. The results of hydraulic analysis clarified that many drainage channels would have enough capacity for the extreme events with 2 year return period if bottle necks are improved. However, in general, the drainage channel does not have enough capacity for severer extreme events. It is required to increase the insufficient capacity for large scale runoff.

(2) Recovery of Decreasing Natural Rainwater Retarding Function

Topographical depressions in drainage area have a natural rainwater retarding function. With the retarding function, the discharge at downstream reach has been suppressed. However, the cases that the depression area is transferred to subdivision and/or commercial area are increasing, due to high pressure for urbanization, causing reduction of the natural retarding function. It is important to make it clear the retarding function in the storm water drainage planning. The coordination with land use plan is required when discussing how to deal with the depression area. If the depression area will be developed and protected from inundation in the future, it is necessary to further enlarge the capacity of drainage channels at downstream reach. However, because it could be difficult to implement the drastic improvement of the drainage channels at downstream reach in general, it is necessary to secure and enhance the rainwater regarding function by installing artificial storage facilities.

(3) Consideration on Limited Space for Channel Improvement in Highly Urbanized Area

Most of the target area for storm water drainage in the present project have been highly urbanized. The channel widening of the existing channel would require many resettlement and reconstruction of the existing infrastructure. Even in the case that the channel improvement is conducted within the existing channel, the part of neighboring road and/or land may be temporally used for the construction works. It seems to be difficult to secure such space, according to the past experience in the project implemented by DPWH-DEO. The difficulty to secure the space for construction works for the channel improvement should be considered for the planning of storm water drainage.

(4) Recovery of Reduced Channel Capacity due to Clogging of Drainage Channel

As shown in Section 2.9.3, many drainage channels have been clogged. The results of the simulation for the drainage network clarified that if all sediment in the pipes is removed, the total flood volume would decrease with about 30% for an extreme event with a 2 year return period. Therefore, the recovery of the original drainage capacity by periodical cleaning of the drainage channel and so on is important and fundamental.

(5) Control of Development and Consideration of Disaster Prevention in Infrastructure Development Project in Flood Risk Area

Although the topographical depressions in drainage area is high risk area for inundation, it faces the pressure of urbanization. The high risk area for the flooding around the Davao River has been identified and it has been reflected to the land use planning in Davao City. On the contrast, the risk map for inundation by inland flooding has not yet prepared, and thus the risk area for inundation by inland flooding has not been considered in the land use planning. It is necessary to identify the risk area for the inundation urgently. It is also desired that regulation against development activities in the risk area be applied. In addition, if the part of the risk area is planned to be utilized as a retarding basin, the land use in such area should be regulated for the future implementation of the construction work for the proposed retarding basin.

To well consider disaster prevention in infrastructure development project, it is important to prepare and disseminate the flood risk map.

(6) Sharing Information on Inundation

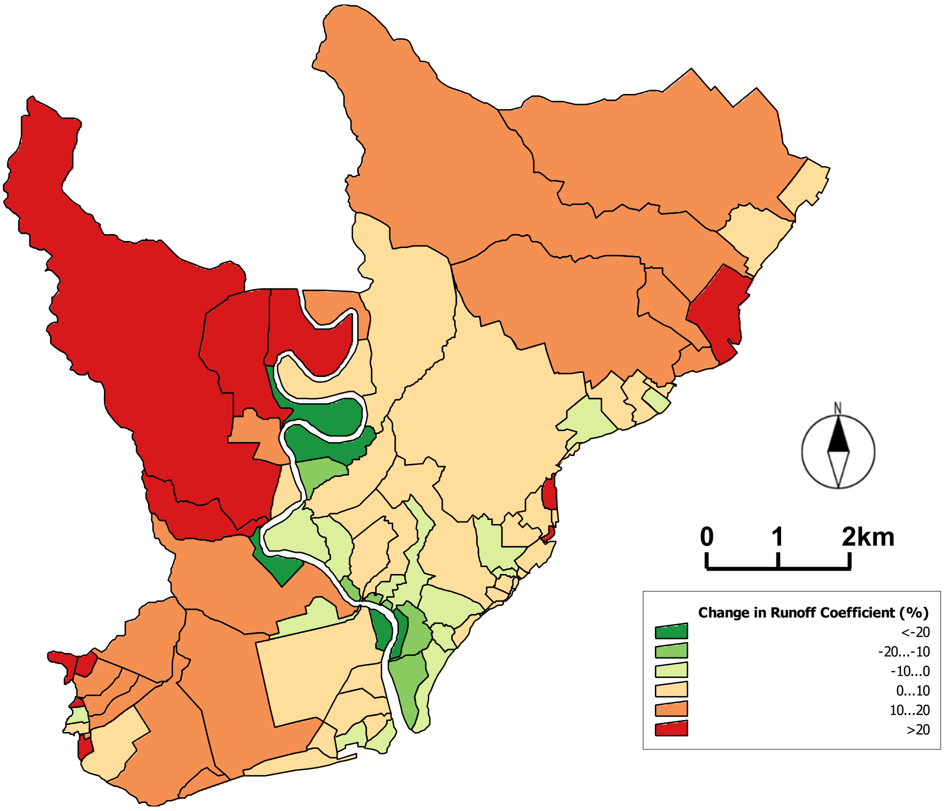
Though the depth of inundation is less than 0.5m and the duration for many of the frequent floods is a few hours at maximum, it affects traffic conditions and economic activities, and thus lowers the urban function. If a lot of stakeholders can share the information of inundation condition in real time, they are able to avoid the inundated area during the extreme event, which is expected to mitigate the loss due the inundation. Currently, the information is somehow shared through social network and/or mass media. As a public support, the enhancement of monitoring of the inundation condition as well as the transmission of the information may be considered.

(7) Consideration in Possible Increase in Runoff by Landuse and Climate Change

In the Infrastructure development plan for Davao City in 2018 supported by JICA the target year of the plan was set at 2045, and the future land use plan in 2045 has been prepared. Figure 2.9.8 shows the change in runoff coefficient based on the future land use plan in 2045. It is expected that the runoff coefficient will increase much in Jerome, Mamay Creek, Sasa Creek and the right bank of Davao River.

As shown in Section 2.7.9, due to the climate change, it is expected that the rainfall intensity may increase by 10% in the middle of 21 century (2036-2065) from that in the current climate condition.

It is expected that the runoff increase due to the change in landuse and climate, which should be incorporated into the planning. As for structural measures, it is necessary to reflect the increase in runoff into the proposed countermeasures as well as the design flood discharge. In addition, in order to adopt the uncertainty in such changes in flexible manner, it is desirable to promote the runoff control measures more.



Source: Project Team

Figure 2.9.8 Change in Runoff Coefficient by Future Land Use Plan in 2045

(8) Improvement of Insufficient Construction Method

A lot of storm water drainage projects in Davao City are on-going. It is sometimes observed that construction mothed is not adequate. Figure 2.9.9 shows the example of the inadequate connection of pipes, which has been reported by DPWH-RO.

Source: DPWH-RO

Figure 2.9.9 Example of Inadequate Connection of Pipes

In DPWH-DEO, the preliminary design for budgeting and selection of contractor is conducted in Planning and Design section, and the construction management is conducted by Construction section. In general, as the change in the design during the construction is not shared with the Planning and Design section, and as build drawings are also not fed back to the Planning and Design section, if the originally planned structures are actually constructed or not is not known in the Planning and Design section. There is a possibility that the entire process of the planning, design and construction is not well managed.

It is necessary to improve the construction method, including the management of the entire process of the planning, design and construction, in the storm water drainage project.

(9) Better O&M Activities by Better Design etc.

It is important to install and maintain the manholes which makes the maintenance activities easy, in order to secure the proper maintenance for drainage channels, especially for drainage pipes. In Davao City, there are many cases that the manholes cannot open and close easily, and the distance between manholes are too long. It is even observed that the manholes have been covered during road improvement. It is necessary to improve the maintenance activities by improving the design of the manholes etc.

(10) Better Coordination for Complicated Implementation of Storm Water Drainage Project

It is expected that the runoff increase due to the change in landuse and climate, which should be incorporated into the planning. As for structural measures, it is necessary to reflect the increase in runoff into the proposed countermeasures as well as the design flood discharge. In addition, in order to adopt the uncertainty in such changes in flexible manner, it is disable to promote the runoff control measures more.

In principle, demarcation of the storm water drainage improvement for both construction and maintenance in Davao City is as follows.

- Drainage along National Road: DPWH
- Other Drainages: DCCEO

However, the case that DPWH implements the project at the drainage which is not along national road is increasing, when budget is secured by DPWH.

Even in DPWH, there are different type of project as follows.

- Storm water drainage improvement project which is implemented by DEO
- Drainage improvement under road improvement project which is implemented by RO

It is required that the private developer install rainwater retarding facilities according to the Ordinance of Davao City. There is a case that the private developer has installed large scale retarding basin which can contribute to reduce the discharge at downstream reach very much. Since such rainwater retarding facilities can be installed by obtaining the permission from DCCEO, it can be said that such facilities are under control of DCCEO.

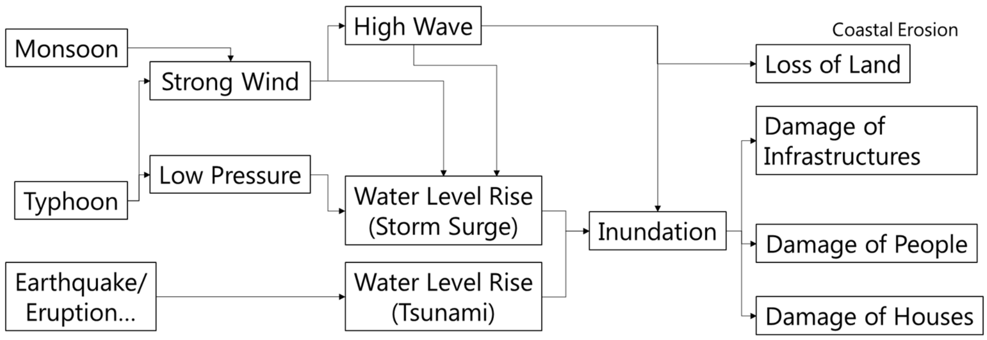
Considering these complicated implementation structure for the storm water drainage project, it is necessary to coordinate well among the relevant organizations for avowing the overlap and contrariety.

2.10 Coastal Disaster Analysis

2.10.1 Coastal Disaster and Damage

(1) Definition of Coastal Disaster

This section gives an overview of coastal disasters. In general, disasters that occur on coasts include high waves, storm surges, tsunamis, coastal erosion and so on. The relationship between each disaster and the causes is shown in Figure 2.10.1. When high waves, high tides, or tsunamis exceed the ground height or facility height of coastal area, inundation occurs, which leads damage to public facilities, and to assets such as people and houses. If storm surges and wave components are overlapped on the astronomical tide level, and flood damage to land will occur.



Source: Project Team

Figure 2.10.1 Diagrams of Coastal Disaster and its External Factors

(2) Past Incidents of Coastal Matters

This project obtained coastal disaster case data of Davao city since 2005 from DCDRRMO. According to DCDRRMO, a total of 54 incidents regarding monsoon waves have occurred since 2005 (see Table 2.10.1). The largest number of 24 cases a year occurred in 2012 and the economic losses in 2006 and 2012 are relatively high. It is clear that most of the damage occurrences are concentrated from July to October. The details of this reason will be described later. It can be inferred that it is based on the topographical and climatic features in the Davao area.

Table 2.10.1 Numbers of Coastal Incidents since 2005

Year	2005	2006	2012	2014	2015	2017	2018	Total
No. of Incidents	1	4	24	11	1	6	7	54
No. of Affected Families	28	166	113	20	0	2	16	-
No. of Casualties	0	0	0	0	0	0	0	-
Estimated Economic Loss (Php 1,000)	217	3,074	2,695	593	16	55	553	-

Source: DCDRRMO

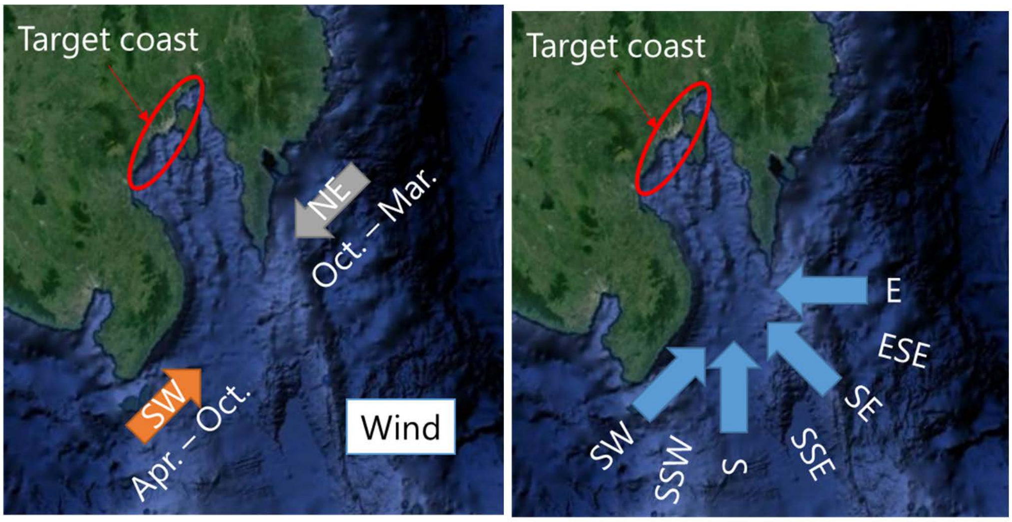
(3) High Tide

The sea level is constantly fluctuating. If there are no unusual events, it can be described as the astronomical tide level caused by the moon and the sun's gravitation, and the earth's rotation. According to the monthly tidal fluctuation from the tide observation records in Davao, the fluctuation of the average tide level itself does not change significantly throughout the year, but average tide level tends to increase from June to October, which is one factor in the appearance characteristics of the above-mentioned coastal disaster cases.

(4) Monsoon Waves

Mindanao Island, including Davao city, is greatly affected by the monsoon. As shown in Figure 2.10.2 (L), monsoon is a wind blowing constantly throughout the year. In the vicinity of Davao the wind from April to October is blowing from the SW, while the wind from October to March is from the opposite direction: NE. Because Davao Bay is about 40 to 50 km in the NE-SW direction, large waves have difficulty in developing based on its topographical characteristics. Therefore, as shown on the right side of Figure 2.10.2 (R), the main waves reaching the Davao coast can be assumed as waves developed by the monsoon wind coming from the outside of the Davao Bay. In addition, considering that Davao Bay has a shape opening in the SSE direction, waves arriving from the outside are limited to seven wave directions from E to SW.

According to the annual frequency distribution of waves outside Davao Bay, focusing on the waves in the directions of SW to E reaching the Davao coast, it seems to occur in May to October with a peak in August. This can be also one of the main factors in the characteristics of the coastal disaster cases in Davao mentioned above.



Source: Project Team & Google Earth

Figure 2.10.2 Monsoon Wind (L) and Wave Directions arriving at Davao Coast (R)

(5) Typhoon

Typhoons are not likely to hit the Davao city area basically, because it is located in a low latitude. There are only three typhoons that have passed within 150 km from Davao city since 1951. Ty201727, VINTA brought heavy rain, but high waves and high tides did not occur. Although the TY195501 passed through the Davao Bay, it is hard to cause a remarkable storm surge and high wave because the central pressure was slightly low at 995 hPa. Only TY197020 could cause storm surges in the Davao Bay in the last 70 years, and the offshore wave height was about 10 m (to be described later). TY 197020 passed through the Davao Bay at a central pressure of 950 hPa and may have caused storm surges.

(6) Coastal Erosion and Sedimentation

DCDRRMO has prepared a coastal erosion and sedimentation map in Davao City. The map determines the erosion and deposition by using the coastlines of June 1950, July 2014 and November 2017, and also applies their progress rates as Low, Moderate, and High. As basic characteristics, the estuary of major rivers (Davao River, Matina River and Talomo River etc.) tends to have sedimentation because a large amount of sediment was supplied. Furthermore, since the main waves act from the south of Davao Bay, the coastal current flows from the northeast to the east, which is the direction of movement of sediment. Therefore, the severe sedimentation area is located in the east, northeast and north side of the erosion area.

(7) Summary of Past Coastal Disaster in Davao

The past coastal disasters on the Davao coast had frequently occurred from July to October, and the factors are as follows.

- High tide: The mean sea level tends to rise on average from June to October
- Monsoon waves: SW waves in April-October, and NE waves in October-March.
- Bay shape: It is difficult for waves to develop inside the bay, and waves from the SSE reach from outside of the bay because the bay mouth is open in this direction.
- Offshore wave occurrence distribution: The occurrence distribution of wave directions SW to E occurs from May to October, with a peak in August.
- Typhoon: A few rare typhoons passing nearby generate high waves in October and November
- Erosion and sedimentation: The estuary has a lot of sediments. In response to the waves from around S direction, the sand drifts to the northeast.

2.10.2 Analysis of Condition of Facilities and Houses along Coastal Area

The field observation was conducted to analyze the present conditions of existing facilities and houses in the coastal area. The sites are indicated in Figure 2.10.3.

Source: Google Earth and Project Team

Figure 2.10.3 Location of Field Survey for Coastal Condition

(1) Coastal Road Projects

The Davao Coastal Road Project was started in 2017 and plans to complete the construction work by 2021. The sections for 2017 were started and steadily proceed. The construction for the 2018 sections has also started. There are some bridges with a gap planned along the road. Sea water comes through the open gap to the area behind the road during high tide. Therefore, it is impossible to completely prevent the high tide by only the coastal road.

(2) Talomo & Matina River Mouth

Sandbanks are formed in the estuary of the Talomo and Matina Rivers, and their shapes are variable. The slope of the estuary seems to be rather gentle. From the aerial photos in the past, the estuary closure in this area has been observed since around 2014.

(3) Davao River Mouth

The shape of the estuary of the Davao River is relatively stable and its slope around the estuary is quite gentle. A new revetment has been constructed on the right bank in the estuary of the Davao River. In addition, the historical maintenance dredging had been carried out in Davao river mouth.

(4) Coastal Local Road

There is a 0.8 m parapet installed on the coastal local road. According to the interview to local people, since the parapet was set up, such flooding events beyond the parapet have not occurred. However, there is a lot of drainage holes along the coastal local road, which leads to inundation through them during high tide. The beach slope is relatively steep, which seems to be about 1/10 to 30 and it is assumed that coastal erosion has occurred.

(5) Santa Ana Port

Santa Ana Port is currently used for the ferries to Samal Island and others. The port has two piers for ferries in front of the reclamation area. The port has a series of coastal seawalls. Upright parapets in Magsaysay Park are installed.

(6) Houses

In order to investigate the situation of the existing houses accumulated in the coastal area, the aerial photographs around the coastal area were carried out using the UAV. There are the three areas that are particularly densely populated. The first is the area between the left bank of the Talomo River and the right bank of the Matina River, and the area at the left bank of the Matina River. Several settlers such as fishermen are here, and they particularly use a high-floored house in the coastal area so as to prevent flooding during high tide. The second is the estuary of the Davao River, especially on the left bank, where there are large settlements and many people (see Figure 2.10.4). The habitants in the coastal area also adopts high-floured houses, which are built about 1 to 2 m high from the ground level. The third is the region that extends north and south of Santa Ana Port. This area has a relatively large water channel, and pumping stations for inland drainage are constructed at the coast of this region. As in the other areas, there are many fishermen and the ships they use.

Source: Project Team

Figure 2.10.4 Houses in Coastal Area (Davao River)

2.10.3 Exiting Countermeasures for High Tide / Storm Surge and Coastal Erosion

No large-scale of measures against storm surges and coastal erosion have been implemented in the past. The projects that affect storm surge and coastal erosion on the Davao coast are described below.

(1) Davao Coastal Road

As mentioned above, the Davao Coastal Road Project was started in 2017 and continues with construction until 2021. Figure 2.10.5 shows the alignment of the coastal road and the construction plan. The 2017 and 2018 sections have been constructed and outlined, but the 2019 section has not been started yet. The design of the sections for 2020 and 2021 are almost completed. The coastal road is not a storm surge protection facility, and large-scale bridges are planned in the Davao River and Matina-Talomo river mouth, and some small-scale bridges are planned for the access of landside residents, which means that the road itself does not have a storm surge protection function. Therefore, countermeasures for storm surge (e.g. sluice gate, dike, seawall) are necessary considering the characteristics of opens. However, the effect of wave reduction is quite large. The waves acting on the land side of the coastal road are significantly reduced except for the opening. Furthermore, if the beach is prone to erosion, further erosion does not occur by constructing the road. Further detail study about the future characteristics of erosion and sedimentation will be conducted by the shoreline analysis at the second stage of master plan formulation.

Source: DPWH RO

Figure 2.10.5 Layout and Construction Plan of Davao City Coastal Road

(2) Jetty

Some parts of the Davao coast have jetties constructed for sandbanks. Some piers for ferries are not made of piles, but landfill structures from the ground level. As a result, these structures can separate coastal area so as to lead to sedimentation at the area of upstream of sand transportation and erosion at the area of downstream of sand transportation. If coastal area has problem with sedimentation/ erosion around these structures like jetties, the direction of sand transportation should be explored.

2.10.4 Tide Analysis

Tide analysis is significant to understand and determine the design scale of the design water level and the astronomical tide. Because the design water level is affected by topography and regional characteristics, it is necessary to consider the conditions specific to the target coast.

(1) Astronomical Tide

As for the astronomical tide, it is necessary to grasp typical specifications of the astronomical tide and to reflect it in the design of coastal structures. According to NAMRIA, which is responsible for determining tide throughout the Philippines, the official tide levels in Davao are based on the data from the 1970-1988 series, as shown in Table 2.10.2.

Table 2.10.2 Official Tide Parameter (NAMRIA)

Series	NAMRIA
	1970-1988
MHHW	0.78
MHW	0.65
MSL	0.00
MLW	-0.65
MLLW	-0.76

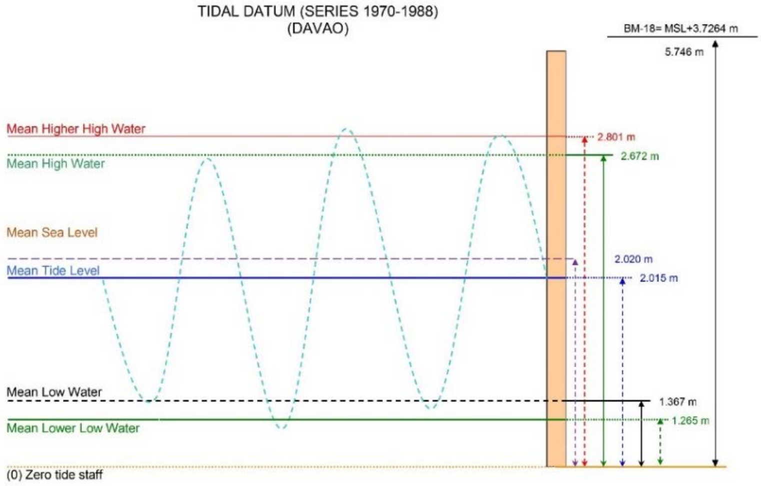
Source: NAMRIA

(2) Observation Data

NAMRIA has been conducting tidal observations from 1948 to the present in Davao. This study uses the observation data from 1948 to 2017 provided by NAMRIA, and the following analysis is based on it. It faces Samal Island and has been relocated slightly north in the early 2000s. The acquisition rate of the observation data from 1993 to 2009 is highly variable. Furthermore, the acquisition rates in 1972, 1973 and 1999 are almost zero.

(3) Tidal Datum

As mentioned above, the Davao's tide datum is based on the MSL calculated in the 1970-1988 series which is the only official datum (NAMRIA), and it was confirmed that BMs are also based on the same MSL. Therefore, this study will use the 1970-1988 series of NAMRIA for the examination MSL. The relationship with the tide level observation reference surface (Zero tide staff) is as shown in Figure 2.10.6.



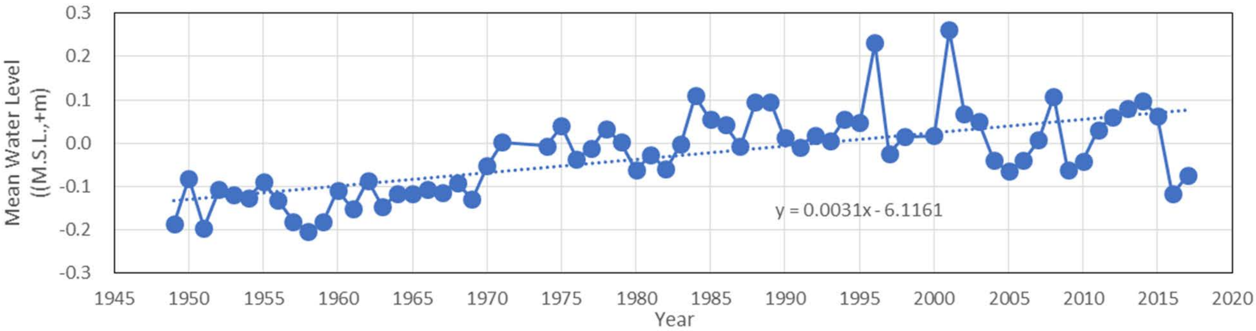
Source: NAMRIA

Figure 2.10.6 Tidal Datum in Davao (NAMRIA)

(4) Historical Data

The basic characteristics of 1948-2017 observation data provided by NAMRIA are analyzed. First, the annual mean sea level over the target period is calculated as shown in Figure 2.10.7. The figure clarified that the annual mean sea level is rising during the observation period with the yearly variation. Moreover, the ratio was 0.0031 m / year although there is annual variation of MSL ± 0.2 m. It was confirmed that the observation data of NAMRIA was properly observed as the mean sea level.

Next, the tide level characteristics were calculated in this study, based on the provided data. Three series of 1970-1988 same as the official data of NAMRIA, 1998-2017 (equivalent to the latest 20 years) and 1989-2017 (equivalent to the latest 30 years), were used as the target period. Looking at the results of this calculation from 1970 to 1988, the difference from the official astronomical tide level of NAMRIA was less than 2 cm, which means that the validity of the astronomical tide level of NAMRIA was confirmed. Therefore, this study will use the official tide level of NAMRIA from 1970 to 1988.

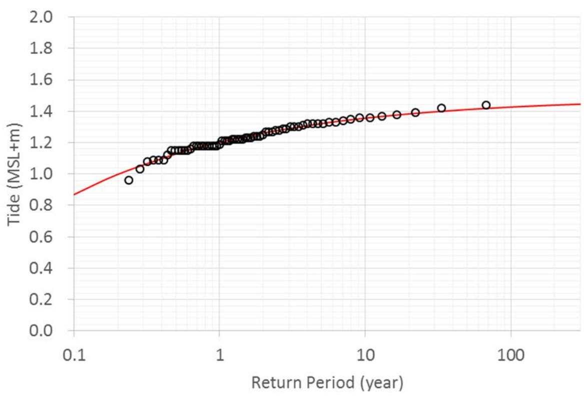


Source: Project Team

Figure 2.10.7 Changes of Annual Mean Sea Level

(5) Statistical Analysis

In order to set the design water level of the target scale, a probabilistic statistical analysis is performed based on the observed tide level data, and the probable tide level for a specific reproduction period in Davao is calculated. In the calculation, the Generalized Extreme Value distribution (GEV) is used which includes three extreme value distributions unified. For probabilistic statistical analysis, the annual maximum tide from 1948 to 2017 at Davao tide station was used. Appling these annual maximum tide level data to the GEV, the optimum parameters are obtained by least-squares method. The relationship between the return periods and the probable tides is as shown in Figure 2.10.8. The probable tide level for each particular return period is shown in Table 2.10.3. The 50-year and 100-year probable values are MSL + 1.41 m and + 1.43 m, in which the difference between them is small, 2 cm.



Source: Project Team

Figure 2.10.8 Results of Statistic Analysis of Tide

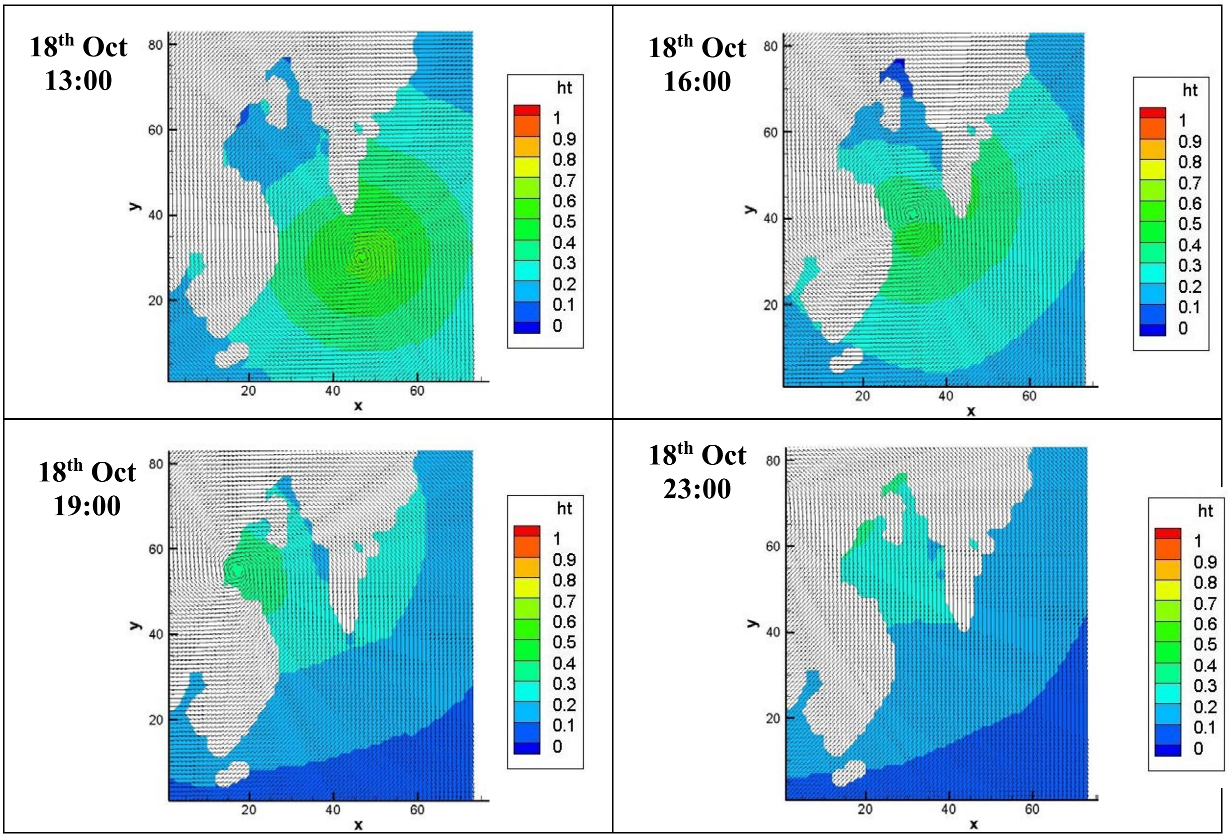
Table 2.10.3 Probable Return Periods of Tide

Return period (year)	1	10	25	50	100
Tide (MSL+m)	1.20	1.36	1.39	1.41	1.43

Source: Project Team

(6) Effect of Storm Surge

As mentioned above, the tide data of the Davao station from 1948 to 2017 did not cover the data during TY197020. The above-mentioned statistical analysis can underestimate the probability of tide because it does not include the tide during the typhoon. Therefore, the storm surge simulation against TY197020 was carried out. In case of high storm surge deviation due to the typhoon, the probability statistical analysis should consider including the storm surge deviation. The storm surge simulation results of TY197020 are shown in Figure 2.10.9. Several tens of centimeters of storm surge was estimated to occur in Davao Bay due to suction effect and wind drift effect. However, the snapshot at 16:00 on October 18 shows that the peninsula on the other side of Davao City prevented the influx of storm surges from the open sea. Although the central pressure of TY197020 was low at about 950 hPa and hit Davao City directly, it was regarded that storm surge deviations themselves were only relatively small because of the course where large storm surges were blocked by the opposite peninsula.



Source: Project Team

Figure 2.10.9 Results of Storm Surge Simulation of Typhoon 1970 No.20

The storm surge deviation rose as the typhoon approached, reaching a maximum of 0.34 m at 20:00 on 18th. It was close to high tide, which exceeded MSL + 1m only at astronomical tide, although it was estimated that the maximum tide level was MSL + 1.35m by adding storm surge deviation to astronomical tide. The probabilistic statistical analysis of the tide level was conducted considering the simulation results of storm surge due to TY197020. The statistical results are almost the same whether considering TY197020 or not.

2.10.5 Wave Analysis

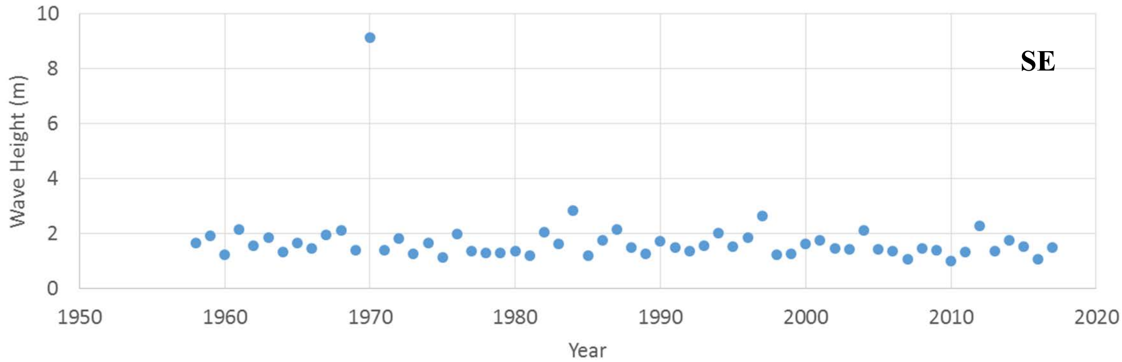
Wave analysis is rather critical to understand and determine the design scale and design waves. As design waves are affected by topography and local characteristics, it is necessary to consider the conditions specific to the target coast. The estimation accuracy of setting the design waves will be improved if there are enough observation data more than the study target years (e.g. 50 years or 100 years), similarly to the case of the tide level. A series of observation data in at least 30 years or more are necessary to set the design waves. However, no waves have been observed in the vicinity of Davao, and NAMRIA has just begun observation in 2018 at Surigao in northern Mindanao Island. In order to set a design wave on the Davao coast, several tens of years of wave data will be necessary. This study will use the long-term reanalysis wave data by the Kyoto University which utilized the reanalyzed meteorological data (JRA-55, JMA), in order to analyze the wave conditions of the target coast. The details of the wave data are explained in the next section.

(1) Reanalysis Data

As mentioned above, this study uses the long-term wave estimation results instead of wave observation data. It is essentially necessary to confirm the consistency with the nearby ocean wave observation results for a certain period. However, since there is no wave observation data around Mindanao Island and the Philippines, this study will directly use the reanalysis wave data.

(2) Historical Data

The historical annual maximum wave heights are shown in Figure 2.10.10, taking wave directions SE as examples. It can be seen that a large wave height was estimated. This was the wave caused by TY197020. Although the storm surge due to the typhoon was relatively small, about 9 m of waves were estimated outside Davao Bay. As for the waves in direction SW, relatively large waves of 5 m or more occurred in November 1964 and November 1990, which were caused by TY196431 and TY199025 that passed through the north of Mindanao Island. The other years had no high waves. This is similar to the trend of the tide level, and it seems that extreme weather events have not occurred except for TY197020. Therefore, the annual maximum waves seems to be determined by the waves due to the average monsoon wind except for the typhoon.



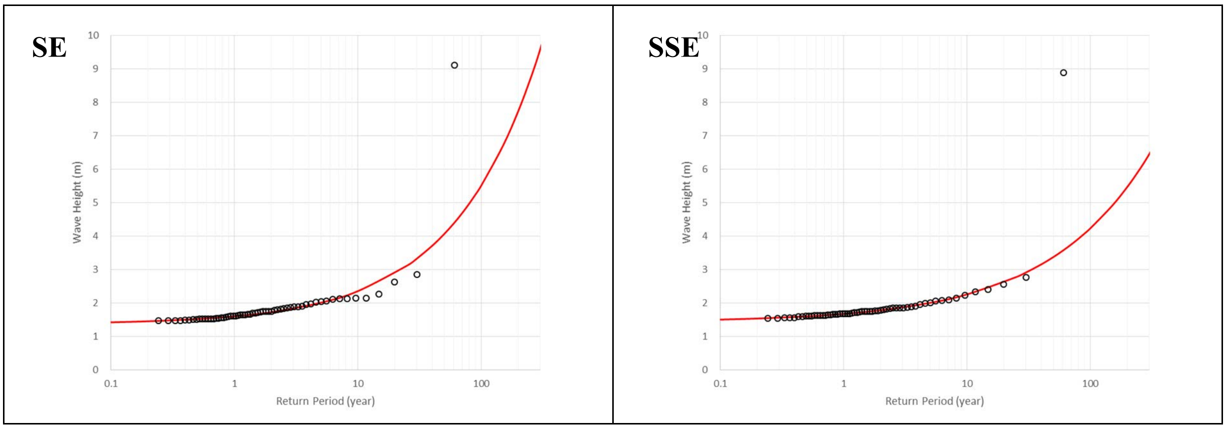
Source: Project Team

Figure 2.10.10 Annual Maximum Wave Heights in Directions of E, SE, S and SW

(3) Statistical Analysis

In order to set design waves of the target scale, this study conducted a probability statistical analysis based on the reanalysis wave data. The probable wave heights for several particular return periods in Davao are calculated. Similarly to the probable tide, the analysis applied a Generalized Extreme Value distribution (GEV) for each wave direction. The relationship between the return period and the probable wave is shown in Figure 2.10.11 as examples in direction SE and SSE.

Next, the probable waves in each direction for each particular return period are obtained and shown in Table 2.10.4. The results indicates that the differences in the probable wave height are based on the occurrence characteristics for each wave direction. The 50-year and 100-year probable wave heights in ESE were the highest, 5.15 m and 7.67 m, respectively. However, this is the result of probabilistic statistical analysis of offshore waves. In order to identify the large waves reaching Davao coast, it is necessary to carry out the wave transformation analysis from the outside of Davao Bay to Davao coast.



Source: Project Team

Figure 2.10.11 Results of Statistical Analysis of Waves (direction in SE and SSE)

Table 2.10.4 Probable Return Periods of Offshore Wave Heights (direction in E-SE)

Return period (year)		1	10	25	50	100
Offshore Wave Height (m)	E	1.65	2.43	3.26	4.30	5.94
	ESE	1.57	2.52	3.64	5.15	7.67
	SE	1.60	2.36	3.12	4.06	5.52
	SSE	1.68	2.26	2.78	3.37	4.24
	S	1.91	2.47	3.07	3.82	5.00
	SSW	2.00	2.65	3.35	4.27	5.73
	SW	1.93	2.74	3.52	4.45	5.84

Source: Project Team

(4) Wave Transformation to Davao Coast

As mentioned above, in order to set the design waves for coastal structures for Davao coast, it is necessary to estimate the wave conditions in Davao coast from the outside of Davao Bay. Therefore, it is necessary to conduct the wave transformation analysis from the offshore waves outside Davao Bay. The transformation analysis should take the refraction effect and the diffraction effect into consideration. The relationship between the offshore wave height *Ho* and the refraction effect *Kr* and the diffraction effect *Kd* and the wave height (*Hn*) at coast are expressed by the following equation.

$$H_n = Kr \cdot Kd \times H_o$$

where Kr·Kd is called the coefficient of refraction and diffraction effect. In order to obtain Kr·Kd, the wave transformation simulation was carried out. The simulation uses the 3rd generation wave model, SWAN (TU Delft), extended to wave transformation in shallow water. The wave analysis results of WW3 conducted by Kyoto University are applied for the offshore boundary as the input condition so as to connect these numerical methods of offshore and nearshore waves.

The following two years were selected as the representative period.

1. 1970: One year including extreme metrological event, TY197020
2. 2012: One year in 2012 as a representative of recent years when the observation accuracy is improved.

Next, the ratio of the wave height near the coast to the offshore wave height was determined for the 7 target wave directions. This ratio is the coefficient of refraction and diffraction effect, Kr Kd. The results of Kr·Kd for each wave direction are shown in Table 2.10.5. The design wave near the Davao coast was estimated by using the above equation with these values. Using these results will determine the target scale for the design waves.

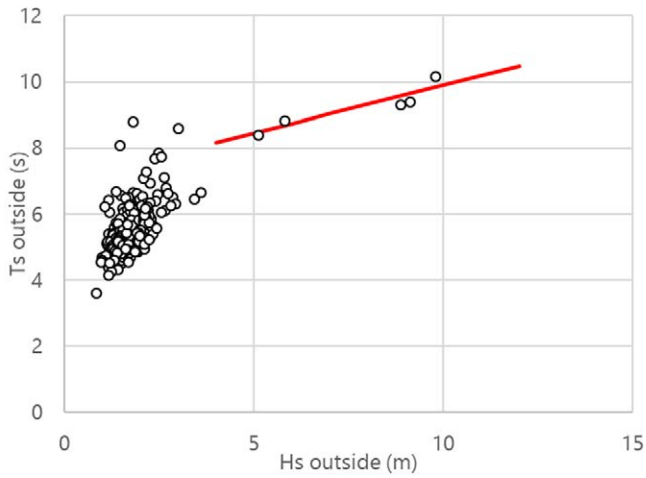
Table 2.10.5 Probable Return Periods of Nearshore Wave Heights (Direction in E-SE)

Return period (year)		1	10	25	50	100	Kr·Kd
Near shore Wave Height (m)	E	0.29	0.43	0.58	0.77	1.06	0.18
	ESE	0.28	0.46	0.66	0.93	1.39	0.18
	SE	0.39	0.58	0.76	0.99	1.35	0.24
	SSE	0.36	0.49	0.60	0.73	0.92	0.22
	S	0.35	0.45	0.56	0.69	0.91	0.18
	SSW	0.22	0.30	0.37	0.48	0.64	0.11
	SW	0.10	0.14	0.18	0.23	0.30	0.05

Source: Project Team

(5) Setting Wave Periods

Based on the characteristics of Davao Bay, the wave periods against design wave heights should be determined. Using the relationship between offshore wave heights and wave periods outside the Davao Bay, the fitting curve, $T_s = 0.29 \times H_o + 7.0$ is derived. Where, *Ts* is wave period against design offshore wave height (*Ho*).



Source: Project Team

Figure 2.10.12 Relationship between Offshore Wave Height and Period

2.10.6 Tidal Current Analysis

Regarding tidal currents, although observation has not been conducted in this project, some significant information on tidal currents is described in the chart provided by NAMRIA. The characteristics of the tidal current in Davao Bay are as follows.

- The direction of the tidal current is northward in flow tide and southward in ebb tide.
- The tidal current is faster in the straits between Samal Island and Davao City. (Up to 2.5 knots)
- In the other sea areas, no noticeably fast tidal current has occurred.

Thus, it is assumed that a tidal flow that affects the sediment transport on Davao coast is not found because it is at most 2.5 knots in the narrow strait. It is found that it is not the main factor of the beach erosion and sedimentation.

2.10.7 Climate Change Impact Analysis

This section discusses the impact of climate change on coastal disasters. The impacts of climate change affecting coastal disasters include sea level rise (SLR), changes of typhoon and low atmospheric pressure and monsoon intensities, which associate the changes of storm surges and high waves, and the resulting coastal erosion and sedimentation characteristics. However, this section will focus on the consideration of sea level rise as described in DGCS.

(1) Sources

There are three types of reference sources for sea level rise to be considered for the impacts of climate change in this project, as shown in Table 2.10.6. 1. Tidal gauge observation data, 2. Projection by PAGASA, 3. DGCS. This project will determine the amount of the sea level rise from the 3 sources.

Table 2.10.6 Sources to be considered for Setting Sea Level Rise

Sources	Description
1. Tide Observation Data	- Practical data in Davao tide station from 1948-2017 - Only historical data, no prediction - Increase rate: 0.0031m/year
2. Prediction by PAGASA (Met Office)	- Met Office predicted the mean sea level change in Philippines in 2016 - 0.2m in 2045 (target year of this project)
3. DGCS	- 0.3m SLR for 2050 in the design - 0.5m SLR for 2100 - Based on IPCC (2013)

Source: Project Team

(2) Sea Level Rise from 1988 to Present

The present astronomical tide uses the official tide level 1970-1988 series of NAMRIA. Therefore, it is necessary to consider the sea level rise after 1988 to the present before any discussion of future sea level rise. This project will formulate the sea level rise from now as follows, using the annual average sea level rise of 0.0031 m / year based on the observation data.

$$SLR\ (present) = 0.0031*(2019-1988) = 0.0031*31 = 0.0961 \approx 0.1\ m$$

This study will propose the SLR at present should be applied at 0.1 m; the official tide level of NAMRIA (1970-1988 series) plus 0.1 m should be used for the astronomical tide.

(3) Sea Level Rise in Future

In addition to the SLR of the present, the future SLR should be considered in this project. At the same time to set the SLR, it is necessary to consider the method to incorporate climate change described in DGCS, which includes two methods to be considered: A: Incorporating into Present Design and B: Planned Upgrade.

There are three types of SLR candidates to be considered in this project as shown in Table 2.10.7. The target year is assumed to be 2045. It is noticed that the values include the SLR from around 2000 which is estimated at 0.1m in this project. This should be discussed taking into account not only for coastal disasters, but also riverine and inland flooding.

Table 2.10.7 Candidates of Sea Level Rise to be considered in This Study

Alternatives	SLR from around 2000	SLR from Present	Description
1. Historical Trend	-	0.1m in around 2045	Increase rate: 0.0031m/year 0.0031*27years (2045-2019) =0.084m
2. Recent Prediction	0.2m in around 2045	0.1m in around 2045	PAGASA prediction in Davao
3. DGCS	0.3m in 2050	(0.2m in 2050)	Following DGCS

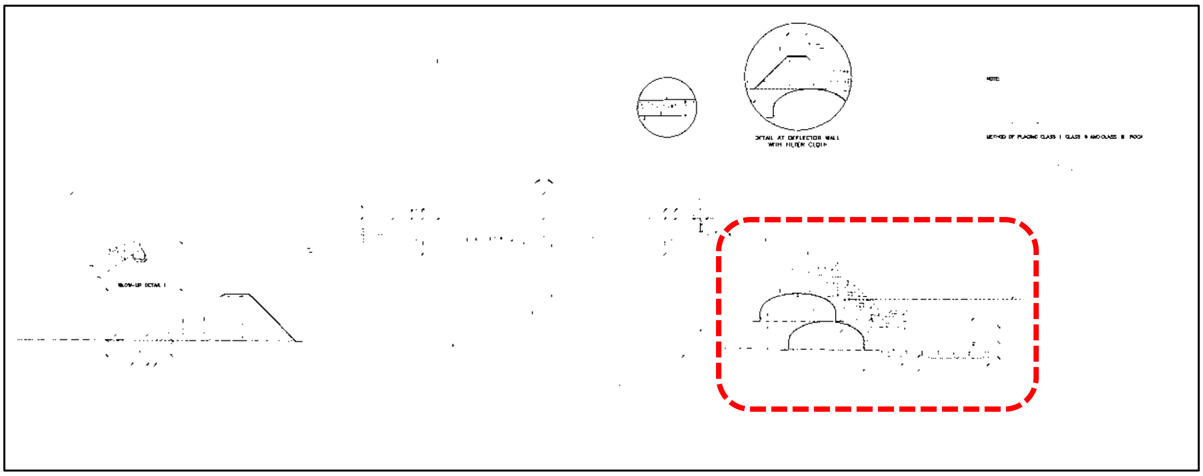
Source: Project Team

2.10.8 Evaluation of the Impact of Existing Projects and Future Development Plans in Coastal Areas

In the coastal area, Coastal Road is currently being planned by DPWH, and some sections were already under construction on the southwest side of the Davao River. The detailed designs on the northeast side of the Davao River are currently being formulated, and discussions with Davao City, etc. are ongoing. In addition, based on interviews with DPWH and Davao City, etc., there is a land reclamation plan on the landward side of Coastal Road. C/P and Project team confirm that the plan should not be included in the M/P. Therefore, the following section will focus on the impact evaluation of the existing and future projects of the Coastal Road project.

(1) Targets

The target of the evaluation is the whole area of the Davao Coastal Road, which is the existing implementation section and the future plan section. The standard cross section is as shown in Figure 2.10.13. Based on the design conditions set in “3.3. Design Target Level”, the structure of the road revetment will be evaluated and the effect on the planed alignment will be considered.



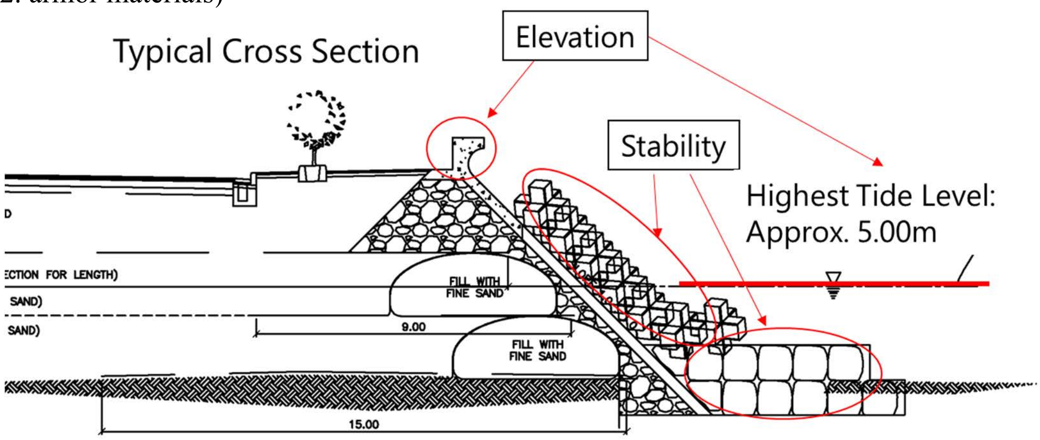
Source: DPWH RO

Figure 2.10.13 Typical Cross Section of Davao City Coastal Road

(2) Methods

The details of the study are as follows.

- Terms to be examined: evaluating whether the road revetment has a function as a coastal structure.
- Conditions to be examined: Using the design conditions set in this project (i.e. design water level and design wave)
- Standards: DGCS and PPA (2009), Technical standards and commentaries for coastal protection facilities in Japan and Technical standards and commentaries for port facilities in Japan
- Points to be examined: Performance of revetment cross section (1. crown height of the revetment, 2. armor materials)



Source: DPWH RO

Figure 2.10.14 Target Point to be studied

(3) Evaluation of Design Condition

Prior to the cross-sectional evaluation of Coastal Road, the design conditions based on the target design level set in this project are compared with the design conditions set in the study of Coastal Road, and their validity is evaluated.

1) Summary of Design Condition

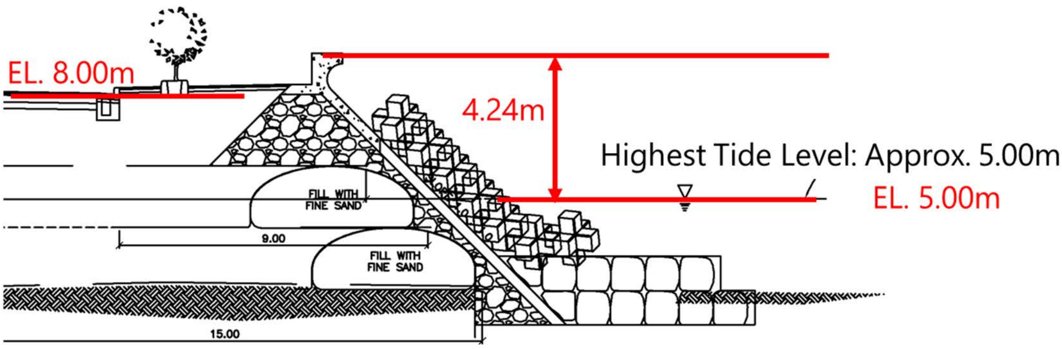
The design conditions adopted in this project is following.

Design Water Level: MSL+1.43m (100 year return period)

Design Wave at Davao Coast: Wave Height=1.6m, Wave Period=9.2s, ESE
Wave Height=1.6m, Wave Period=8.6s, SE

2) Evaluation of Design Water Level

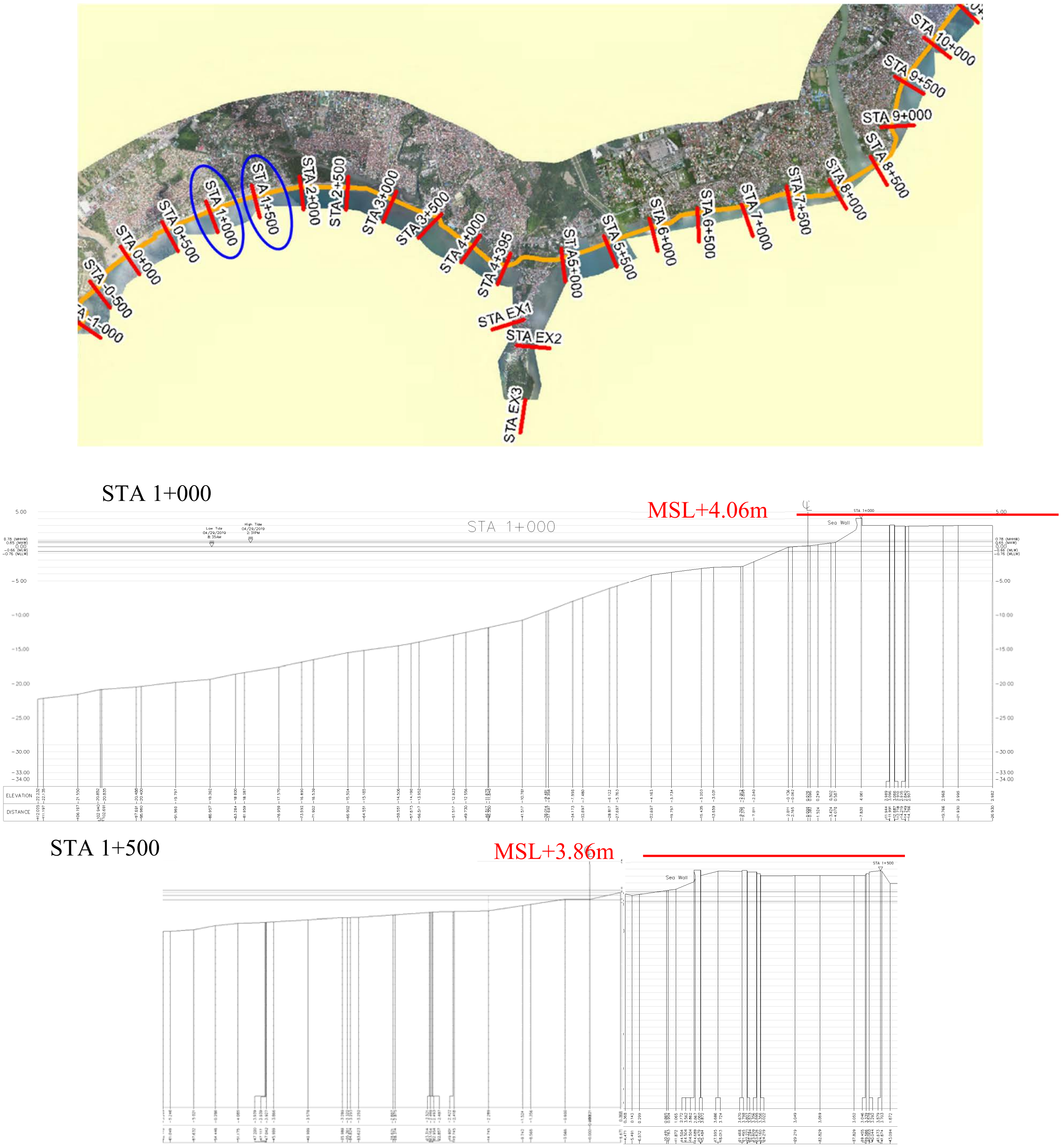
Since DPWH RO manages their elevations with not the NAMRIA official tide level but their original basis, the design water level set by DPWH in the NAMRIA official tide level is calculated based on the standard cross-section from DPWH.



Source: DPWH RO

Figure 2.10.15 Target Point to be studied

Based on the results of the cross-sectional survey of the coastal area implemented in this project, the design water level at the official NAMRIA tide level was estimated by the relationship between the design water level and the crown height of the coastal facilities at the locations where the coastal facilities were already completed (STA.1 + 000, 1 + 500). As a result, the original design water level is much lower than the design water level adopted in this project as shown in Table 2.10.8.



Source: Project Team

Figure 2.10.16 Survey Results of Cross-sections (Sta. 1+000, Sta. 1+500)

Table 2.10.8 Evaluation Results of Design Water Level

Items	Original	Evaluation	Proposal
Design Water Level	EL. 5.00m	MSL-0.24m	MSL+1.43m

Source: Project Team

3) Evaluation of Design Wave

The wave conditions adopted in the previous projects are as follows. The conditions followed the DGCS based on the breaking wave height at the structural design depth. This breaking wave height indicates the maximum wave height that can occur at the water depth. It might be the only way to use it in the Philippines because the Philippines have no observation wave data, but it seems to be extremely conservative. The wave conditions adopted in this project are as summarized above, and the comparison and evaluation of both are as shown in Table 2.10.9.

Design Wave at Davao Coast: Wave Height=3.04m, Wave Period=4.5s

Equation 7-2

$$H_b = 0.8d_s$$

where:

H_b = maximum breaking wave height (m)

d_s = design depth at the toe of the structure

Source: DGCS Vol. III

CALCULATION:

A. DESIGN WATER LEVEL

DWL = 4 m

(DATA FROM ACTUAL CONDITION/HIGHEST TIDE)

B. DESIGN WAVE HEIGHT

INITIAL DESIGN CASE						
SEA BED ELEVATION	=	0.100 m				
STRUCTURE DEPTH (ds)	=	4.000	-	0.100	=	3.900 m
BREAKING WAVE HEIGHT (Hb)	=	0.780	x	ds		
	=	0.780	x	3.90	=	3.042 m

Source: DPWH RO

Table 2.10.9 Evaluation Results of Design Wave

Items	Original	Evaluation	Proposal
Design Wave Height	3.04m	Very conservative	1.6m
Design Wave Period	4.5s	Very short	8.6-9.2s

Source: Project Team

(4) Evaluation of Cross Section

1) Crown Height

The crown height of Coastal Road from the design water level used in the current design is as follows.

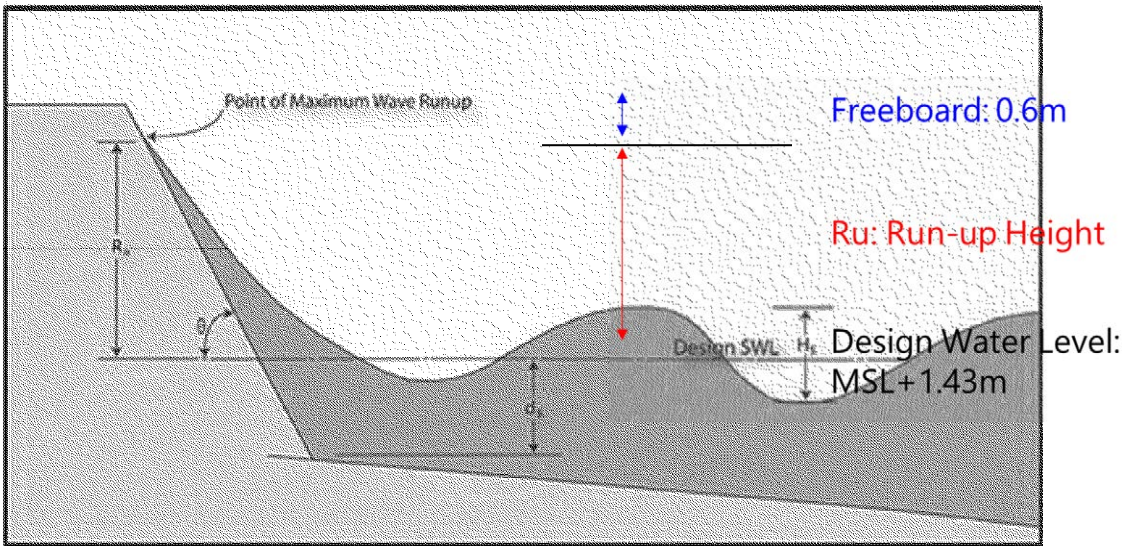
Elevation of Seawall: Around EL. 9m = MSL+4.0m

Next, based on the design conditions set in this project, the crown height of the coastal facility is set by the method described in DGCS as follows.

Height of Structure

The height of the structure should be designed to prevent overtopping for the protection level identified in Section 7.1.2. A freeboard of 0.6 m should be added to design still water level plus wave runup.

Figure 7-4 Overview of Parameters for Wave Runup



Equation 7-3

$$R_u = 1.6H_s(r\xi)$$

With an upper limit of:

$$R_u = 3.2rH_s$$

where:

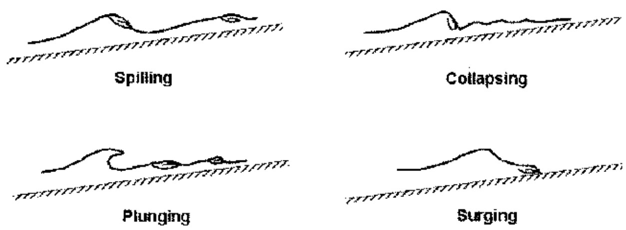
Ru	=	vertical height of runup on slope (m)
Hs	=	significant wave height (m)
r	=	coefficient of armor roughness (= 0.55 for riprap)
ξ	=	dimensionless breaker parameter from Table 7-4.

Source: DGCS Vol. III

Table 7-4 Dimensionless Breaker Parameter

Value of the Dimensionless Breaker Parameter (ξ)	Type of Wave (Figure 7-5)
$\xi < 0.5$	Spilling
$0.5 < \xi < 2.5$	Plunging
$2.5 < \xi < 3.5$	Collapsing
$\xi > 3.5$	Surging

Figure 7-5 Types of Waves



Source: DGCS Vol. III

ξ can be calculated by the following method.

$$\xi = \frac{\tan\theta}{\sqrt{H/L_o}}, \quad L_o = \frac{g}{2\pi}T^2$$

Where, T is wave period, θ is seabed slope.

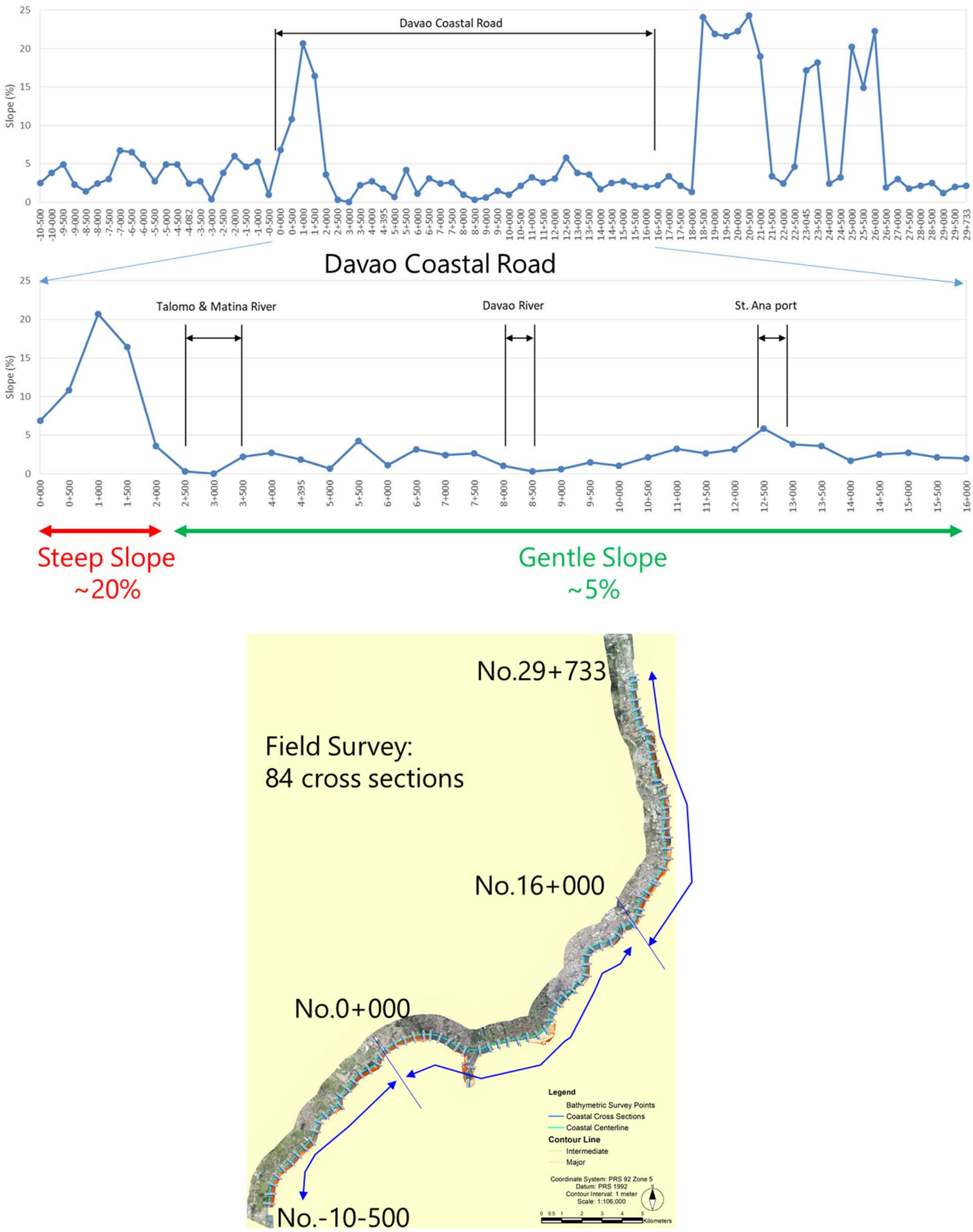
Consequently, it can be seen that the run-up height of the wave depends on the gradient (the gradient of the seabed and structures) in addition to the wave height, period, and material of the slope.

Therefore, the seabed gradient near the shoreline was calculated from the cross-sectional survey results for the Coastal Road, and the results are shown in Figure 2.10.17. From the figure, it was found that there are two main features: a section with a gentle seabed gradient, less than 5% and a section with a relatively steep seabed gradient, less than 20%.

Using these seabed gradients, the wave run-up height was calculated. The required elevation of crown height considering the margin was calculated and the result is shown in Table 2.10.10. In the table, five types of seabed gradients were used: 1%, 2%, 5%, 10%, and 20% as a representative. The calculation is performed in two cases: with and without wave-dissipating blocks.

Figure 2.10.18 shows the result of calculating the required elevation of crown height of the Coastal Road. From the figure, the crown height is sufficient for Sta.2 and after, but the elevation in the section from Sta.0 to Sta.2 is a shortage of 0.6m for freeboard. Based on this result, DPWH starts to consider the installation of overtopping fences that is 0.6m or more.

Table 2.10.11 summarizes the results of necessary evaluation of the crown height.



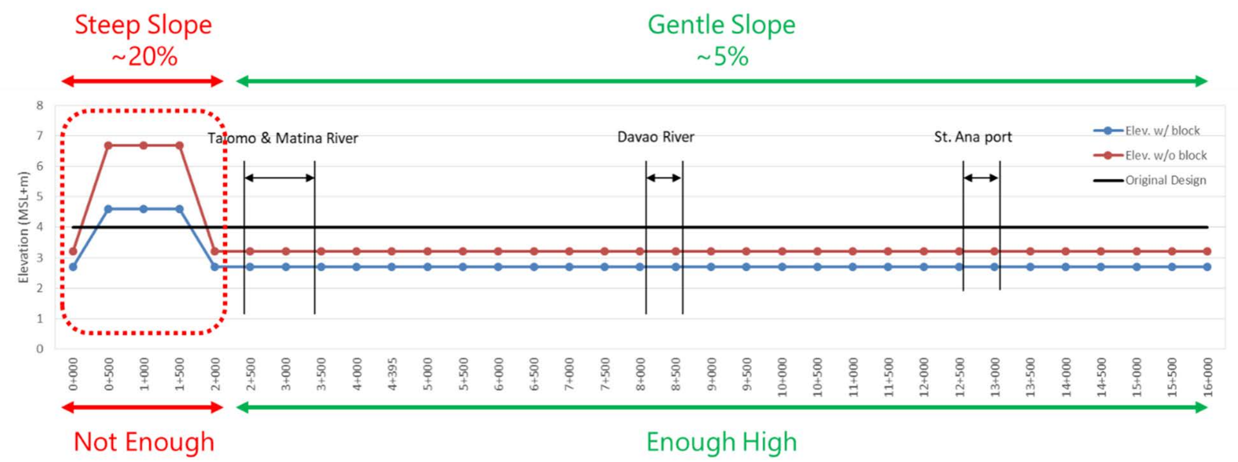
Source: Project Team

Figure 2.10.17 Seabed Gradient at each cross section (top: gradient, bottom: location map)

Table 2.10.10 Estimation Results of Run-up Height and Necessary Elevation

Conditions			Slope θ (%)				
Items	**Unit**	**Symbol**	**20**	**10**	**5**	**2**	**1**
Breaker Parameter	(-)	ξ	1.82	0.91	0.45	0.18	0.09
Wave Height	(m)	Hs	1.60	1.60	1.60	1.60	1.60
Wave Period	(s)	T	9.20	9.20	9.20	9.20	9.20
Wave Length	(m)	Lo	132.04	132.04	132.04	132.04	132.04
With Concrete Blocks							
Roughness coefficient	(-)	r	0.55	0.55	0.55	0.55	0.55
Runup Height	(m)	Ru	2.56	1.28	0.64	0.26	0.13
Water Level	(MSL+m)	-	1.43	1.43	1.43	1.43	1.43
WL + Runup	(MSL+m)	-	3.99	2.71	2.07	1.69	1.56
Freeboard	(m)	-	0.60	0.60	0.60	0.60	0.60
Required Elev.	(MSL+m)	-	**4.60**	3.40	**2.70**	2.30	2.20
Without Concrete Blocks							
Roughness coefficient	(-)	r	1.00	1.00	1.00	1.00	1.00
Runup Height	(m)	Ru	4.65	2.33	1.16	0.47	0.23
Water Level	(MSL+m)	-	1.43	1.43	1.43	1.43	1.43
WL + Runup	(MSL+m)	-	6.09	3.76	2.60	1.90	1.67
Freeboard	(m)	-	0.60	0.60	0.60	0.60	0.60
Required Elev.	(MSL+m)	-	**6.70**	4.40	**3.20**	2.50	2.30

Source: Project Team



Source: Project Team

Figure 2.10.18 Necessary Elevation of Crown Height

Table 2.10.11 Evaluation Results of Elevation of Crown Height

Items	Original	Evaluation	Proposal
Elevation	MSL+4.0m (Elevation 9.m)	Not Enough for Sta.0.00 to 2.00	MSL+4.6m
		Enough for Sta. 2.00 to 16.000	Same as original

Source: Project Team

2) Armor Materials

Two types of Armor materials are used on the sea side of the coastal facility on Coastal Road. 1: concrete block, 2: Armor rocks. The Armor materials of the original design by DPWH RO are as follows.

Weight of Concrete Blocks: 2.0t/unit
Weight of Armor Rocks: 2.0t/unit

Based on the design conditions set in this project, the necessary weight of the armor material is calculated by the method described in DGCS as follows. The DGCS calculates using the following Hudson formula, using wave height, unit weight, empirical coefficient, and so on. H=1.6m is explained above and K_D=1.0 is referred in the DGCS.

Equation 7-1

$$W_{50} = \frac{w_r H^3}{K_D (s_r - 1)^3 cot\theta}$$

where:

W_{50}	=	median weight of armor units
w_r	=	unit weight of armor units (kN/m³)
H	=	design wave height (refer discussion below)
K_D	=	empirical coefficient (refer discussion below)
Sr	=	specific gravity
θ	=	slope of revetment

For Concrete Blocks

$$W = \frac{2.3 \times 1.6^3}{8.0 \times 1.0 \times \{(2.3 / 1.03) - 1.0\}^3} = 0.63 \text{ t/unit}$$

For Armor Rocks

$$W = \frac{2.65 \times 1.6^3}{2.0 \times 1.0 \times \{(2.65 / 1.03) - 1.0\}^3} = 1.39 \text{ t/unit}$$

Table 2.10.12 Evaluation Results of Armor Materials

Items	Original	Evaluation	Proposal
Concrete Blocks	2.0t	> 0.63t	Same as original
Armor Rocks	2.0t	> 1.39t	Same as original

Source: Project Team

(5) Effect on Environment of Planed Alignment of Coastal Road

The design conditions set in this project have the following characteristics.

- Waves are quite small, about half of the design waves set by DPWH.
- On the other hand, the period of design wave is comparatively low, and overtopping can occur in case that waves act directly.
- The tidal current can be slightly observed, but the impact is rather small throughout the section.

Therefore, it can be noticed that the maritime condition is not greatly affected by the planned alignment of Coastal Road. However, regardless of the alignment, the following concerns should be noted about water closures.

Concerned Items

- Although the water area on the land side has some openings after the construction of Coastal Road, it is a closed water area, and it is concerned that seawater exchange will be sufficient or not.
- Natural beaches will be lost, following by effect of the ecosystem, living, environment and landscape may occur.
- In coastal areas, domestic wastewater is directly discharged, and if the seawater exchange is insufficient, the living environment may be considerably deteriorated.
- In some areas, rainwater drainage is also discharged naturally, and it is concerned whether it can be discharged naturally after the construction of Coastal Road.

Basically, such a large-scale landfill development plan requires a detailed assessment of the impact on the environment and decision-making activities involving stakeholders such as residents. However, this project only raises concerns because the Coastal Road plan is an ongoing plan before this project starting.

2.10.9 Numerical Analysis on Storm Surge and Coastal Erosion from the View Point of Coastal Protection

The following section evaluates the present and future defense structures of the Davao coast using the target scales according to the section “3.3 Target Design Level” with conducting a series of numerical analysis on storm surge and coastal erosion.

The most impact factor in the coastal area of Davao City is the Coastal Road. Therefore, Davao City's coastal area is largely divided into three parts. Storm surge and coastal erosion analysis will be conducted in the following 3 zones. Furthermore, this study will examine the cases with/without existing and future projects in order to understand the impact of these projects.

Zone 1: From Davao City South to starting point of Coastal Road
Zone 2: Coastal Road construction sections
Zone 3: End point of Coastal Road -North Davao City

(1) Storm Surge Inundation

1) Outline

As mentioned above, no storm surges due to typhoons have occurred on the Davao coast. Therefore a storm surge inundation simulation is conducted for normal astronomical high tide levels, or design tide levels that are set as the target level. The following three cases are performed. Case 1 is to perform the inundation simulation for the target scale set as the current condition before the construction of the Davao Coastal Road and estimate the inundated condition. Case 2 is to perform the inundation simulation with Davao Coastal Road completed and evaluate the effects of the coastal roads. Case 2 will also clarify which area the inundation situation is remarkable. Case 3 is to perform inundation simulations not only at the 100-year probable tide of the target level, but also at 1-year, 10-year, 25-year, and 50-year probable tide for use in B / C analysis. Obviously, no inundation due to storm surge in the residential and industrial area will occur after implementing the countermeasures of this project.

1. Before construction of Davao Coastal Road (current status)
2. After completion of Davao Coastal Road
3. After completion of all ongoing projects (for B/C analysis of countermeasures)

2) Models

The study used the analysis model described in “Guide for Development of Storm Surge Inundation Area Map” in Japan. This model is based on the equations of motion and continuity equations that apply nonlinear long-wave theory, and incorporates various effects into the vertically integrated shallow water theory. Please refer to the guideline for the basic formula.

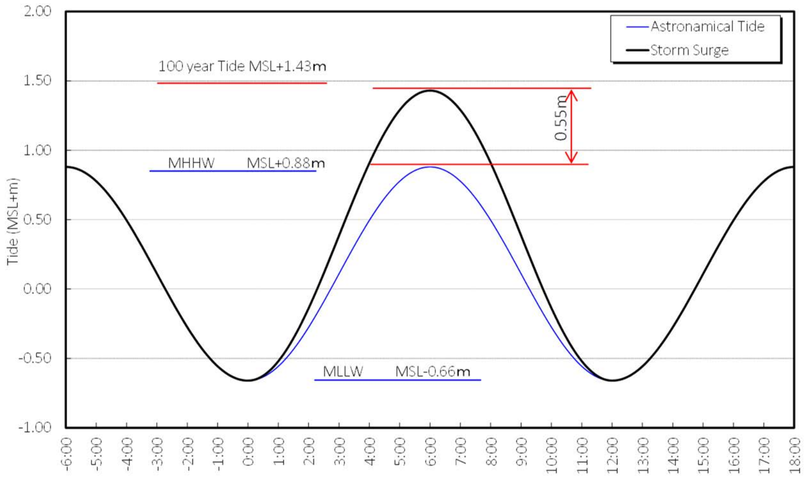
3) Calculation Conditions

The main analysis conditions are as shown in Table 2.10.13. The tide level to be examined is a 100-year probable tide level, but inundation simulation was also performed for the probable tide level for 1 to 50 years (see Table 2.10.3) for B / C studies only in case 3. Case 3 was also implemented for tidal levels taking into account climate change (+0.1 m for all tidal levels). The ground elevation data used in this project was integrated using LAIDER and IFSUR data (see Figure 2.10.20). The roughness coefficient was set as shown in Table 2.10.14 based on the current land use classification data and based on the "Guideline for Creating Storm Surge Inundation Area Map". The result is shown in Figure 2.10.21.

Table 2.10.13 Calculation Conditions

Item	Value	Comment
Target Tide	MSL+1.43m	100 year probable tide
Duration	12 hours	Based on observations
Astronomical tide	From -0.66m to +0.88m	From MLLW to MHHW
Friction Coefficient	Based on Present Land use	
Model	Shallow Water Equations	
Grid size	dx=25m dy=25m	The topography is based on LAIDER and IFSUR
Cases	1: Before construction of Coastal Road 2: After construction of Coastal Road 3: After construction of ongoing project	

Source: Project Team



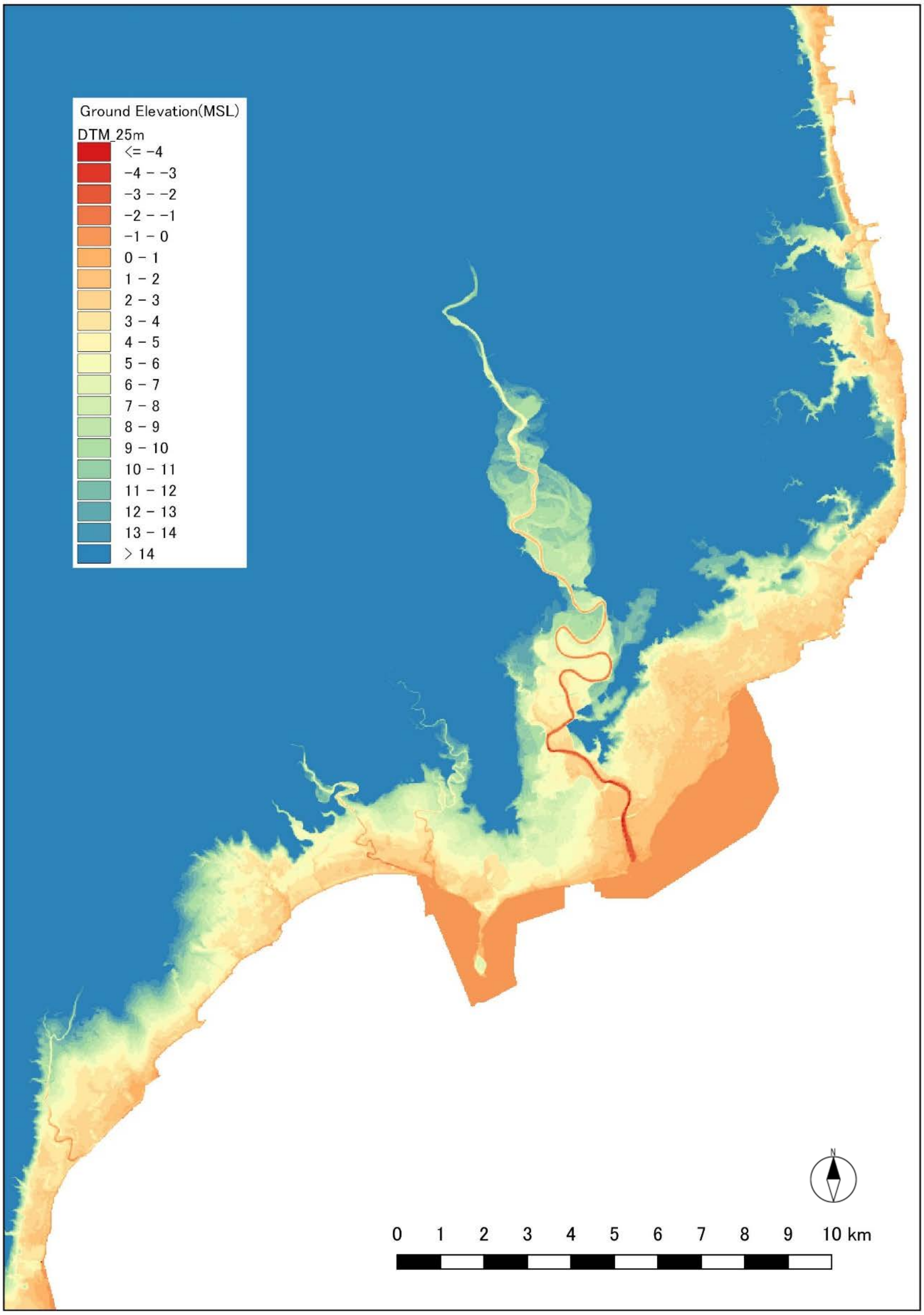
Source: Project Team

Figure 2.10.19 Tide Curve

Table 2.10.14 Roughness Coefficient for Storm Surge Simulation

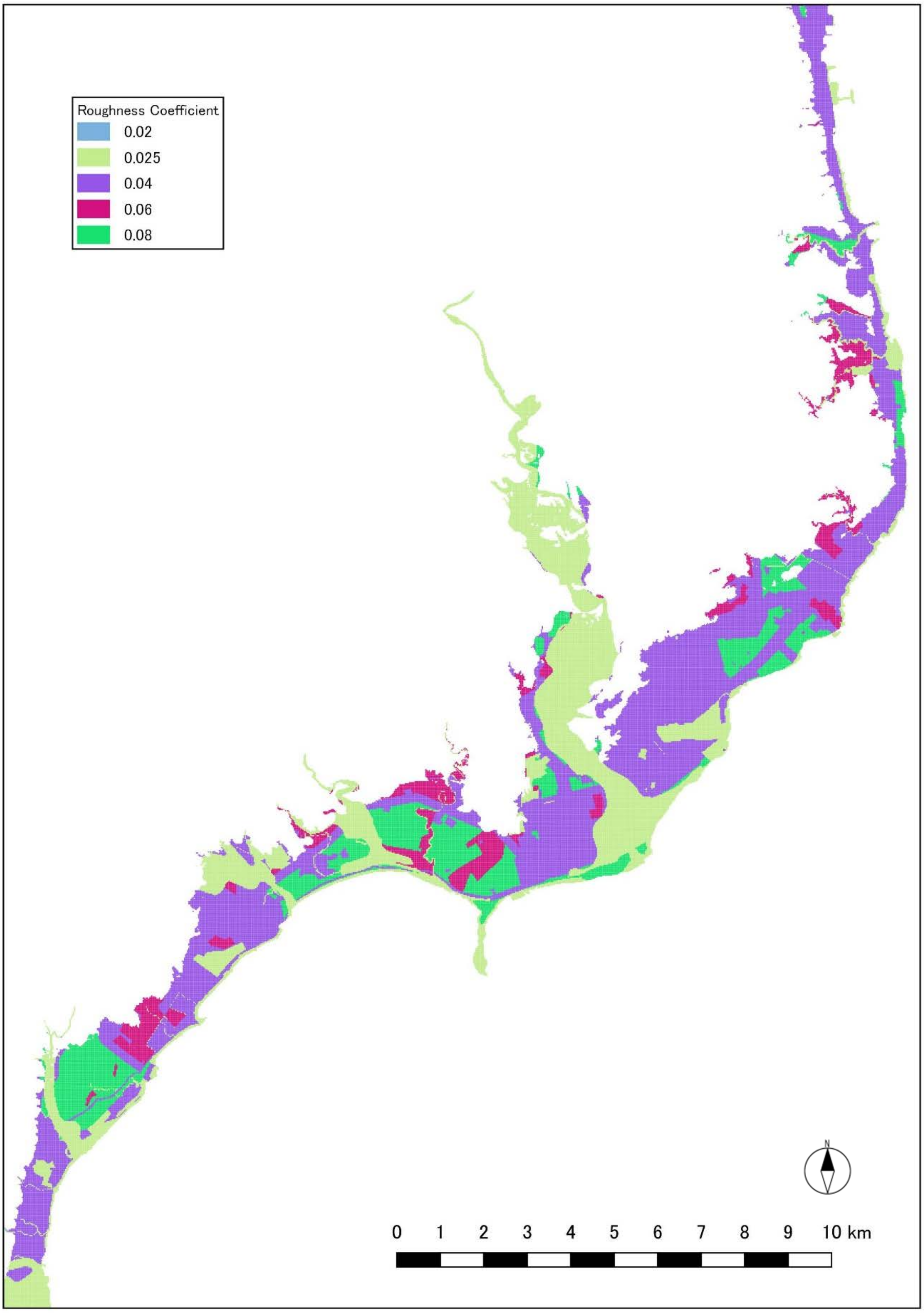
Category	Roughness Coefficient
Residential (High)	0.08
Residential (Medium)	0.06
Residential (Low)	0.04
Industrial	0.04
Water, others	0.025
Agricultural	0.02
Forest	0.02

Source: Project Team



Source: Project Team

Figure 2.10.20 Ground Elevation Data



Source: Project Team

Figure 2.10.21 Roughness Coefficient Distribution

4) Results

As the results for the analysis cases shown in Table 2.10.15, the maximum inundation depth distribution for each case is shown below.

Case 1 (current status: before the construction of Coastal Road, 100-year probability tide) is shown in Figure 2.10.23, Case 2 (after the construction of Coastal Road, 100-year probability tide) is shown in Figure 2.10.24, and the results of 1-year, 10-year, 25-year, 50-year, and 100-year probable tides in Case 3 (after the completion of the Ongoing project) are shown in Figure 2.10.25 to Figure 2.10.34, respectively.

Table 2.10.15 Calculation Cases

Case	Tide	Calculation Condition
Case 1	100 year probable tide	Before construction of Davao Coastal Road
Case 2	100 year probable tide	After construction of Davao Coastal Road
Case 3	1, 10, 25, 50 and 100 year probable tide	After completion of ongoing projects (Davao Coastal Road, River Flood wall improvement)

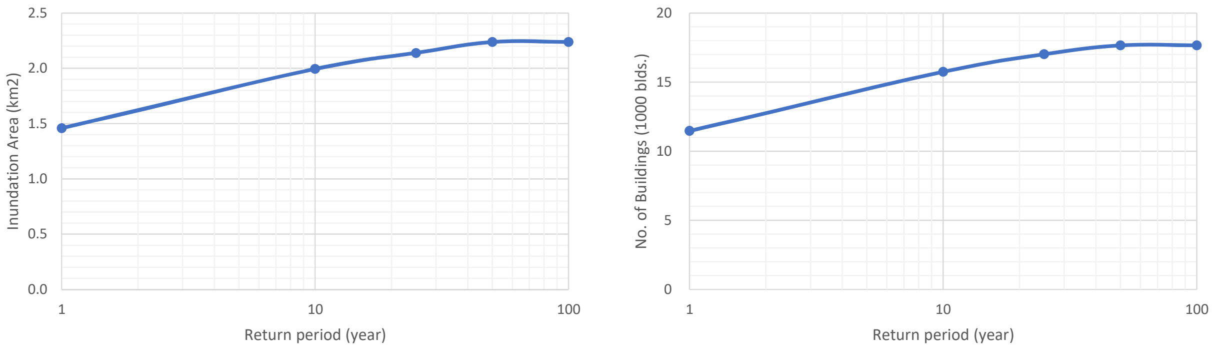
Source: Project Team

Table 2.10.16 shows the inundation area and the number of damaged buildings as a summary of the analysis results for each case. Figure 2.10.22 shows the relationship in the inundation area and the number of damaged buildings with each return period in Case 3.

Table 2.10.16 Summary of Inundation Simulation

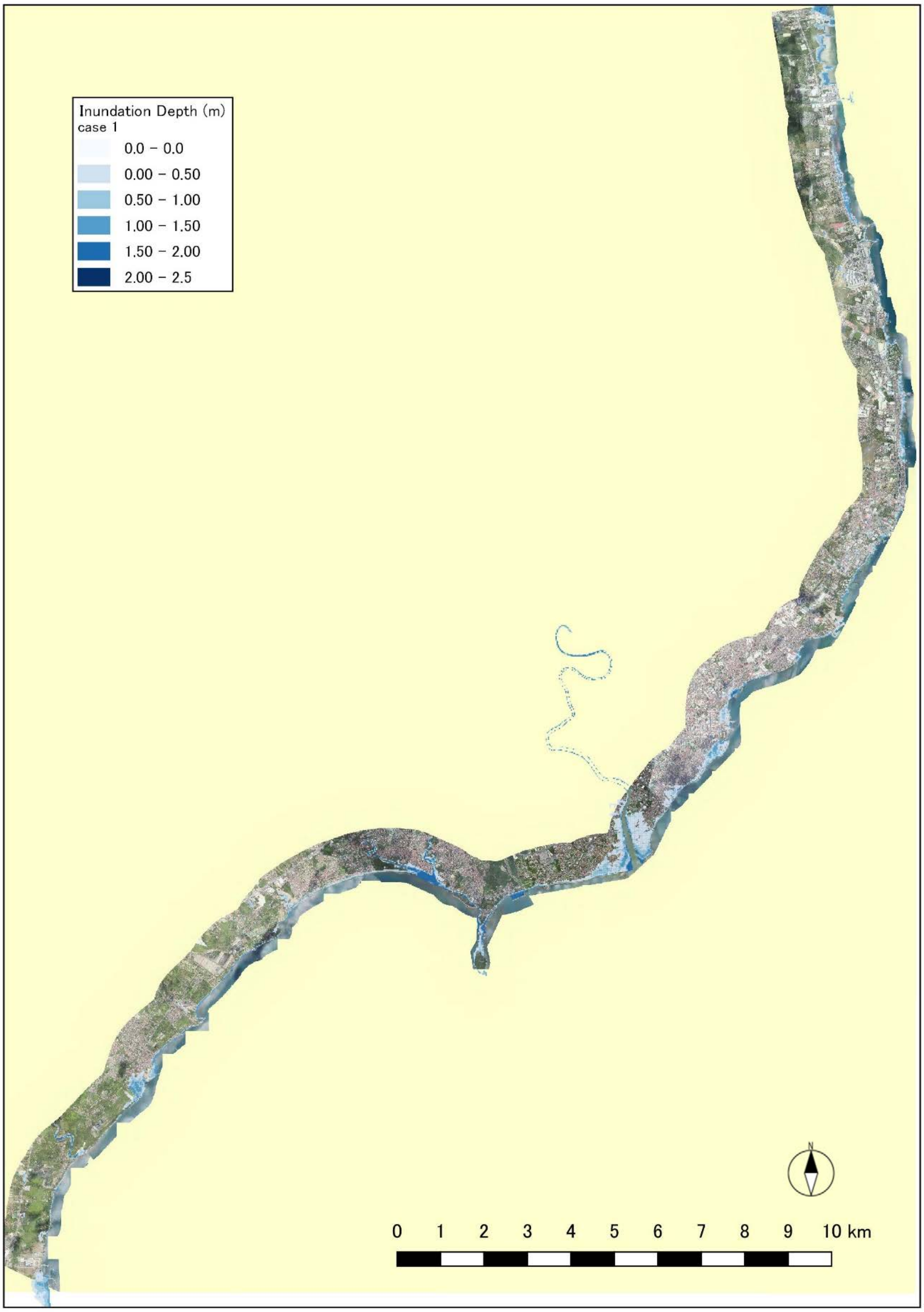
Case	Return period (year)	Inundation Area (km^2)	No. of Affected Buildings (1000 blds.)
1	100	2.2	18.2
2	100	2.2	18.2
3	1	1.5	11.5
	10	2.0	15.8
	25	2.1	17.0
	50	2.2	17.7
	100	2.2	17.7

Source: Project Team



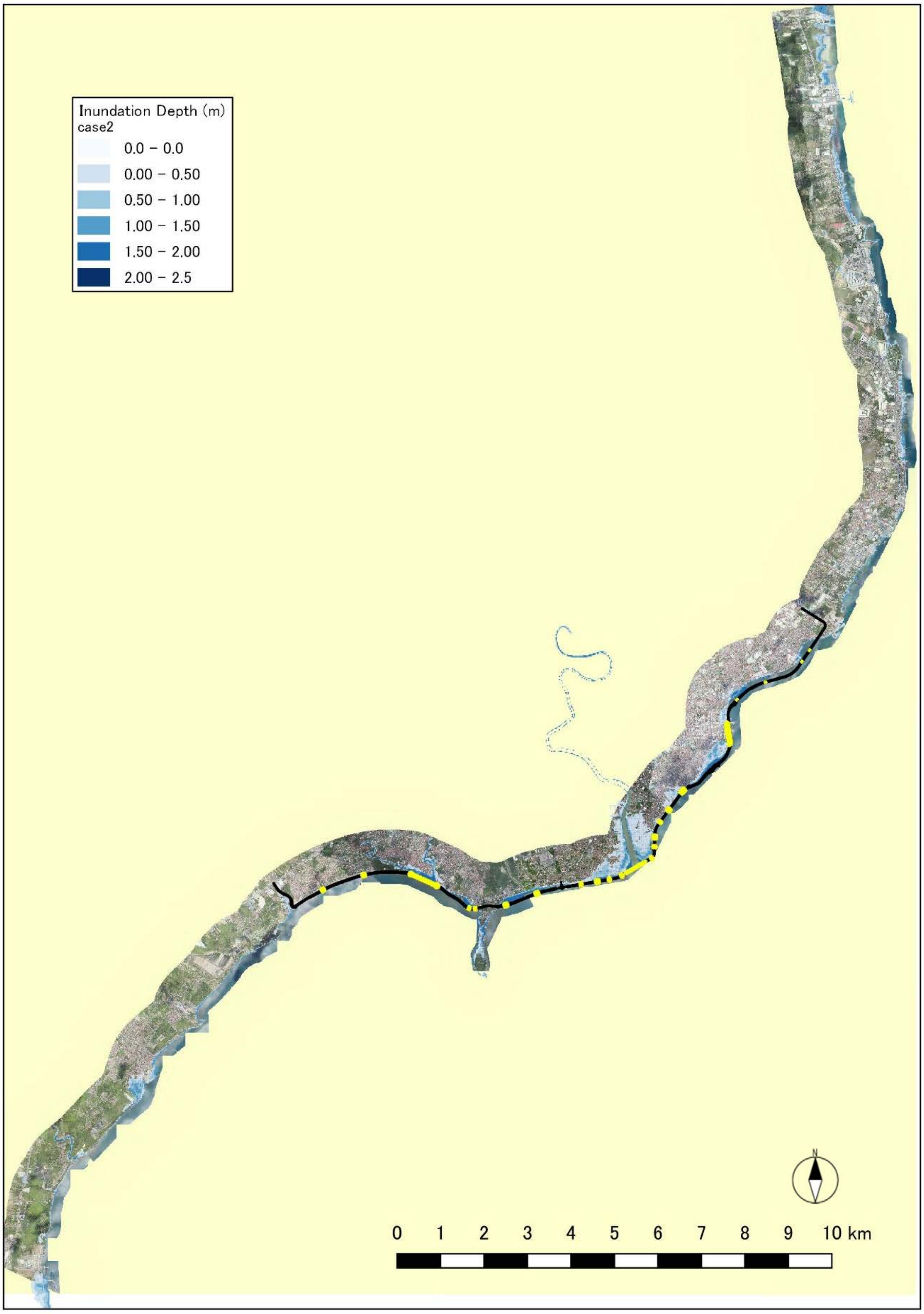
Source: Project Team

Figure 2.10.22 Calculation Results in Case 3 (L: Inundation Area, R: Damaged Buildings)



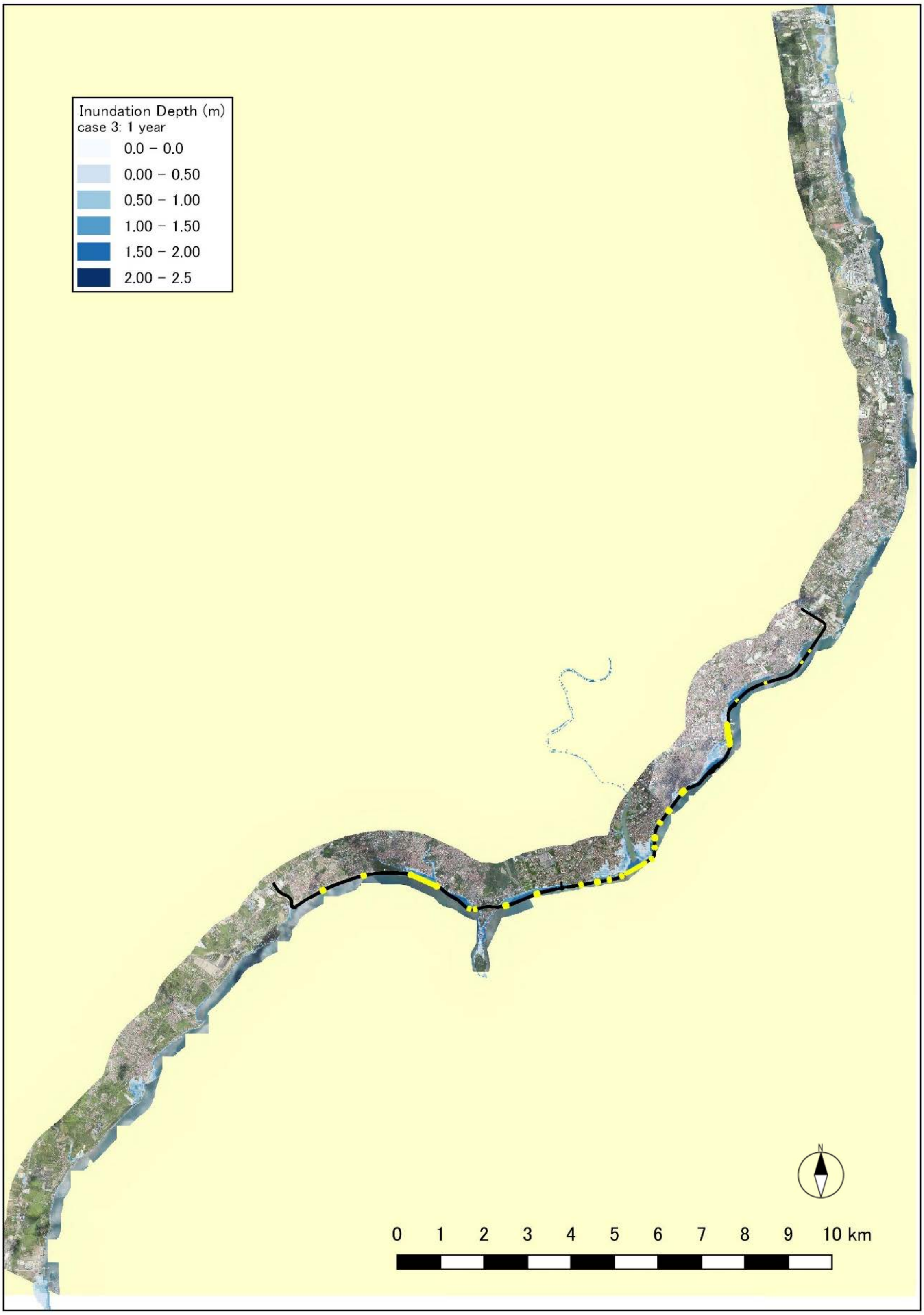
Source: Project Team

Figure 2.10.23 Maximum Inundation Depth Distribution (Case 1: 100-year tide)



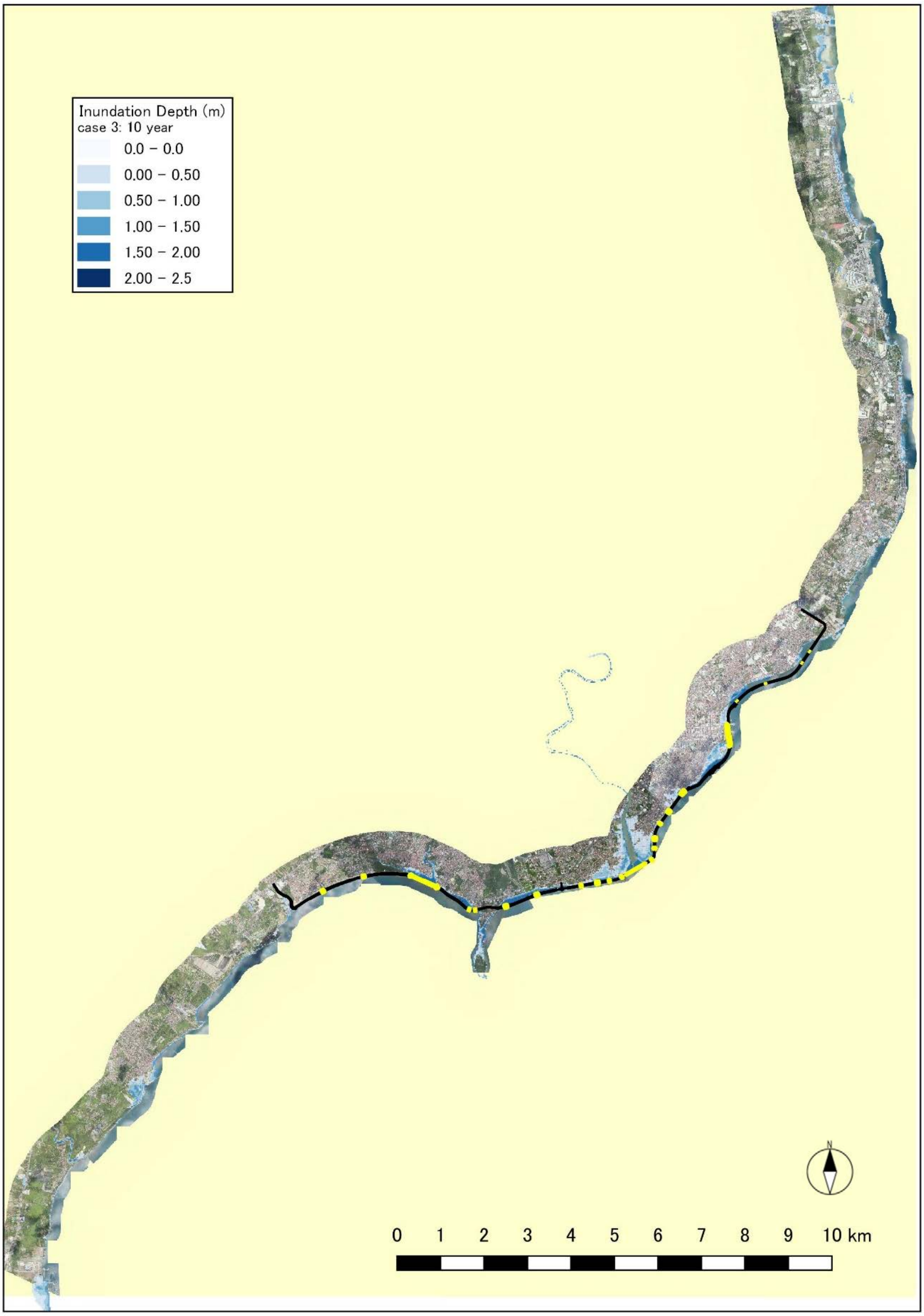
Source: Project Team

Figure 2.10.24 Maximum Inundation Depth Distribution (Case 2: 100-year tide)



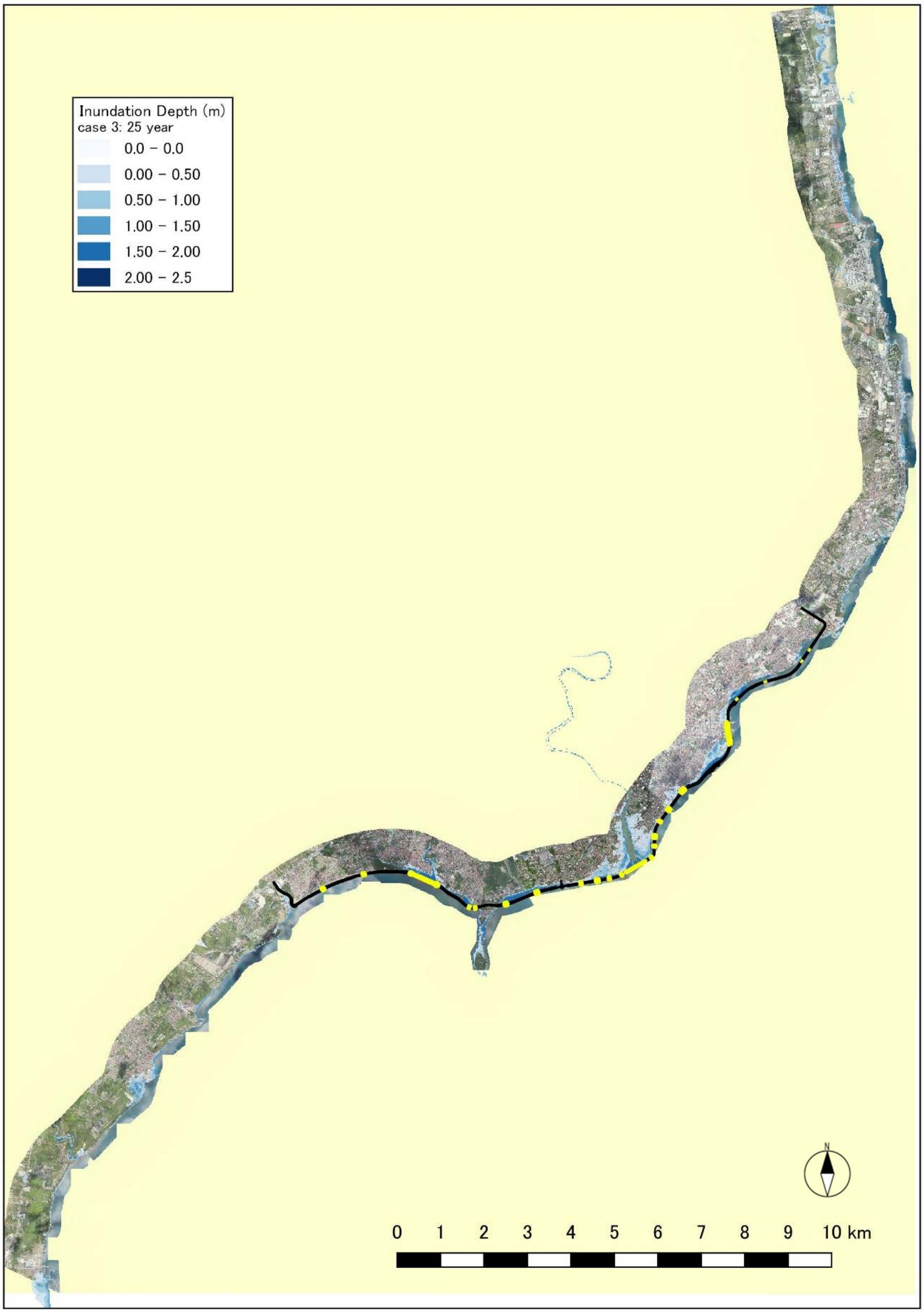
Source: Project Team

Figure 2.10.25 Maximum Inundation Depth Distribution (Case 3: 1-year tide)



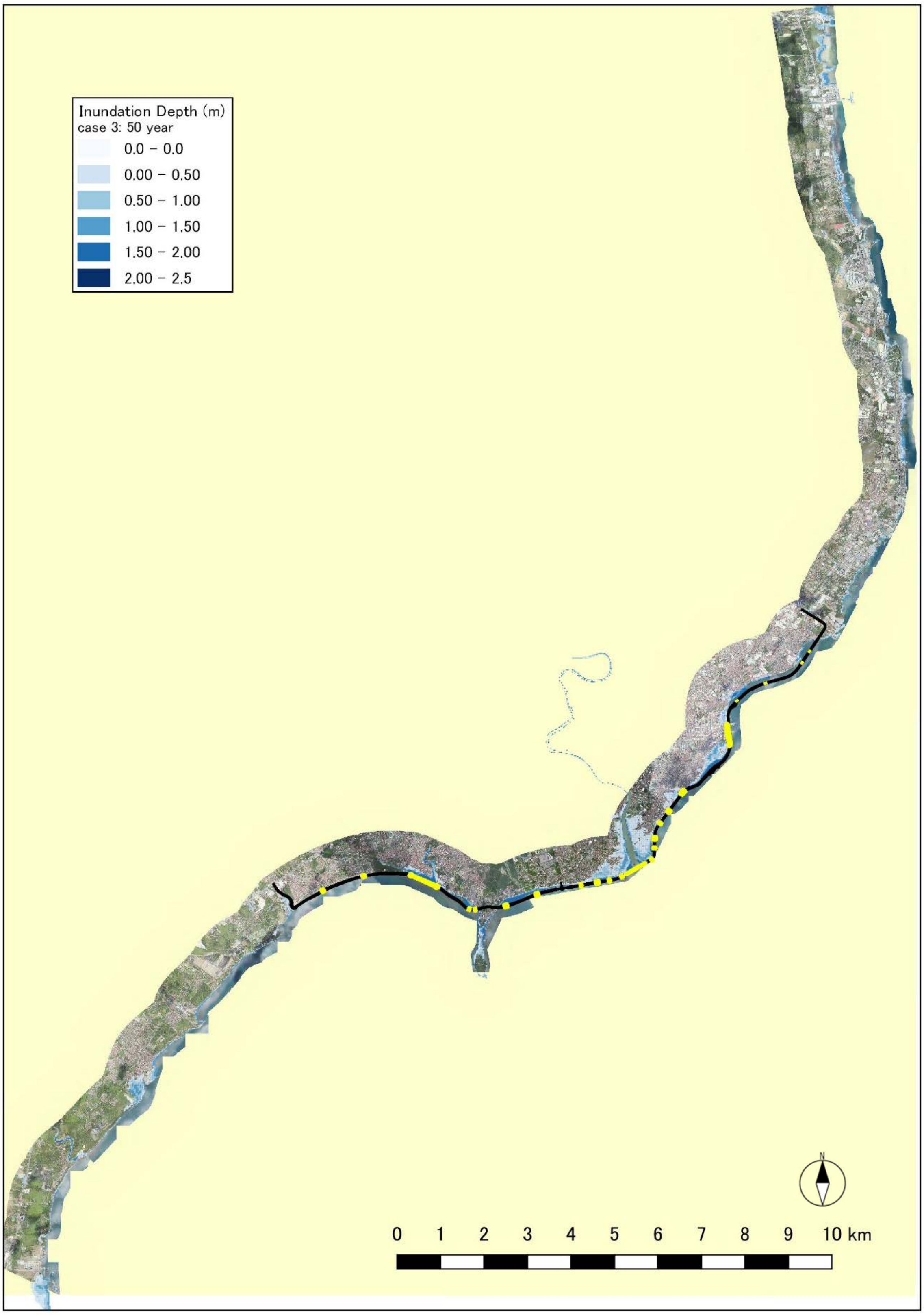
Source: Project Team

Figure 2.10.26 Maximum Inundation Depth Distribution (Case 3: 10-year tide)



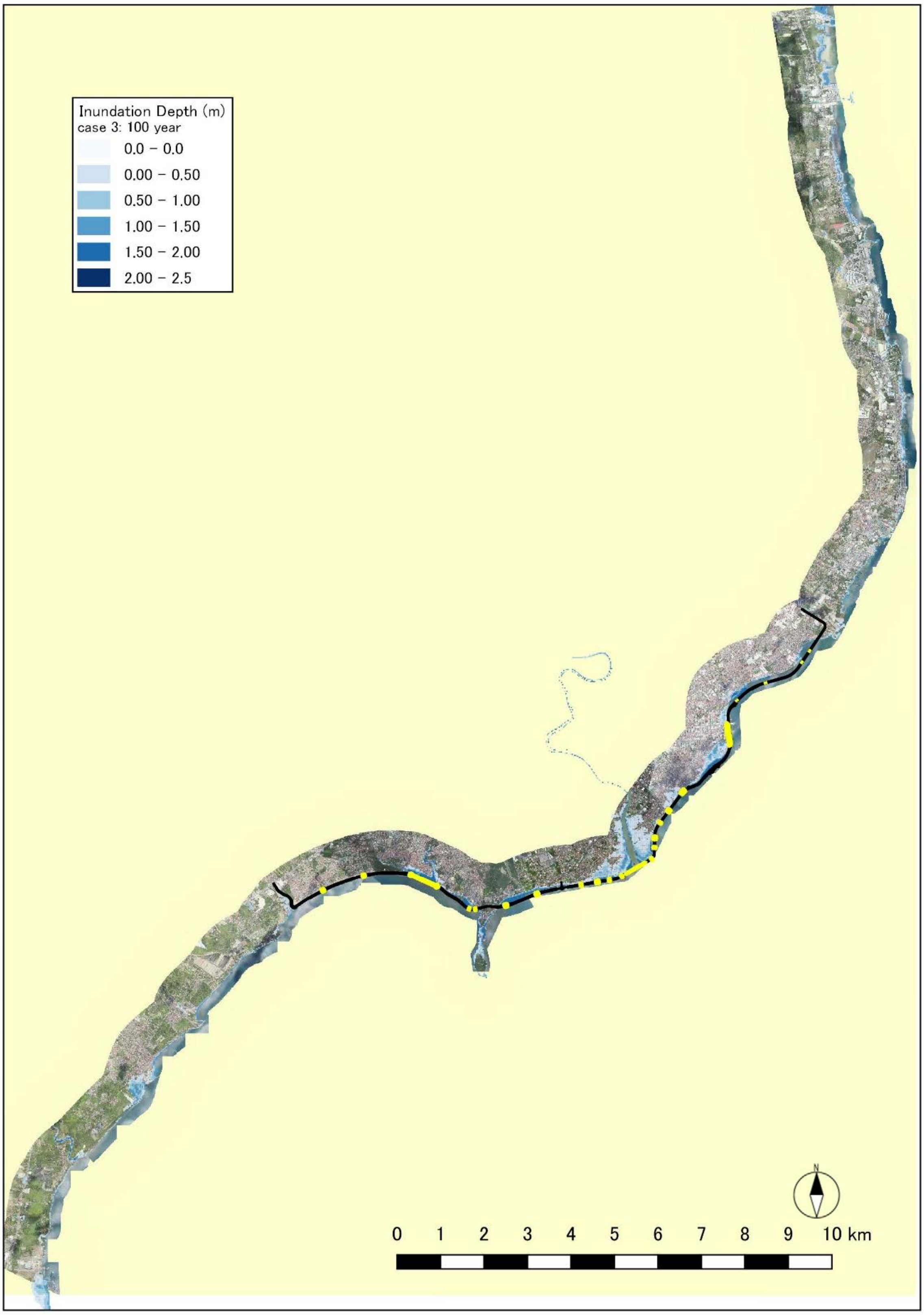
Source: Project Team

Figure 2.10.27 Maximum Inundation Depth Distribution (Case 3: 25-year tide)



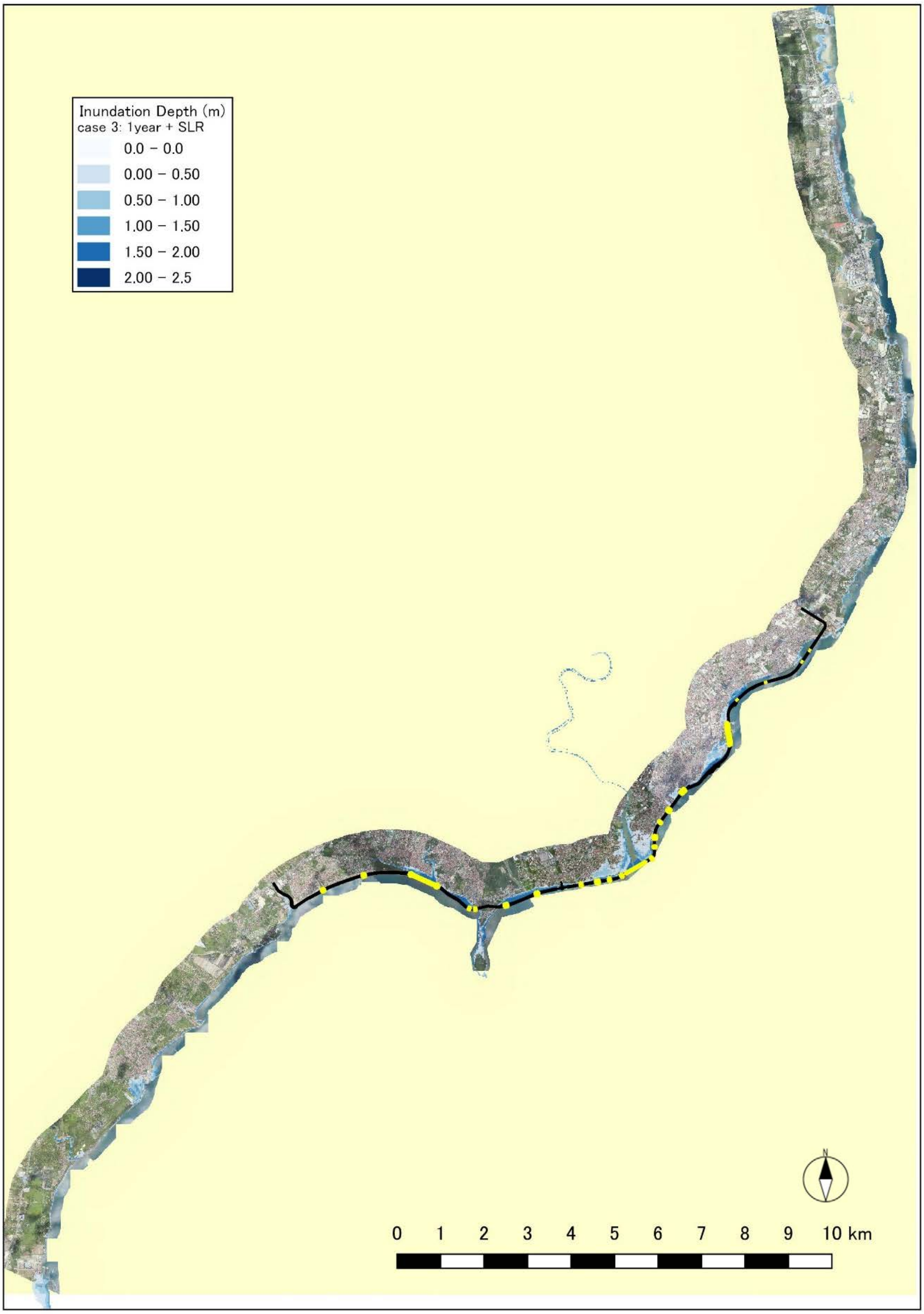
Source: Project Team

Figure 2.10.28 Maximum Inundation Depth Distribution (Case 3: 50-year tide)



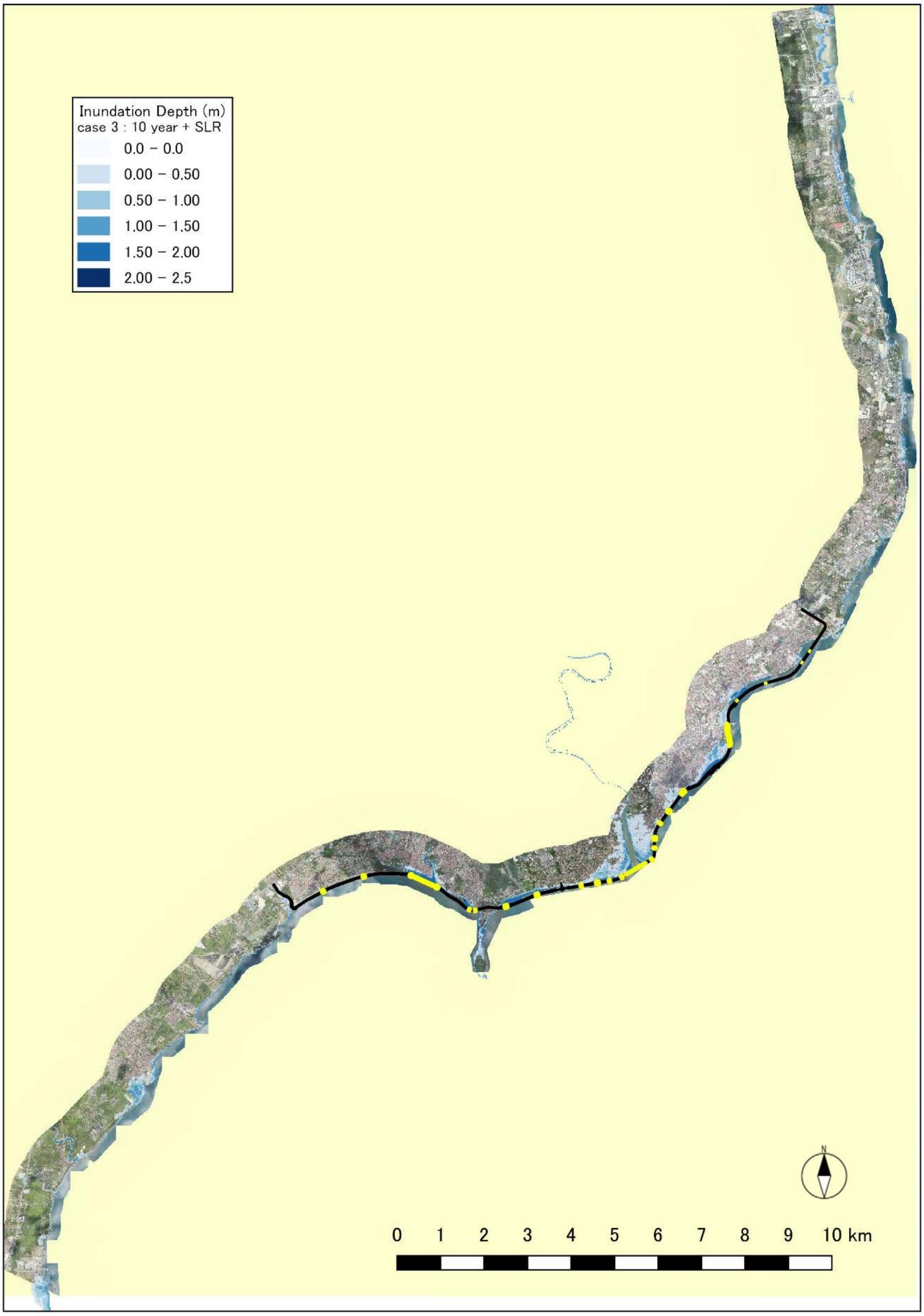
Source: Project Team

Figure 2.10.29 Maximum Inundation Depth Distribution (Case 3: 100-year tide)



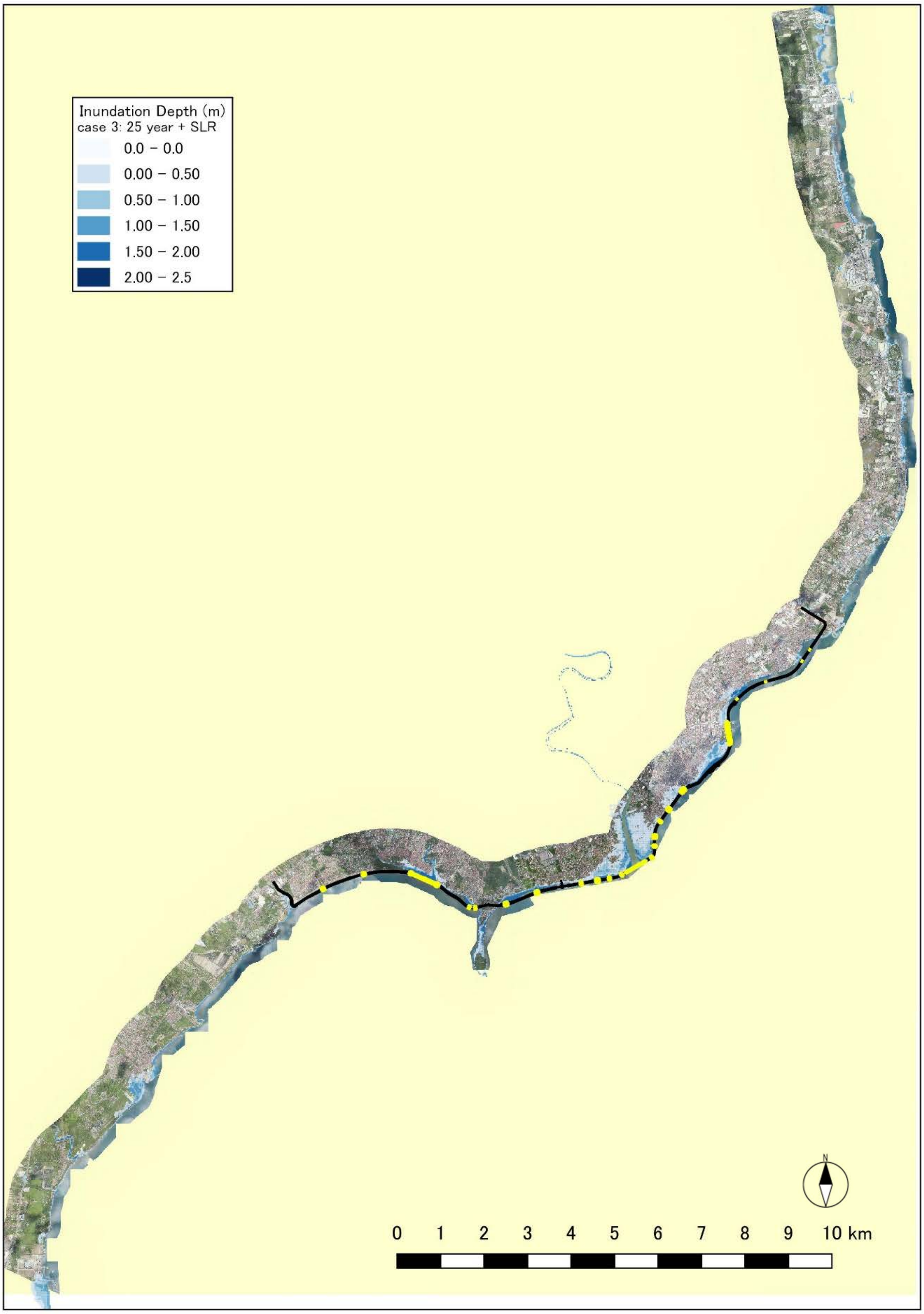
Source: Project Team

Figure 2.10.30 Maximum Inundation Depth Distribution (Case 3: 1-year tide + SLR)



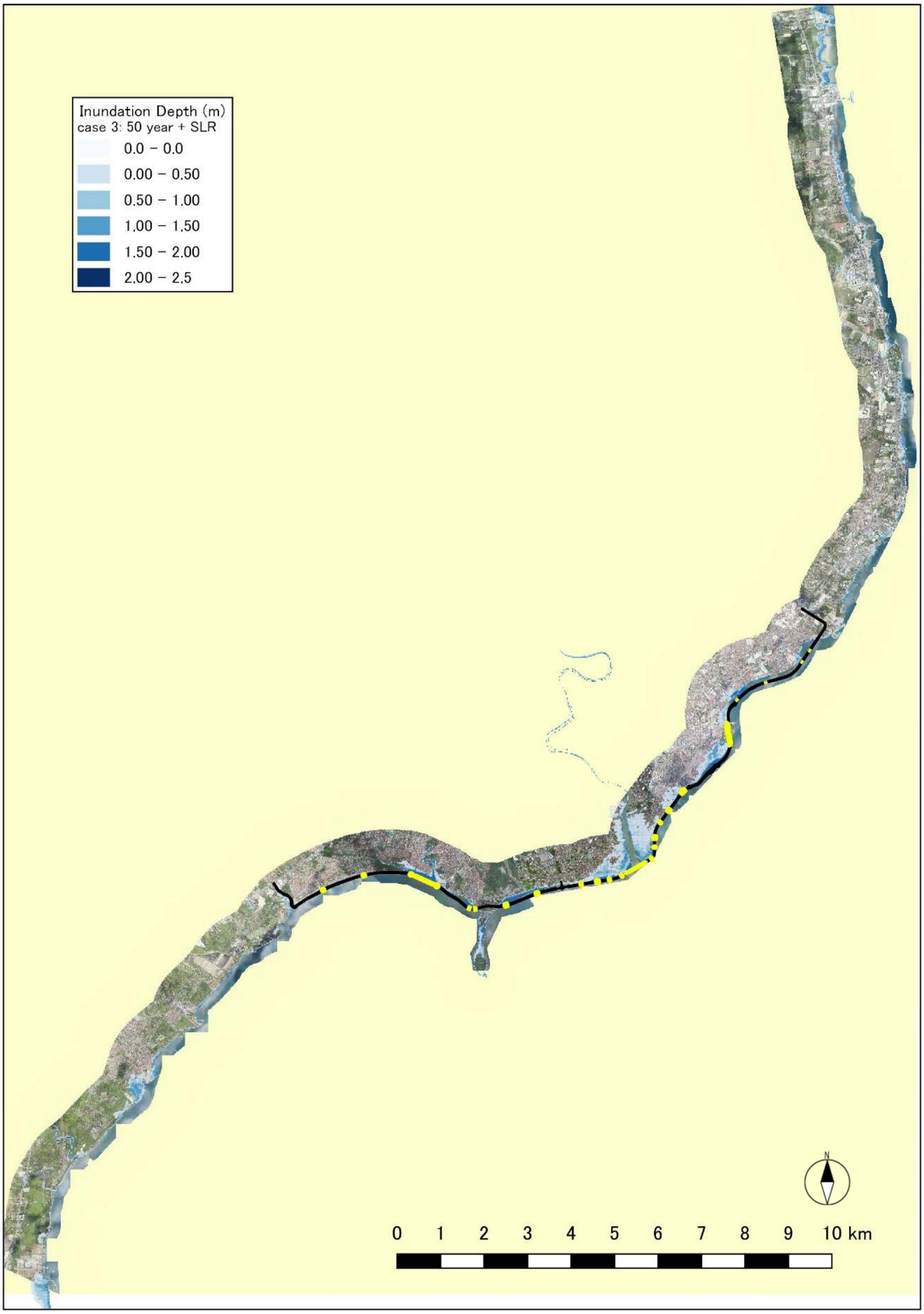
Source: Project Team

Figure 2.10.31 Maximum Inundation Depth Distribution (Case 3: 10-year tide + SLR)



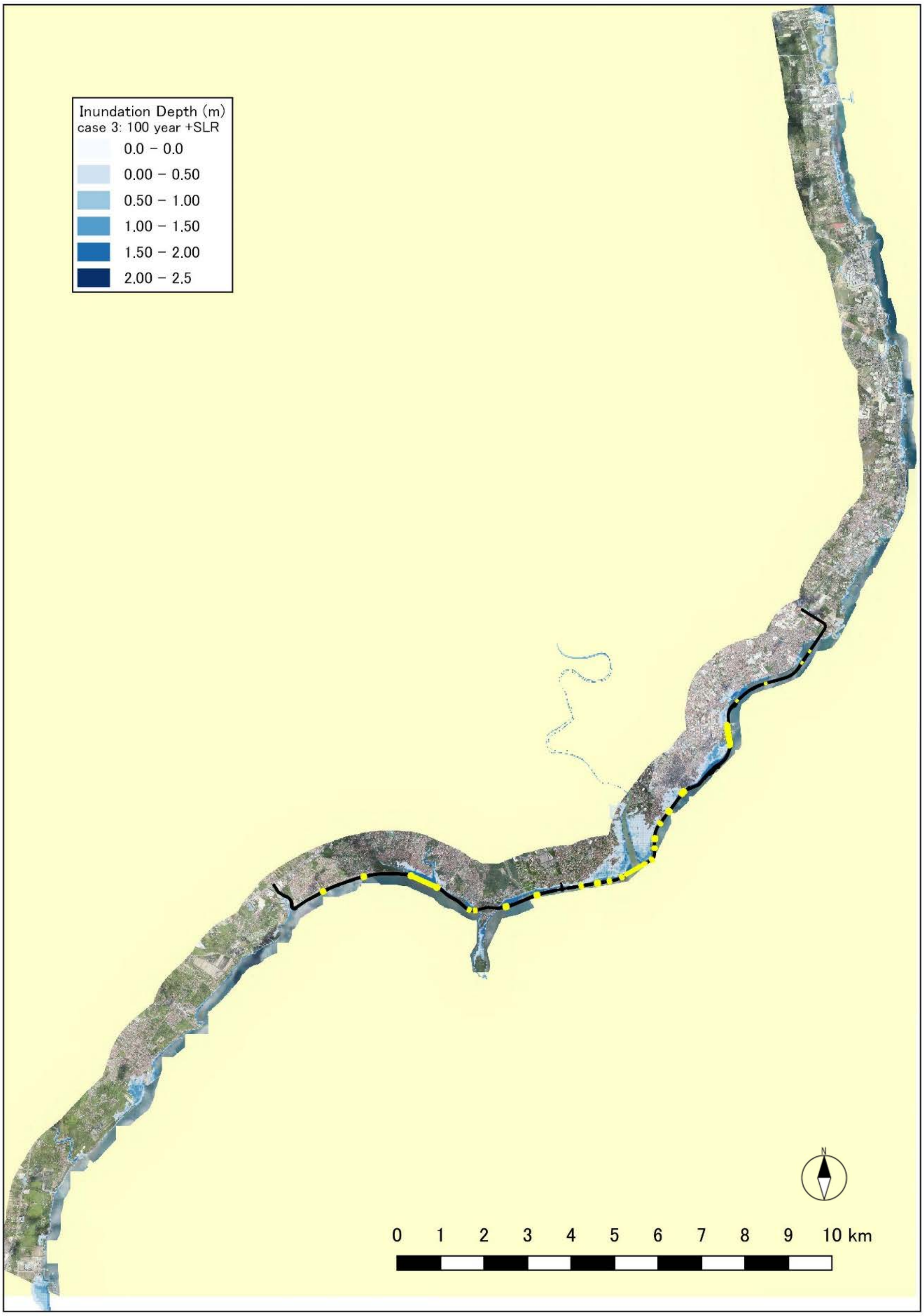
Source: Project Team

Figure 2.10.32 Maximum Inundation Depth Distribution (Case 3: 25-year tide + SLR)



Source: Project Team

Figure 2.10.33 Maximum Inundation Depth Distribution (Case 3: 50-year tide + SLR)

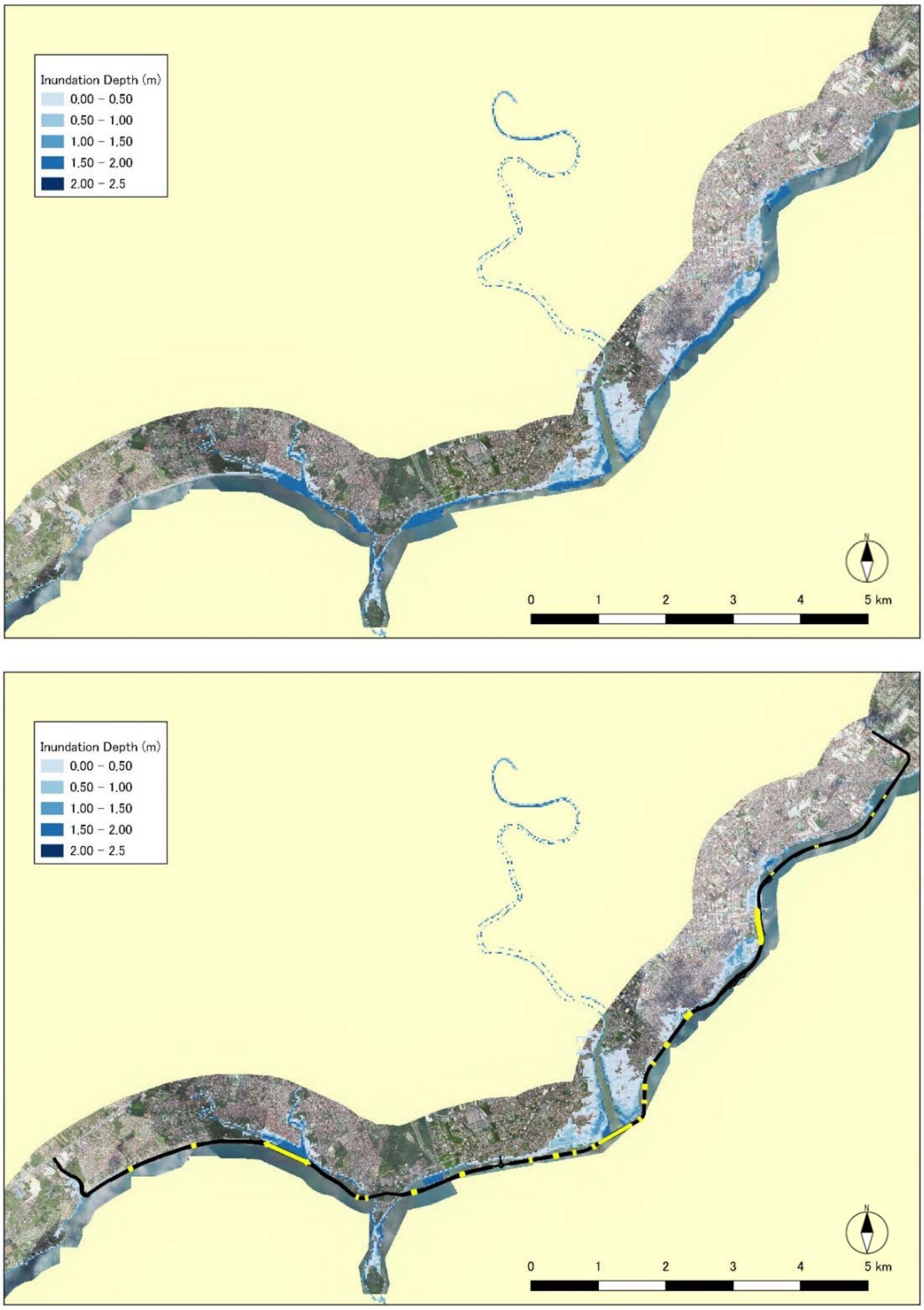


Source: Project Team

Figure 2.10.34 Maximum Inundation Depth Distribution (Case 3: 100-year tide + SLR)

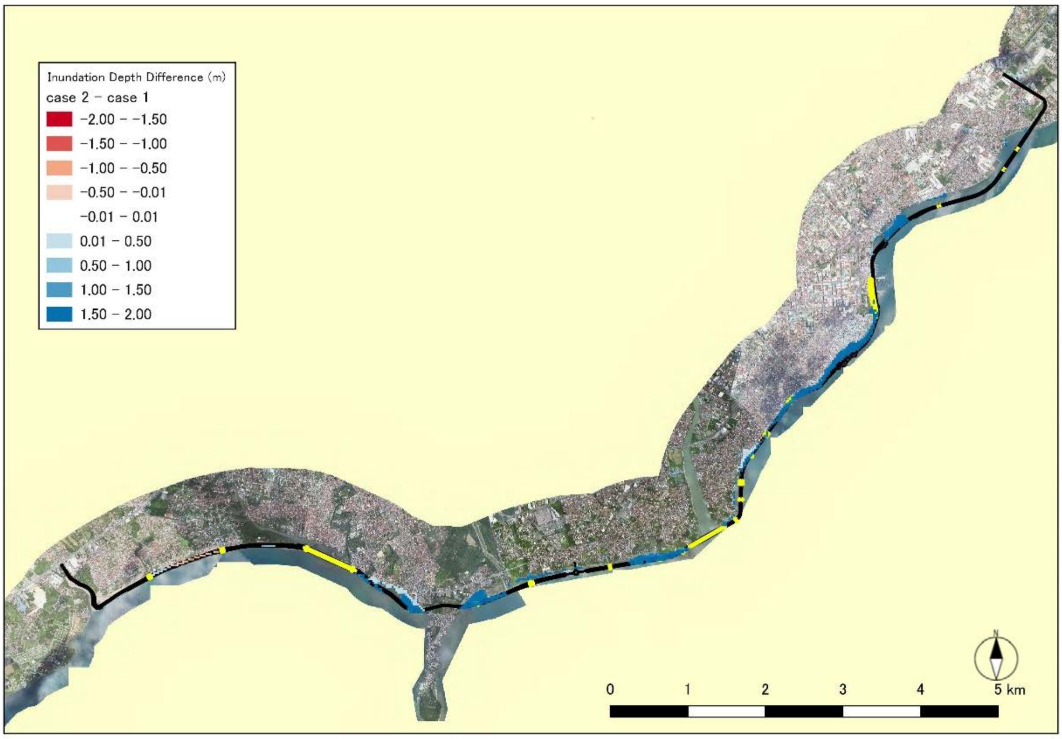
5) Impact Evaluation

Figure 2.10.35 shows the impact of the inundation situation before and after the construction of Coastal Road, focusing the Coastal Road section. Coastal Road has several openings, such as bridges, from which seawater can come around. Therefore, even after the construction of Coastal Road, the inundation area did not change significantly. Figure 2.10.36 shows the difference in inundation depth before and after the construction of Coastal Road. It was found that there was no effect in inundation in the land area. Therefore, coastal road alone has little effect to protect the inundation along the Davao City coast, and other measures are necessary.



Source: Project Team

Figure 2.10.35 Comparison of Maximum Inundation (top: case 1, bottom: case 2)



Source: Project Team

Figure 2.10.36 Difference Distribution in Maximum Inundation Depth (case 2- case 1)

(2) Coastal Erosion

1) Outline

The following three cases were carried out to investigate the current and future shoreline changes regarding coastal erosion analysis. Case 1 is for the model construction and validation by carrying out the shoreline analysis of the present condition (before the construction of Davao Coastal Road) from the past coastline. After that, using the developed model, the future shoreline analysis without any interventions (e.g. coastal road) was conducted to evaluate future coastline. Finally, the shoreline analysis is performed under the conditions after the completion of Coastal Road to evaluate the impact of Coastal Road on the shoreline (case 3). By comparing Case 2 and Case 3, the impact of Coastal Road construction on shoreline changes on the Davao coast is examined. Each case also grasps the sections where erosion and sedimentation are remarkable.

1. Change of shoreline from the past to the present condition (before construction of Coastal Road)
2. Change of future shoreline without completion of Davao Coastal Road
3. Change of future shoreline with completion of Davao Coastal Road

2) Models

This study used, as a shoreline change analysis model, a 1-line model applied to the analysis of long-term shoreline prediction. The outline of the analysis model is as follows.

The shoreline change model is a model that captures the beach profile as a change of one representative contour line (often a shoreline). The basic assumption of this method is as follows.

i) Sand transport along coast is the only factor of beach profile change.
ii) Sand transport occurs at the only representative target depth.
iii) Regarding the beach profile, the slope does not change, and it keeps its shape, and moves parallel to the shore.

The shoreline model is mainly composed of the following three calculation parts. Shoreline change is calculated with repeating these steps.

i) Calculation of wave transformation

The wave transformation model is calculated using the wave transformation model, and the breaking waves at each grid point are calculated. If there are structures offshore such as breakwaters, consider the effects of these structures.

ii) Calculation of coastal sand transport

Calculate the amount of sediment transport using the coastal sediment transport equation based on the breaking wave parameters and the slope of the shoreline calculated in step 1). If there is a structure such as a jetty or breakwater, consider separately reduction of coastal sand transport.

iii) Calculation of shoreline change

The amount of shoreline change at each grid point is calculated by substituting the coastal sedimentation amount calculated in step ii) into the continuity equation of sand. If there are structures such as dikes, the amount of shoreline change will be separately modified, and the amount of coastal sedimentation will be modified so that the continuity equation of sand is satisfied.

3) Calculation Conditions

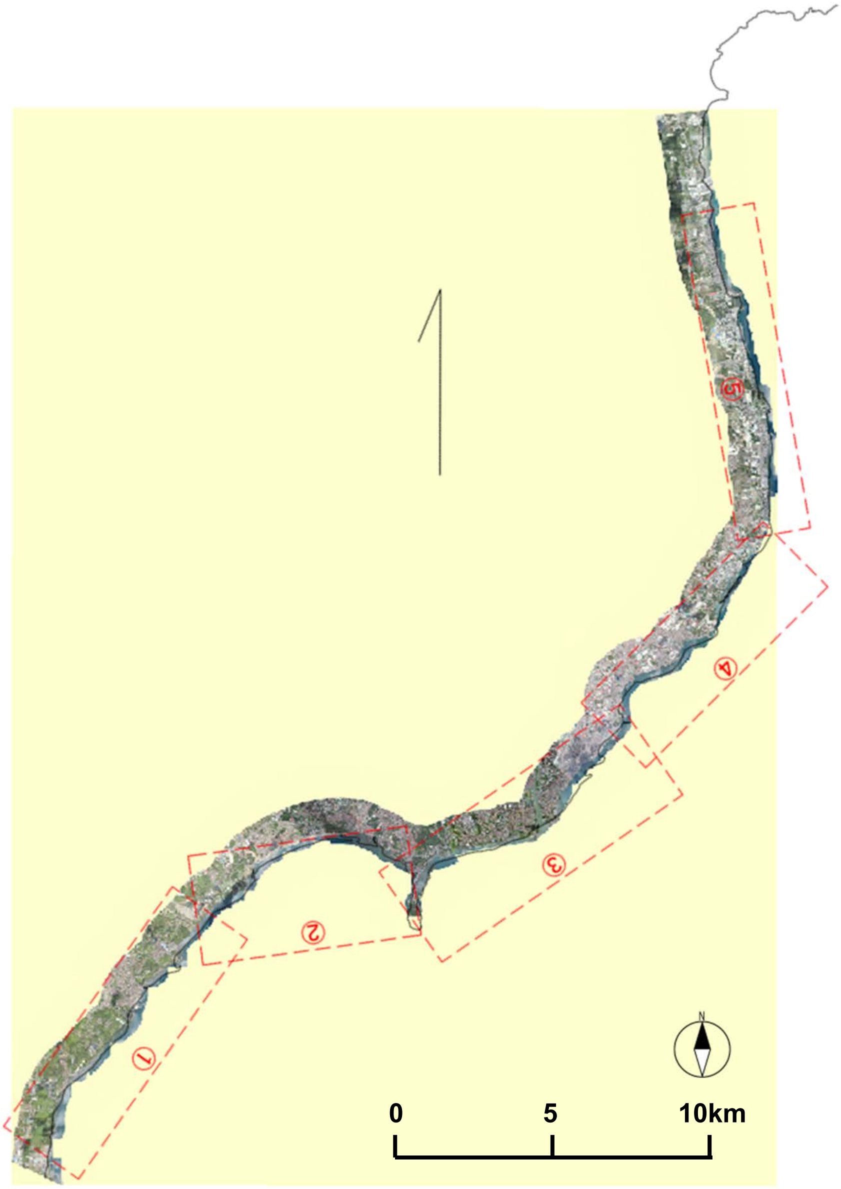
The analysis conditions for this study are shown in Table 2.10.17. Case 1 was performed for model development and verification of the coefficient of sediment transport and the amount of sediment discharge from the 2 main rivers (Davao River and Matina-Talomo River), and then predicted the future of Cases 2 and 3. For the prediction calculation, a long-term shoreline change trend was grasped, targeting 10 years after reaching the equilibrium state. Therefore, as the tide level, the average tide level was applied, and the annual energy average wave (set from the reanalyzed wave data described above) was also applied for the wave condition. In Case 1 and Case 2, shoreline change analysis were performed with MSL + 0.0m as the target shoreline. However, in the case 3 (after the Coastal Road construction), the shore line analysis used MSL-2.0m as the target counter line because some sections have no sand at MSL + 0.0m. Using the results examined the impact of Coastal Road construction.

Table 2.10.17 Calculation Conditions of Coastal Erosion Analysis

Item	Value	Comment
Tide	MSL+0.0m	Constant
Wave Wave Height Wave Period Wave Direction	Annual Average H=0.20m T=3.2s 154 deg from N	Based on reanalysis wave data
Duration	2017 to 2027 (10 years)	Considering the equilibrium of sediment transport
Sediment Discharge	Davao: 58,000 m^3/yr Matina & Talomo: 2,100 m /yr	Based on the validation results
Model	1 line model	For long term analysis
Target contour	Case1 and 2: MSL+0.0m Case 3: MSL-2m	

Source: Project Team

The target calculation area is as shown in Figure 2.10.37, which divided the coast of Davao City into five areas as a relatively straight line. The Coastal Road section is from Area 2 to Area 4.



Source: Project Team

Figure 2.10.37 Calculation Region for Shoreline Analysis

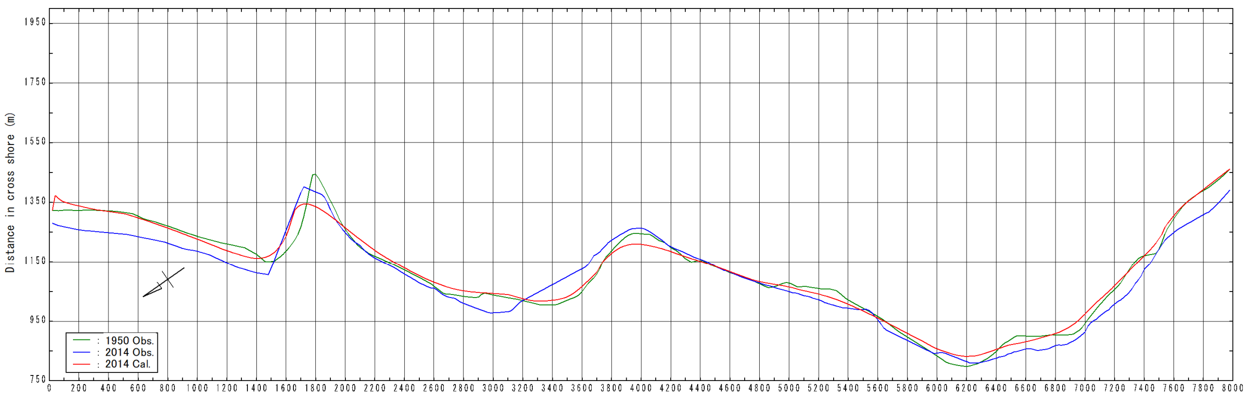
4) Results: Case 1

In Case 1, the calculation model was developed by performing the analysis of past shoreline changes along the coast of Davao City, using the coastline from 1950 to 2014 obtained from Davao City. As the analysis results, the actual measurement results (Obs.) in 1950 and 2014 and the calculation results (Cal.) in 2014 are shown in Figure 2.10.38 to Figure 2.10.42 for each area. A summary of the analysis results is shown in Table 2.10.18.

Table 2.10.18 Results in Case 1

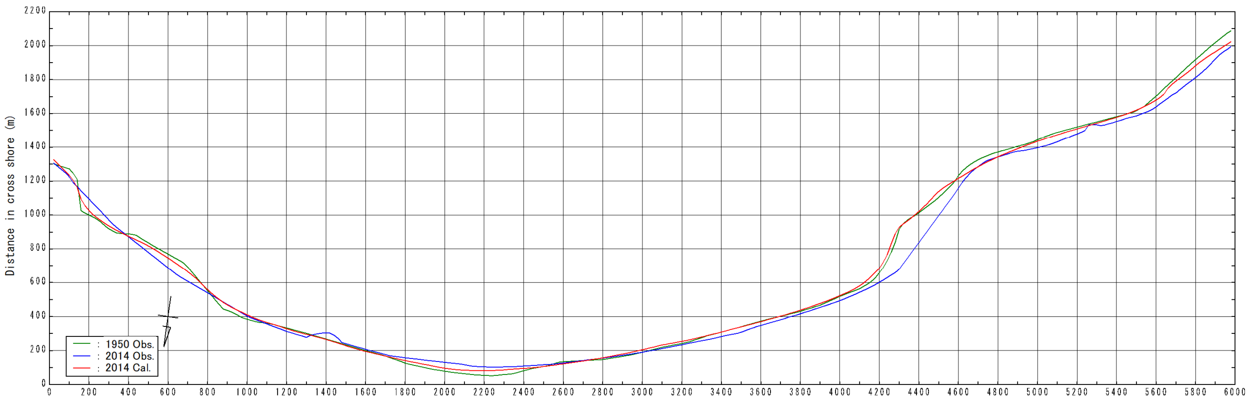
Area	Results
1	Although there are differences in the amount and characteristics in the details, the results of the model can express the characteristics of the sedimentation and erosion in the whole area, especially the shoreline recession near No. 1800 and after No. 5000.
2	Although there are differences in quantity and characteristics in detail, the model expressed the characteristics of the sedimentation and erosion for entire area.
3	Although there are differences in the amount and characteristics in the details, the results of the model can express the characteristics of the sedimentation and erosion in the whole area, especially the sedimentation from No. 2800 to No. 5000.
4	Although there are differences in quantity and characteristics in detail, the model expressed the characteristics of the sedimentation and erosion for entire area.
5	Although there are differences in the amount and characteristics in the details, the results of the model can express the characteristics of the sedimentation and erosion in the whole area, especially the shoreline recession from No. 2400 to No. 2600.

Source: Project Team



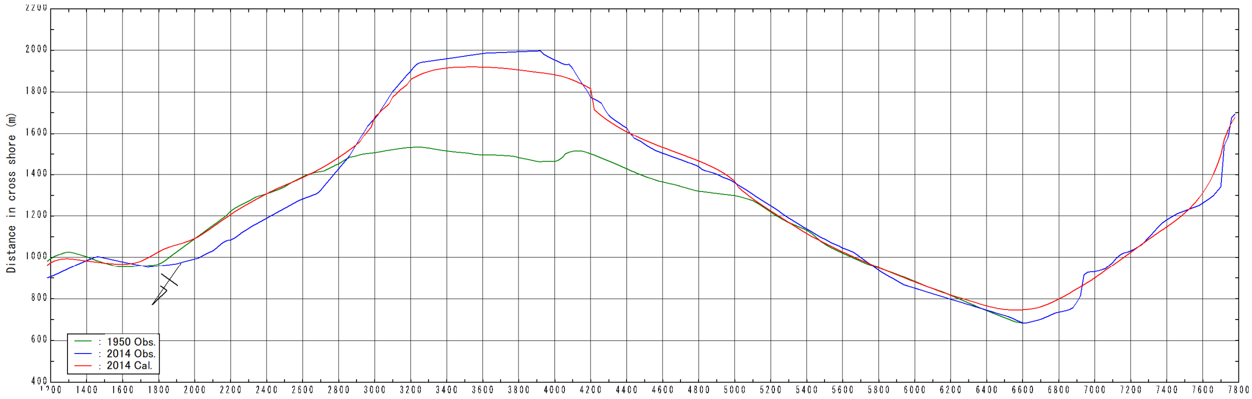
Source: Project Team

Figure 2.10.38 Results of Shoreline Analysis (Case 1: Area 1)



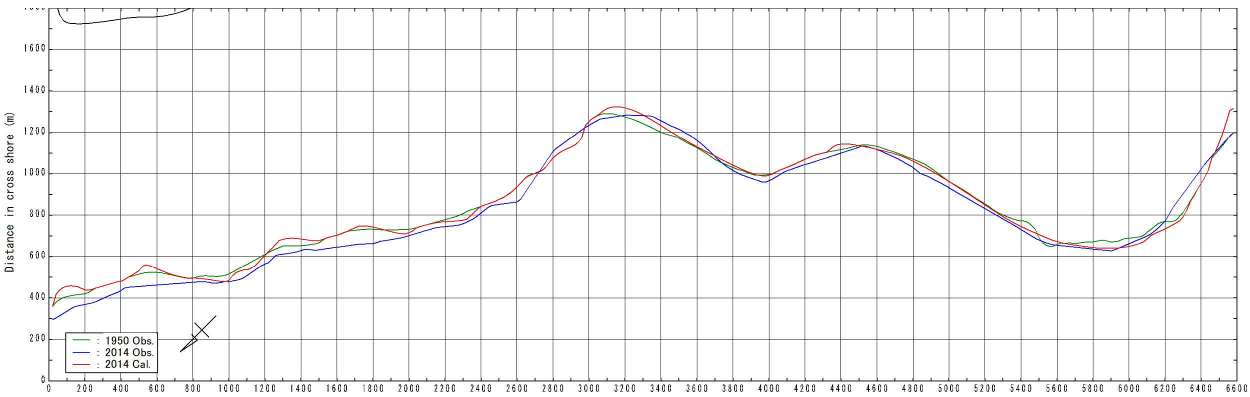
Source: Project Team

Figure 2.10.39 Results of Shoreline Analysis (Case 1: Area 2)



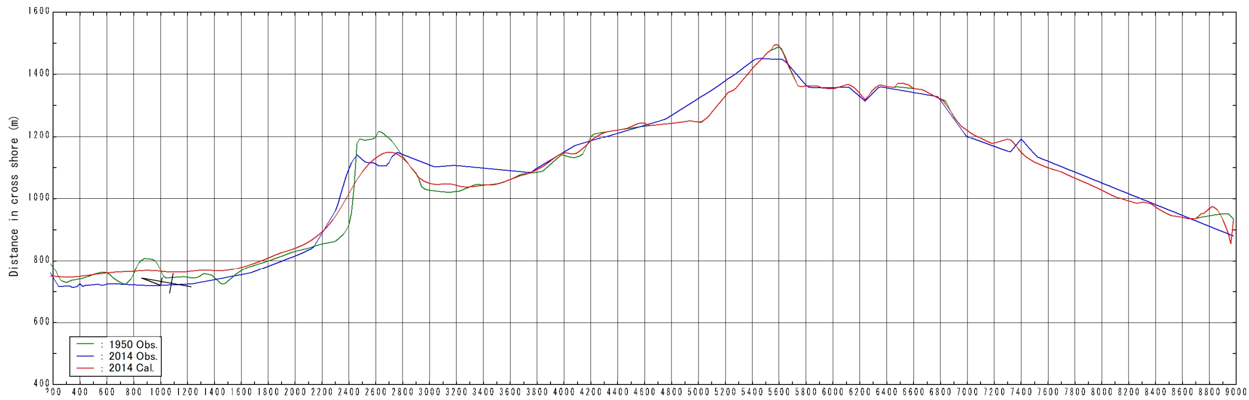
Source: Project Team

Figure 2.10.40 Results of Shoreline Analysis (Case 1: Area 3)



Source: Project Team

Figure 2.10.41 Results of Shoreline Analysis (Case 1: Area 4)



Source: Project Team

Figure 2.10.42 Results of Shoreline Analysis (Case 1: Area 5)

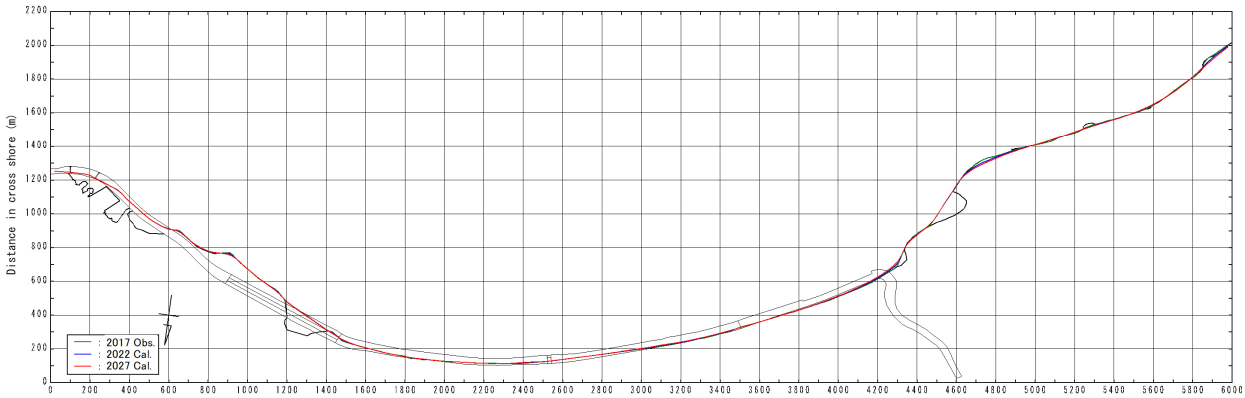
5) Results: Case 2 (Future Prediction without Coastal Road)

Figure 2.10.43 to Figure 2.10.45 show the results of analysis of the future change of the shoreline without the Coastal Road construction in Case 2 (Area 2 to 4). The Coastal Road is shown in this study for reference, but is not reflected in actual calculations. The analysis results are summarized in Table 2.10.19.

Table 2.10.19 Results in Case 2

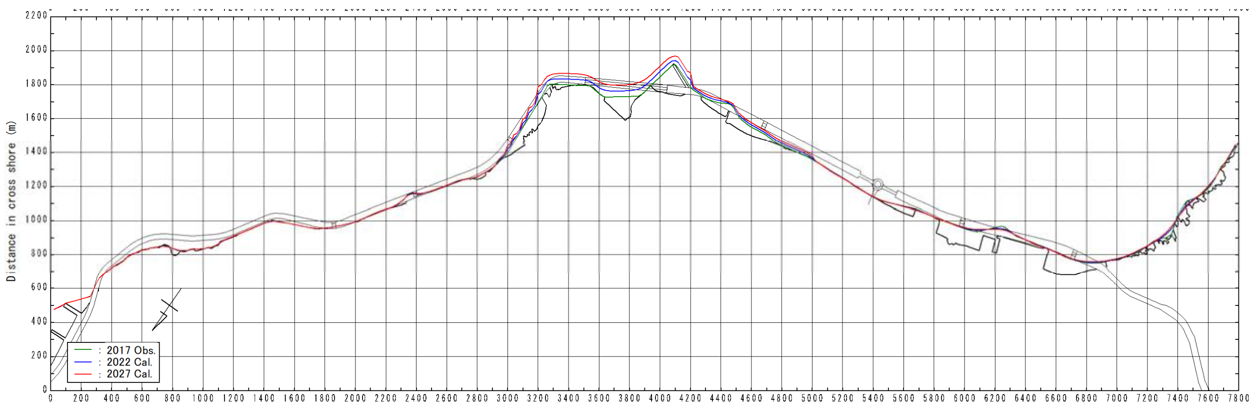
Area	Results
2	There is no significant change in the shoreline in the whole area.
3	At the mouth of the Davao River, sedimentation occurs due to sediment discharge from the river, indicating that the supplied sediment is transferred to the east and west of the river. The sedimentation is about 30 to 100 m at the estuary.
4	There is no significant change in the shoreline in the whole area.

Source: Project Team



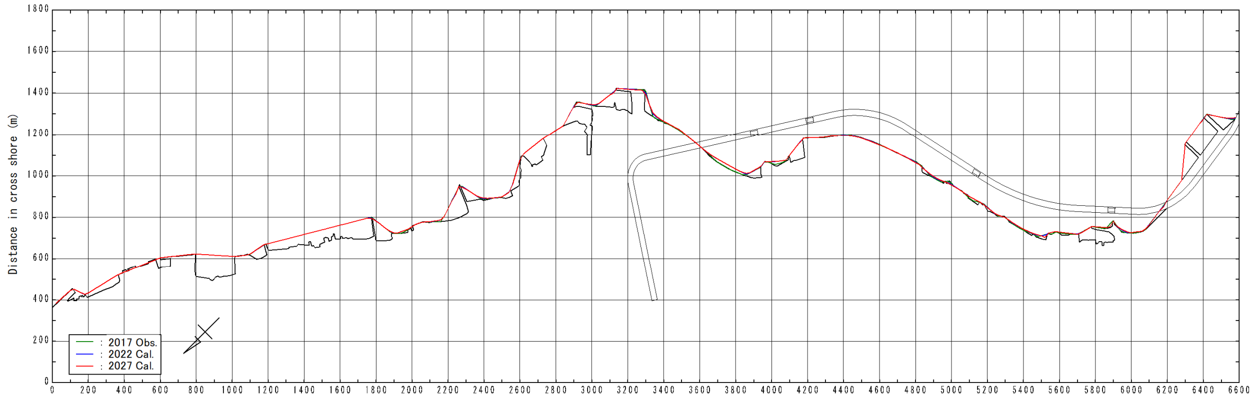
Source: Project Team

Figure 2.10.43 Results of Shoreline Analysis (Case 2: Area 2)



Source: Project Team

Figure 2.10.44 Results of Shoreline Analysis (Case 2: Area 3)



Source: Project Team

Figure 2.10.45 Results of Shoreline Analysis (Case 2: Area 4)

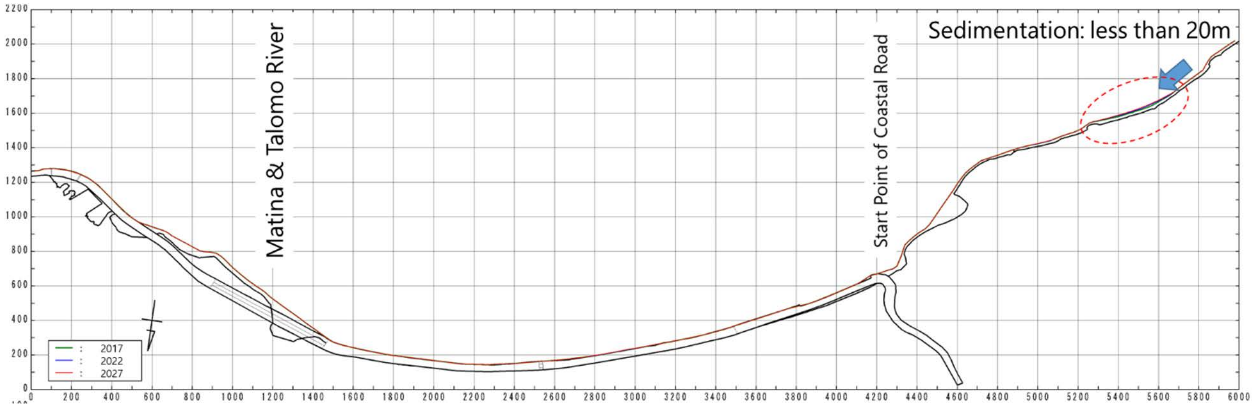
6) Results: Case 2 (Future Prediction with Coastal Road)

Figure 2.10.46 to Figure 2.10.48 show the analysis results of the future change of the shoreline (Areas 2 to 4) after the construction of Coastal Road in Case 3. It should be noted that this study was conducted for MSL-2.0m, not MSL + 0.0m. The analysis results are summarized in Table 2.10.20.

Table 2.10.20 Results in Case 3

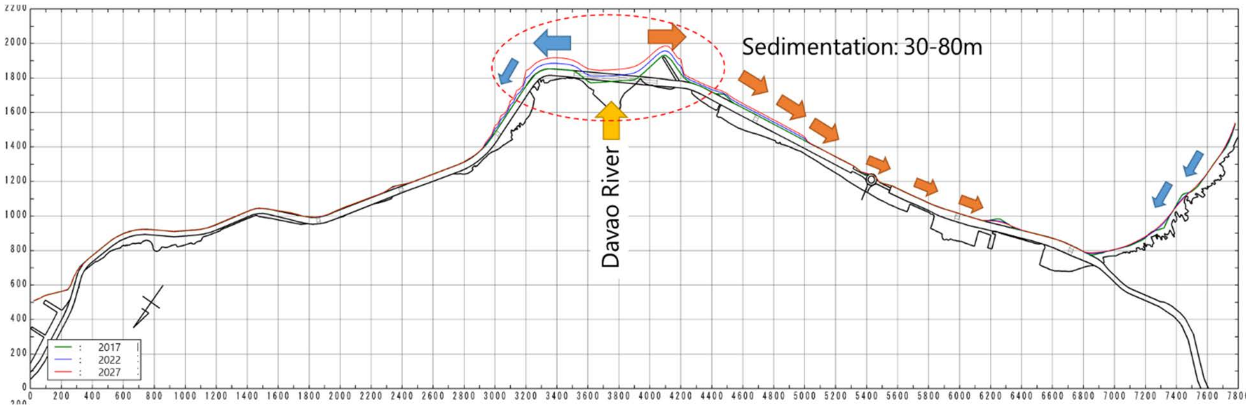
Area	Results
2	There is no significant change in the shoreline in the whole area except for the slight sedimentation at the south side of Coastal Road.
3	At the mouth of the Davao River, sedimentation occurs due to sediment discharge from the river, indicating that the common sediment tends to move eastward and westward. The sedimentation is about 30-80m at the estuary.
4	There is no significant change in the shoreline in the whole area.

Source: Project Team



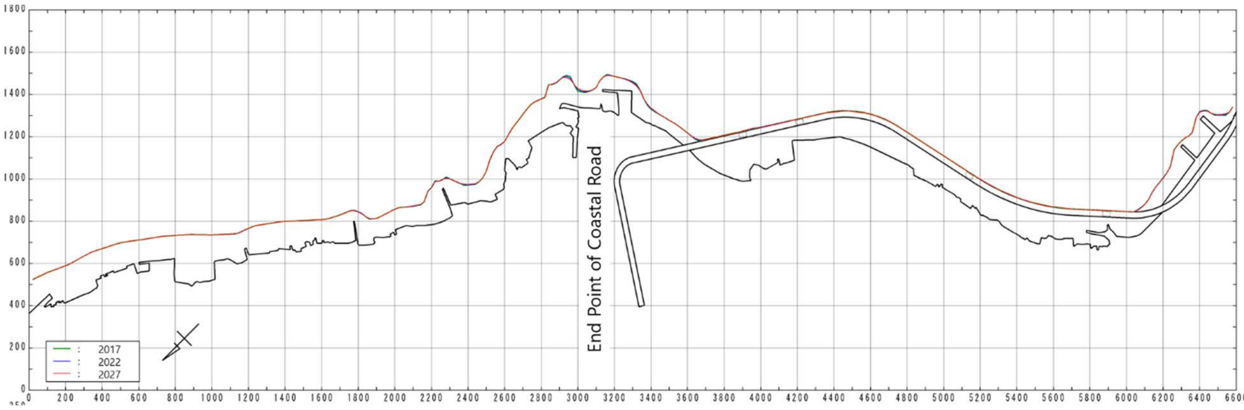
Source: Project Team

Figure 2.10.46 Results of Shoreline Analysis (Case 3: Area 2)



Source: Project Team

Figure 2.10.47 Results of Shoreline Analysis (Case 3: Area 3)



Source: Project Team

Figure 2.10.48 Results of Shoreline Analysis (Case 3: Area 4)

Comparing the results of Case2 and Case3 to understand the impact of Coastal Road construction on shoreline changes, there seems to be no significant change in Areas 2, 3 and 4. Since the shorelines in Area 2 and Area 4 are generally stable, no significant change in the future can be estimated. Regarding Area 3, the shoreline is accelerated due to the sediment discharge from the Davao River. However, the impact of sediment discharge is large and the construction of Coastal Road has little effect.

From the above, the impact of Coastal Road construction on future shoreline changes seems to be relatively small.

2.10.10 Key Issues in Coastal Disasters

The followings are the major issues related to coastal disasters identified through basic surveys, field inspections, field surveying, numerical analysis, interviews with stakeholders, workshops, etc.

(1) Adequate flood protection facilities

In most of the coastal areas, the annual maximum tide with a 1-year probability does not cause inundation of residences, but higher tidal levels can cause inundation, especially in densely populated areas. Therefore, there is a need to develop facilities that can protect against flooding even against a storm surge of the target level.

(2) Enhancement of flood protection capacity with securing the continuity of facilities (e.g., handling inundation from breakup at drainage channels, drainage holes, etc.)

In some coastal areas, there are scattered locations where coastal levees have been constructed. However, levees can only provide protection against storm surge inundation if they are continuous as a line, so they cannot function as protective facilities against storm surge if they are divided by drainage channels, or if drainage holes for rainwater drainage are left in place. Therefore, it is necessary to ensure the continuity of facilities and strengthen the capacity of flood protection facilities.

(3) Measures for lowland housing densely located in coastal areas

There are lowland areas in coastal areas where raised-floor-style houses are densely built. As raised-floor-style houses, they are protected from flooding to some extent by securing a clearance from the sea surface, but they are very vulnerable to storm surge inundation and waves. As a countermeasure for lowland housing, structures with sufficient flood protection should be constructed, but in addition, it is also necessary to take into consideration comprehensive measures including non-structural measures (hazard maps, evacuation plans, disaster risk reduction education, etc.).

(4) Development regulations in flood risk areas (coastal lowlands)

Despite the fact that the coastal lowlands of Davao City are flood risk areas, development and illegal occupation of coastal areas for residential use is progressing. In terms of land use planning, there are areas where development is restricted in riverine areas by identifying and indicating flood risk areas, but in many coastal areas, there are no restrictions due to the lack of hazard maps for coastal disasters. Therefore, land use regulations that discourage future development in flood risk areas in coastal areas are needed.

(5) Sharing information on flooding

In the coastal areas of Davao City, storm surges and high waves cause damage several times a year. In many cases, it is assumed that inundation damage is caused by the combination of wind waves and rainfall during astronomical high tide. Therefore, it is possible to prepare for inundation in advance by sharing ocean and meteorological information and the accompanying flood information. Thus, public support is required to disseminate and share flood-related information.

(6) Clarification of the implementation system for coastal flooding countermeasures

The organization responsible for countermeasures against coastal disasters is unclear. As a result, DPWH and others have constructed coastal levees and other protective facilities in response to requests from local communities, rather than taking comprehensive measures, but this has only been a coping strategy. It is necessary to create a whole working flow with clarifying the implementation system for promoting coastal projects, setting the target level and implementing countermeasures.

(7) Improvement of Design Guideline for Coastal Facilities

The current guidelines for coastal facilities are very limited, with only 14 pages of information. In addition, there are very few engineers who have implemented coastal projects. Even when they had experience in coastal projects, it is only by applying cross-sections that have been implemented in other areas to the target area, and the design technology has not been developed. It is necessary to formulate comprehensive guidelines and to train engineers who can learn and practice these guidelines.

(8) Clarification of maintenance and management systems and implementation methods

In addition to the lack of a clear organization for implementing countermeasures, the organization responsible for maintenance and management is not clear, and its implementation methods have not been established. As a result, structures are left as they are even if they have deteriorated. In addition to training engineers in countermeasures and design, it is necessary to establish a maintenance management system after construction and guidelines for its implementation method.

(9) Consideration of the possibility of increased coastal flood due to climate change

With respect to coastal disaster, the factors affected by climate change are sea level rise, increased waves, increased storm surge deviation, and increased coastal erosion associated with these factors. Sea level rise directly increases inundation and accelerates erosion. Although the DPWH guidelines indicate how to take climate change impacts into account, it is necessary to fully discuss with the C/P and others how to handle this issue in the master plan development and reflect it in the master plan.

2.11 Design Criteria of Flood Countermeasure (Riverine flood, Inland flood, High Tide / Storm Surge)

2.11.1 Conditions of Existing Structures

In the target area of the project, there are existing structure measures against riverine flood, inland flood and coastal flood that have been constructed in the past, such as embankment, revetment, drainage channels, etc. This chapter describes the types of major structure measures that have been constructed against each of the riverine flood, the inland flood and the coastal flood, together with issues identified with regard to the conditions of those structures. Inventory of structure measures against riverine flood is compiled including structures that exist or being constructed as of July 2019, reflecting the information on the extensive construction projects provided by DPWH-DEO.

(1) Issues and Conditions of Structure Measures

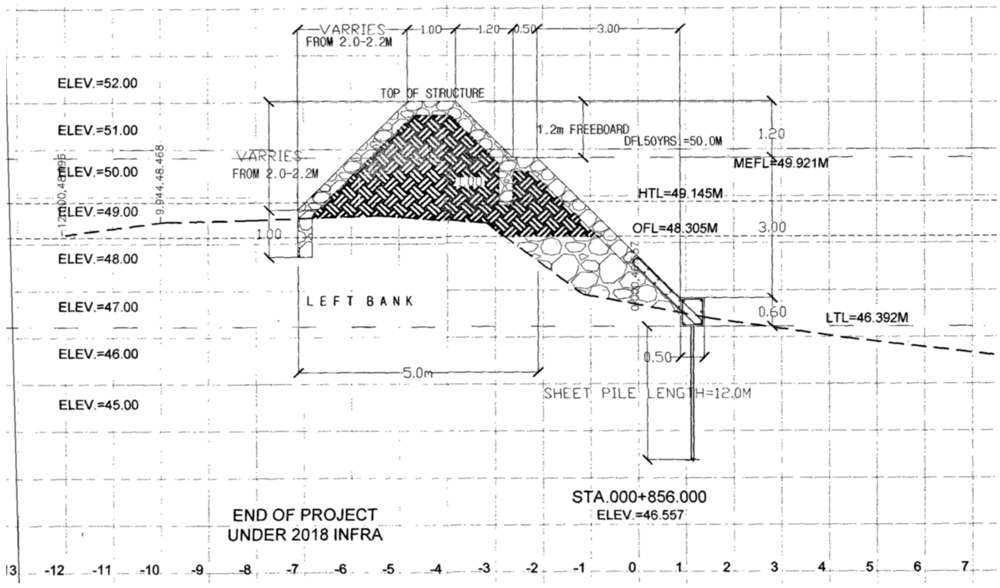
1) Riverine Flood

There are existing embankments and revetments being developed intermittently along each of the three rivers as measures against riverine flood. On top of that, underground box-culvert floodway exists at a meandering section of Talomo River aiming to divert floodwater in the downstream. There are no existing flood retarding ponds, flood gates or weirs for the three rivers. (Locations and individual structures are summarized in the inventory mentioned later)

a) Embankment and Revetment (Concrete Revetment)

There are two main types of structures that can be seen along the three target rivers, the concrete revetment and gabion pile-up. Concrete revetment is the type of structure widely adopted for old constructions that have been completed before the DPWH-DEO's extensive construction projects launched in 2017.

The standard cross section of concrete-revetment type embankment is shown in the following figure from the design documents provided by DPWH-DEO. Rubble concrete is used here with steel sheet piles as foundation. The embedded depth of the steel sheet pile is 12m, but it is considered to be designed and used as bearing piles and they are not designed as cantilever sheet piles that support earth pressure from the embankment, thus scour depth is unlikely to be considered in the design.



Source：DPWH DEO

Figure 2.11.1 Standard Cross Section of Concrete-Revetment Type Embankment

Table 2.11.1 shows the conditions and issues of concrete-revetment type embankments as observed on site. Its foundation consists of gabions as well, whose embedded depth is 2 meters (2 units piled-up). On top of that, gabion mattress is installed in front of revetment.

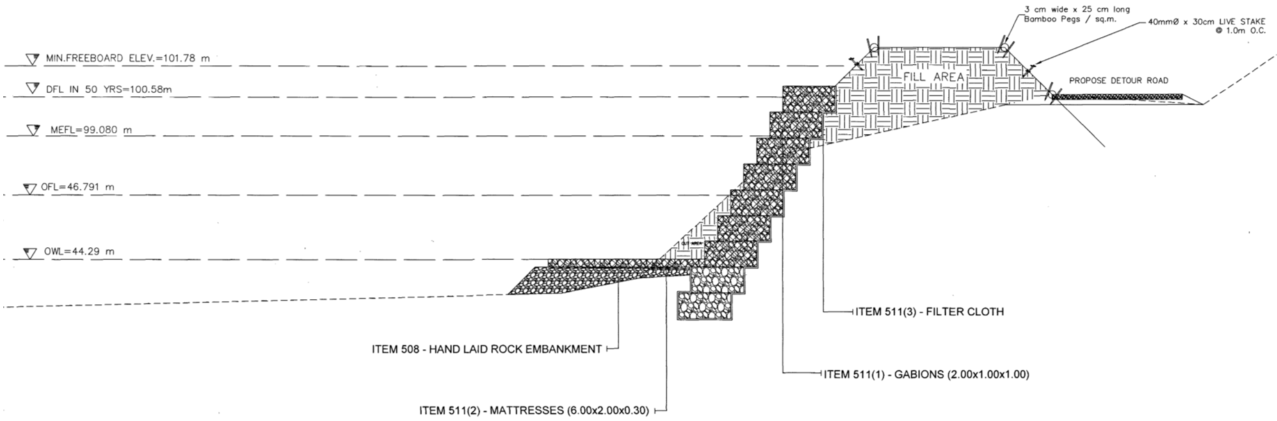
Table 2.11.1 Conditions of concrete-revetment type embankment

Site Photo	Conditions and Issues
	Concrete Revetment at Davao River (13+300 km; Right Bank) Steel sheet piles are installed as foundation of the concrete revetment. The sheet piles are considered to be designed and used as bearing piles and they are not designed as cantilever sheet piles that support earth pressure from the embankment and revetment.
	Concrete Revetment at Davao River (2+800 km; Right Bank) If the steel sheet piles is not totally buried under the riverbed, capacity calculation as cantilever sheet pile is required considering earth pressure and wall height from the design riverbed level (Design documents of this section don't exist due to old construction). The alignment / slope gradient / crest height is not constant here.
	Concrete Revetment at Davao River (6+200 km; Right Bank) (Under construction) Rubble concrete is widely and typically adopted for the three rivers. The slope gradient is 1:1, which is shown in the standard design drawings of DPWH.

Source：Project Team

b) Embankment and Revetment (Gabion Pile-up)

Gabion pile-up is the type of structure widely adopted in a series of construction started by DPWH-DEO in 2017. The standard cross section of gabion pile-up type embankment is shown in the following figure from the design documents provided by DPWH-DEO. The foundation is also gabion-shaped, and the depth of penetration is 2m (2 steps). In addition, a gabion mattresses are installed in front of the revetment.



Source：DPWH DEO

Figure 2.11.2 Standard Cross Section of Gabion Pile-up Type Embankment

Table 2.11.2 shows the conditions and issues of gabion pile-up type embankments as observed on site.

Table 2.11.2 Conditions of gabion pile-up type embankment

Site Photo	Conditions and Issues
	Gabion Pile-up at Davao River (7+400 km; Left Bank) There are sections where gabions are installed with a steeper gradient than designed gradient, which is generally 1:0.5. Assessment of the stability needs to be carried out for the gradient to be actually implemented.
	Gabion Pile-up at Davao River (4+800 km; Right Bank) Irregularities of piled-up units are observed which may be caused by settlement due to the insufficient bearing capacity of the subsurface soil.
	Gabion Pile-up at Davao River (9+900 km; Left Bank) Filter cloths have to be installed on the back of gabions to prevent backfilling soil to be sucked out. Although it is considered in the DPWH-DEO's drawings, there are sections where filter cloths are not properly installed and sinking of the soil can be observed.
	Gabion Pile-up Wall at Talomo River (1+800km Right bank) Gabion pile-up wall without soil embankment can be seen at lower section of Talomo River. This type of cross section cannot be found in design documents, and thus considered to be a provisional structure due to restricted land conditions. This type of wall cannot be construed as a structure measure against riverine flood.

Source：Project Team

c) Underground floodway

An underground box-culvert floodway is installed on the left bank of Talomo River, the inlet being located at around 2+650k and the outlet at around 1+850k.

Source：Project Team

Figure 2.11.3 Location of Underground Floodway at Talomo River

Table 2.11.3 Conditions of Underground Floodway at Talomo River

Site Photo	Conditions and Issues
	Inlet of the underground floodway at Talomo River (at around 2+650km) It is composed of three units of box culvert, the inner height of the box being about 2.5m and the width being about 3.0m. The top slab thickness is about 0.7m, whose upper surface continues to the berm of concrete revetment. On top of that exists an embankment of 1.6 meters (height from the berm), which is partially shaved off by a newly constructed bridge. No inflow of ordinary river water.
	Outlet of the underground floodway at Talomo River (at around 1+850km) The structure is the same as that of the inlet, while the outlet is always filled with water. Unlike the inlet, there is no embankment behind, and there are roads and houses at the same elevation as the top slab of the culvert. However, there is an embankment with a height of about 3.2 m in the downstream (left bank 1+706 k), showing discontinuity of structural measures.

Source：Project Team

d) Cross-river Structure; Bridge

With regard to cross-river structures along target rivers, a number of bridges cross over the channel. Davao River particularly has many piers, abutments, and protection revetments located inside the channel. For the design of pier foundations constructed inside the channel, DPWH design standards (Design Guidelines, Criteria and Standards 2015) stipulates to estimate and consider the scour depth, which is also the case with planned constructions mentioned in 2.4, whose general drawings assume about 2.4 m of scour depth corresponding to 100-year flood for a bridge over Davao River.

Regarding the existing bridges, exposed foundation piles can be seen at Maa Bridge at about 6.0 km point of the Davao River, and at Pan Philippines Highway Bridge at about 13 km point of the same river, due to degradation of riverbed. Although it was not possible to confirm how the scour depth was taken into consideration in the initial design, the riverbed is considered to be degraded by at least about 2 m in this section.

Table 2.11.4 Piles Constructed inside the channel of Davao River

Site Photo	Conditions and Issues
	Maa Bridge at around 6 km point of Davao River Exposed pile foundations can be seen due to the degradation of riverbed.
	Pan Philippines Highway Bridge at around 13 km point of Davao River Exposed pile foundations of piers and that of revetment can be seen due to the degradation of riverbed.

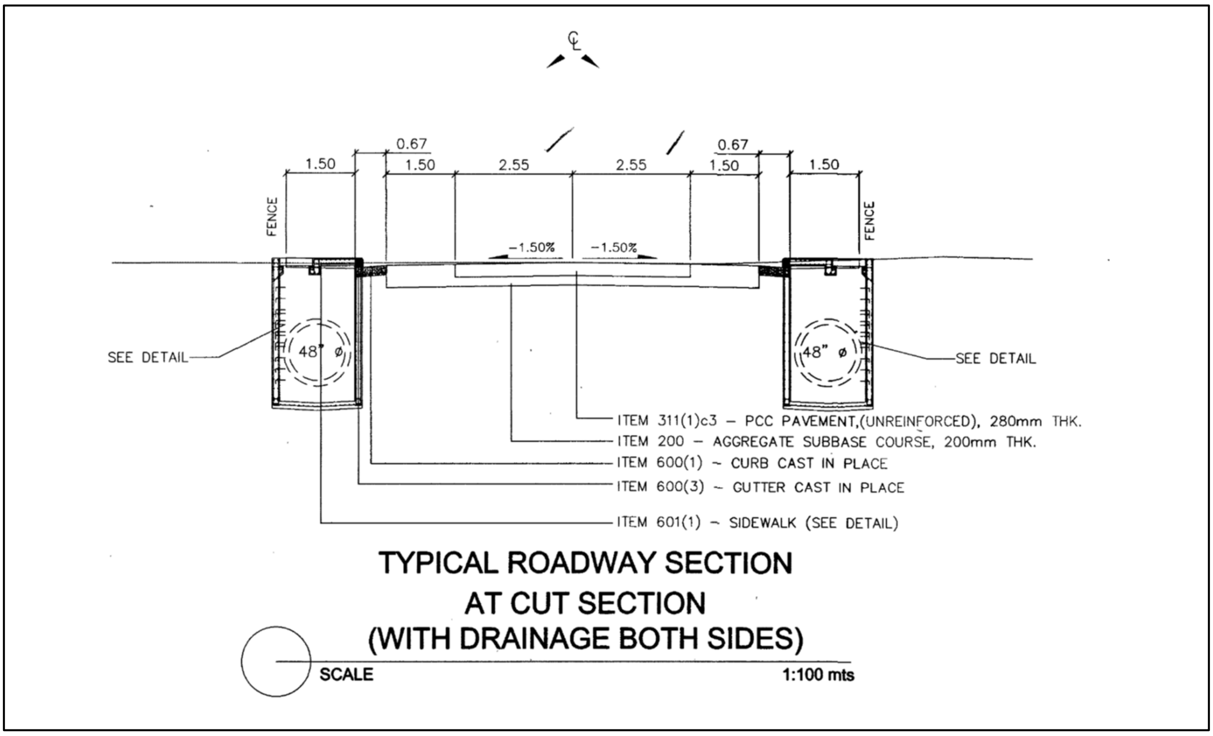
Source：Project Team

2) Inland Flood

Existing structure measures related to inland flooding include road side gutters, catch basins, tributary and main drainage channels (open channel and buried pipe lines). The drainage system is connected to rivers or the coast where water is drained by gravity. However, the development of structures is falling behind and the dimension of existing structures is inadequate, therefore inland flooding remains an issue. Conditions of existing structure measures are described here based on collected information and site observation.

a) Road side gutters, catch basins and drainage channels

The standard cross section including road side gutters, catch basins and pipe-culvert drainage channels is shown in the following figure from the design documents provided by DPWH-DEO. As shown in the figure, the precast pipelines are generally installed right under the sidewalk or road shoulder on both sides, while it is also common to see them installed under the road center for a smaller road that has only one-lane width. Structural details are specified in the standard design of DPWH, and accordingly, all of the design compiled by DWPH-DEO is based on it.



Source：DPWH DEO

Figure 2.11.4 Standard Cross Section of Inland Flood Structure Measures (Gutter, Catch Basin and Pipeline)

Table 2.11.5 shows the conditions and issues of gutters, catch basins and drainage channels as observed on site.

Table 2.11.5 Conditions of Gutters, Catch Basins and Drainage Channel

Site Photo	Conditions and Issues
	District where gutters, catch basins and tributary pipeline have recently been installed. (Guerrero Street) In the current design based on the DPWH standards, the spacing between catch basins (inlet) is 20m, which often coincides with manhole. The manhole has a concrete lid, while DPWH-DEO is planning to replace it by ductile iron lid due to recurring abrasions and damages caused by heavy traffic running on it.
	Conditions of gutters along a small road with a single lane (Daang Patnubay) Gutters are not installed in a continuous manner and placement of ditch basins is partial as well. Water stagnates at a low place along the road. Similar cases can be observed along the main roads in Davao City, due to inadequate placement of gutters and ditch basins.
	Connection of tributary channels (underground pipelines) to the main drainage channel (open channel). (Roxas Avenue) In addition to the concrete-revetment type structure as in the photo, there are channels with gabion pile-up revetment and grouted gabion revetment for main drainage channel. (Issues are common with structure measures against riverine flood)

Source：Project Team

b) Connection with River and Coast (Drainage Outfall)

Tributary and main drainage channels are all connected to river or coast at their outfall where water is drained by gravity. Although there are no existing pumping station or sluice gate for the purpose of discharging water from drainage channel to river or coast, one pumping station is being planned by DPWH-DEO along Davao River. Sluice gates are also being planned along the coast.

Table 2.11.6 shows the conditions and issues of structures installed at the outfalls as observed on site.

Table 2.11.6 Conditions of Structures installed at the Outfalls

Site Photo	Conditions and Issues
	Outfall of pipe-culvert along Davao River at 2+700km (Right bank) Pipe-culvert is supported by gabion pile-up revetment. The site is located on the cut bank of the meandering river and foundation of the revetment is eroded and carried away making the gabion under the culvert overhung and pipe-culvert unstable.
	Outfall of pipe-culvert along Davao River at 18+300km (Left bank) Pipe-culverts protrude out from the revetment in many places. It is preferable to place wing wall between the revetments to avoid protruding of the pipes.
	Outfall of box-culvert along Davao River at 2+500km (Left bank) A flap gate (1.8m x 1.8m) is installed at a outfall of drainage channel. Opening and closing of the gates may be difficult due to poor installation of the hanging bracket and sedimentation in front.

Source：Project Team

3) Coastal Flood

For structure measures against coastal flood, construction of the coastal road by DPWH-RO is underway as described in 2.10 on top of existing structures (sea wall and jetty). The coastal road has concrete revetment, wave-breaker and foot protection on its sea side in order to protect the road from waves, but the facility as a whole does not ensure protection against storm surge due to openings (bridges) placed to allow residents' (fishermen's) access. Table 2.11.7 shows the conditions and issues of structure measures against coastal flooding as observed on site. (cf Section 2.10 for the standard cross section of coastal road)

Table 2.11.7 Conditions of Structures related to Coastal Flood

Site Photo	Conditions and Issues
	Seawall (parapet) along the local coastal road (Nograles Avenue) The parapet wall along the local road was built along with the rehabilitation of the road. Residents reported that there has not major events where the wall was overtopped. Although existence of drainage outfalls without gate suggest that storm surge may flow backwards to landside.
	Situation of the coastal road being constructed (near the river mouth of Talomo River) The coastal road has an alignment that runs beyond the existing coastline, and is equipped with wave-break and foot protection. Rubbles are generally used for embankment inside the revetment.
	Situation of the opening along the coastal road of residents' access. Openings along the coastal road to ensure residents' access unable to ensure protection against storm surge by the coastal road as a whole.

Source：Project Team

(2) Overview of Existing Structure Measures against Riverine Flood

In the target three rivers, embankments and revetments have been constructed along certain section as countermeasure against riverine flood. On top of that, DPWH-DEO (DEO (I)) has launched an extensive embankment / revetment construction projects since 2017 for a number of rivers under its jurisdiction.

Current status of structure measures of each river is organized as follows. For structure measures that exist as well as those under construction as of June 2019 are summarized in data sheet, with site photo and standard cross sections based on the collected design documents and site observation. Design and construction projects by DPWH-DEO is based on datum level set independently in each project, and protection height of structure measures lacks longitudinal consistency, which remains a serious issue.

1) Davao River

The situation of structure measures against riverine flood along Davao River is shown in Table 2.11.8, Figure 2.11.5 and Figure 2.11.6. Existing structures as well as those under construction as of June 2018 were taken into account, together with structures planned to be constructed in 2019. In Davao River, there are only embankment and revetment, and there no flood retarding pond, floodway or flood gate.

Table 2.11.8 Structure Measures against Riverine flood along Davao River

River	R/L	Start	End	Structure	Year	Status
Davao	R	0+512	1+550	Concrete Revetment	2018	Existing
Davao	R	1+567	1+830	Concrete Revetment	2019	Planned
Davao	R	2+300*	2+790*	Concrete Revetment	Unknown	Existing
Davao	R	2+790	3+008	Concrete Revetment	2019	Planned
Davao	R	4+450*	4+600*	Gabion Pile-up	Unknown	Existing
Davao	R	4+600*	5+100*	Gabion Pile-up	2018	Existing
Davao	R	5+290	5+750*	Gabion Pile-up	2016	Existing
Davao	R	6+50*	6+200*	Concrete Revetment	Unknown	Existing
Davao	R	6+200*	6+450*	Gabion Pile-up	Unknown	Existing
Davao	R	7+400*	8+120*	Gabion Pile-up	2016	Existing
Davao	R	8+120	9+800*	Gabion Pile-up	2018	Existing
Davao	R	9+800*	10+000	Boulder Riprap Wall	Unknown	Existing
Davao	R	10+000*	10+680*	Gabion Pile-up	2018	Existing
Davao	R	10+680	11+650	Gabion Pile-up	2019	Planned
Davao	R	12+300*	12+400*	Concrete Revetment	Unknown	Existing
Davao	R	12+670	12+980	Concrete Revetment	2019	Planned
Davao	R	13+20	13+340	Concrete Revetment	2019	Planned
Davao	R	14+50	14+100	Concrete Revetment	2019	Ongoing
Davao	R	15+110	16+205	Gabion Pile-up	2019	Planned
Davao	R	16+205*	16+768	Gabion Pile-up	2018	Existing
Davao	R	16+768	17+460	Gabion Pile-up	2016/2017	Existing
Davao	R	17+460	19+498	Gabion Pile-up	2018	Existing
Davao	L	0+512	0+775	Concrete Revetment	2019	Planned
Davao	L	1+600	2+189	Concrete Revetment	Unknown	Existing
Davao	L	2+189	2+550	Concrete Revetment	2018	Ongoing
Davao	L	2+550	2+687	Concrete Revetment	2019	Planned
Davao	L	2+730	2+782	Concrete Revetment	Unknown	Existing
Davao	L	2+782	3+176	Concrete Revetment	2019	Planned
Davao	L	5+650*	5+850*	Gabion Pile-up	2019	Ongoing
Davao	L	6+32	6+832	Gabion Pile-up	2019	Planned
Davao	L	7+000*	7+200*	Gabion Pile-up	2018	Existing
Davao	L	7+200*	8+000*	Gabion Pile-up	2016/2017	Existing
Davao	L	8+000*	8+490*	Gabion Pile-up	2018	Existing
Davao	L	8+490*	9+892	Gabion Pile-up	2019	Planned
Davao	L	9+892	10+547	Gabion Pile-up	Unknown	Existing
Davao	L	10+547	11+370	Gabion Pile-up	2016	Existing
Davao	L	11+370	12+53	Gabion Pile-up	2018	Existing
Davao	L	12+53	12+812	Gabion Pile-up	2019	Planned
Davao	L	12+812	12+980	Precast Concrete Block	2018	Existing
Davao	L	13+32	13+508	Concrete Revetment	2015-2016	Existing
Davao	L	13+508	14+8	Gabion Pile-up	2017	Existing
Davao	L	14+8	15+93	Gabion Pile-up	2018	Existing
Davao	L	16+701	16+850*	Gabion Pile-up	2017	Existing
Davao	L	17+250	18+626	Gabion Pile-up	2018	Existing
Davao	L	18+190	18+440	Concrete Revetment	Unknown	Existing
Davao	L	18+626	19+706	Gabion Pile-up	2019	Planned
Davao	L	20+346	20+721	Gabion Pile-up	2018	Planned
Davao	L	20+721	20+924	Gabion Pile-up	2018	Existing
Davao	L	20+924	21+24	Gabion Pile-up	2016	Existing
Davao	L	21+24	22+300	Concrete Revetment	Unknown	Existing

Location of structure (start/ end point) is based on DPWH-DEO documents, except the ones with * where the location information was missing or incoherent and thus assumed by Project Team

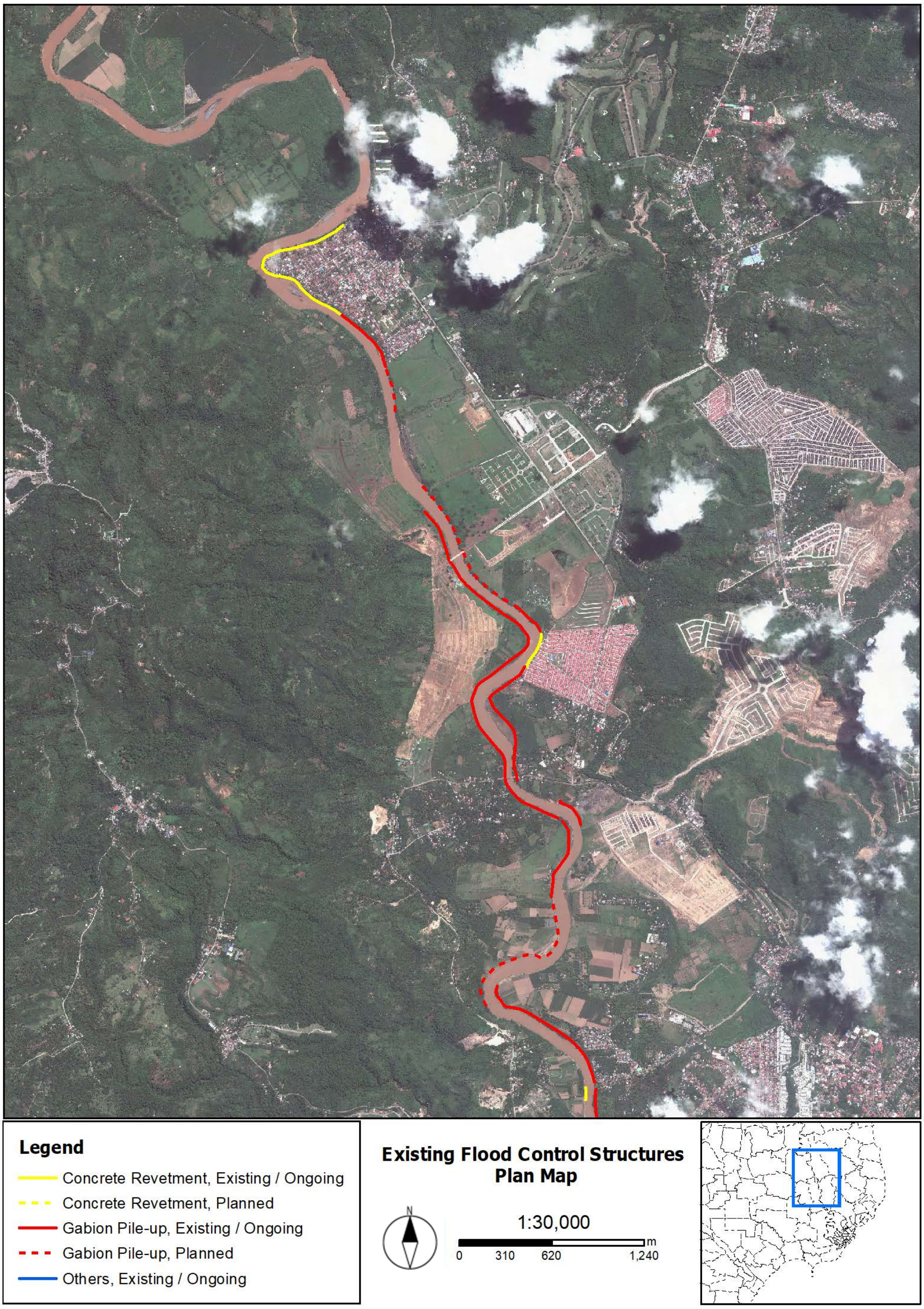
Source：Project Team

As mentioned above, structure types are classified into two major types, concrete revetment and gabion pile-up. As shown in Figure 2.11.5 and 2.11.6, concrete revetments can be seen at urban and residential areas along the downstream of Davao River, from the river mouth up to around the 3 km point for existing structures as well as for planned structures. In the upstream of that, most of the structures are gabion pile-up type, except for the existing revetments in the vicinity of old urban areas and residential areas.

In sections where concrete revetments are being constructed, there are restrictions on the site (i.e. the gabion pile-up type has earth embankment with wider footprint area), houses and roads exist right behind the revetment (i.e. the gabion pile-up type is not designed to bear traffic and building load, making it impossible to have houses and roads in the very vicinity) and difficulty in the foundation construction (i.e. there's no high-water riverbed and difficult to build a cofferdam for dry construction), which are considered to be the reason why concrete revetment was adopted. On the other hand, gabion pile-up type is less expensive and thus considered to be adopted in places where there are no restrictions.

Source：Project Team

Figure 2.11.5 Location of Existing Structures against Riverine Flood (Davao River ; downstream)



Source：Project Team

Figure 2.11.6 Location of Existing Structures against Riverine Flood (Davao River ; midstream)

2) Talomo River and Matina River

The situation of structure measures against riverine flood along Talomo River and Matina River is shown in Table 2.11.9 and Figure 2.11.7. Existing structures as well as those under construction as of June 2018 were taken into account, together with structures planned to be constructed in 2019. Except a floodway in Talomo River, all listed structures are embankments and revetments.

Table 2.11.9 Structure Measures against Riverine flood along Talomo River and Matina River

River	R/L	Start	End	Structure	Year	Status
Talomo	R	1+100*	1+300*	Gabion Pile-up	2019	Ongoing
Talomo	R	1+401	2+268	Gabion Pile-up	2018	Existing
Talomo	R	2+315	2+980	Gabion Pile-up	2019	Planned
Talomo	L	0+904	0+988	Gabion Pile-up	2015	Existing
Talomo	L	1+250*	1+418	Gabion Pile-up	Unknown	Existing
Talomo	L	1+418	1+495	Concrete Revetment	2014	Existing
Talomo	L	1+495	1+706	Gabion Pile-up	2013/unknown	Existing
Talomo	L	1+706	1+856	Concrete Revetment	2013/unknown	Existing
Talomo	L	1+850*	2+650*	Underground Floodway	Unknown	Existing
Talomo	L	2+500*	2+700*	Concrete Revetment	Unknown	Existing
Talomo	L	2+724	2+899	Gabion Pile-up	2019	Planned
Matina	R	0+240	0+650*	Gabion Pile-up	2018	Planned
Matina	R	0+650*	0+890	Gabion Pile-up	2017	Existing
Matina	R	0+890	1+860	Gabion Pile-up	2014/unknown	Existing
Matina	R	2+260	2+720	Gabion Pile-up	2018	Existing
Matina	R	2+720	2+908	Gabion Pile-up	2016	Existing
Matina	R	2+930	2+960	Concrete Revetment	Unknown	Existing
Matina	R	3+178	3+360	Gabion Pile-up	2018	Existing
Matina	R	4+450*	4+720*	Concrete Revetment	Unknown	Existing
Matina	R	4+720	5+340	Gabion Pile-up	2019	Planned
Matina	R	5+600*	5+900*	Gabion Pile-up	2018	Existing
Matina	L	0-50*	0+50*	Concrete Revetment	Unknown	Existing
Matina	L	1+200*	1+350*	Grouted Riprap / Brick	Unknown	Existing
Matina	L	1+350*	1+450*	Concrete Revetment	Unknown	Existing
Matina	L	1+890	2+490	Gabion Pile-up	2019	Planned
Matina	L	2+500	2+680	Gabion Pile-up	2018	Ongoing
Matina	L	2+750*	2+850*	Concrete Revetment	Unknown	Existing
Matina	L	2+930	2+958.5	Concrete Revetment	2014	Existing
Matina	L	5+600*	5+900*	Gabion Pile-up	2018	Existing

1 Location of structure (start/ end point) is based on DPWH-DEO documents, except the ones with * where the location information was missing or incoherent and thus assumed by Project Team

Source：Project Team

There are two major types of revetment structures for Talomo River and Matina River as well, concrete revetment type and gabion pile-up type. Concrete revetments are mainly located at urban area along Talomo River as well as in the upstream and downstream of bridges along Matina River. On the other hand, gabion pile-up type is mostly used in recent constructions.

Many of the concrete revetments of both rivers are constructed in old days (before 2014 or unknown) and, in addition to the restrictions on the site and its land use, it is considered that gabion pile-up was not among the commonly used revetment types at that time and the selection of structure may have been done in this background. In recent construction along both rivers, the gabion pile-up type is considered to be adopted on the premise that affected houses are relocated and that there are no restrictions on the site.

Source：Project Team

Figure 2.11.7 Location of Existing Structures against Riverine Flood (Talomo and Matina River)

2.11.2 Current Situation of Design Guidelines

DPWH's design guidelines for structure measures against each type of flood is as follows, as per confirmed by DPWH-BOD.

Table 2.11.10 DPWH's Design Guidelines for Structure Measures (Riverine Flood, Inland Flood and Coastal Flood)

No.	Name of Guidelines	Riverine Flood	Inland Flood	Coastal Flood
1	Design Guidelines, Criteria and Standards, Volume 3 Water Engineering Project, DPWH 2015 (DGCS Vol.3)	●	●	●
2	Technical Standards and Guidelines for Planning and Design, Volume 1: Flood Control, DPWH-JICA 2010	●	●	
3	Philippine Port Authority (PPA) Engineering Standards for Port and Harbor Structures – Volume II (2009)			●

Source：Project Team

(1) Riverine Flood

For the design of structure measures against riverine flood, Design Guidelines, Criteria and Standards, Volume 3 Water Engineering Project (hereinafter mentioned as "DGCS Vol.3) is the only official guideline adopted by DPWH-BOD, although DPWH-BOD explained that Technical Standards and Guidelines for Planning and Design, Volume 1: Flood Control (DPWH-JICA 2002) is also referred, the document referred in the preparation of DGCS Vol.3. In the DGCS Vol.3, only the basic concept of design (eg. mentions on the necessity to conduct seepage analysis in the design of embankment, to conduct stability analysis in the design of gabion wall and sheet piles) is described, without giving the details of analysis models and calculation conditions such as design load combinations. The specific analysis and calculation methods are currently to be determined by individual engineer, while DPWH-BOD is not recommending any specific analysis and calculation methods or softwares.

For facilities that are not detailed in DGCS, namely flood retarding basin, overflow dike and dam, there are no other guidelines and accordingly, design criteria is proposed independently for similar projects in the past (such as Parañaque floodway).

DPWH-BOD has an intention to update the contents of DGCS, especially for items with insufficient descriptions, which is not planned specifically.

(2) Inland Flood

For structure measures against inland flood, the guidelines adopted by DPWH-BOD is the same DGCS Vol.3 as for structure measures against riverine flood. DGCS Vol.3 has a chapter dedicated for the drainage where basic concept of the design is explained.

In addition, DPWH has a standard design for gutters, catch basins, drainage channels (pipe-culvert and box-culvert), inlet and outlet structures and flap gates, which is referred when determining specifications of basic structures.

(3) Coastal Flood

For structure measures against coastal flood, although DGCS Vol.3 is the guidelines adopted by DPWH-BOD, the same guidelines as for riverine flood, DGCS Vol.3 mentions to refer Philippine Port Authority (PPA) Engineering Standards for Port and Harbor Structures – Volume II (2009) as well. According to DPWH-BOD, they explained that DGCS Vol.3 is the first guidelines to be referred in the design of structures while PPA is referred for items that are not detailed in DGCS Vol.3. PPA (2009) basically follows the contents of Technical Standards and Commentaries for Port and Harbour Facilities in Japan.

DGCS Vol.3 has only 14 pages in the chapter 7 dedicated for coastal structures, the description being quite limited. On the other hand, PPA (2009) which follows Japanese technical standards has extended contents with several hundred of pages. Since DPWH does not have a department specialized in coastal engineering and they have very few costal engineers, it is challenging for them to understand the contents of PPA (2009) and apply it to structure design. It is therefore common practice for them to simply apply structures that have been constructed for other projects, according to hearing from DPWH.

2.12 Present Condition of Non-structural measures

In order to conduct effective flood control measures, it is important to consider non-structural measures in addition to the implementation of structural measures from the following viewpoints.

- Early implementation of non-structural measures is expected without waiting for the completion of structural measures since the construction work requires relatively long years.
- Countermeasures for worst case flood exceeding the target design level are required even after completion of structural measures. It is necessary to recognize that floods exceeding the target design level could occur as a natural phenomenon.
- The need for measures to avoid increasing the planned flood external force due to human influences associated with improper maintenance of structures and unregulated development, etc. Although it is not easy to quantitatively consider the effects of measures such as runoff regulation from urban areas to river channels, it can contribute to the reduction of external forces as well as structural measures.

For considering the detailed activities on non-structural measures, the present activities implemented by the government of the Philippines and donors are investigated in this Section.

In Davao city, the City Disaster Risk Reduction and Management Plan 2017-2022 has been formulated, which comprehensively covers activity items required for non-structural measures corresponding to each phase of the disaster management cycle as shown in Table 2.12.1. The surveyed items in the Stage 1 which is important for flood control measures considering best combination with structural measure, are related to the one underlined in Table 2.12.1.

Table 2.12.1 Davao CDRRMP 2017-2022 and surveyed activities in the Stage 1 (underlined)

PREVENTION AND MITIGATION	PREPAREDNESS	RESPONSE	REHABILITATION AND RECOVERY
･Greening Program mentioned in (4) ･Solid Waste Management ･Relocated/regulated households mentioned in (5) ･Retrofitted existing public infrastructures and facilities mentioned in (6) ･Desilting of rivers and natural waterways mentioned in (7) ･Hazard maps and risk assessment mentioned in (3) ･Mainstreamed DRR CCA in Barangay Annual Investment Plan ･End-to-end monitoring system for forecasting and early warning mentioned in (1) ･Risk financing and insurance schemes ･Intervention for conflict resolution	･Davao City IEC Program mentioned in (3) ･DRR training manuals ･DRR Training Institute ･Community Based DRRM Training for the Barangays ･Earthquake and fire drills and other multi-hazard drills mentioned in (3) ･DRRM capacity building interventions for City and DRRMCs ･Health epidemics as first responders ･DRR-CCA in the new K to 12 Curriculum ･Functional and staffed City DRRMO and Barangay DRRMCs ･Proper utilization of the Barangay's LDRRMF ･Comprehensive City and Barangay DRRM Plans ･Functioinal 182 BDRRMC ･Evacuation Centers at the Barangay Level mentioned in (2) ･Davao City Response Plans ･Davao City Contingency Plans and Business Continuity Plans ･Organized Post Disaster Needs Assessment Team, etc ･Formed network among DRR Stakeholders ･Accredited Community Disaster Volunteer Groups	･Standard Operating Procedure ･Incident Command System ･Deployment of Pre-Disaster Risk Assessment Team ･Timely Searched, Rescued and Retrieved ･Management of safety and security ･Management of the dead and missing individuals ･Efficient and systematic relief operations ･Early Recovery Support ･Efficient and effective delivery of basic services	･Post Disaster Assessment and Needs Analysis ･Recovery and Rehabilitation Plan ･Monitored and Evaluated Recovery and Rehabilitation ･Support from private groups ･Business/ Economic Continuity Plan ･Livelihood Opportunities ･Safe relocation ･Disaster-resilient housing units ･Settlers association ･"Psycho-social" Interventions ･"Reforestation"/ ecosystem rehabilitation and recovery ･DRR-CCA resilient infrastructures

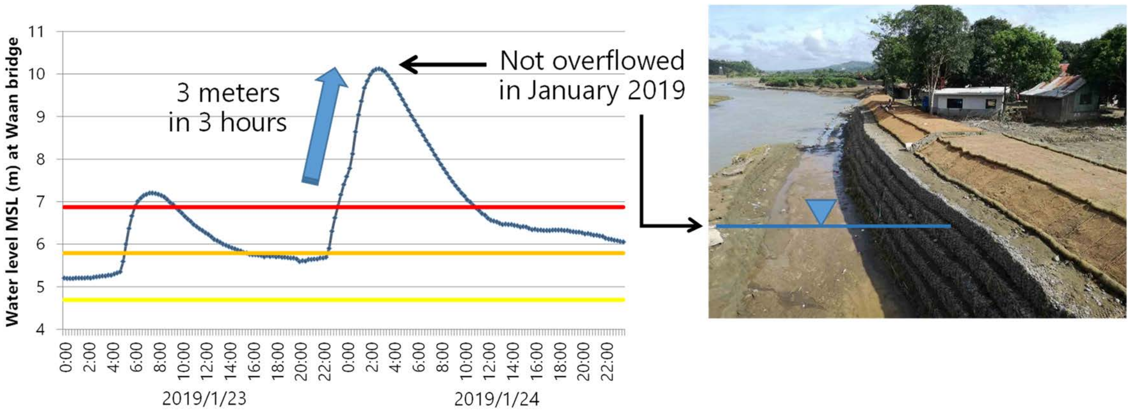
Source: Prepared by JICA Project Team based on Davao City DRRMP 2017-2022

(1) End-to-end monitoring system for forecasting and early warning

Regarding the meteorological and hydrological observation in the target area of the Project, the Davao River Basin Flood Forecasting and Warning Center (DRBFFWC) was established under PAGASA in 2018, and seven water level gauges and seven rainfall gauges have been installed under support of JICS. Among them, six water level gauges and five rainfall gauges in the Davao river basin, one water level gauges and two rainfall gauges in Talomo river basin, and no gauges in Matina river basin, were installed.

The data above is being monitored by DRBFFWC and CDRRMO as a real-time observation system. Based on these data, a flood advisory or flood bulletin is issued by DRBFFWC, and the information is disseminated to the related organizations through OCD, and to barangays through CDRRMO by mobile phone, land phone, e-mail, messenger applications and others.

On the other hand, as mentioned in section 2.7.3, the condition of Davao river is changing due to ongoing construction work of DPWH DEO since 2017 which will last until 2022. Therefore, the danger water levels set by PAGASA are not getting matched with the latest river channel conditions. As shown in Figure 2.12.1 below, the water level data at Waan Bridge over the Davao River during heavy rainfall in January 2019 had exceeded the red (Critical) danger level by more than three meters, however water was not overflowing at that time according to interviews with the residents.



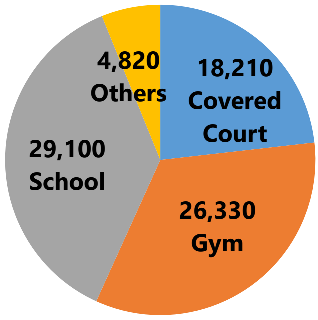
Source: JICA Project Team

Figure 2.12.1 Water Level Data at Waan Bridge in January 2019 Flood

Compared with Davao River, Talomo River and Matina River don't have enough lead-time to take prompt DRR actions before flooding since the flood wave propagation time is relatively short. Especially for Matina River, when there were more than 30 fatalities in the 2011 flood, therefore it is necessary to establish EWS in such short-medium rivers even though there are no water level observation stations along Matina River.

(2) Evacuation Centers

In Davao City, 91 facilities are currently designated as shelters, and it is estimated that a total of 78,460 people can be accommodated. Of these, covered courts, gymnasiums, and schools are mainly designated, and the breakdown of the number of people who can be accommodated in each evacuation center is shown in the Figure 2.12.2 below.



Source: Prepared by JICA Project Team based on CSSDO data

Figure 2.12.2 Breakdown of the Number of People Who Can be Accommodated in Evacuation Centers

In addition, new shelters are being constructed to prepare for future large-scale disasters. In the Los Amigos area, located in the middle reaches of Talomo River, expansion of an existing shelter and construction of a new shelter are underway, and shelter construction is also planned in the Ma-a and Mahayag areas.

On the other hand, the population living in the hazard prone area of landslide and flood in Davao city calculated based on the hazard map prepared by DOST and MGB is estimated to be about 430,000, therefore the capacity of shelters may not be enough.

(3) Hazard maps and risk assessment, Davao City IEC Program, Earthquake and fire drills and other multi-hazard drills

In Davao City, there are several existing flood hazard maps as described below. First, MGB conducted hazard assessment based on topographical, soil quality and disaster historical information, and created a 1:10,000 scale hazard map for floods and landslides. However, this hazard map was created before typhoon Vinta, therefore MGB recognizes that updating is necessary. The other is the flood hazard map created in 2015 in the DREAM program led by the University of the Philippines (UP). It has been created with 5-year, 25-year, and 100-year probability using the HEC-MHS model and ground data from LiDAR. In addition, flood hazard maps and storm surge hazard maps were also organized in Project NOAH implemented by DOST, and can be viewed on their website.

As mentioned above, several organizations create maps with different methods and accuracy, hence each flood hazard map has different map accuracy/scale, different calculation conditions like various flood scale, and different inundation area. In addition, there is no sufficient explanation from preparing agency when distributing the map. Therefore, although maps are distributed to barangays, and barangay offices have maps, the barangay offices sometimes gets confused about which map to use and how to use it. It is considered that one of the issues is that it is not linked to effective disaster management activities such as utilization for evacuation drill due to the lack of understanding on how to utilize them.

Also, the distribution of educational materials to residents and the implementation of training are effective as awareness activities. As current situation, flood-fighting drills are not conducted although earthquake drills led by Davao city are conducted once a year.

In addition, as an IEC activity related to flood, IFI (International Flood Initiative), whose secretariat is ICHARM in Japan, collaborates with DPWH, PAGASA and DOST XI to build a platform related to water resilience and disasters, and is conducting activities. For Davao City, the Online Synthesis System (OSS) was developed to integrate knowledge and information on real-time flood forecasting and climate change impact assessment and allow local stakeholders to learn about them through e-learning. The e-learning and workshop for candidates of “Facilitators” in Davao City was held for about one month in 2021.

(4) Greening Program

In the Davao River Basin, DENR has confirmed that 135,469 ha, or 76% of the basin area of 175,960 ha, is a forest area. Of this forest land, 32% is distributed in the upper Bukidnon and the remaining 68% in the middle and lower parts of the basin, Davao del Norte and Davao City.

DENR formulated the Davao River Basin Management and Development Plan in 2015, and measures and funds required for 15 years were proposed. In this plan, activities for forest protection of 33,327 ha, forestlands rehabilitation of 20,000 ha, forestlands productive development of 17,800 ha and mangrove rehabilitation of 25 ha were proposed.

As for mangrove conservation, as mentioned above in section 2.4, the coastal road projects with a distance of approximately 12 km along the coastline of Davao City are ongoing, and there is concern that this will have a major impact on mangroves. In the view of DENR officer, mangrove conservation will be considered again after the completion of the said coastal road project. Moreover, it is mentioned in the CLUP formulated by Davao City that the expansion of informal settlers along the coast is causing damage to mangroves.

(5) Relocated/regulated households

In the three rivers targeted by this project, there are clearly residents who are illegally occupied within the limits along river set by the Water code. The current situation is confirmed visually. The quantitative grasp continues to be investigated in the Stage 2.

(6) Retrofitted existing public infrastructures and facilities

According to the estimation of the infrastructure development project, the urban area of Davao City is expected to be about doubled from 14,057 ha in 2017 to 28,190 ha in 2045. With the progress of urbanization, there is a concern that the flood arrival time will be faster and the runoff to the river will increase due to the reduction of the water holding and retarding functions in the basin.

In Davao City, the ordinance for the proper harvesting, storage and utilization of rainwater was established in 2009, and the installation of a rainwater catchment system is stipulated in the construction of private residences, commercial and industrial buildings, etc., as an effective flood mitigation measure. Then, under Executive order No. 45 from Davao City, the Implementing rules and Regulations (IRR) of the above-mentioned ordinance was issued in 2014. The issuance of this IRR promotes the installation of a rainwater catchment system, and Davao City has issued a building permit to facilities with 2,497 cases in 2015 and 3,879 cases in 2016. On the other hand, according to the research results of 2018 by Ateneo de Davao University et al., it is reported that the proportion implemented properly is only about 30% of the subjects. In Davao City's view, it is considered necessary to finalize a technical manual for planning and installation of rainwater catchment systems and to build a database to manage existing rainwater catchment systems.

Source: 2018 Annual Report, Interface Development Interventions

Figure 2.12.3 Examples of Rainwater Catchment System in Davao

In Davao City, the preparation and approval of city ordinance concerning the mainstreaming, promoting, and institutionalizing permeable pavement system is underway. Since this ordinance has not been approved, the content has not yet been released to the public. Regardless of the presence or absence of this ordinance, cases have also been confirmed where private companies in Davao City have independently created permeable pavement systems for parking lots.

(7) Desilting of rivers and natural waterways

Davao City has established the Ancillary Service Unit (ASU) under the City Mayor's Office in 2017 through Executive Order No. 05 in order to maintain the drainage network and to properly secure the sidewalk space. The drainage network is cleaned up with the CEO's equipment and 200 human resources under the ASU. ASU has issued a monthly report from 2018 which mentions the locations of clean-up activities, the date, the total amount of waste extracted, and the total length of cleaned drainage channels. It is reported that the waste of 2,875 m3 was extracted and the drainage channel with a total extension of 52,990 m was cleaned in 2018, mainly at locations where urban flood damage was serious, and the activities are still ongoing.

In addition, 300 volunteers have been taking part in the first Saturday and third Saturday mornings to clean up rivers and the coast in Davao City since October 2017. This activity is conducted in accordance with Executive Order No. 41, and Davao City provides a daily allowance to the participants.

On the other hand, in the ASU's opinion, the above-mentioned cleaning and maintenance activities alone cannot cover all drainage channels in Davao City, and cooperation from the barangay level and awareness raising activities for the residents are necessary. In addition, illegal disposal of construction materials such as gravel and sand by construction companies also has a major impact on drainage systems, and it is considered necessary to further strengthen the monitoring system.

2.13 Current Main Laws, Regulations and Orders related to Flood (Riverine Flood/Inland Flood/Storm Surge and High Tide)

2.13.1 Current Main Laws/Regulations/Orders

(1) National Government Level

1) Presidential Decree 1067 (Water Code of the Philippines)

The Water Code of the Philippines known as Presidential Decree 1067 was passed in order to establish the basic principles and framework relating to the appropriation, control and conservation of water resources to achieve the optimum development and rational utilization of these resources. The Code defines the extent of the rights and obligations of water users and owners including the protection and regulation of such rights. The Code also serves as a basic law governing the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources and rights to land related thereto.

The nature of water rights may be drawn from the five “underlying principles” enumerated in Article 3:

a) All waters belong to the State;
b) All waters that belong to the State cannot be the subject of acquisitive prescription;
c) The State may allow the use or development of waters by administrative concession;
d) The utilization, exploitation, development, conservation and protection of water resources shall be subject to the control and regulation of the government through the National Water Resources Council (NWRC);
e) Preference in the use and development of waters shall consider current usage and be responsive to the changing needs of the country.

Table 2.13.1 provides salient sections of the Code which are of importance to flood control management.

Table 2.13.1 Salient Section of the Water Code Related to Flood Control Management

Items	Summary Description
Article 51	The banks of rivers and streams and the shores of the seas and lakes throughout their entire length and within a zone of 3 meters in urban areas, 20 meters in agricultural areas and 40 meters in forest areas, along their margins are subject to the easement of public use in the interest of recreation, navigation, floatage, fishing and salvage. No person shall be allowed to stay in this zone longer than what is necessary for recreation, navigation, floatage, fishing or salvage or to build structures of any kind. **Amended Implementing Rules and Regulations** *Section 31 Determination of Easements* For purposes of Article 51 of the Code, all easements of the public use prescribed for the banks or rivers and the shores of seas and lakes shall be reckoned from the line reached by the highest flood which does not cause inundation or the highest equinoctial tide whichever is higher. Any construction or structure that encroaches into such easement shall be ordered to be removed or caused to be removed by the Board in coordination with DPWH, LGU or appropriate government agency or local government unit.
Article 53	To promote the best interest and the coordinated protection of flood plain lands, the Secretary of Public Works, Transportation and Communications may declare flood control areas and promulgate guidelines for governing flood plain management plans in these areas.
Article 54	In declared flood control areas, rules and regulations may be promulgated to prohibit or control activities that may damage or cause deterioration to lakes and dikes, obstruct the flow of water, change the natural flow of the river, increase flood losses or aggravate flood problems.
Article 55	The government may construct necessary flood control structures in declared flood control areas, and for this purpose it shall have a legal easement as wide as may be needed along and adjacent to the river bank and outside of the bed or channel of the river.

Items	Summary Description
Article 56	River beds, sand bars and tidal flats may not be cultivated except upon prior permission from the Secretary of the Department of Public Works, Transportation and Communication and such permission shall not be granted where such cultivation obstructs the flow of water or increase flood levels so as to cause damage to other areas.
Article 65	Water from one river basin may be transferred to another river basin only with approval of the Council. In considering any request for such transfer, the Council shall take into account the full costs of the transfer, the benefits that would accrue for the basin of origin without the transfer, the benefits that would accrue in the receiving basin on account of the transfer, alternative schemes for supplying water to the receiving basin, and other relevant factors.

Source: Water Code of the Philippines

2) Philippine Disaster Risk Reduction Management Act of 2010 (RA 10121)

The enactment of Republic Act 10121 otherwise known as the Philippine Disaster Risk Reduction and Management Act of 2010 laid out the basis for a paradigm shift from disaster preparedness and response to disaster risk reduction and management (DRRM). Table 2.13.2 summarizes the significant features of the Act.

Table 2.13.2 Summary of Significant Feature of RA 10121

Main Section	Important Features
Section 2 – Declaration of Policy	DRRM will adopt an approach that is holistic, comprehensive, integrated and proactive in lessening the socio-economic and environmental impact of disaster including climate change, and will promote the involvement and participation of all sectors and stakeholders concerned, at all levels in the local community.
Section 4 – Scope	Provides the development of policies and plans and the implementation of actions and measures pertaining to all aspects of disaster risk reduction and management, including good governance, risk assessment and early warning, knowledge building and awareness raising, reducing underlying risk factors and preparedness for effective response and early recovery.
Sections 5-13: Institutional Mechanism	DRRM institutional mechanism: 1) Disaster Risk Reduction and Management Council networks from the national, regional, provincial, city/municipal and barangay levels. 2) Local DRRM Offices in every PDRRMC, CDRRMC/MDRRC and BDRRM Committee 3) Office of the Civil Defense (OCD) 4) Disaster volunteers
Section 21-22	Establishing and regulating the National/Local Disaster Risk Reduction and Management Fund "Not less than 5% of the estimated revenue from the regular sources shall be set as the N/LDRRMF to support disaster risk management efforts.

Source: Philippines Disaster Risk Reduction and Management Act 2010

The Act mandates the Department of Interior and Local Government (DILG) to formulate a National Disaster Risk Reduction Management Plan (NDRRMP) which serves as the national guide on how sustainable development can be achieved through inclusive growth while building the adaptive capacities of communities; increasing the resilience of vulnerable sectors; and optimizing disaster mitigation opportunities with the end in view of promoting people's welfare and security towards gender-responsive and rights-based sustainable development.

In accordance to the NDRRMF, the NDRRMP articulated four distinct yet mutually reinforcing priority areas, namely, (a) Disaster Prevention and Mitigation; (b) Disaster Preparedness; (c) Disaster Response; and (d) Disaster Recovery and Rehabilitation. Each priority area has its own long term goal, which when put together will lead to the attainment of the goals and vision of DRRM. Table 2.13.3 provides the summary of the long term goals in accordance to four priority areas.

Table 2.13.3 Summary of Long Term Goals of DRRM, Philippines

Priority Area	Long Term Goals	Objectives
Prevention and Mitigation	Avoid hazards and mitigate their potential impacts by reducing vulnerabilities and exposure and enhancing the capacities of communities.	Reduce vulnerability and exposure of communities to all hazards
		Enhance capacities of communities to reduce their own risks and cope with the impacts of all hazards
Disaster Preparedness	Establish and strengthen the capacities of communities to anticipate, cope and recover from the negative impacts of emergency occurrences and disasters	Increase the level of awareness in the community to the threats and impacts of all hazards, risks and vulnerabilities
		Equip the community with the necessary skills to cope with the negative impacts of disaster
		Increase the capacity of institutions
		Develop and implement comprehensive national and local disaster preparedness policies, plans and systems
Disaster Response	Provide life preservation and meet the basic subsistence needs of affected populations based on acceptable standards during or immediately after disaster	To decrease the number of preventable deaths and injuries
		To provide basic subsistence needs of affected population
		To immediately restore basic social services
Rehabilitation and Recovery	Restore and improve facilities, livelihood and living conditions and organizational capacities of affected communities, and reduced disaster risks in accordance with the "building back better" principle	To restore people's means of livelihood and continuity of economic activities and business
		To reconstruct infrastructure and other public utilities
		To assist in the physical and psychological rehabilitation of persons who suffered from the effects of disaster.

Source: NDRRMP

3) Republic Act 9729 (Climate Change Act)

In 2009, the Republic Act 9729 or the Climate Change Act was enacted into law. The law mandates mainstreaming climate change (CC) considerations into government policy and planning. This piece of legislation provided the foundation in the creation of the Climate Change Commission, the National Framework Strategy on Climate Change (NFSCC) for 2010-2022, and the National Climate Change Action Plan (NCCAP) for 2011-2028.

As a result of these policy reforms, the scope of the government's climate change response has been further defined across agencies and at the national and local levels. Contained in the NFSCC and the NCCAP are several time-bound targets of the government in relation to climate change adaptation, mitigation, and disaster risk reduction (CCAM-DRR).

4) Presidential Decree 1152 of 1977 Environmental Code of the Philippines

The Environmental Code of the Philippines stipulates provision regarding flood control. Section 34 provides measures in flood control program in addition to the pertinent provisions of existing laws:

- Control of soil erosion on the banks of rivers, the shores or lakes and the sea-shores;
- Control of flow and flooding in and from rivers and lakes;
- Conservation of water which, for purposes of this Section shall mean forms of water, but shall not

include captive water;

- Needs of fisheries and wildlife and all other recreational uses of natural water;
- Measures to control the damming, diversion, taking, and use of natural water, so far as any such act may affect the quality and availability of natural water for other purposes; and
- Measures to stimulate research in matters relating to natural water and soil conservation and the application of knowledge thereby acquired.

In addition to the above mentioned Presidential Decrees and Republic Acts, Table 2.13.4 provides other related significant Presidential Decrees, Republic Acts, Department Orders, Executive Orders and others related to flood control management issued by various agencies and departments .

Table 2.13.4 List of Relevant Laws, Regulations and Orders on Flood Control

PD/RA/DO/EO	Title	Issuing Agency
PD 1586 1978	Environmental Impact Statement System	-
RA 11038 2018	Expanded National Integrated Protected Areas System Act	-
RA 10752 2016	The Right-of-Way Act	-
DO 116 S2018	Tree Cutting and Earth-balling Permit Application Process and Requirements for DPWH Infrastructure Projects	DPWH
DO 124 S2017	Directing the Use of the DPWH Right-of-Way Acquisition Manual by All Concerned.	DPWH
DO 57 S2016	Environmental Impact Assessment (EIA) for DPWH Projects and Tree Cutting Permit Application	DPWH
DO 23 S2015	Flood Control and Drainage Slope Protection Policy	DPWH
DO 139 S2014	Guidelines on River Dredging Operations for Flood Control	DPWH
AO 05 2019	Implementing Rules and Regulations of RA 7586, RA11038	DENR
AO 15 2017	Guidelines on Public Participation under the Philippine Environmental Impact System	DENR
AO 13 1992	Establishment of Buffer Zone within Forest Land	DENR
EO 510 2006	Creation of River Basin Control Office (RBO)	DENR
MC 30 2020	Interim Guidelines on Public Participation in the implementation of the Philippine Environmental Impact Statement System (PD1586) during the state of national public health emergency	DENR EMB

Source: Compiled by JICA Project Team

(2) Local Government Unit Level

The Local Government Unit enacted ordinances and policies to support and localized the implementation of the National laws and regulations related to flood control. Table 2.13.5 provides a summary of major local policies and ordinances relative to flood control management in the city.

Table 2.13.5 Local Policies and Ordinances Passed by the City Council of Davao City Related to Flood Control and Drainage

Local Ordinance	Title
Ordinance #0298-09	Proper Harvesting, Storage and Utilization of Rainwater in Davao City
Ordinance #0333-15	Creating a Technical Working Group to facilitate the process of Desilting Operations in the Rivers and Streams in the Watershed Areas in Davao City
Ordinance #0310-07	Watershed Code of Davao City or Watershed Protection, Conservation and Management
Ordinance #0361-10	Davao City Ecological Solid Waste Management
Ordinance #117-01	Water Resource Management and Protection Code of Davao City

Source: Compiled by JICA Project Team

2.13.2 Legal Aspects related to River Boundary

The significant legal basis in river boundary is broadly illustrated in the Civil Code of the Philippines (RA 386), which are stipulated in Title 2 and 4 of the Civil Code shown in Table 2.13.6. and these were enhanced by the provision of the Water Code of the Philippines (PD 1067) under Chapter 2 and 4, ownership and control of waters, respectively.

Table 2.13.6 Civil Code of the Philippines in Relation to Water Rights and Ownership

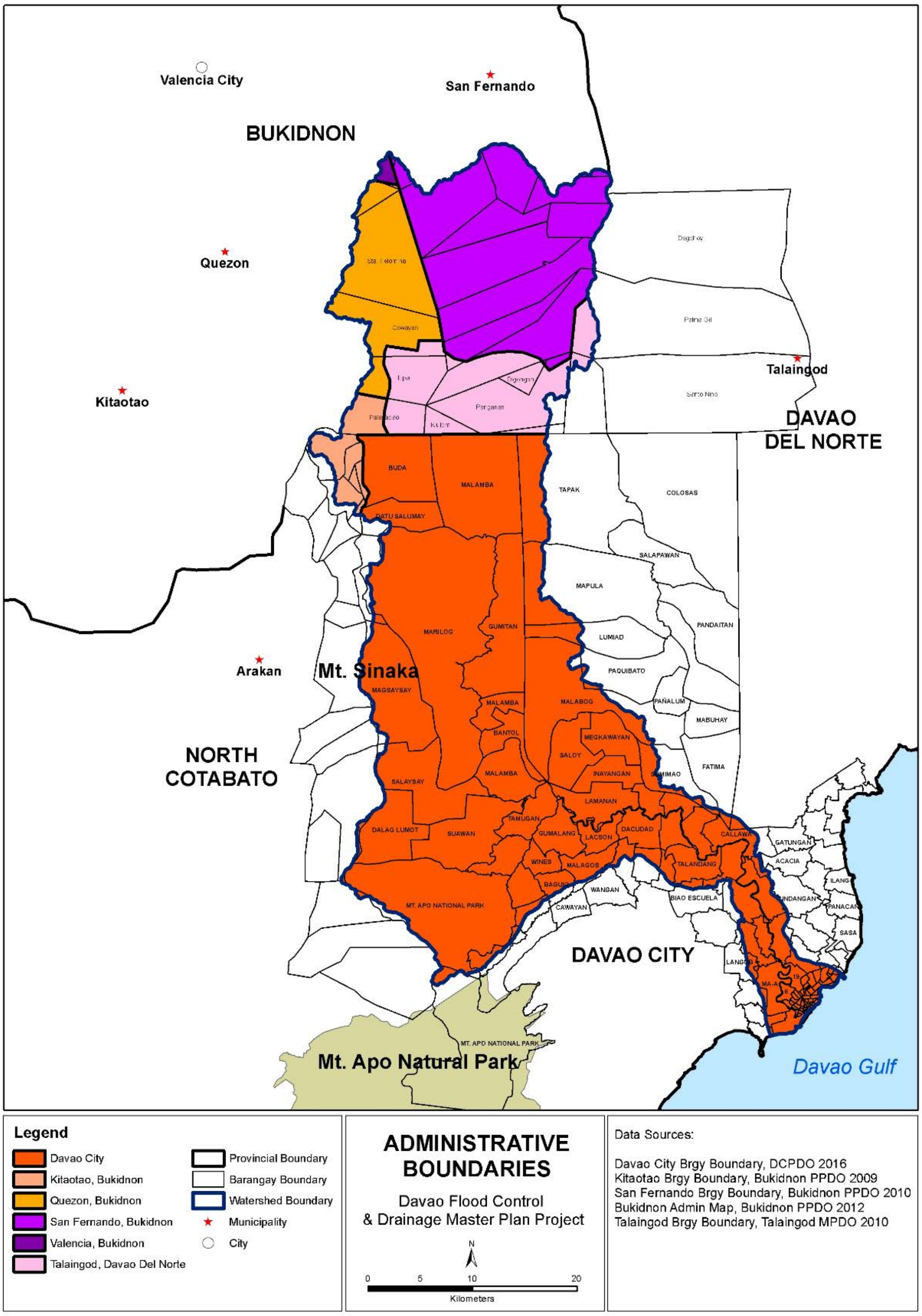
Ref #	Provision of the Code
Title II. Chapter 1: Ownership In General	
Art 461	River beds which are abandoned through the natural change in the course of the waters ipso facto belong to the owners whose lands are occupied by the new course in proportion to the area lost. However, the owners of the lands adjoining the old bed shall have the right to acquire the same by paying the value thereof, which value shall not exceed the value of the area occupied by the new bed.
Art 462	Whenever a river, changing its course by natural causes, opens a new bed through a private estate, this bed shall become of public dominion
Art 463	Whenever the current of a river divides itself into branches, leaving a piece of land or part thereof isolated, the owner of the land retains his ownership. He also retains it if a portion of land is separated from the estate by the current.
Title IV. Chapter 1- Some Special Properties Section 1. - Ownership Of Waters	
Art 502	The following are of public dominion: (1) Rivers and their natural beds; (2) Continuous or intermittent waters of springs and brooks running in their natural beds and the beds themselves; (3) Waters rising continuously or intermittently on lands of public dominion; (4) Lakes and lagoons formed by Nature on public lands, and their beds; (5) Rain waters running through ravines or sand beds, which are also of public dominion; (6) Subterranean waters on public lands; (7) Waters found within the zone of operation of public works, even if constructed by a contractor; (8) Waters rising continuously or intermittently on lands belonging to private persons, to the State, to a province, or to a city or a municipality from the moment they leave such lands; (9) The waste waters of fountains, sewers and public establishments.
Art 503	The following are of private ownership: (1) Continuous or intermittent waters rising on lands of private ownership, while running through the same; (2) Lakes and lagoons, and their beds, formed by Nature on such lands; (3) Subterranean waters found on the same; (4) Rain waters falling on said lands, as long as they remain within the boundaries; (5) The beds of flowing waters, continuous or intermittent, formed by rain water, and those of brooks, crossing lands which are not of public dominion.

Source: Compiled by JICA Project Team

The Water Code of the Philippines as well as the proposed National Water Security Act of 2013 have not explicitly provided the definition of river area nor delineated river boundaries of river areas, however, there are various efforts undertaken by various agencies to define its administrative boundaries. Such efforts aimed at effectively and efficiently respond to the issues and problems of the river basin and ensure appropriate management of the river resource.

As mentioned in this Report, the Davao River Basin is shared by Davao City, Province of Bukidnon and Davao del Norte. At present, an dispute over water rights and water control existed between the Province of Bukidnon and Davao del Norte, of which the area is now managed and controlled by the Province of Bukidnon. According to the Davao River Basin Management and Development Master Plan, river boundaries are define based on its physical boundary and the socio-political boundaries of the areas as showed in Figure 2.13.1. Such definition though only provides the legal basis of its boundaries and management.

With the existing disputes of the two provinces mentioned, the Davao River Basin Alliance becomes a significant avenue assuming the joint responsibility for ensuring that the river and its watershed are sustainably managed and controlled.



Source: Project Team modified from Davao River Basin Management and Development Plan, 2015

Figure 2.13.1 Administrative Boundaries of Davao River Basin

2.14 Condition of Framework for Project Implementation and Maintenance related to Flood (Riverine Flood, Inland flood, Storm Surge and High Tide)

2.14.1 Main Organizations

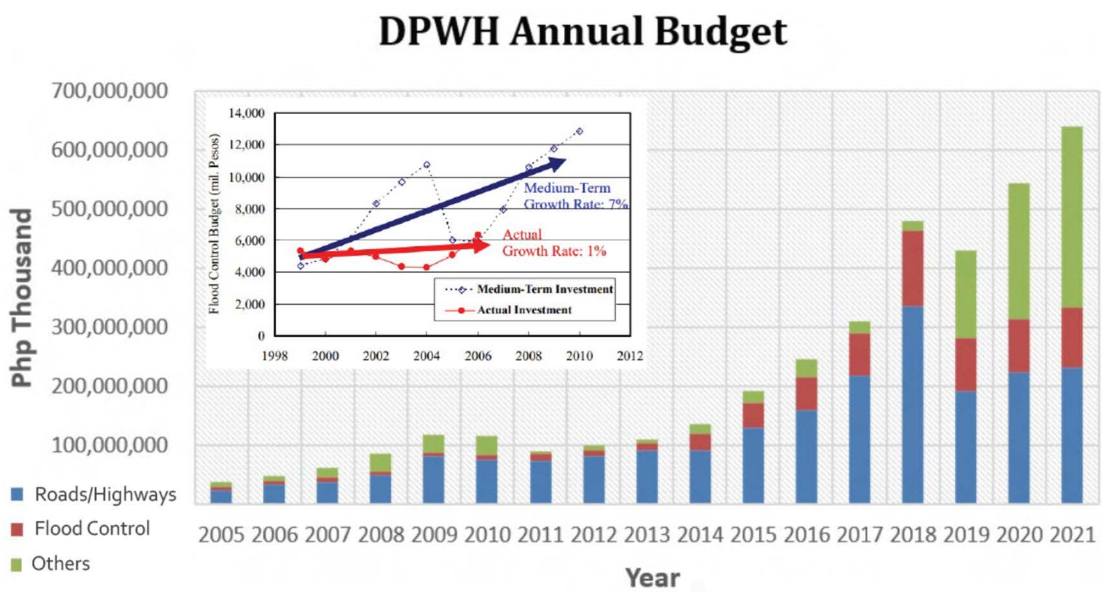
(1) Department of Public Works and Highways (DPWH)

1) Department of Public Works and Highways (DPWH)-Central Office

The Department of Public Works and Highways (DPWH) is one of the three departments of the government undertaking major infrastructure projects. It is mandated to undertake (a) the planning of infrastructure, such as national roads and bridges, flood control, water resources projects and other public works, and (b) the design, construction, and maintenance of national roads and bridges, and major flood control systems.

The Department of Public Works and Highways functions as the engineering and construction arm of the Government tasked to continuously develop its technology for the purpose of ensuring the safety of all infrastructure facilities and securing for all public works and highways the highest efficiency and quality in construction.

To support the National Government policies on `Build, Build and Build Thrust`, DPWH has aggressively implemented its infrastructure program and has increased tremendously its budget more than five times from about 90B in 2011 to approximately 480B in 2018. The budget fell in 2019, but has since been on the rise again. Figure 2.14.1 illustrates the DPWH budget allocation by category from 2005-2021.



Source:https://www.undrr.org/sites/default/files/inline-files/Philippines_JFANO_IRF2022%20%281%29-compressed.pdf

Figure 2.14.1 DPWH Infrastructure Program, 2005-2021

2) Unified Project Management Office-Flood Control Management Cluster, DPWH-UPMO-FCMC

Under the new mandate, all flood control related management is under the Unified Project Management Office-Flood Control Management Cluster with the following roles and functions:

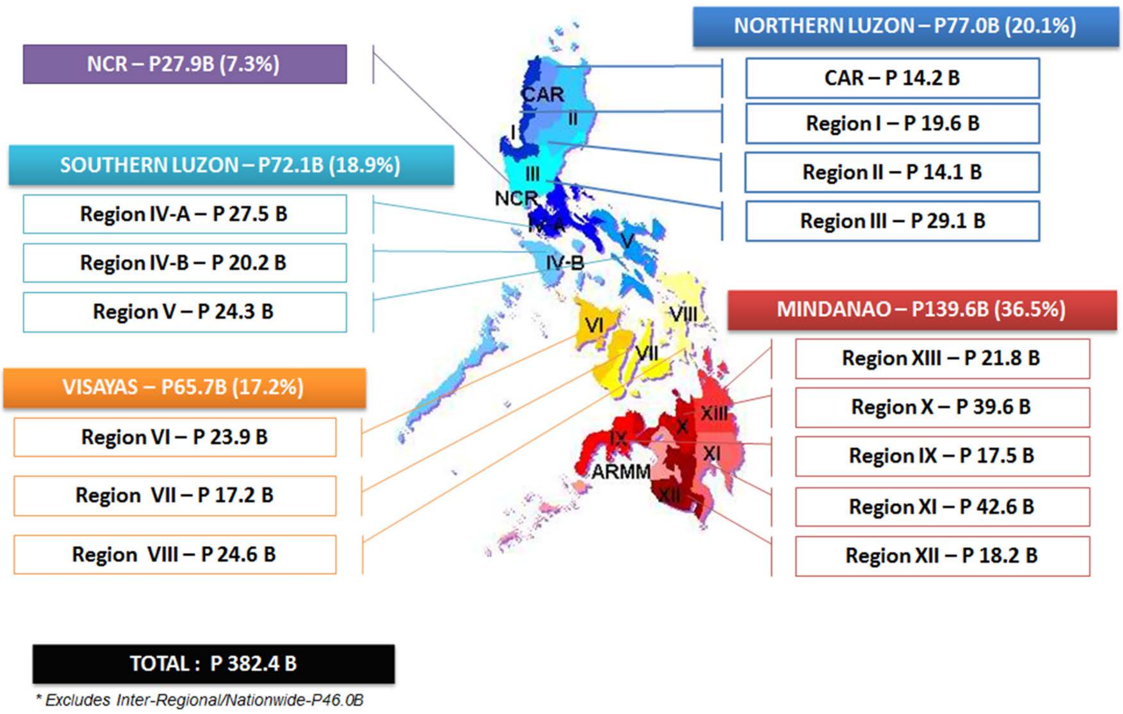
- Provide technical comments, advise the M/P and F/S on related flood control projects
- Coordinate the planning, design, construction, organization and maintenance of proposed measures related to flood control projects in coordination with concern agencies
- Manage the proposed measures related to flood control projects.

The Office of the Project Director is supported by a core staff and an operation support staff. The core staff is five functional units namely; administrative support unit, planning and programming support unit, procurement support unit, contract management unit and monitoring and reporting unit. On the other hand, the operation support staff is composed of the flood control management office, project managers, construction operations for foreign-assisted projects, construction operations for locally funded projects and operation and maintenance.

3) Department of Public Works and Highways-Regional Office XI

The Regional Office of the Department of Public Works and Highways (DPWH) is currently responsible for the planning, design, construction and maintenance of infrastructure, especially the national highways, flood control and water resources development system, and other public works in accordance with national development objectives. In view of the decentralization law, the Regional Office of DPWH envisions to complimenting the initiatives undertaken by the local government units.

In 2017, the Region received the highest budget allocation of Php 42.6B out of the total budget of Php 382.4B. Figure 2.14.2 shows the allocation of budget by region. As this Figure indicates, Region XI garnered the highest budget allocation of Php 42.6B which is approximately 30% of the total budget for Mindanao.



Source: DPWH

Figure 2.14.2 Allocation of Budget by Region, 2017

4) District Engineering Office (DEO)

There are two District Engineering Office (DEO) in Davao City, which are Davao City DEO and Davao City II DEO. Davao City DEO covers the 2 districts in Davao City namely, District 1 consists of the Poblacion and Talomo areas, covering an approximate 54 barangays; District 2 consists of areas in Agdao, Buhangin, Bunawan and Paquibato with approximate coverage of 46 barangays. Davao City II DEO covers District 3 which is composed of Baguio, Calinan, Marilog, Toril and Tugbok servicing a total of 82 barangays.

In terms of manpower, Davao City DEO is composed of an approximate 97 staff and 508 job orders. Table 2.14.1 provides the number of staff by section/unit in the Davao City DEO. The Planning and Design Unit at the DEO plays a vital role in the overall planning and design of flood control measures.

Table 2.14.1 Number of Manpower at DEO First District

Section/Unit	No. of Staff with Plantilla Positions	Job Orders
Office of the District Engineers	6	36
Administrative Section	15	31
Cashier Unit	3	5
Finance Section	5	15
Construction Section	14	102
Maintenance		
Engineers Office	2	2
Field Operation	10	152
Equipment Service Unit	7	6
Planning and Design Section	14	96
Procurement Section	6	12
Quality Assurance Section	11	48
Supply and Property Unit	4	5
Total	**97**	**508**

Source: DEO 1st District, Davao City

(2) Local Government Unit of Davao City

The enactment of the 1991 Local Government Code represent a major step forward in decentralization in the Philippines as it mandates the Local Government Units the local autonomy in managing local affairs by devolving planning functions, expenditures and taxing including flood control planning and management.

The Code also provides a provision that public work and infrastructure projects and other facilities funded by the national government under the annual General Appropriation Act, other special laws, pertinent executive orders, and those wholly or partially funded from foreign sources, are not covered under Section 17, except in cases where the local government unit concerned is duly designated as the implementing agency for such projects, facilities, programs and services.

Given the provision of the Code, LGUs are in close coordination with national agencies in implementing projects which are partially funded by the national government and those are foreign assisted projects. In the context of Davao City, delineation of functions and responsibilities of DPWH is contained in the Department Order 23 of 2015 that provides the policies, guidelines and procedures for the implementation of flood control, drainages/slope protection projects funded and proposed by the national government under the DPWH Infrastructure Program.

The functions of flood control management in Davao City are managed and are under the responsibility of four major department in the City Government namely:

1) City Engineers Office (CEO)

The City Engineer's Office is the engineering arm of the City Government of Davao. Its functions are outlined in Article 7, Section 477 of the Local Government Code. The roles and functions of the City Engineer`s Office are summarized below:

- Maintenance of all public roads, streets and bridges and ensure that these are structurally stable and safe to all motorists.
- Urban drainage maintenance including the maintenance of all canals, on both inlets and outlets throughout the city by securely cleaning and de-clogging them from debris and other refuse.
- Waterworks implementation in new rural water systems including maintenance of existing rural water systems (such as pumps, submersible motors, distribution networks and its components).
- Demolition, inspection and investigation of complaints pertaining to illegal structures and informal settlers; conducts dialogues and executes demolition works; executes summary demolition work for on-going illegal constructions; removes illegal streamers and regulates sidewalk vendors along the city & national roads.
- Programming and design of works for various infrastructure projects; conduct investigations on complaints pertaining to right of way and boundary conflicts.
- Quality control of construction materials used in various infrastructure projects
- Implementation of city funded and barangay funded projects such as roads, drainage, bridges, public buildings and other structures.

2) City Disaster Risk Reduction and Management Office (CDRRMO)

The Republic Act 10121 known as the Philippine Disaster Risk Reduction and Management Act of 2010, Section 12 (c-6) mandates the establishment of Local Disaster Risk Reduction and Management Office. The Act authorizes the formulation and implementation of a comprehensive and integrated Local Disaster Risk Reduction and Management Plan in accordance to the national, regional and provincial development framework and policies on disaster risk reduction. This shall be carried out in close coordination with the local development council.

In the context of Davao City, the City Disaster Risk Reduction Management Office (CDRRMO), together with the relevant stakeholders have initiated the formulation of the Davao City Risk Reduction Management Plan 2017-2022. The plan was prepared on the basis of the flood hazard map, landslide susceptibility map, terrain classification, and liquefaction susceptibility and erosion susceptibility maps. Based on the analysis, the plan has laid out comprehensive strategies on thematic areas and stipulates responsible agencies to carry out the disaster risks and reduction activities (see Table 2.14.2).

Table 2.14.2 Performance Target, DCRRMO

Thematic Area/s	DCRRMO Target	Responsible Agency
Disaster Prevention and Mitigation	60% reduction on exposed and vulnerable population and 100% increase in the average capacity ratings of barangays	City Environment and Natural Resource) (CENRO)
Disaster Preparedness	90% of DC communities, agencies and CSOs are engaged in proactive activities such as training, orientation and simulation exercises.	City Disaster Risk Reduction Management Office (CDRRMO)
Disaster Response	100% of the burden or impact of the disaster will be addressed by the City	City Social Services Development Office (DSSDO)
Disaster Rehabilitation and Recovery	90% of disaster affected communities are to be rehabilitated and have built their life better after disaster.	City Planning and Development Office (CPDO)

Source: City Disaster Risk Reduction and Management Plan, 2017-2022

3) City Planning and Development Office (CPDO)

The City Planning and Coordinator's Office (CPDO) served as the Secretariat for the Legislative Council mandated to formulate the Comprehensive Land Use Plan (CLUP) and the Local Development Council mandated to formulate the Comprehensive Development Plan (CDP). The CPDO is tasked to perform all related development planning matters and planning processes under the Local Government Code.

In the context of flood control management, CPDO has a major role in terms of land use and zoning. Currently, CPDO in coordination with the DENR is formulating the forest land use plan that will provide further guidelines and policies in the utilization and conservation of forest areas. This effort was initiated to magnify the delineation of alienable and disposal land and to focus attention in the strict policies in the utilization of forest areas.

4) City Environment and Natural Resources Office (CENRO)

The CENRO plays a vital role in flood control management in Davao. To date, CENRO is updating its 10 year Integrated Social Waste Management Plan and hopes to address the following concerns:

- Improvement in the collection and transportation of municipal waste
- Improvement in the sanitary land fill
- Enhancement in the municipal recycling facilities
- Establishment of waste to energy facility
- Strengthening education, information and communication program on solid waste management

2.14.2 Other Related Organizations

(1) Department of Science and Technology (DOST)/PAGASA

The Executive Order No. 128 mandates the Department of Science and Technology (DOST) to "provide central direction, leadership and coordination of scientific and technological efforts and ensure that the results are geared towards the utilization in areas of maximum economic and social benefits for the people".

The DOST host the country's Atmospheric, Geophysical, Astronomical Services Administration (PAGASA) whose functions are to provide adequate, up-to-date data, and timely information on atmospheric, astronomical and other weather related matters in order to help the people and the government prepare for disaster caused by typhoons, landslides, storm surge, extreme climate events, climate change, among others. Table 2.14.3 provides the detailed services of PAGASA.

Table 2.14.3 Services of PAGASA

Services	Details
Weather Forecast & Tropical Cyclone Warning	• 24-Hr Public Weather Forecast issued twice daily and 4-day Extended Weather Outlook for Selected Cities • 5-day Weather Outlook for Selected Tourist Areas • Severe Weather Bulletins: 6-hourly Tropical Cyclone Warnings • Hourly Tropical Cyclone Update • Shipping forecasts & Tropical Cyclone Warning for Shipping • Gale Warning • Storm Surge Warning • Rainfall Warning system • Thunderstorm Alert System
Flood Forecasting & Warning Services	• Basin Flood Bulletins for Telemetered Basins and General Flood Advisories for the Non-Telemetered Basins • Dam Discharge Warning Information during Spilling Operation of the Monitored dams • Community-Based Flood Early Warning System • Daily hydrological forecasts during Non-Flood Watch
Climatological & Farm Weather Services	• Daily Farm Weather Forecast & Advisories • 10-day Regional Agro-climatic Weather & Advisories • 10-day Philippine Agro-climatic Review & Outlook • El Niño/La Niña Watch/Advisory and Information • Monitoring and Prediction of Seasonal Rainfall • Climate Projections for Climate Change Adaptation Activities
Research and Development	• Conduct of R&D on Hydrometeorology, Tropical Meteorology, Weather Modification, Meteorological and Hydrological Instruments and on Astronomy, Space Science and applications • Dispatch Storm Chaser Team to areas threatened and affected by typhoons • Conduct Calibration, Repairs & Testing (for private and government sectors) of Barometers and other related Equipment • Assist Researchers from Different Schools, Colleges, Universities and other Agencies
Astronomical Services	• Philippine Standard Time (PST) • Promotion of Astronomy through Stargazing/Telescoping Sessions and Planetarium Shows • Planetarium tour in selected areas in Luzon
Information, Education and Public Outreach	• Public Awareness Campaign on Natural Hazards, specifically Weather, Climate, Typhoons, Floods, Storm Surges and other related hazards • Conduct of Seminars/Workshops on Meteorological & Hydro-meteorological Hazards • Conduct of Seminar for Science Teachers on Basic Astronomy • Public Information Drive for the target areas of monitored Dams • Conduct of Flood Drills • Conduct of Annual Media Seminar-Workshops on PAGASA Services • Conduct of Annual Typhoon and Flood Awareness Week • Participation in Special Events like Exhibitions, School Celebration and other government and non-government organizations • Development of PAGASA print materials and non-print materials (flyers, brochures, posters and exhibit display materials

Source: http://bagong.pagasa.dost.gov.ph/products-and-services

(2) Department of Environment and Natural Resources (DENR)

The Department of Environment and Natural Resources (DENR) is the primary agency responsible for the conservation, management, development, and proper use of the country's environment and natural resources, specifically forest and grazing lands, mineral resources, including those in reservation and watershed areas, and lands of the public domain, as well as the licensing and regulation of all natural resources as may be provided for by law in order to ensure equitable sharing of the benefits for the welfare of the present and future generations. The DENR is mandated to achieve the following objectives:

1. Assure the availability and sustainability of the country's natural resources through judicious use and systematic restoration or replacement, whenever possible;
2. Increase the productivity of natural resources in order to meet the demands for forest, mineral, and land resources if a growing population;
3. Enhance the contribution of natural resources for achieving national economic and social development;
4. Promote equitable access to natural resources by the different sectors of the population; and
5. Conserve specific terrestrial and marine areas representative of the Philippine natural and cultural heritage for present and future generations.

The DENR plays a pivotal role in the conservation and preservation of all major watershed and catchment areas, river basin in the country and in Davao City, it played a proactive role in the protection of the Davao River Basin and launched various efforts in the development and sustainability of river and catchment basin.

(3) National Commission of Indigenous Peoples (NCIP)

The NCIP was established under Republic Act 8371 to protect and promote the interest and well-being of the indigenous peoples. Its powers and jurisdiction are summarized below:

- To serve as the primary government agency through which ICCs/IPs can seek government assistance and as the medium, through which such assistance may be extended;
- To formulate and implement policies, plans, programs and projects for the economic, social and cultural development of the ICCs/IPs and to monitor the implementation thereof;
- To request and engage the services and support of experts from other agencies of government employ private experts and consultants as may be required in the pursuit of its objectives;
- To issue certificate of ancestral land/domain title;

The importance of NCIP in flood control management lies on the fact that majority of the people in the upland areas in Davao belongs to various indigenous groups. Coordinative efforts are essential in order to bring in the indigenous community in mainstreaming them into the discussion of protecting, conserving the watershed areas.

(4) National Water Resources Board (NWRB)

The NWRB, formerly the National Water Resource Council is the primary agency task to manage the water resources in the Philippines. It coordinates and regulates all water related activities in the country that has an effect in the physical environment and economy. It was created to supervise the implementation of the Water Code. Under Executive Order No. 124-A, the NWRB is tasked, among others, to:

- Coordinate and integrate water resource development activities of the country;
- Formulate general criteria, methods and standards for data collection, project investigation, formulation, planning design and feasibility evaluation, and rules and regulations for the exploitation and optimum utilization of water resources;
- Review and approve water resource development plans and programs of other agencies;

- Undertake river basin surveys, inventories and appraisals, and develop comprehensive basin-wide plans of storage and control to maximize the conservation and multi-purpose use of water;
- Undertake hydrologic surveys and establish, operate and maintain observation station networks and centralized water resources data center;
- Conduct and/or promote special studies and researches with other government or agencies on related aspects of water resources development.

(5) Non-government Organizations

Davao City hosts various developmental NGOs working to protect, conserve and preserve watershed areas. Among these significant NGOs is provided in Table 2.14.4.

Table 2.14.4 Significant NGOs relevant to Flood Control Management, Davao

NGO Name	Brief Details
Sustainable Davao Movement	The Sustainable Davao Movement, a network of NGOs and POs committed to promote Davao City as a green city, planted mangroves and cleaned up the coast of Sitio Malamboon in Brgy. 76A to mark the group's first anniversary and celebrate Earth Day. The members of the SDM network includes the Interface Development Interventions Inc., the Ateneo de Davao University, METSA Foundation, Foundation for the Philippine Environment, Philippine Eagle Foundation, Masipag Mindanao, Matigsalog Tribe, Blissful Village, Agro-Eco Philippines, Ecoteneo, UCEAC, Youth for Climate Change, Cycle for Life, MISSION Davao, OROL-Gitib, and Save Shrine Hills Movement.
Interface Development Intervention	IDIS was established in 1999 to mainstream environmental assessment in development planning and envisions the following: • Expanded and conducive policy environment for the protection and management of watersheds • Replicable practices of watershed protection and management and sustainable living • Broad environmental partnerships strengthened in advocating for watershed protection and sustainable living
Kinaiyahan Foundation, Inc	The KFI was established in September 1988 as a non-government environmental organization focusing on environmental education and advocacy. It was set up by four social development workers in Davao City at the height of the growing concern about the fast degradation of ecological systems. As an environmental NGO, it was pro-actively involved in facilitating community empowerment through popular education, promotion of indigenous knowledge and systems, appropriate and environment-friendly technologies, policy advocacy, and linkage-building towards the building of healthy and sustainable communities. Its vision is rooted in the concept of a liberating sustainable development.

Source: http://idisphil.org
https://edgedavao.net/competitive-edge/2017/04/25/environment-group-observes-earth-day/
http://kinaiyahan.50webs.com

2.15 Study for Project Evaluation Criteria

2.15.1 General

Project evaluation is conducted to evaluate and select the most appropriate one among the proposed structural and non-structural menus.

(1) Principles

A comprehensive project evaluation reflecting different points of view such as the expected flood protection level (disaster risk reduction effects and start of the countermeasures effectiveness, and socio-economic and environmental impacts and others, is conducted to find out the best combination of countermeasures which can enable the achievement of the required flood protection level during the M/P target period.

Since the target and basic principles of countermeasures against River Floods, Rainwater Urban (Inland) Flooding and Storm Surge differ, evaluation axis, criteria and methodology differ.

The common methodology and process are explained in this section.

(2) Methodology and Process

The following figure shows the alternative evaluation process.

Step 1: Proposal of possible Countermeasures (Individual)

↓ By reflecting River Basin Characteristics, Needs and other factors, possible countermeasures (Individual) are proposed.

Step 2: Dismissal of Countermeasures difficult to implement based on “pre-requisites”

↓ Pre-requisites indispensable to implement countermeasures are set and countermeasures which cannot complete those requirements are abandoned.

Step 3: “Schematic” Evaluation

↓ Based on the results of a qualitative schematic evaluation, the advantages and disadvantages of each countermeasures are analyzed, and the most adequate individual countermeasures (2 or 3).

Step 4: Proposal of Combination of Countermeasures

↓ Resulting from the Schematic Evaluation (Step 3), combination of countermeasures is considered and proposed.

Step 5: “Detailed” Evaluation

↓ The comprehensive evaluation of countermeasures is conducted by using quantitative and fair / objective evaluation criteria, as much as possible.

Step 6: Selection of the most adequate countermeasures

The most adequate countermeasures of the Flood Control Plan is selected.

Source: Project Team

Figure 2.15.1 Process of Alternatives Evaluation

<u>Step 1: Proposal of possible Countermeasures (Individual)</u>

By reflecting the environmental and socio-economic aspects of the River Basin, Actual Countermeasures and Technologies adopted by DPWH and Davao City, possible countermeasures (individual) enabling the achievement of the plan’s objectives in term of Flood Protection, are proposed.

Step 2: Dismissal of Countermeasures difficult to implement based on "pre-requisites"

Pre-requisites from the points of view of legal framework, social and environmental constraints are set based on the review of laws, orders, guidelines and other basic documents. The countermeasures which cannot complete those requirements are judged as difficult to implement and are dismissed.

The pre-requisites are proposed in the Table 2.15.1.

Table 2.15.1 Pre-requisites

Pre-requisites	Outline
Legal Framework	The countermeasures which are difficult to implement because of the actual legal framework of the Philippines and Davao City are dismissed.
Social Context	Countermeasures which are susceptible to affect social and cultural protected areas are dismissed (including the impacts during the construction period).
Environmental Context	Countermeasures which are susceptible to affect environmental protected areas and existing sectors highly dependent on natural resources (such as tourism and fishery) are dismissed (including the impacts during the construction period).

Source: Project Team

Step 3: "Schematic" Evaluation

The third step aims to conduct a general qualitative evaluation of the countermeasures satisfying the pre-requisites and to extract the most superior countermeasures to analyze in detail (Table 3.4.1 of Chapter 3 illustrates the image of the schematic evaluation). The items to conduct schematic evaluation are shown in theTable 2.15.2.

Table 2.15.2 Items to consider for the primary screening/schematic evaluation

Items to classify	Outline
Outline of the countermeasures	Types, scale and location of the countermeasures are classified.
Estimated Target Discharge	The estimated discharge (rough estimation) that can be controlled by the countermeasures are indicated.
Period / years needed for Construction	Time needed to implement countermeasures, excluding land acquisition and relocation, are estimated.
Construction Cost (rough estimation)	Construction cost of countermeasures, excluding land acquisition and relocation, are estimated (rough estimation).
Size of relocation and land acquisition (rough estimation)	The area of land acquisition and number of houses to relocate in order to implement countermeasures are estimated. In addition, the time and procedures needed are analyzed and roughly estimated. Including the time needed of land acquisition and relocation, countermeasures which difficult to implement within the plan target period are dismissed.
Other issues requiring Special Procedures	Other issues to consider and requiring special procedures are indicated. For example: Restrictions related to the countermeasures itself (such as maximal levee height, pomp capacity), Special Procedures (such as consultation of specific groups/ethnic minorities) Need of further survey (such as geological survey to assess the possibility of dams) Etc.

Source: Project Team

The advantages and disadvantages of each countermeasure are clarified based on the analysis of the items described above. Resulting from this schematic evaluation, a few ascendant countermeasures (2 or 3) are extracted.

Step 4: Proposal of Combination of Countermeasures

The possible and effective combinations of the individual countermeasures selected through the Schematic Evaluation (Step 3) are considered and proposed.

Step 5: "Detailed" Evaluation

Resulting from the Schematic Evaluation (Step 3), a few ascendant countermeasures are selected and the combination of these countermeasures are considered and proposed (Step 4). The evaluation results of the M/P are shown in Section 3.15.

Table 2.15.3 shows some draft indicators for River Floods Countermeasures.

Even if the detailed evaluation indicators for River Floods Countermeasures, Rainwater (inland) Flooding Countermeasures and Storm Surge Countermeasures vary depending on their basic implementation principles and characteristics, the general evaluation axis are expected to be similar.

- **A. Flood Protection Level (Expected damage reduction):**

  Expected damage reduction effects are evaluated.

- **B. Economic Effectiveness:**

  Benefit-Cost analysis is conducted to evaluate the profitability and economic effectiveness of the countermeasures.

- **C. Feasibility in regards with social restrictions:**

  The other issues requiring special procedures related to land acquisition, relocation and other precautions remarked during the schematic evaluation (Step 3) are assessed in detail, and the concrete procedures to follow and coordination to arrange are checked. The feasibility is assessed based on the labor, time and cost needed to complete all needed requirements.

- **D. Feasibility from the technical viewpoint to construct countermeasures:**

  In addition to the engineering degree of difficulty, the actual capacities of related agencies in terms of human resources, budgetary limitations and others are assessed. On the other hand, the possibility to implement countermeasures under the support of external Partners for Development / donors is analyzed.

- **E. Sustainability:**

  The actual resources (human and budgetary) allocated to infrastructures maintenance and renew, possibility of technical cooperation from external Partners for Development /donors to enable more efficient and effective inspection of infrastructure through the implementation of innovative technologies is assessed.

- **F. Flexibility:**

  Flexibility to deal with future uncertainties (such as the possibility to change the structure size) is assessed.

- **G. Social and Natural Environment Impacts:**

  Based on the SEA results, impacts to society and natural environment are assessed.

Step 6: Selection of the most adequate countermeasures

Resulting from the detailed evaluation, the most appropriate menu is selected.

2.15.2 Setting of Evaluation Criteria

The evaluation criteria or axis were considered by reviewing: (1) NEDA's ICC (Investment Coordination Committee) Project Evaluation Procedures and Guidelines (of 2004, revised in 2016), (2) DPWH's priority project selection criteria, (3) Reports of past flood control projects in the Philippines (such as the preparatory survey for flood risk management project for Cagayan de Oro river (FRIMP-CDOR)), and (4) evaluation criteria used in Japan (such as the ones proposed in September 2010 by the Advisory Committee on the Future Flood Management).

Since (4) covers the items proposed in (1), (2) and (3), the evaluation criteria proposed are basically the ones used in Japan but contextualized into the Philippines' context.

In addition, as a result of the review of past studies in the Philippines and Japan, there are many cases in which the evaluation criteria are not weighted, and due to the difficulties to justify the weighting, all evaluation criteria are assessed with the same degree of importance.

The following evaluation axis are proposed to assess the countermeasures selected in the M/P. The evaluation results of the M/P are shown in Section 3.15.

Table 2.15.3 Evaluation axis of the M/P

Axis	Explanation
A. Flood Protection Level (Expected damage reduction)	Expected damage reduction, timing when the effects of countermeasures appear are compared.
B. Economic Effectiveness	Total cost, cost for land acquisition and relocation are compared.
C. Feasibility in regards with legal and social restrictions	Scale of land acquisition and relocation, Prospects on the coordination with land owners and other stakeholders are considered.
D. Feasibility from the technical viewpoint to construct countermeasures	In addition to the engineering degree of difficulty, the actual capacities of related agencies in term of human resources, budgetary limitations and others are assessed.
E. Sustainability	By analyzing the actual resources (human and budgetary) allocated to infrastructures' maintenance and renewal, and future possible coordination schemes, issues and rooms for improvement related to countermeasures sustainability are assessed.
F. Flexibility	Flexibility of the countermeasures (such as modifications of structures scale) to deal with future uncertainties (such as sea level rise and changes in rainfall pattern due to Climate Change and High urbanization along rivers and seashore) is considered.
G. Social and Natural Environment Impacts	Based on the SEA results, impacts to society and natural environment are assessed.

Source: Project Team