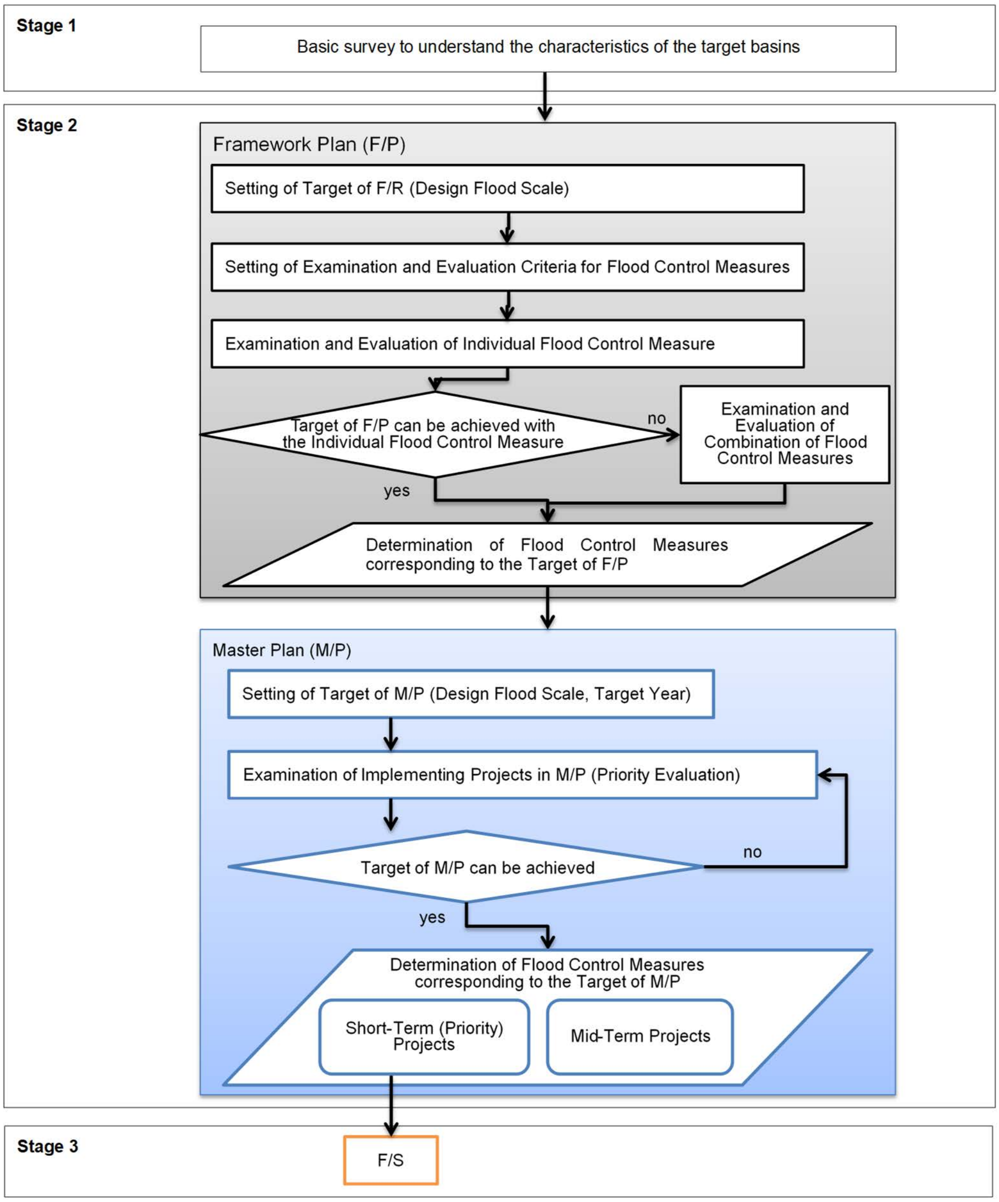
Chapter 3 Master Plan

3.1 Approach to Master Plan

3.1.1 General

Objectives of the Project are to formulate an integrated flood control master plan covering riverine floods, inland floods and coastal floods for Davao River, Matina River and Talomo River basins, and to conduct feasibility study on urgent and/or priority project(s) for the Davao river. The master plan for the Matina River basin will be formulated by C/P.

The above integrated flood control master plan will be formulated as two phased plans, consisting of a framework plan of a long-term plan toward the final flood control target and a master plan of a concrete plan until a certain target year, as mentioned in 3.1.2. The work flow for formulation of the integrated flood control plan is shown in Figure 3.1.1.



Source: Project Team

Figure 3.1.1 Work Flow for Formulation of the Integrated Flood Control Plan

3.1.2 Premises and Conditions for Master Plan

(1) Target Area

The target areas of the M/P are the Davao City urbanized area, the Davao River Basin with a basin area of 1,755 km^2, the Matina River Basin with a basin area of 70 km^2, and the Talomo River basin with a basin area of 204 km^2. The area of the whole target area is about 2,200 km^2. In the target area, agriculture is the main source of land use, but development is advancing in the downstream part of each river where Davao urbanized area spreads. The main industry of Davao City, which is the center city of Davao Region and the third largest city in the Philippines, is commerce.

The Davao River is 191 km from its origin to the river mouth, and the main tributaries are the Tamugan River and the Suawan River, which originate from the western mountainous region of the basin. The Matina River and the Talomo River are 24 km and 54 km from their origin to the river mouth, respectively.

(2) Type of Plan

In this Project, in order to formulate the plan for gradually developing optimal flood control measures without reworking, toward the final flood control target / target design level in the target river basins, it is proposed to formulate two phased plans, referencing a concept of flood control planning for Pasig – Marikina River in 1990. One plan is a long-term plan to show policy to propose optimal combination of flood control measures targeted at the final design level of floods. Another plan is a concrete plan to propose flood control measures to be implemented until a certain target year, which is halfway through the achievement of all the measures targeted at final design level of floods.

The former one, which will be a long-term plan to show the policy, will be called "framework plan (F/P)", and the latter, which will be a concrete plan up to a certain target year, will be called "master plan (M/P)". We examine formulate the F/P and the M/P that will be a part of F/P. In this regard, however in case that measures to be planned in the F/P can be implemented until target year of the M/P, F/P become the same as M/P and will be just called as “M/P”.

(3) Target Year of the Plans

As mentioned in the above (2), in this Project, F/P and M/P will be prepared. F/P will be situated as a future final figure of the basins, therefore, specified target year will not set. Target year will be set only for M/P. The target year for M/P is set to 2045 by the following reason.

In the target area of this Project, the future land use plan and population forecasting in 2045 was organized as a future socio-economic framework in the project for the Davao City Infrastructure Development Plan and Capacity Building Project (2018, JICA). This 2045 is consistent with the National Framework Plan 2016-2045, Mindanao Space Strategy and Framework Plan 2015-2045, and the Davao Regional Spatial Framework 2015-2045, which are high-level plans for urban development in Davao City. From the above, the target year of M/P of this Project will be set to 2045, with the aim of utilizing the various results in the existing plan and being consistent with the existing plans.

(4) Land Use

The present land use condition of Davao City in 2017 and the future land use plan with 2045 as the target year are organized in the Davao City Infrastructure Development Plan and Capacity Building Project (IM4Davao) (2018, JICA). Also, Davao City is updating their land use plan referencing the above outputs from IM4Davao and will finalize it as CLUP 2019-2028 within 2020. In this Project, while respecting the present land use condition and future land use plan prepared in the IM4Davao as well as referencing new land use plan of CLUP2019-2028 to have been prepared, planning activities will be carried out using those data as basic data. On the other hand, in the IM4Davao, flood risk was only partially evaluated using existing analyzed results, and the future land use plan has not been fully considered for flood risk. Therefore, in parallel with the planning activities, revision of future land use plan from the view point of flood risk will be recommended discussing with Davao City on the basis of the assumed inundation area and the flood control measures examined in this Project. At this time, it is considered that the “river boundary (described in Section 3.2)” recommended in this Project is properly reflected to the land use plan.

3.1.3 Characteristics and Issues of Flood Damage

In Davao City, which is located downstream of the target three rivers, existing flood measures of both structural and non-structural measures are not sufficient, and Davao City suffers frequent flood damage. In recent years, flood control by DPWH DCDEOs, which are structural measures mainly consisting of revetment and dikes along rivers, has progressed, but since it was not planned by comprehensively examining the characteristics of the basins, as well as it is in the process of development, flood risk is still high.

Large-scale riverine floods have been recorded in the Davao River in 2002 and 2017, in the Matina River Basin in 2002 and 2011, and in the Talomo River Basin in 2000 and 2002. In addition, in December 2017, typhoon Vinta landed in the target area, and it caused serious damage especially on the Davao River. With regard to inland flooding, damage is remarkable in the Davao city urbanized area, and extensive damage frequently occurs especially in the Poblacion and Agdao areas, which hinders economic activities. On the other hand, no serious damage has been reported due to floods by storm surges and coastal erosion along the coastal area.

Table 3.1.1 summarizes the flood characteristics and issues of the target area obtained from the basic study.

Table 3.1.1 Flood Characteristics and Issues of the Target Area

Flood type	Flood Characteristics / Issues
Flood in 3 rivers 【Riverine flood】	- In three target rivers, floods occur almost every year. Since 2000, floods with more than 1 thousand affected families occurred 2-3 times and floods with casualties occurred 1-2 times in each river. - The magnitude of floods that occur frequently is the inundation depth with less than 1m and the inundation duration with about several hours. There is an impact on houses, household goods and crops by the floods. - In the three target rivers, flood damage is large and the frequency of flooding is high in the downstream parts of the rivers. - Flood control measures have been partially implemented in the downstream in the target rivers but developed intermittently. There are sporadic cases where design conditions such as design flood discharge appear to be different. - Artificial factors such as land use change, cutting trees, sub-division development and improper waste disposal are also recognized as causes of flood.
Inland flood in the city 【Inland flood】	- There is frequent inland flooding in many locations in Davao City. - Though the depth of inundation is less than 0.5m and the duration is a few hours at maximum in many cases for the frequent floods, it affects traffic condition and economic activities - Artificial factors such as clogging of sediment and garbage in drainage channels, illegal dumping of garbage and construction waste, building construction without proper drainage, occupation of buildings in drainage channels and change in land use are also recognized as causes of flood.
Coastal conservation and storm surge measures 【Coastal flood】	- Although no huge disaster happened regarding the coastal matters in Davao, several small incidents in the coastal area occurred in from July to October. The factors of these incidents are based on the relatively high neap tide and waves arriving from SSE which is open to ocean. - The damage usually occurred in the low elevation coastal area where the people use a high-floored house. Human factors such as the expansion of illegal residents and changes in land use are also recognized. - In some cases, the high tide in the sea overlaps with rainfall, causing inland and coastal flooding at the same time.

Source: Project Team

3.1.4 Basic Principles for Formulation of Master Plan

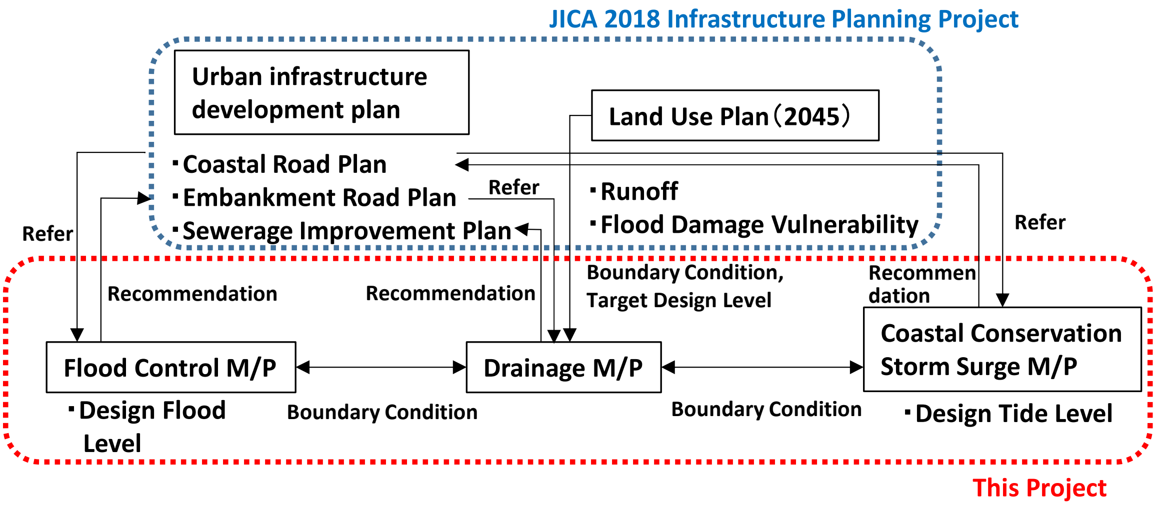
Following five basic principles are established for formulation of integrated flood control master plan for the target area.

(1) Formulation of integrated flood control master plan including measures against riverine flooding, inland flooding and coastal flooding by storm surge and coastal erosion
(2) Consideration for Climate Change Adaptation in Planning and Design for Flood Control Structure Structures
(3) Consideration of the optimal combination of structural and non-structural measures based on the evaluation from a broader perspective
(4) Formulation of well-coordinated plan for smooth project implementation based on consensus building among stakeholders
(5) Formulation of a plan that contributes to the revision of related plans as needed while maintaining consistency with existing related plans

Each principle is described in detail below.

(1) Formulation of an integrated flood control master plan including measures against riverine floods, inland floods and coastal floods by storm surge and coastal erosion

This Project aims to formulate an integrated flood control master plan, including measures for riverine flooding, inland flooding in the city and coastal flooding due to storm surges, overviewing all the river basin area. In formulating the M/P, the three types of flood, Riverine flood, Inland flood and Coastal flood are examined in parallel along with each approach as shown in Table 3.1.2. Three types of floods are examined at the same time coordinating and harmonizing 1) major factors of each flood, 2) mutual effects and 3) various conditions such as design level of three types of flood as shown in Figure 3.1.2. It aims at planning effective and efficient measures for the three types of flood, and for not negatively influencing the other flood types.



Source: Project Team

Figure 3.1.2 Principal for Formulation of Integrated Flood Control M/P

Table 3.1.2 Approach for Examination of M/P for each Flood Type

Flood type	Approach for Examination of M/P
Flood in 3 rivers 【Riverine flood】	• To clarify the natural conditions, social conditions, past flood damage, and flood characteristics of the entire river basin, and then to discuss the river area, planning conditions and target design level with a consideration of remarkable matters such as ongoing flood control project of 2018 to 2019, and the regulatory zones where Davao City has already established (having inundation control effect). • For alternative countermeasures, to consider the possibility of multipurpose dams in the upper stream, flood retarding basins in the mid-lower stream areas, conservation and development regulation of river area for sustaining natural flood retarding function, river channel improvement, and other non-structural measures. Also, to discuss the project implementation and maintenance system from the viewpoint of flood management for entire basin.
Inland flood in the city 【Inland flood】	• To clarify the current conditions such as drainage system, drainage area, capacity of drainage channels and existing/future plans, and then to discuss appropriate planning conditions and target design level including concept of "allowable inundation depth". • For alternative countermeasures, to look for an optimized combination of structural measures such as drainage improvement and construction of retarding facilities, together with examining a drainage method (gravity drainage, or pump drainage), and basin control measures such as on-site run-off reduction measures and damage mitigation measures.
Coastal conservation and storm surge measures 【Coastal flood】	• To clarify the past coastal floods in the target area from the past disaster record, waves and tide levels and the scientific research, and then to discuss an appropriate target design tide level. • For alternative countermeasures, to look for optimal structural / non-structural flood measures, considering characteristics of target coastal area.

Source: Project Team

(2) Consideration for Climate Change Adaptation in Planning and Design for Flood Control Structures

The F/P and M/P have a long planning period, so it is necessary to consider the impact of future climate change. For adaptation to climate change, analyzing the latest research results of the Philippines and target areas and referencing the policies of the Philippines and DPWH's policy (DGCS), the impact of climate change is estimated. Then, it is decided how to handle it in the plans, that is, incorporating into the design or planned upgrade.

Through discussion with DPWH, PAGASA and other related organizations, it was finally decided that “incorporating into the design” is applied in this Project.

The conditions of climate changes in 2036-2065 which was set as the planning conditions for F/P and M/P with the target year of 2045 are as follows:

- ✓ Mean Temperature: to increase by 1.2 degrees compared to the condition in 2000.
- ✓ Rainfall: the probable rainfall for annual maximum daily rainfall increases by 10% from the climate condition in 2019.
- ✓ Mean sea level: to be 0.2m higher than the level in 2000, and 0.1m higher than the level in 2019.

(3) Consideration of the optimal combination of structural and non-structural measures based on the evaluation from a broader perspective

For selection of countermeasures in the F/P and M/P, various alternative measures will be evaluated from a wide range of perspectives, such as project effects, economics, natural and social constraints, and technical feasibility, and then the optimal combination of structural and non-structural measures will be examined. In addition, as for the non-structural measures, measures for the entire basin will be considered, including forest conservation measures as preservation of the storage effect in the basin.

In addition, the economics of F/P will be evaluated in terms of optimal combination of measures, which can minimize project costs, and the economics of M/P will be evaluated not only in terms of minimizing project costs, but also B/C or economic internal rate of return, etc.

(4) Formulation of well-coordinated plan for smooth project implementation based on consensus building among stakeholders

In order to promote broad understanding from various stakeholders utilizing the methodology of Strategic Environmental Assessment (SEA), the exchange of opinions and building consensus among the stakeholders will be promoted through a series of public consultations to have started from Stage 1. Based on the results, properly reflecting the contents of consensus to the plans, a well-coordinated plan will be formulated toward the smooth implementation of the plan, taking into consideration the project delay factors of environmental issues, acquiring land and/or resettling residents.

(5) Formulation of plan that contributes to the revision of related plans as needed while maintaining consistency with existing related plans

The plans in this Project will be formulated conforming with existing plans in Davao city, for example, the Davao City Infrastructure Development Plan and Capacity Building Project, 2018, supported by JICA, as well as utilizing various data organized in the existing plans, for example, socio-economic data, land use plan and population projection, which are the basis of the formulation of the Davao City Infrastructure Development Plan. This also aims at conducting the Project efficiently and keeping consistency with the prerequisite and planning conditions of the existing plans.

In addition, existing related plans will be reviewed from the viewpoint of flood risk and necessary recommendations will be done.

3.1.5 Basic Concept of Riverine Flood Control Master Plan

(1) Major Issues on Riverine Flood

The following major issues on riverine flood have been identified during the Basic Study in this Project.

i. Improvement of present situation of implementation of flood control measures with different design levels
ii. Increase in insufficient flow capacity for large scale runoff
iii. Recovery of decreasing natural retarding function
iv. Planning of measures harmonizing with development along the river and in the surrounding area, with the viewpoint of urban planning
v. Consideration in possible increase in runoff by landuse and climate change
vi. Control of development in flood risk area
vii. Sharing information related to flood
viii. Consideration in artificial factors such as cutting trees, improper waste disposal and informal settlement
ix. Enhancement of flood control planning capacity
x. Better operation and maintenance activities
xi. Better coordination for project implementation including land acquisition and resettlement

(2) Objective of Riverine Flood Control

The objective of the flood control is defined as follows.

To reduce severe damage and loss due to inundation by riverine flood, to secure proper urban function as regional center and to contribute to further proper development

(3) Strategies of Riverine Flood Control

Considering the identified major issues, the strategies to achieve the objective of the riverine flood control are set as follows.

- To implement optimal measures to increase flow capacity of river channel and to increase flood water detention capacity with consistent design level
- To promote non-structural measures to ensure effectiveness of structural measures and to further reduce damage and loss
- To improve entire cycle of planning, design, construction and O&M by capacity enhancement of relevant organizations

On the basis of the strategies, the riverine flood control plan, which consists of structural measures and non-structural measures as shown in Table 3.1.3, is formulated.

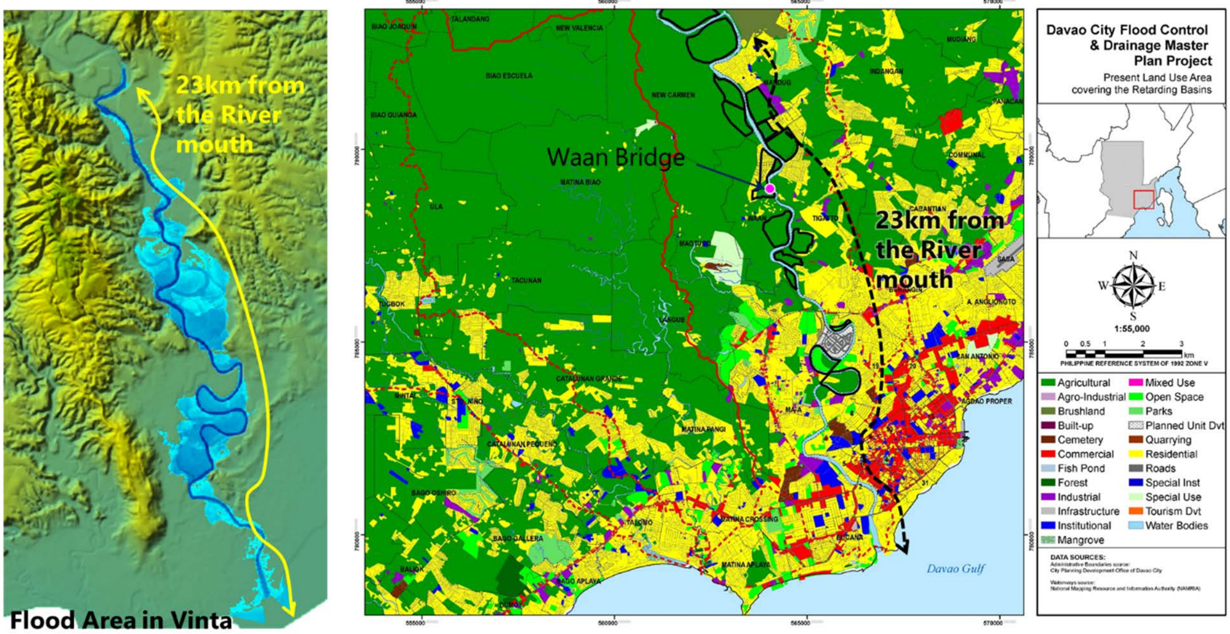
Table 3.1.3 Strategies and Measures for Riverine Flood Control

<table>
<tr><th>Major Issue</th><th>Strategy</th><th>Measure</th></tr>
<tr><td>i. Improvement of present situation of implementation of flood control measures with different design levels
ii. Increase in insufficient flow capacity for large scale runoff
iii. Recovery of decreasing natural retarding function
iv. Planning of measures harmonizing with development along the river and in the surrounding area, with the viewpoint of urban planning
v. Consideration in possible increase in runoff by landuse and climate change</td><td>• To implement optimal measures to increase flow capacity of river channel and to increase flood water detention capacity with consistent design level</td><td><Structural Measures>
• Channel improvement (dredging, dike/floodwall, widening, cut-off works, etc.)
• Installation of flood water detention facility (retarding pond, dam)
• Installation of Diversion channel</td></tr>
<tr><td>vi. Control of development in flood risk area
vii. Sharing information related to flood
viii. Consideration in artificial factors such as cutting trees, improper waste disposal and informal settlement</td><td>• To promote non-structural measures to ensure effectiveness of structural measures and to further reduce damage and loss</td><td rowspan="2"><Non-Structural Measures>
• Preparation and dissemination of hazard map / risk map
• Landuse control related to proposed structural measures
• Establishment of real-time monitoring system for flood related information
• Establishment of flood forecasting and early warning system and evacuation system
• Awareness activities
• Enhancement of operation and maintenance activities
• Capacity enhancement of entire process of project for riverine flood control, including Coordination among Relevant Organizations
• Others</td></tr>
<tr><td>ix. Enhancement of flood control planning capacity
x. Better operation and maintenance activities
xi. Better coordination for project implementation including land acquisition and resettlement</td><td>• To improve entire cycle of planning, design, construction and O&M by capacity enhancement of relevant organizations</td></tr>
</table>

Source: Project Team

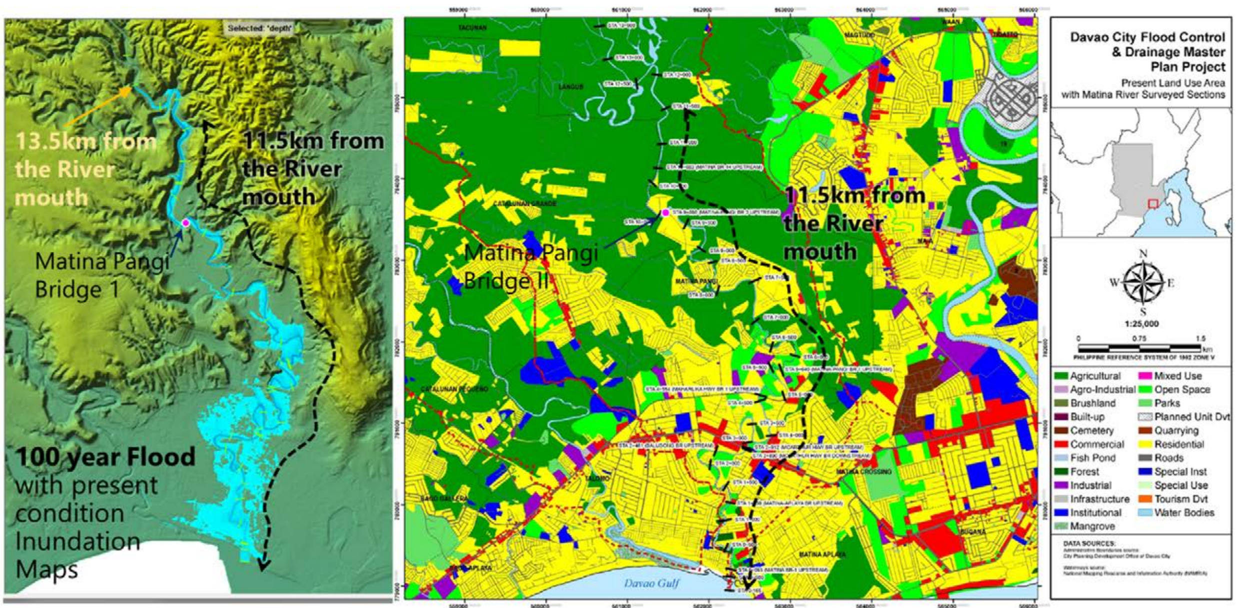
(4) Target Area of Riverine Flood Control Master Plan

In the Master Plan for riverine flood control, structural measures and non-structural measures are proposed targeting at Davao, Matina and Talomo rivers. Structural measures targets at downstream area of each river where is frequently and severely damaged by riverine floods, whereas non-structural measures targets at all river basin areas. Area to be protected by structural measures in each river are shown in Figure 3.1.3 to Figure 3.1.5. These area were identified from inundation records, inundation analysis results, present land use condition, future land use plan, topographic conditions and so on. Area to be protected for Davao river is a section from river mouth to 23km, for Matina river is a section from river mouth to 11.5km and for Talomo river is a section from river mouth to 6km.



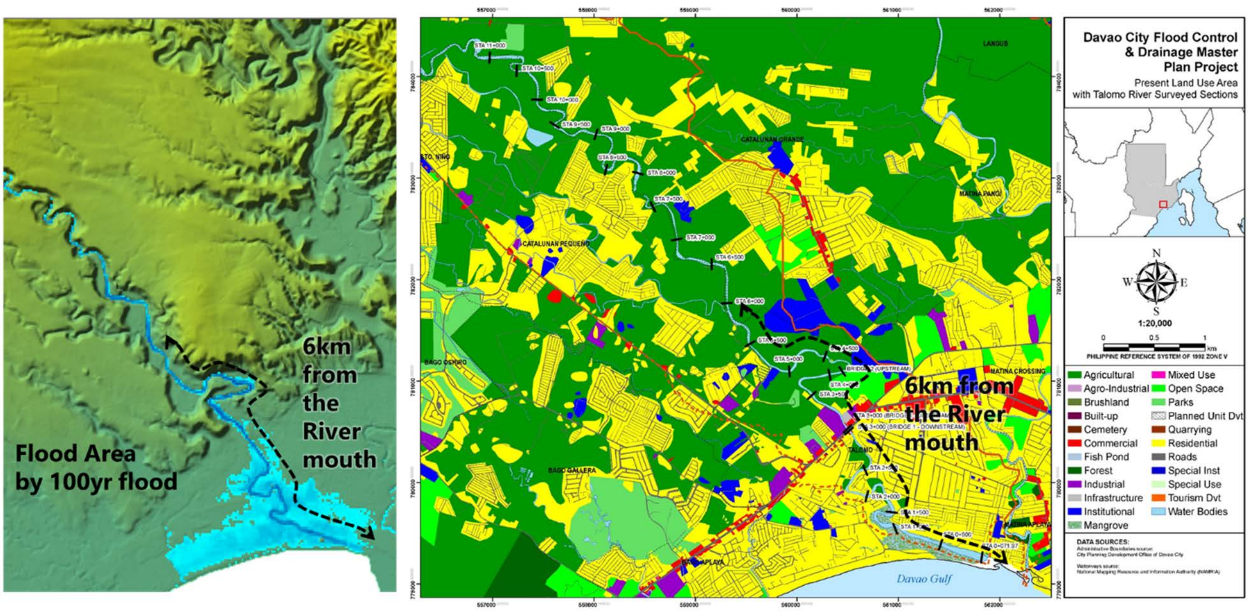
Source: Project Team

Figure 3.1.3 Area to be Protected by Structural Measures in Davao River



Source: Project Team

Figure 3.1.4 Area to be Protected by Structural Measures in Matina River



Source: Project Team

Figure 3.1.5 Area to be Protected by Structural Measures in Talomo River

3.1.6 Basic Concept of Storm Water Drainage Improvement Plan

(1) Major Issues on Storm Water Drainage

The following major issues on storm water drainage have been identified during the Basic Study in this Project.

i. Increase in Insufficient Drainage Capacity for Large Scale Runoff
ii. Recovery of Decreasing Natural Rainwater Retarding Function
iii. Consideration on Limited Space for Channel Improvement in Highly Urbanized Area
iv. Recovery of Reduced Channel Capacity due to Clogging of Drainage Channel
v. Control of Development and Consideration of Disaster Prevention in Infrastructure Development Project in Flood Risk Area
vi. Sharing Information on Inundation
vii. Consideration in Possible Increase in Runoff by Landuse and Climate Change
viii. Improvement of Insufficient Construction Method
ix. Better O&M Activities by Better Design etc.
x. Better Coordination for Complicated Implementation of Storm Water Drainage Project

(2) Objective of Storm Water Drainage Improvement

The objective of the storm water drainage improvement is defined as follows.

To reduce severe damage and loss due to inundation by storm water and to secure proper urban function as regional center

(3) Strategies of Storm Water Drainage Improvement

Considering the identified major issues, the strategies to achieve the objective of the storm water drainage improvement are set as follows.

- To upgrade drainage system mainly by securing and enhancing rainwater retarding function
- To secure the original capacity of drainage by proper O&M such as periodic cleaning of drainage channels

- To promote non-structural measures to ensure effectiveness of structural measures and to further reduce damage and loss
- To improve entire cycle of planning, design, construction and O&M by capacity enhancement of relevant organizations

On the basis of the strategies, the storm water drainage improvement plan, which consists of structural measures and non-structural measures as shown in Table 3.1.4, is formulated.

Table 3.1.4 Strategies and Measures for Storm Water Drainage Improvement

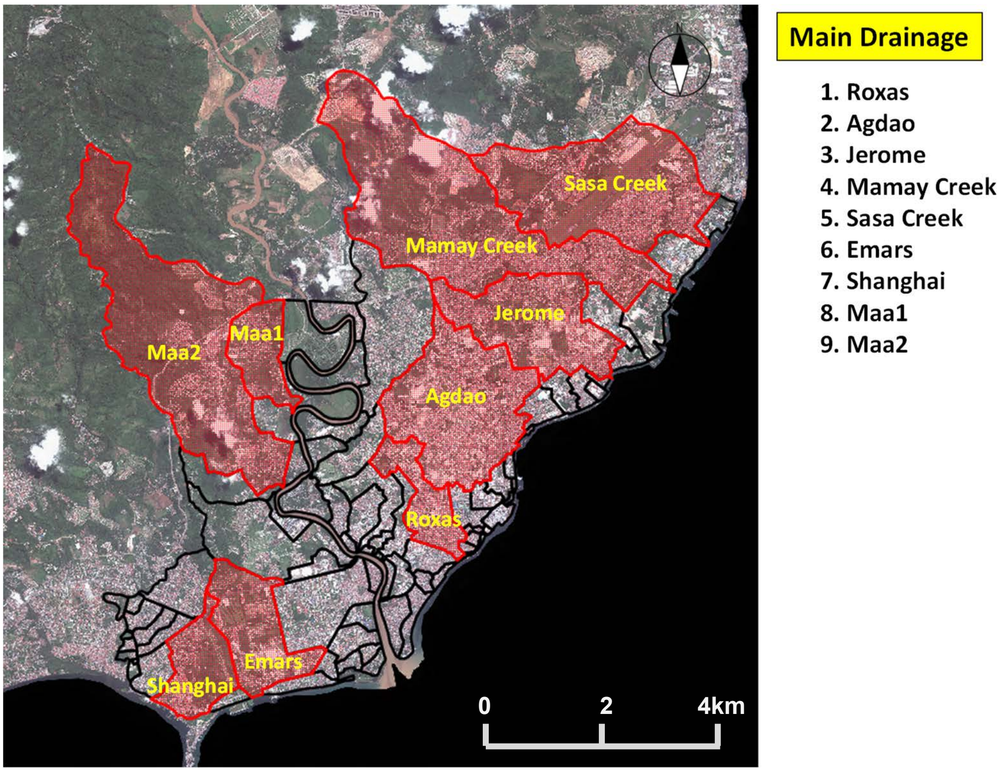
Major Issue	Strategy	Measure
i. Increase in Insufficient Drainage Capacity for Large Scale Runoff ii. Recovery of Decreasing Natural Rainwater Retarding Function iii. Consideration on Limited Space for Channel Improvement in Highly Urbanized Area	• To upgrade drainage system mainly by securing and enhancing rainwater retarding function	**<Structural Measures>** • Channel Improvement • Installation of Diversion Channel/Bypass Channel • Installation of Retarding Basin
iv. Recovery of Reduced Channel Capacity due to Clogging of Drainage Channel	• To secure the original capacity of drainage by proper O&M such as periodic cleaning of drainage channels	**<Non-Structural Measures>** • Establishment of Real-Time Monitoring System for Inundation • Preparation and Dissemination of Hazard Map / Risk Map • Landuse Control related to Proposed Structural Measures • Further Promotion of On-site Rainwater Storage Facilities • Capacity Enhancement of Entire Process of Project for Storm Water Drainage Improvement, including Coordination among Relevant Organizations • Others
v. Control of Development and Consideration if Disaster Prevention in Infrastructure Development Project in Flood Risk Area vi. Sharing Information on Inundation vii. Consideration in Possible Increase in Runoff by Landuse and Climate Change	• To promote non-structural measures to ensure effectiveness of structural measures and to further reduce damage and loss	
viii. Improvement of Insufficient Construction Method ix. Better O&M Activities by Better Design etc. x. Better Coordination for Complicated Implementation of Storm Water Drainage Project	• To improve entire cycle of planning, design, construction and O&M by capacity enhancement of relevant organizations	

Source: Project Team

(4) Target Area of Storm Water Drainage Improvement Master Plan

The Master Plan for storm water drainage improvement mainly targets the midtown of Davao City (Poblacion area and its surrounding area) as well as nine main drainage areas shown in Figure 3.1.6. The followings are examined.

- As for the nine main drainage areas, countermeasures for mitigation of inundation caused by overflow from main drainage channels are proposed.
- As for the area where the drainage inventory survey was conducted in the midtown of Davao City, priority areas for mitigating local inundation are identified utilizing the results of inventory survey.



Source: Project Team

Figure 3.1.6 Target Area of Storm Water Drainage Improvement Master Plan

3.1.7 Basic Concept for Coastal Disaster

(1) Main Issues of Coastal Disaster Countermeasures

The main issues related to coastal inundation countermeasures extracted through the Basic Study are as follows.

i. Development of sufficient flood protection facilities
ii. Enhancement of inundation protection capacity to ensure continuity of facilities (separation in drainage channels, flooding from drainage holes, etc.)
iii. Countermeasures for low elevation houses densely located along the coast
iv. Development regulations in inundation risk areas (coastal lowlands)
v. Sharing inundation information
vi. Clarifying the implementation organization for coastal flooding countermeasures
vii. Improvement of design technical capacity for coastal facilities
viii. Clarification of maintenance system and implementation method
ix. Consideration of possible inundation increase due to climate change

(2) Objectives of Coastal Disaster Countermeasures

The objectives of the countermeasures against coastal disaster are set as follows.

"Reduce the damage caused by coastal inundation and ensure appropriate use of coastal areas according to land use, such as residence and industry."

(3) Strategy of Coastal Disaster Countermeasures

In order to achieve the objectives of coastal disaster countermeasures, the strategies for coastal inundation improvement based on the main issues will be set as follows.

- Development of sequent coastal structures that can protect against inundation (including drainage facilities)
- Promotion of non-structural measures to ensure the effectiveness of structural measures and further reduce damage
- Improvement of the planning, design, construction, and maintenance cycle by enhancement of the capacity of related organizations

Based on this strategy, a series of coastal disaster countermeasure plan including both the structural and non-structural countermeasures shown in Table 3.1.5 is formulated.

Table 3.1.5 Strategies and Countermeasures for Coastal Disaster

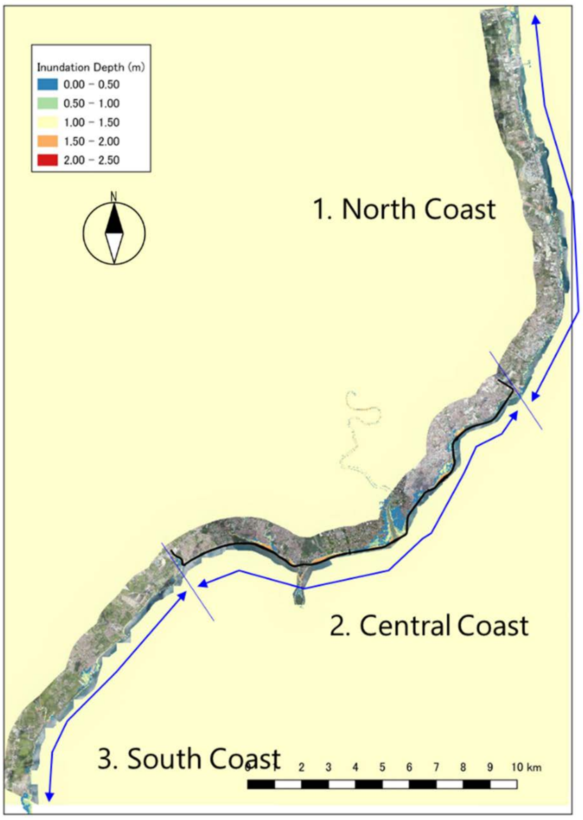
<table>
<tr><th>Main Issue</th><th>Strategy</th><th>Menu of Measure</th></tr>
<tr><td>i. Development of sufficient flood protection facilities
ii. Enhancement of inundation protection capacity to ensure continuity of facilities (separation in drainage channels, flooding from drainage holes, etc.)</td><td>• Development of sequent coastal structures that can protect against inundation (including drainage facilities)</td><td>[Structural measures]
• Establishment of coastal dike
• Installation of tide gates in drainage channels
• Installation of flap gates in openings such as drain holes</td></tr>
<tr><td>iii. Countermeasures for low elevation houses densely located along the coast
iv. Development regulations in inundation risk areas (coastal lowlands)
v. Sharing inundation information</td><td>• Promotion of non-structural measures to ensure the effectiveness of structural measures and further reduce damage</td><td rowspan="2">[Non-structural measures]
• Enhancement of maintenance activities
• Establishment of real-time flood monitoring system and early warning information system
• Preparation and dissemination of hazard maps / risk maps
• Land use regulations, including restrictions on housing construction in coastal lowlands
• Training of coastal engineers and clarification of responsible organizations
• Capacity building for the entire cycle of the coastal development project, including coordination among stakeholders
• Other</td></tr>
<tr><td>vi. Clarifying the implementation organization for coastal flooding countermeasures
vii. Improvement of design technical capacity for coastal facilities
viii. Clarification of maintenance system and implementation method
ix. Consideration of possible inundation increase due to climate change</td><td>• Improvement of the planning, design, construction, and maintenance cycle by enhancement of the capacity of related organizations</td></tr>
</table>

Source: Project Team

(4) Target Area of the M/P of Coastal Disaster

This M/P for Coastal disaster countermeasures proposes coastal inundation countermeasures for the coastal area of Davao City shown in Figure 3.1.7, divided into three areas according to their characteristics.

- There are almost no coastal protection facilities in the northern and southern areas, so flood protection measures will be proposed by installing new coastal protection facilities.
- The central area includes a Coastal Road section, and coastal inundation protection measures will be proposed based on the possibility of sequent protection with Coastal Road.



Source: Project Team

Figure 3.1.7 Target Area of the M/P of Coastal Disaster

3.1.8 Design Guidelines Proposed for Structural Measures

Based on the current situation of design guidelines as confirmed in 2.11.2, design guidelines proposed for the planning and design of structural measures for riverine flood, inland flood (storm water drainage) are summarized as below. Any particular considerations to be made for structural measures for respective component (riverine flood, storm water and coastal flood) will be mentioned in corresponding chapter (3.4 to 3.8).

(1) Riverine Flood

For the implementation of the project, items that are not detailed in DGCS's guidelines will be proposed with reference to Japanese design standards listed in Table 3.1.6, as confirmed by DPWH-BOD.

Table 3.1.6 Japanese Codes and Guidelines that may be applied for Riverine Flood

No.	Name of codes and guidelines	Remarks
1	Revised Explanation of Cabinet Order concerning Structural Standards for River Management Facilities, etc: (Japan River Association 1999)	Dam and other structures
2	Technical Standard of Disaster-prevention Regulating Pond, : (Japan River Association 2001)	Retarding Basin
3	Design Mechanics of Revetment, (Japan Institute of Country-ology and Engineering 2007)	Revetment
4	Design and Construction Guidelines for Gabion Pile Up Revetment (Ministry of Construction 1988)	Gabion
5	Design Guidelines for Restoration Works (National Association of Disaster Prevention, 2021)	Sheet Pile
6	Guidelines on Retaining Wall, Handbook for Road Engineering (Japan Road Association 2012)	Floodwall, Gabion Pile-up
7	Technical Criteria for River Works: Practical Guide for Design (MLIT 2021)	Dam

Source：Project Team

(2) Inland Flood

As for design of structure measures against inland flood, items that are not detailed in DPWH's guidelines will be proposed with reference to Japanese design standards, as is also the case with riverine flood. Table 3.1.7 shows Japanese codes and guidelines to be referred, except those already cited for riverine flood.

Table 3.1.7 Japanese Codes and Guidelines that may be applied for Inland Flood

No.	Name of codes and guidelines	Remarks
1	Design Guidelines of Flexible Sluiceway Structure (Japan Institute of Country-ology and Engineering 1998)	Sluice Gate
2	Handbook for Road Engineering, General Outline (Japan Road Association 2009)	All drainage facilities

Source：Project Team

(3) Coastal Flood

For the design of coastal structures, items that are not detailed in DPWH's guidelines will be proposed with reference to Japanese design standards listed in Table 3.1.8, as confirmed by DPWH-BOD.

Table 3.1.8 Japanese Codes and Guidelines that may be referred for Coastal Flood

No.	Name of codes and guidelines	Remarks
1	Technical Standards and Commentaries for Coastal Structures in Japan (National Association of Agriculture and Coast Conservation, National Association of Fisheries infrastructure, National Association of Sea Coast, The Ports and Harbours Association of Japan:2018)	
2	Technical Standards and Commentaries for Port and Harbour Facilities in Japan	

Source：Project Team

3.1.9 Construction Quality of Structural Measures

In order for structural measures to be effective as planned and designed, it is of utmost importance to ensure the quality of construction work. In future detailed design, therefore, it is necessary to consider the safety factor etc. to be set on the safe side, based on the quality of the construction on site. This is also effective in terms of landscape and maintenance.

As an example of local construction quality, steel sheet piles are one of the typical structural elements used in diverse construction works. However, there are cases where the joints of sheet piles have not been properly interlocked, or the sheet piles are installed in a way that alignment and height are uneven, which may affect the stability of the revetment. It is therefore important to ensure the control of the works to ensure construction quality.

3.2 River Boundary

3.2.1 General

There is Water Code (Presidential Decree 1067) as the law related to river boundary in Philippines. In this law, it is stipulated that Easement along the banks of rivers and streams for the public use and Flood Control Area for promoting the best interest and the coordinated protection of flood plain lands. As the present status of the Davao City, Davao City is presently carrying out setting easement along each river including the Davao river as the work for preparation of CLUP 2019-2028, whereas flood control area that the Secretary of DPWH may declare is not examined yet.

The works by the Davao City for setting easement is to show approximate range of easement on the GIS map and further field works by officials is necessary to determine clear alignment of easement. However, the banks of rivers and maximum water level as basis for setting range of easement is uncertain, therefore, setting of easement is actually hard work.

Considering the above present situations, this Project proposes setting river boundary with the aims of clarifying river area and conducting proper river management inside clarified river area. This activity will contribute to i) securing required land to flow down flood water safely, ii) protection from living and reconstruction of houses in highly flood prone areas, iii) control of land use and development in the river area not to obstruct flood flow, iv) securing necessary construction area for river structures such as dike embankment, flood plain, revetment, sluice gate, etc., and v) preserving natural retarding function of the river and surrounding area of the river.

The river boundary is desirable to be determined by comprehensively studying and examining 1) a range that is be originally regarded as a river channel from the viewpoint of river landform and past land use, 2) a range effective for the flow of floods, and 3) the flood risk degree along the river channel; however, in general, area along the rivers particularly in the downstream part of river are developed and/or developing area in many cases, which can be a major constraint on the setting of river boundaries.

In this Project, river widening for area to be protected by structural measures and retarding ponds in the upstream and inside of the area to be protected are proposed as major structural measures against riverine flood as described later. In this Project, the river boundary will be examined at following two levels for area to be protected by structural measures and its upstream area based on the proposed plan of structural measures.

Level 1: Within the area to be protected by structural measures, where is determined considering present land use and future land use plan

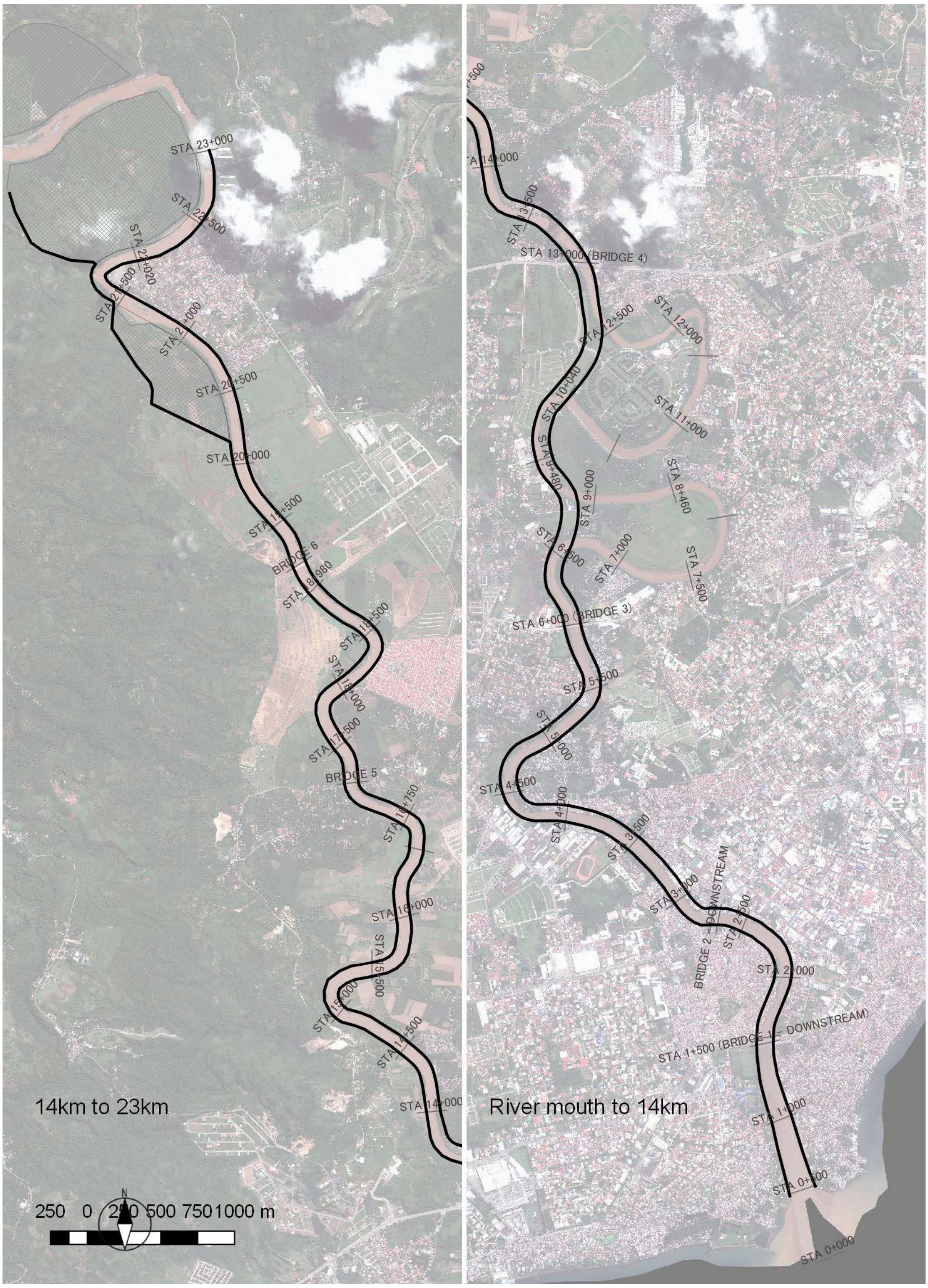
- To establish river alignment and to clarify area of retarding ponds, and then to set and recommend the river boundary for indicating river area consists of inner area of the river bank and necessary area for river structures like retarding ponds. Easement is assumed to be set outside the river boundary.

Level 2: Upstream area of the area to be protected by structural measures in Davao River

- To identify flood inundation areas along the rivers and to set and recommend the recommended river conservation zone which includes river areas in order to maintain the flood retarding function of river and surrounding river area as natural retarding ponds.

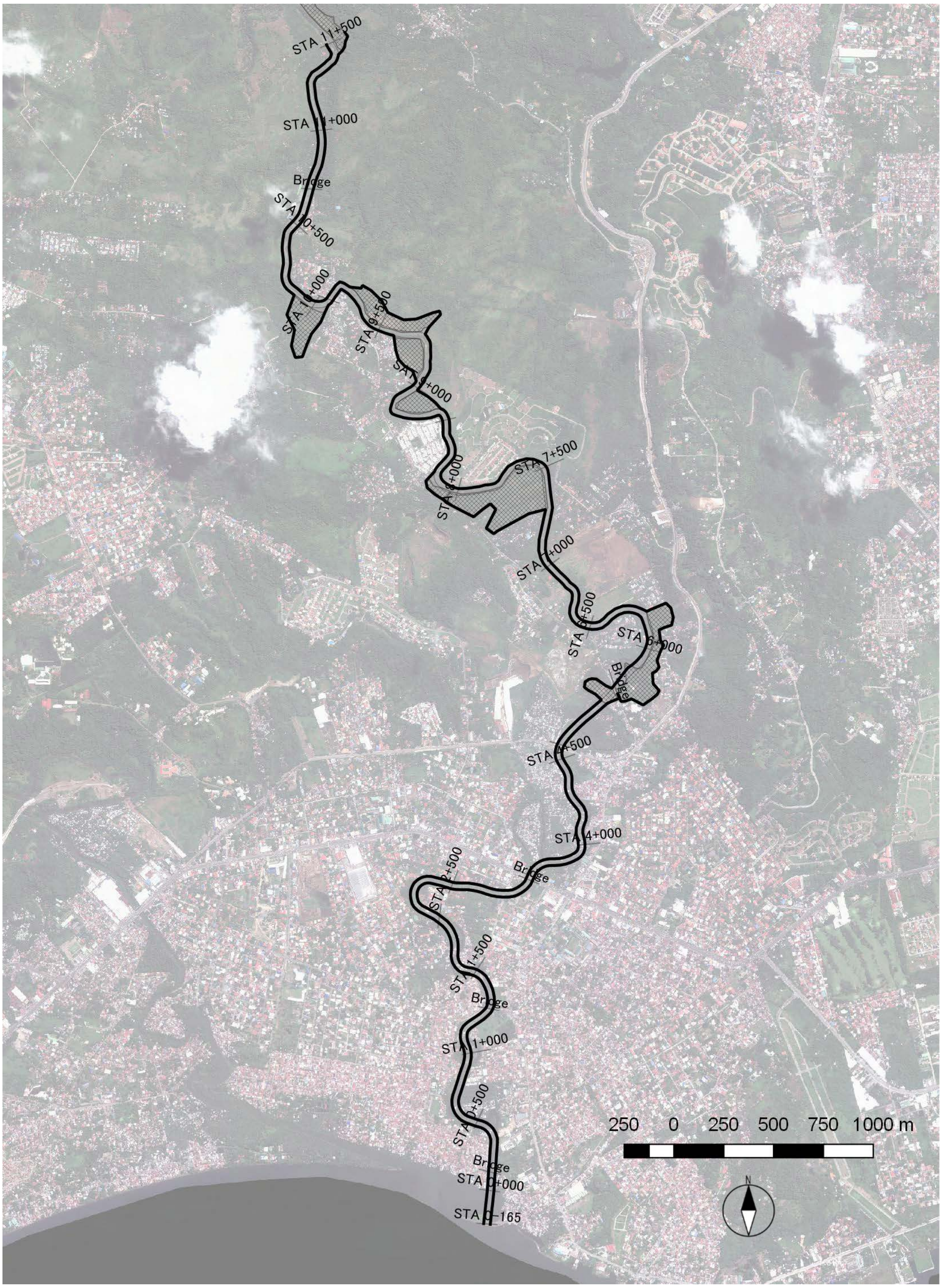
3.2.2 Establishment of River Boundary

The setting of river boundary along the target three rivers for the area of Level 1 was started by data collection and analyzing i) river alignment (alignment of dike and revetment) regarded as the present river channel where DPWH DEO plans/implements flood control works, ii) present river flow capacity, iii) present land use along present river channel and future land use plan including land use policy like Water Area, No-Build Zone, Open Space, and iv) river morphology and transition of shape of river channel. Then, through examination of alternatives of structural measures, optimal alignment and width of river channel was investigated. Finally, recommended river boundary was set as an alignment of recommended structural measures. Recommended river boundary for Davao, Matina and Talomo rivers are shown in Figure 3.2.1 to Figure 3.2.3. Also, recommended river conservation zone in the upstream area of area to be protected by structural measures in Davao river is shown in Figure 3.2.4, which is the possible inundation area by 100 year scale flood.



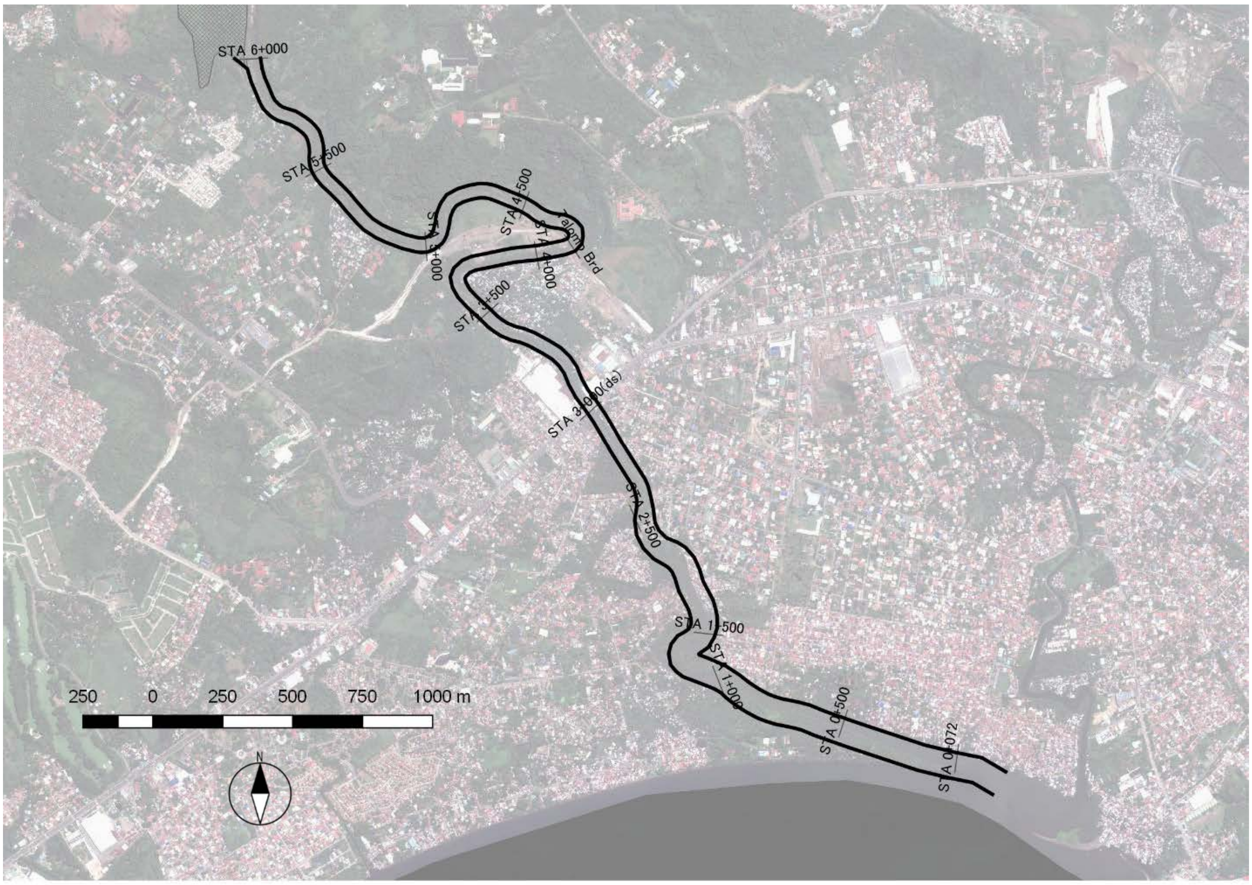
Source: Project Team

Figure 3.2.1 River Boundary to be Recommended in the Protected Area by Structural Measures in Davao River



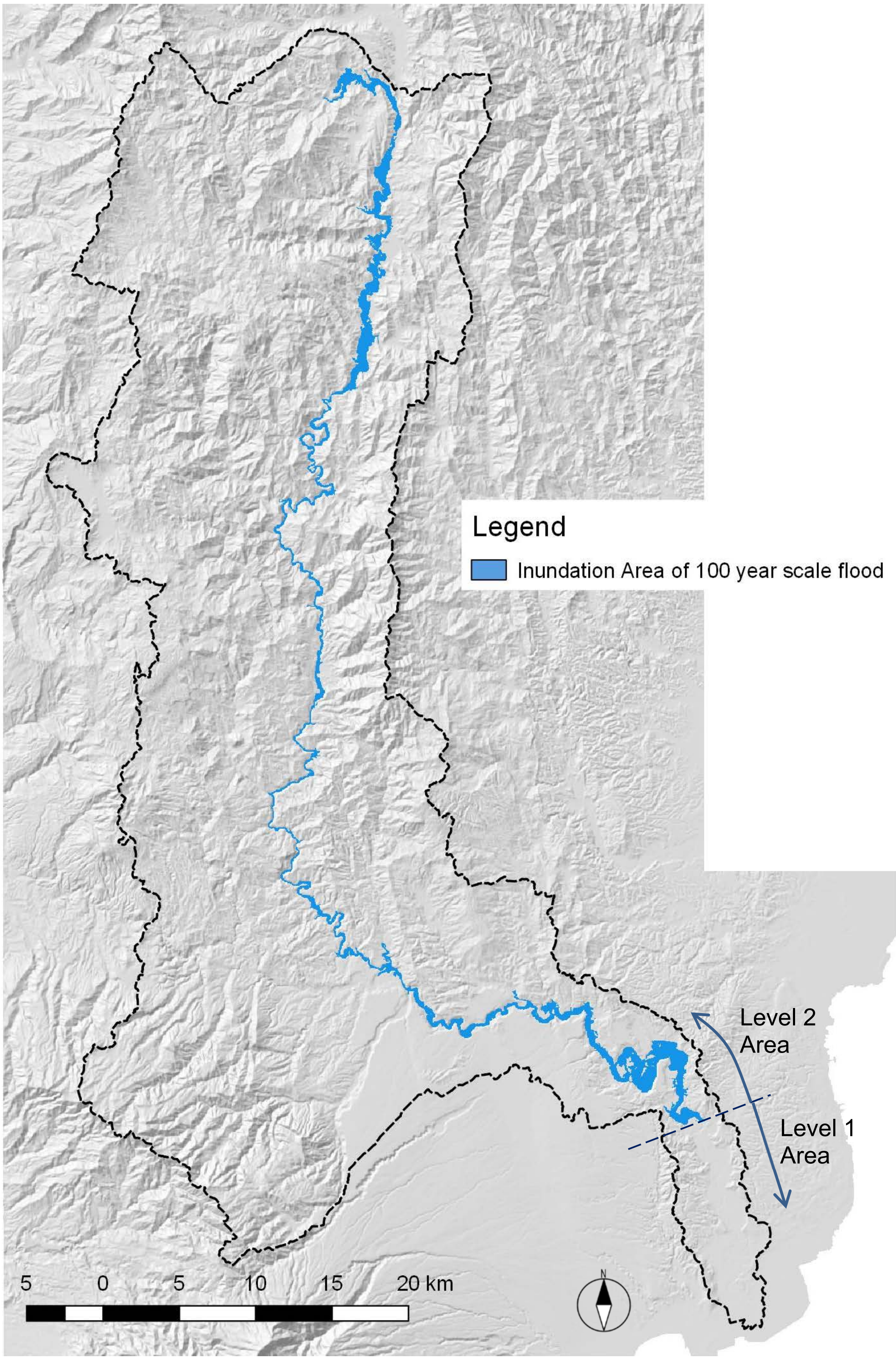
Source: Project Team

Figure 3.2.2 River Boundary to be Recommended in the Protected Area by Structural Measures in Matina River



Source: Project Team

Figure 3.2.3 River Boundary to be Recommended in the Protected Area by Structural Measures in Talomo River



Source: Project Team

Figure 3.2.4 Recommended River Conservation Zone in the Upstream of Protected Area by Structural Measures in Davao River

3.3 Target Design Level

Regarding the design level for riverine floods, it is recommended in DGCS, 2015 that in the absence of a risk assessment or master plan, design flood for principal and major rivers (40 sq.km drainage area and above) is 100-year flood. Also, DPWH Memorandum for Upgrades on Flood Control and Road Drainage Standards dated on June 21, 2011 indicated that the design flood for principal and major rivers (40 sq.km drainage area and above) is 50-year flood with sufficient freeboard to contain the 100-year flood. In addition, as for drainage and coastal structures, design level as shown in Table 3.3.1 are recommended in the DGCS, 2015 and the DPWH Memorandum.

Table 3.3.1 Design Level in DGCS of DPWH and DPWH Memorandum

Flood Type	DGCS, 2015	DPWH Memorandum for Upgrades on Flood Control and Road Drainage Standards dated on June 21, 2011 "The minimum flood return periods to be used for the design of flood control and road drainage facilities"
Flood in 3 rivers 【Riverine flood】	In the absence of a risk assessment or master plan, design flood is: For principal and major rivers (40 sq.km drainage area and above) 100-year flood For small rivers (below 40 sq. km drainage area) 50-year flood	d. Rivers For principal and major rivers (40 sq.km drainage area and above) 50-year flood with sufficient freeboard to contain the 100-year flood For small rivers (below 40 sq. km drainage area) 25-year flood with sufficient freeboard to contain the 50-year flood
Inland flood in the city 【Inland flood】	In the absence of a drainage master plan or a risk assessment, the capacities for different drainage infrastructure may be used: Major Drainage System Drainage Capacity 100 year flood Minor System a. Drainage pipes Design Capacity: 15-year flood Check Capacity (for freeboard): 25-year flood b. Culverts Design Capacity: 25-year flood Check Capacity (for freeboard): 50-year flood c. Esteros/creeks/drainage channels Design Capacity: 15-year flood Check Capacity (for freeboard): 20-year flood	a. Drainage pipes 15-year flood with sufficient freeboard to contain the 25-year flood b. Culverts i. Box 25-year flood with sufficient freeboard to contain the 50-year flood ii. Pipe 15-year flood with sufficient freeboard to contain the 25-year flood c. Esteros/creeks 15-year flood with sufficient freeboard to contain the 25-year flood
Coastal conservation and storm surge measures 【Coastal flood】	In the absence of master planning or independent discussion, protection level is: Rural Areas, Sport fields and Parks: 25 year Urban Areas: 100 year Roads Expressway: 100 year National Road: 50 year Other Road: 50 year	Not mentioned

Source: Project Team

In this Project, it was agreed among related organizations in the Steering Committee meeting held in September 2019 that the design level of the F/P is set to those as shown in Table 3.3.2 with reference to the above-mentioned provisions. As for M/P, it was agreed in the above Steering Committee meeting that the design level is decided considering the economics and environmental and social impacts. Concretely, especially for riverine flood, the design level will be set with the following concept:

- The design level will be set in consideration of the importance of each basin and the investment scale and implementation schedule up to the target year (assuming 2045).

The design level of M/P which is the results of investigation and discussion with related organizations in Stage 2 is shown in Table 3.3.3. The design level of the M/P finally becomes the same design level as F/P as explained later in Section 3.4.

Table 3.3.2 Design Level for F/P

Flood Type		Design Level to be applied
Flood in 3 rivers 【Riverine flood】	Davao River	100-year flood
	Matina River	
	Talomo River	
Inland flood in the city 【Inland flood】		for Main Drainage Channel: 25-year flood
Coastal conservation and storm surge measures 【Coastal flood】		100 year (corresponding to "Urban Areas" of DGCS)

Source: Project Team

Table 3.3.3 Design Level for M/P

Flood Type		Design Level to be applied
Flood in 3 rivers 【Riverine flood】	Davao River	100-year flood
	Matina River	
	Talomo River	
Inland flood in the city 【Inland flood】		for Main Drainage Channel: 25-year flood
Coastal conservation and storm surge measures 【Coastal flood】		100 year

Source: Project Team

(1) Peak Discharge of Target Design Level for Three Rivers

Peak discharges of target design level for three rivers to be applied in F/P and M/P were investigated. For the Davao river, comparing investigation and discussion were carried out with relative organizations after getting various values by statistical analysis of observed annual maximum discharge, by runoff analysis using three patterns of design rainfall and of historical maximum. Among those values, the maximum value, which was the runoff analysis result using the rainfall pattern of the flood in January, 2001, was selected as the target peak discharge in this plan for the Davao river. For Matina and Talomo rivers, values by runoff analyses using design rainfall patterns were set as the target peak discharges. The design rainfalls used in the runoff analyses were set considering the climate change impact, therefore, each peak discharge of target design level already takes into account the climate change impact. The peak discharge of the target design level of each river at each control point is shown in Table 3.3.4 .

Table 3.3.4 Peak Discharge of Target Design Level for Each River (Final Target Discharge in this Project under the condition with Impact of Climate Change)

River	Control Point		Target for F/P		Target for M/P	
	Name	Distance from river mouth	Design Level	Peak discharge (m^3/s)	Design Level	Peak discharge (m^3/s)
Davao	Waan Bridge	17km	100-year flood	3,400m^3/s	100-year flood	3,400m^3/s
Matina	Matina Pangi Bridge II	9.9km	100-year flood	440 m^3/s	100-year flood	440 m^3/s
Talomo	Mintal Bridge	13.4km	100-year flood	580 m^3/s	100-year flood	580 m^3/s

Source: Project Team

3.4 Structural Measures of Riverine Flood in Davao River

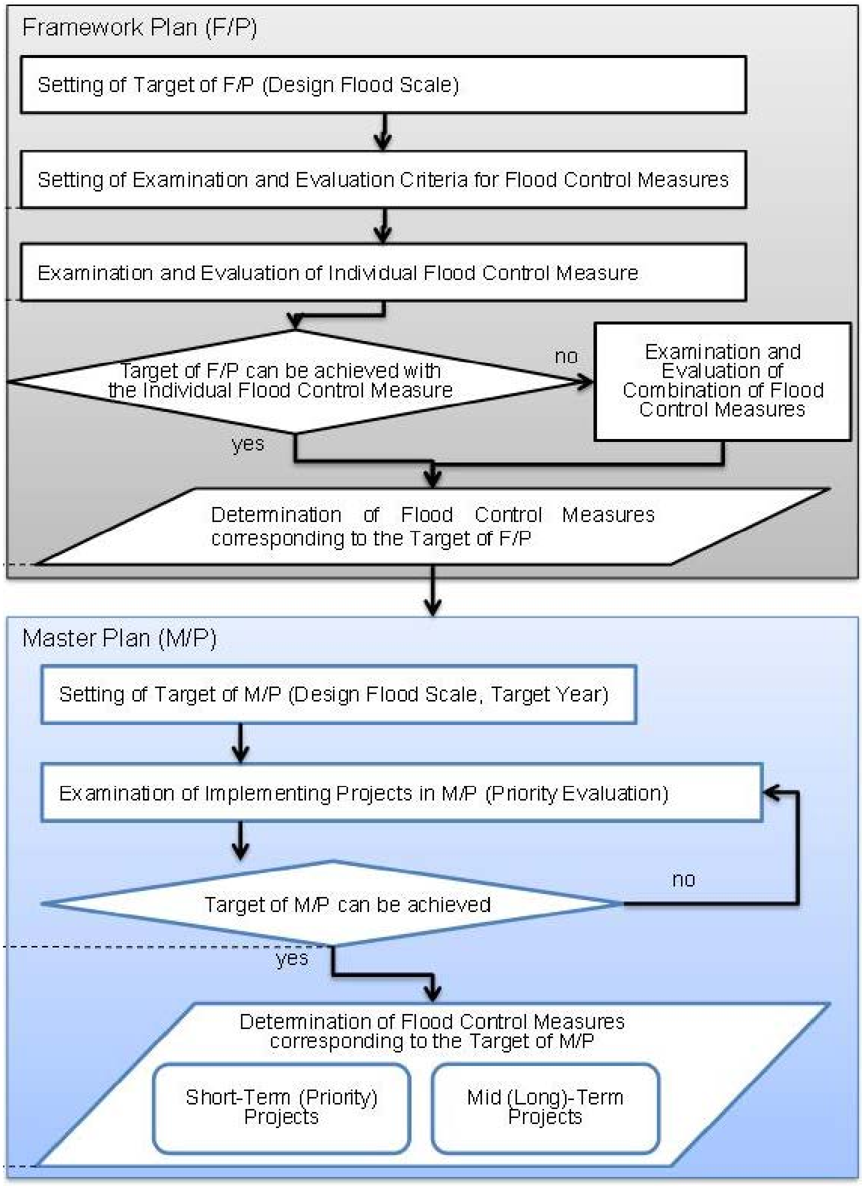
The examination of alternatives for structural measures (examination of alternatives as a combination plan for structural measures) against riverine flood for Davao, Matina and Talomo rivers was carried out according to the following procedure.

1. As for each assumed structural measure, to examine the scale of a structural measure in case of its independent implementation, including its technical limitations as well as to evaluate each structural measure schematically. This examination aims at basic analysis to examine the selection of flood control methods and the optimal combination of measures in the next step mentioned below.
2. To examine and make alternative plans for the combination of structural measures, and examine the optimal combination using the evaluation axis and indicators.

The above mentioned procedure for considering the structural measures and their combination is shown in Figure 3.4.1, and the evaluation axis and indicators are described in Section 2.15.

In addition, regarding how to deal with the impact of climate change in this Project as the first stage of examination of structural measures, "incorporating into the design" was decided to be applied as described in Section 3.1.4 (2).

Furthermore, the discharge amount of target design flood is a basic condition in considering structural measures. Since the design flood discharge was studied using limited hydrological information in this Project, however, design flood discharge might be revised after fully enhancing and stocking hydrological information in future. In some cases, the target flow rate may be revised. Widening of river channel and construction/heightening of dike, which are alternative measures, have a great impact on the area, therefore it was duly considered when planning of structural measures not to implement widening the river channel or heightening the dike repeatedly in future even if the design flood discharge is revised.



Source: Project Team

Figure 3.4.1 Procedure for considering the Structural Measures and their Combination

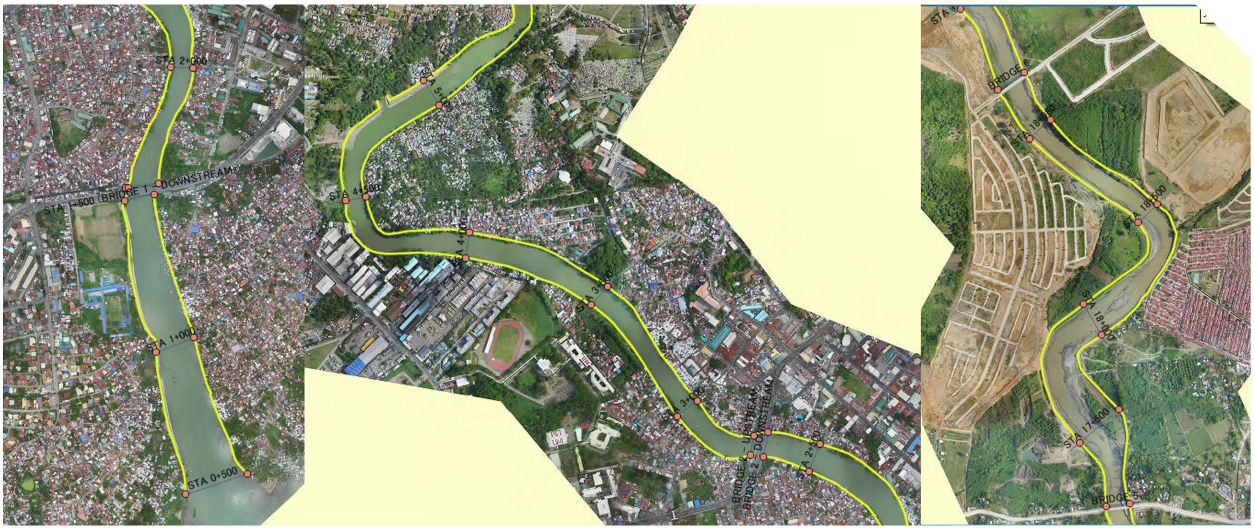
3.4.1 Examination of Alternatives of Structural Measures for Framework Plan in Davao River

(1) Examination of Individual Flood Control Measure

The examination of individual flood control measure of riverine flood in the Davao River focuses on five types of structural measures which are dike/flood wall, river channel improvement (widening), retarding pond, dam and diversion channel (underground channel) targeting the 100-year flood (3,400 m3/s peak discharge including the impact of climate change). The details of each structural measures are described below.

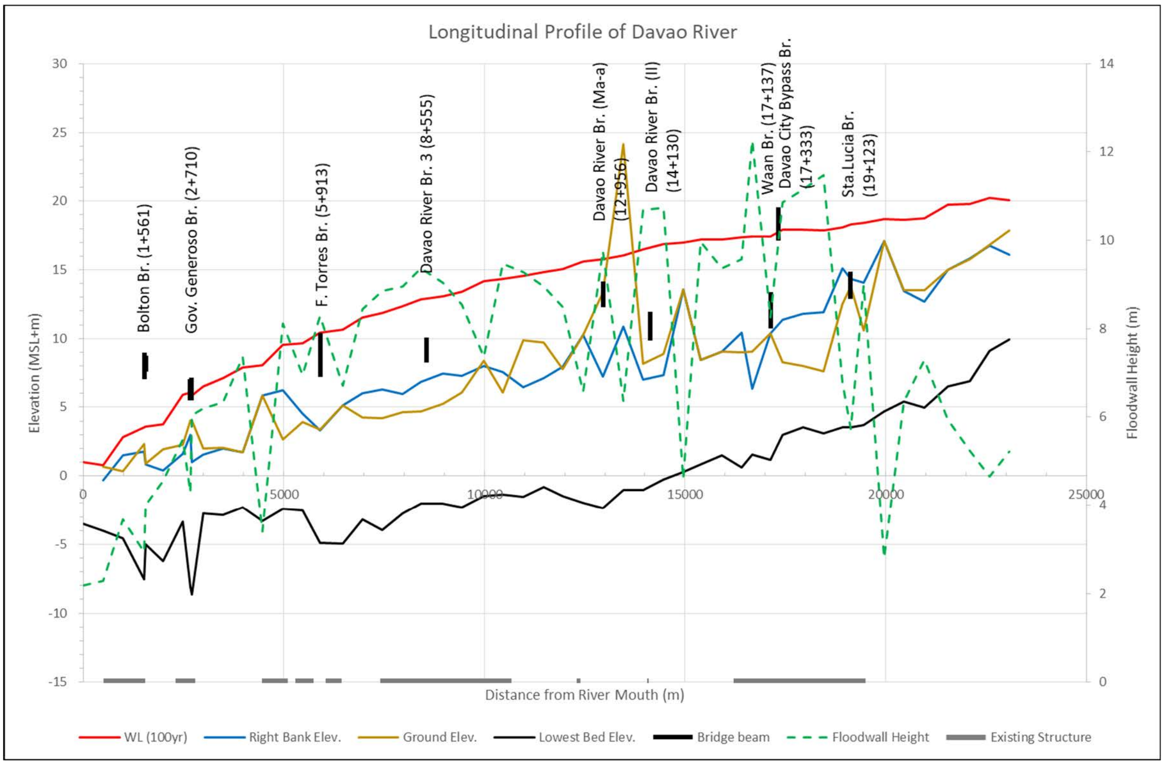
1) Dike / Flood wall

The alignment of newly proposed dike / flood wall was set on the current riverbank or behind the existing dike and/or revetment, and the necessary dike / flood wall height to be accommodated the design flood discharge amount with the river channel width between the dikes / flood walls was calculated by 1D non-uniform flow calculation. Figure 3.4.2 shows an example of setting the alignment of dike / flood wall. Also, Figure 3.4.3 and Figure 3.4.4 show the water level and necessary dike / flood wall height for 100-year flood as a result of non-uniform flow calculation for each of the right and left banks. Figure 3.4.3 and Figure 3.4.4 show the current river bank elevation (dike elevation), the ground elevation, and the lowest riverbed elevation together. The necessary flood wall height including the free board (1.2 m) can be read from the axis on the right side of the figure. The necessary flood wall height is 7.3m on average and 12.3m at the maximum.



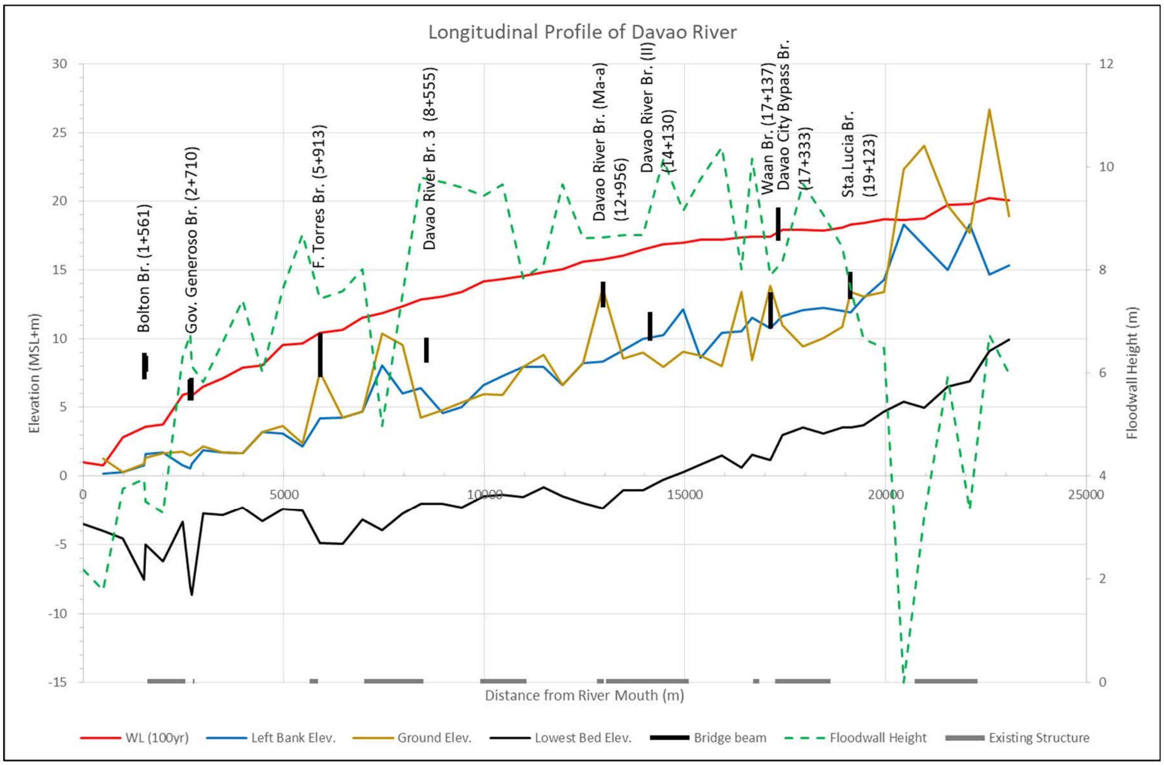
Source: Project Team

Figure 3.4.2 Example of Alignment of Dike / Flood wall in Davao River



Source: Project Team

Figure 3.4.3 Longitudinal Profile and Necessary Height of Dike / Flood wall in Davao River (Right bank)



Source: Project Team

Figure 3.4.4 Longitudinal Profile and Necessary Height of Dike / Flood wall in Davao River (Left bank)

In the examination of individual flood control measures, the required facility scale, available discharge amount, construction period, cost (direct construction cost, land acquisition cost, building compensation cost and bridge replacement cost (if necessary)), the number of affected buildings, period required for relocation (assuming that one year is required for every 100 affected buildings), and the disadvantages and restrictions, were confirmed. Table 3.4.1 summarizes the examination results for each item.

Table 3.4.1 Examination Result of Individual Implementation of Floodwall in Davao River

Outline of structure	- Concrete Wall + Pile Foundation - Average height: about 7.3m (with free board of 1.2m) - Maximum height: about 12.3m - Installed on both sides of the river from the river mouth to 23 km
Discharge amount to be accommodated	3,400 m^3/s (100% of 100 year flood)
Construction period	Appox. 8 years
Direct construction cost + land acquisition cost + compensation cost for building + Bridge replacement	Appox. 32 billion Php
Number of affected buildings (Relocation required)	Appox. 1,390 buildings (with 10m distance from proposed alignment)
Period required for relocation	Appox. 14 years
Disadvantages / restrictions	- Risk of housing collapse arises by break of dike with more than 2m height. - 100-year HWL is 4.5m higher in average than flood level in Vinta. - Existing 8 Bridge replacement is necessary.

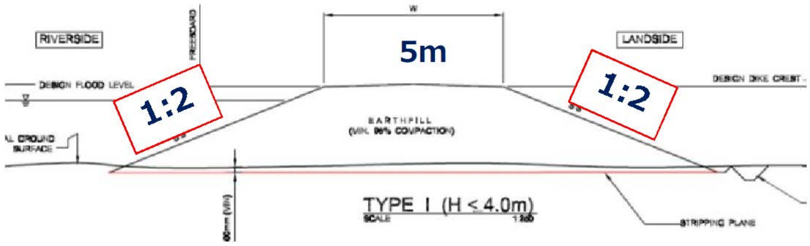
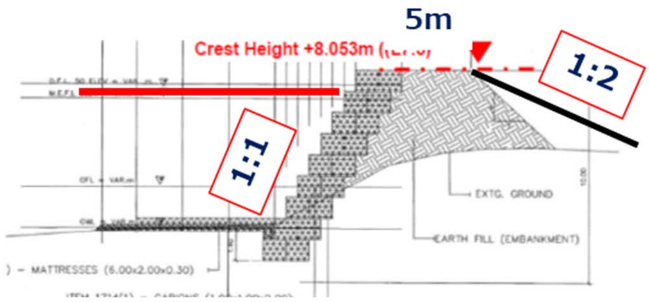
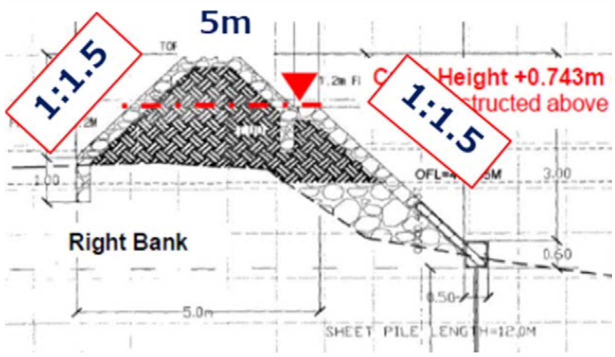
Source: Project Team

The structure of the dike / flood wall applied in the above examination is described below.

A. Structure Type of Dike / Flood wall

Dike / flood wall (Levee / Embankment) is classified into two types, soil-embankment type and concrete-wall type. Table 3.4.2 shows variations of structure for soil-embankment type. As shown in the table, there are 1) standard soil embankment as seen in DPWH standard drawing, 2) Soil embankment with piled-up gabion used as revetment as seen in ongoing construction works and 3) Soil embankment with concrete revetment.

Table 3.4.2 Soil-Embankment Type Structure

1) Soil Embankment (Standard type)
 (DPWH standard drawing)
2) Soil Embankment with gabion pile-up as revetment
 (DPWH DEO construction drawing)
3) Soil Embankment with concrete revetment
 (DPWH DEO construction drawing)

Source: Project Team

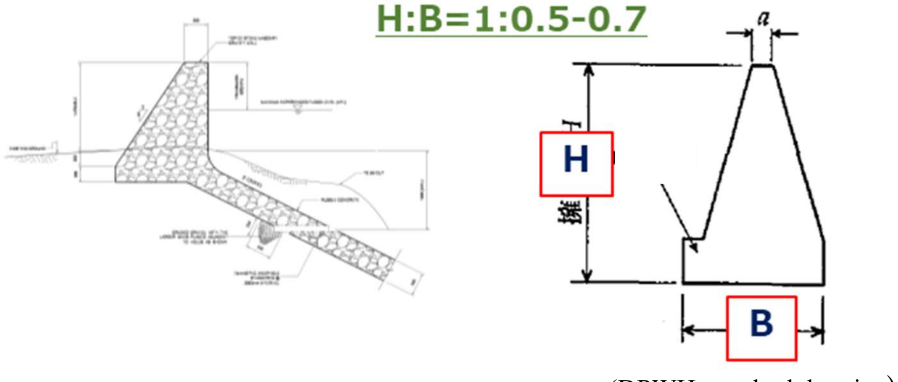
Among the variations mentioned above, 3) Soil embankment with concrete revetment is selected as standard structure for embankment-type levee (Dike), considering site constraints and ease of maintenance for DPWH.

For variations of concrete-wall type structure, as shown below, there are 4) Gravity wall as seen in DPWH standard drawing and 5) Inverted T-type wall, as adopted in Cagayan de Oro River in the north of Mindanao Island. According to DPWH DGCS, concrete wall, which is referred to as "floodwall", can be desirably adopted to ensure the protection corresponding to freeboard only.

Similarly, inverted T-type walls already constructed in the Philippines by DPWH have a embankment (counter-weight) behind the wall, which makes the actual height of the stand-alone wall to be less than 1 meter. This applies for both type of variations, although, 4) Gravity wall can only be applied where the geotechnical conditions of the soil are good.

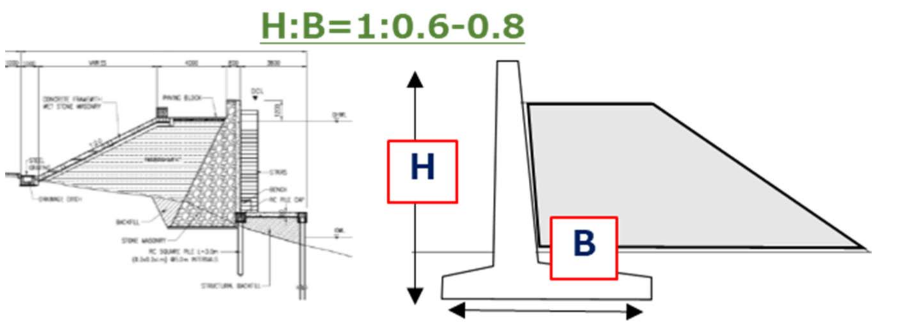
Table 3.4.3 Concrete-wall Type Structure

4) Gravity wall



(DPWH standard drawing)

5) Inverted T-type wall (with embankment behind)



(DPWH section adopted in Cagayan de Oro River)

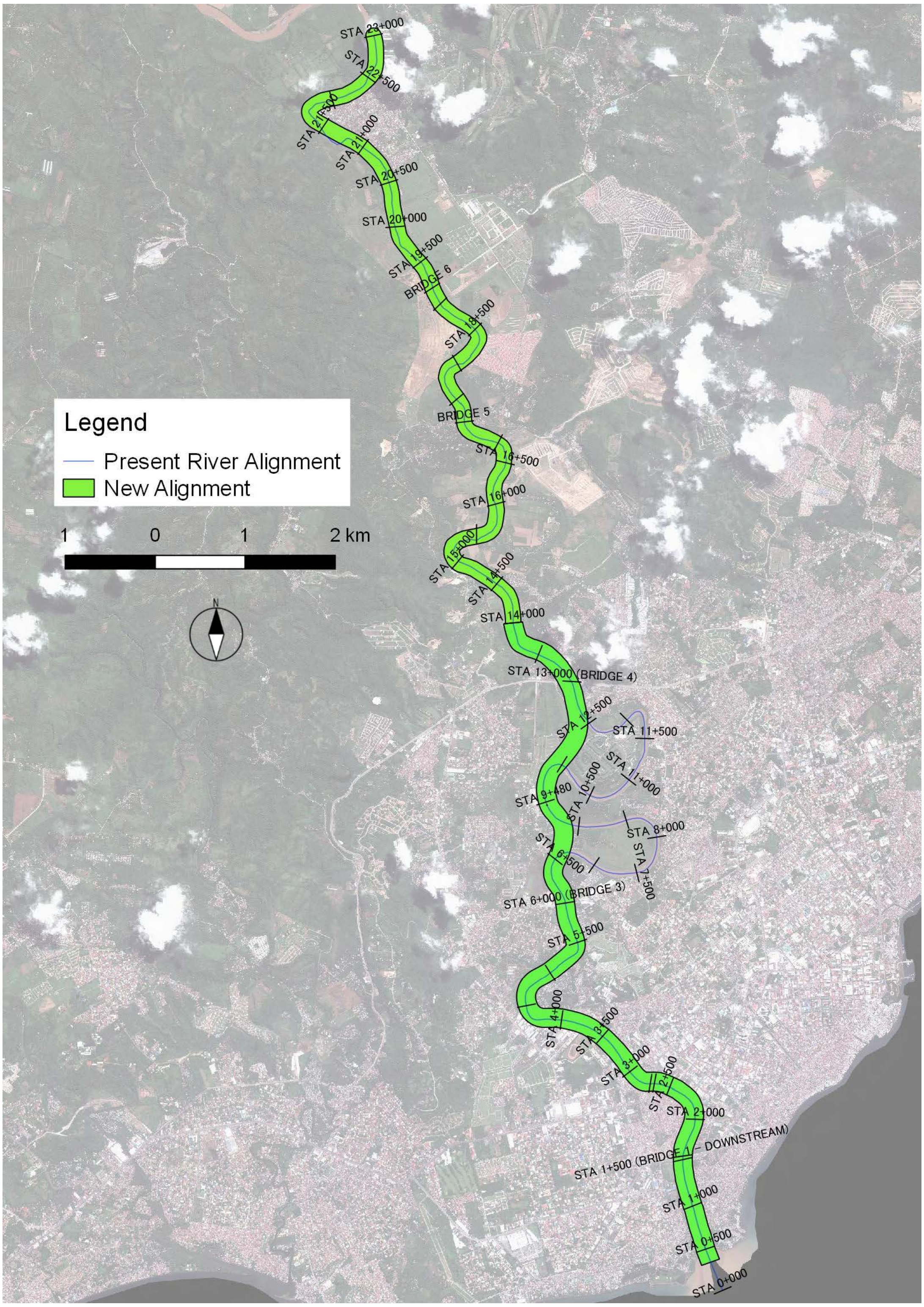
Source: Project Team

Due to the possible distribution of soft soils along Davao River, 5) Inverted T-type wall with embankment behind is selected as standard structure of concrete wall-type levee (Flood wall). DPWH also requires access/maintenance road along the levee, for which, in this case, embankment behind the wall can be used for this purpose.

In addition, in the examination of Table 3.4.1, the cost was estimated under the condition that the 5) Inverted T-type wall with embankment behind, which can reduce the required land width compared to the soil-embankment type structure, was adopted, in consideration of the current situation in Davao City, where urbanization is progressing and land use along the river is restricted.

2) River Improvement (Widening)

In the examination of the proposed river widening, the river alignment was reviewed considering the cut-off works (see Figure 3.4.5), and the required widening width was confirmed for flowing the design flood discharge in the reviewed river alignment. As a condition for the hydraulic analysis, the widened cross section will be a single cross section with slope of 1: 1, and the free board is not considered (HWL is equivalent to the top of slope after widening), and the cost is calculated based on conditions that free board is covered by a parapet. This is because the Davao River has long sections where private houses are densely located on both sides of the river. As a result of the examination, the shape of cross section from the river mouth to 14km required for 100-year flood is an inverted trapezoidal with a riverbed width of 191.4m, a height of 7.2m and a width between the top of slope on both banks of 205.8m. And the shape of cross section from 14km to 23km for 100-year flood is with a riverbed width of 154.7m, a height of 7.2m and a width between the top of slope on both banks of 169.1m. Table 3.4.4 shows the results of the examination.



Source: Project Team

Figure 3.4.5 Comparison of Present River Alignment and Proposed River Alignment in Davao River

Table 3.4.4 Examination Result of Individual Implementation of Widening in Davao River

Outline of structure	Widening channel width from about 80m to about 210m in average (about 130m widening) with condition of “without freeboard”
Discharge amount to be accommodated	3,400 m^3/s (100% of 100 year flood)
Construction period	Appox. 10 years
Direct construction cost + land acquisition cost + compensation cost for building + Bridge replacement	Appox. 17 billion Php
Number of affected buildings (Relocation required)	Appox. 5,200 buildings
Period required for relocation	Appox. 52 years
Disadvantages / restrictions	− Existing 6 Bridges replacement (lengthening) is necessary. − Cost for re-development of affected area (urbanized area) is required.

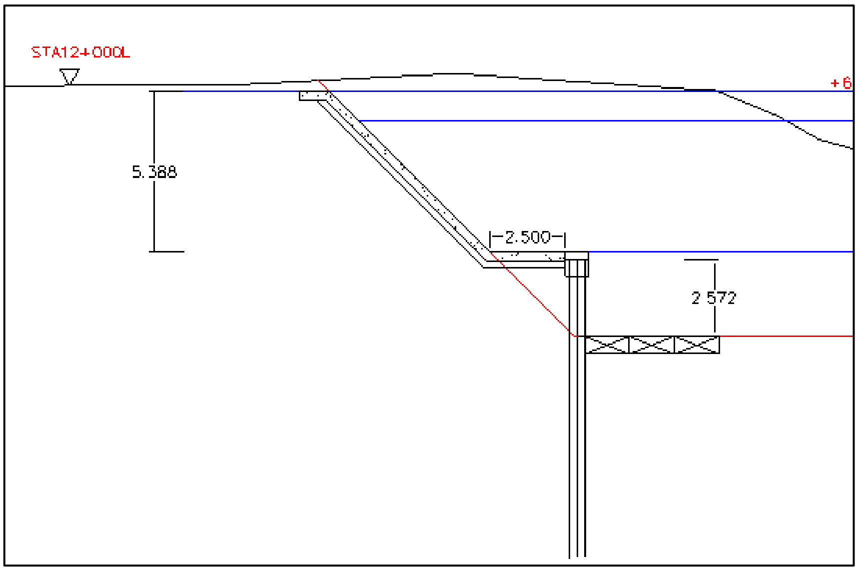
Source: Project Team

The structure of the widening applied in the above examination is described below.

A. Structure Type of River Improvement (Widening)

For river improvement (widening) of Davao River as part of structure measures, revetment height after the widening (height difference between the planned riverbed elevation and ground elevation) is expected to be about 5m to 8m, which largely exceed the applicable range of height for self-supporting steel sheet piles, which is less than 4 meters considering the foot protection in front.

For this reason, the standard revetment structure after widening of the river should preferably be a combination of concrete revetment (above mean water level, H=approx. 5 m) and steel sheet pile (below mean water level) (Figure 3.4.6). It is also necessary to have a platform behind the crest of steel sheet pile in order to reduce the embankment load that affects the steel sheet pile.

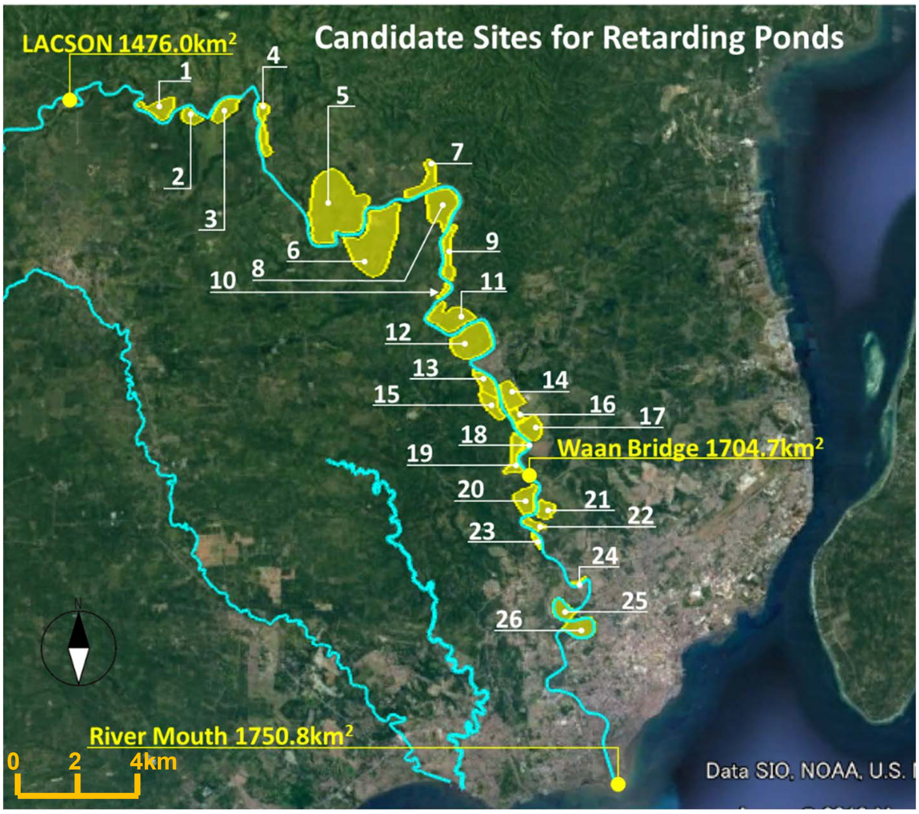


Source: Project Team

Figure 3.4.6 Revetment Structure of Widening (River Improvement)

3) Retarding Pond

In the examination of the proposed retarding pond, sites that could be used as retarding ponds were selected in the downstream area (from the river mouth to the junction of the Tamugan River) using the topographical and present land use data. The location and list of the selected candidate sites are shown in Figure 3.4.7 and Table 3.4.5, respectively.



Source: Project Team

Figure 3.4.7 Candidate Sites for Retarding Ponds in Davao River

Table 3.4.5 List of Candidate Sites for Retarding Ponds in Davao River

No.	Distance from River Mouth		Area	Capacity	No.	Distance from River Mouth		Area	Capacity	No.	Distance from River Mouth		Area	Capacity
	*(km)	Side	(km^2)	(MCM)		*(km)	Side	(km^2)	(MCM)		*(km)	Side	(km^2)	(MCM)
1	44.8	Left bank	0.42	2.10	10	26.2	Right bank	0.07	0.35	19	17.3	Right bank	0.37	1.85
2	43.6	Right bank	0.22	1.10	11	23.8	Left bank	0.76	3.80	20	15.4	Right bank	0.44	2.20
3	42.2	Right bank	0.39	1.95	12	21.8	Right bank	1.03	5.15	21	15.7	Left bank	0.25	1.25
4	39.4	Left bank	0.37	1.85	13	20.2	Right bank	0.31	1.55	22	14.5	Left bank	0.15	0.75
5	33.2	Left bank	2.93	14.65	14	19.7	Left bank	0.43	2.15	23	14.0	Right bank	0.07	0.35
6	32.2	Right bank	2.19	10.95	15	19.6	Right bank	0.33	1.65	24	11.9	Left bank	0.04	0.20
7	31.0	Left bank	0.44	2.20	16	19.2	Left bank	0.12	0.60	25	9.0	Left bank	0.32	1.60
8	29.0	Right bank	0.85	4.25	17	18.5	Left bank	0.42	2.10	26	6.7	Right bank	0.50	2.50
9	27.2	Left bank	0.39	1.95	18	17.9	Right bank	0.05	0.25	Total			13.86	69.30

Source: Project Team

As an initial examination, the capacity that can be allocated in the retarding ponds was calculated by assuming that a 5m deep retarding pond would be developed at each candidate site. The discharge amount that can be accommodated by the developed retarding ponds was calculated on the assumption that all the candidate sites would be developed for retarding ponds. Table 3.4.6 shows the results of the examination on the proposed retarding ponds. In case the current discharge amount in the target area of the Davao River to be protected by structural measures is 600m3/s, the individual measure by retarding ponds will not be able to cope with the 100-year flood even if all the candidate sites of retarding pond can be developed.

Table 3.4.6 Examination Result of Individual Implementation of Retarding Pond in Davao River

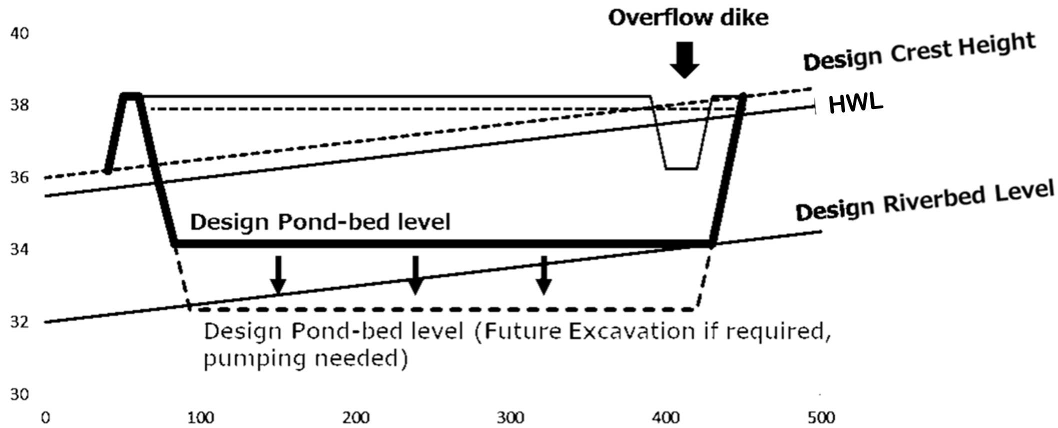
Outline of structure	Total area : 14 km^2 Gross Capacity: 70 million m^3 (assumed average water depth of retarding pond is 5 m)
Discharge amount to be accommodated	Approx. 2,560m^3/s (91% of remaining flood discharge of 100 year flood in case that estimated present river capacity of protected area is 600m^3/s)
Construction period	Appox. 25 year
Direct construction cost + land acquisition cost + compensation cost for building	Appox. 61 billion Php
Number of affected buildings (Relocation required)	Appox. 750 buildings
Period required for relocation	Appox. 8 years
Disadvantages / restrictions	

Source: Project Team

The structure of the retarding pond applied in the above examination is described below.

A. Structure Type of Retarding Pond

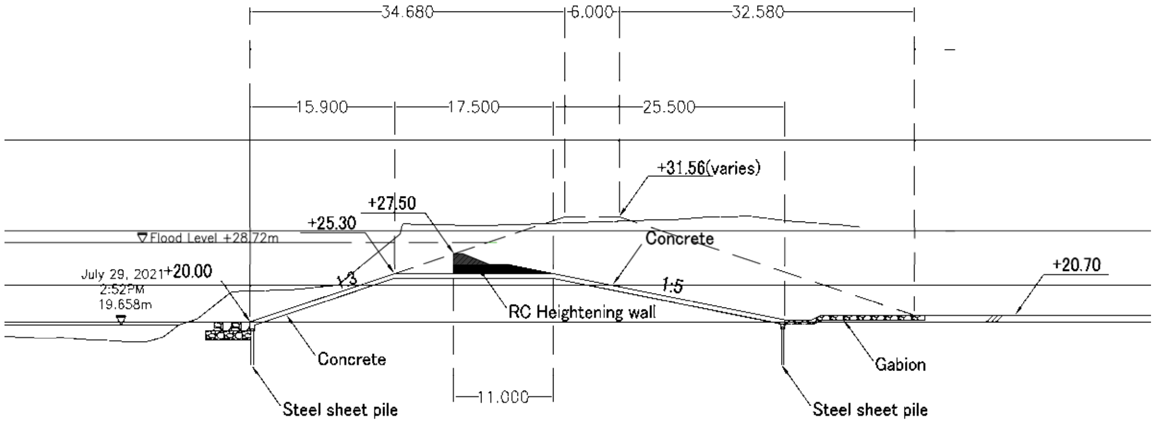
Retarding pond is composed of various structures, such as overflow dike, surrounding levee and drainage date. In the facility planning of retarding pond, natural drainage is to be considered so that planned basin-bed elevation will be equal to the planned / current riverbed elevation of the Davao River. The height of surrounding levees should be the same with Davao River's design levee height taken at the upstream end of the pond. Excavation of the ground down to the planned pond elevation is necessary, if the existing ground level of the candidate site is high, which is seemingly the case here.



Source: Project Team

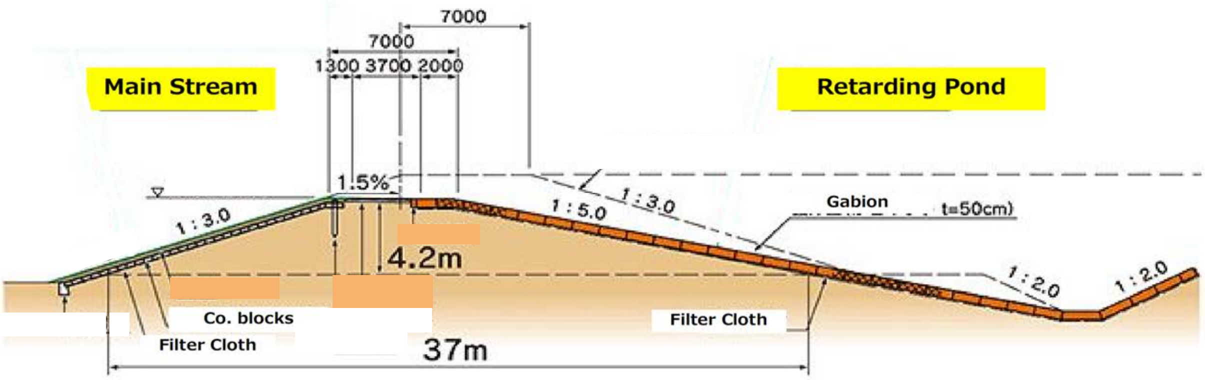
Figure 3.4.8 Concept for Facility Planning of the Retarding Pond

Structural forms of the overflow dike in retarding pond include concrete facing type, gabion type form and concrete block form, etc. Consideration should be given to the structure selection of each facility during F/S and detailed design, taking into account the durability of the structure based on site conditions, ease of maintenance, material availability and price, etc. In the M/P phase, the gabion type is adopted, gabions currently being used extensively in revetment works.



Source: Project Team

Figure 3.4.9 Structure Type of Overflow Dike (Concrete revetment type)



Source: Japan MLIT HP

Figure 3.4.10 Structure Type of Overflow Dike (Gabion type)

4) Dam

In the examination of the proposed dam, the most downstream candidate site was selected from five candidate sites in the previous study (Mater Plan Study on Water Resources Management in the Republic of the Philippines, 1998). Reasons why the most downstream candidate site was selected are 1) it has the largest catchment area (approx. 1455 km^2), which accounts for 83% of the entire Davao River basin area, 2) the amount of water that can be stored is sufficient (The discharge amount of 100-year flood (3,400 m^3/s) can be stored by the dam with the height of 63m), and 3) the development in the downstream is desirable for security reasons. The dam site is located 62 km from the river mouth. For the examination, dam type is assumed as a rock-fill dam.

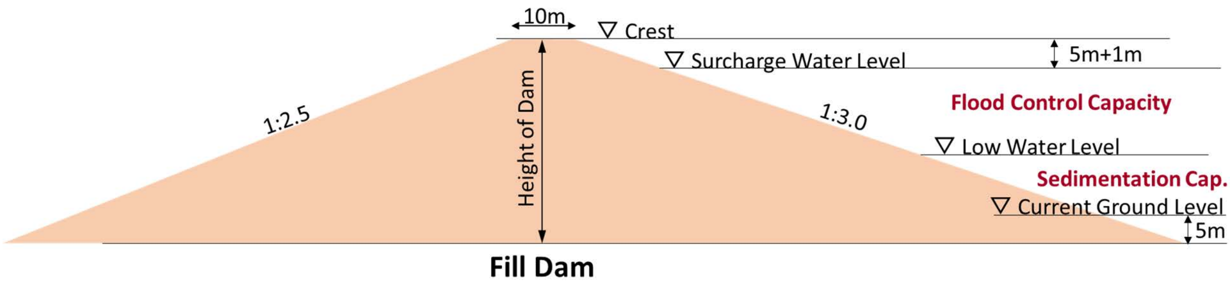
In case the present river flow capacity in the target area of the Davao River to be protected by structural measures is 600m^3/s, the dam height is required to be 54 m to store the remaining amount of the 100-year flood discharge (2,800 m^3/s), and the storage capacity including sedimentation capacity (sedimentation capacity + flood control capacity) is 115 million m^3. Table 3.4.7 shows the results of the examination.

Table 3.4.7 Examination Result of Individual Implementation of Dam in Davao River

Outline of structure	Fill dam with 54m height (detention capacity is 115 million m^3)
Discharge amount to be accommodated	Approx. 2,800m^3/s (100% of remaining flood discharge of 100 year flood in case that estimated present river capacity of protected area is 600m^3/s)
Construction period	Appox. 20 years
Direct construction cost + land acquisition cost + compensation cost for building	Appox. 46 billion Php
Number of affected buildings (Relocation required)	Appox. 720 buildings
Period required for relocation	Appox. 8 years
Disadvantages / restrictions	The existing road will sink about 7.4 km length in total. Ponding area includes restricted area that may have serious environmental and social impacts.

Source: Project Team

The general drawing of the fill dam applied in the above examination is shown in Figure 3.4.11.

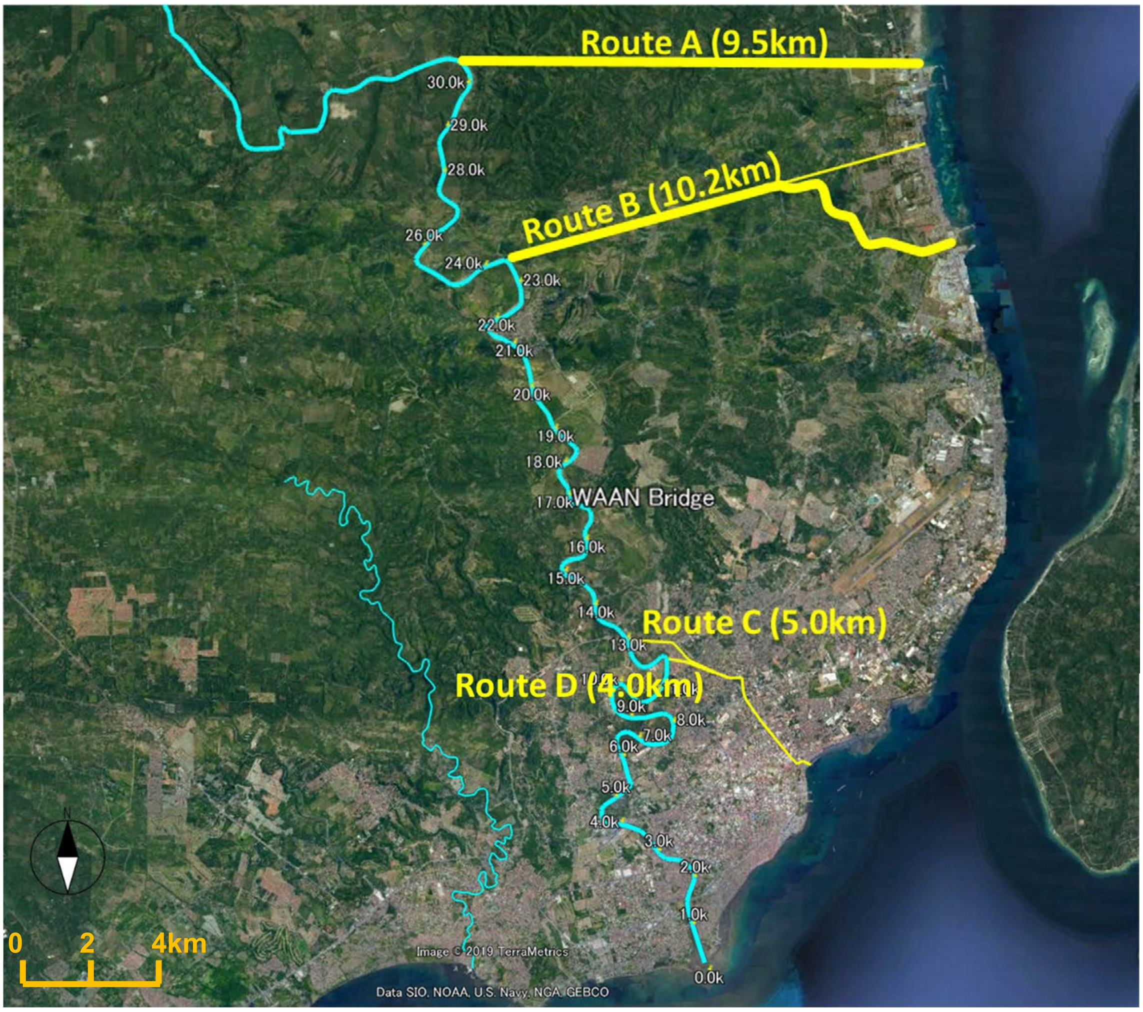


Source: Project Team

Figure 3.4.11 General Drawing of Fill Dam

5) Diversion Channel

In the examination of the proposed diversion channel, the four candidate routes shown in Figure 3.4.12 were compared and examined. As an another option, it can also consider that an open-type diversion channel from the 13k point, which is just upstream side of the current urban area, to the sea through the area on the right bank of the Davao River where urbanization is not relatively advanced at present. However, this option was excluded from examination objects because there are many development area approved by Davao City in the downstream of this route, and the coastal area is blocked by the ongoing construction of coastal road.



Source: Project Team

Figure 3.4.12 Examined Routes of Diversion Channel in Davao River

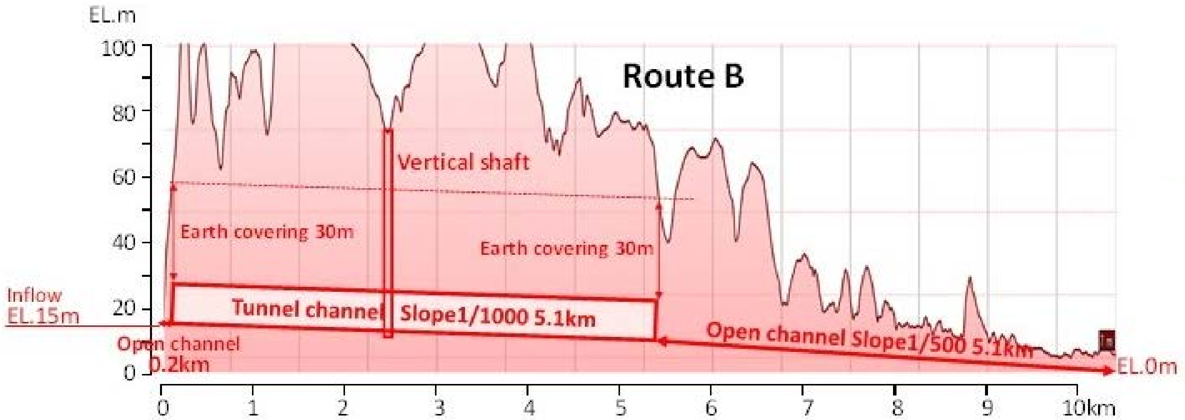
Routes A and B are combinations of open channel and tunnel, and Routes C and D are combinations of underground diversion channel and pump. As a result of the cost comparison, Route B was the cheapest, so the examination of diversion channel as individual measure is conducted for the Route B. Table 3.4.8 shows the results of the examination.

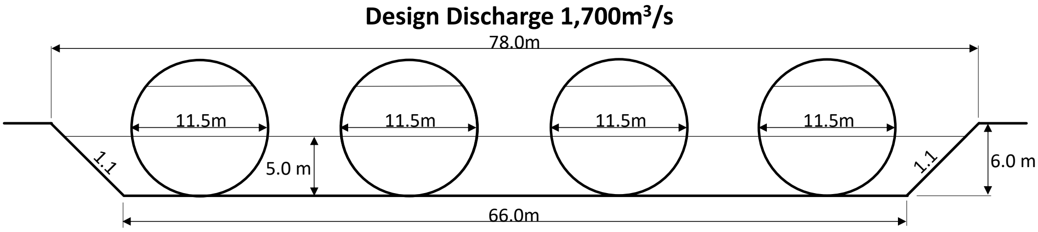
Table 3.4.8 Examination Result of Individual Implementation of Diversion Channel in Davao River

Outline of structure	Combination of open channel and shield tunnel
Discharge amount to be accommodated	Approx. 2,800m^3/s (100% of remaining flood discharge of 100 year flood in case that estimated present river capacity of protected area is 600m^3/s)
Construction period	Appox. 10 year
Direct construction cost + land acquisition cost + compensation cost for building	Appox. 463 billion Php
Number of affected buildings (Relocation required)	Appox. 290 buildings
Period required for relocation	Appox. 3 years
Disadvantages / restrictions	

Source: Project Team

Figure 3.4.13 shows a longitudinal profile and a cross section of Route B assumed in the above examination (the cross section is an example when the target discharge is 1700 m^3/s).





Source: Project Team

Figure 3.4.13 Longitudinal Profile and Example of Cross Section for Route B of Diversion Channel in Davao River

6) Examination Result of Individual Flood Control Measure

As a result of the examination for five types of individual structural measures, it was found that any of the measures could cope with 100-year flood, but had the following challenges.

- Dike / Flood wall:
  An average height of about 7m and a maximum of about 12m are required. It is a very high dike / flood wall, and the risk is extremely large in case of the dike break.
- Widening:
  It is necessary to widen the present average river width of about 80m to about 210m. The number of affected buildings will be more than 5,000, which has a large social impact.
- Retarding pond & Dam:
  The cost is two to three times as much as dike / flood wall or widening.

For dam, the impact on the natural and social environment at the dam site and flooded area was checked. As a result, it was confirmed that the flooded area includes significant sensitive areas that may have a serious environmental and social impact from the social and environmental aspects, except when targeting extremely small discharges. Regarding this restricted area, "Although structural measures should not be avoided due to principle objectives of flood control; it shall be given special attention and environmental impact evaluation." If measures to mitigate the impact are to be taken as a result of the impact assessment, it will take a considerable amount of time to realize.

- Diversion channel (Underground diversion channel):
  The cost is about ten times as much as retarding pond or dam

Based on the above examination results, it can be judged that each individual flood control measure is difficult to cope with the design flood discharge by solo implementation of the measure, therefore, it is necessary to examine an optimal combination that can cope with the 100-year flood by considering combination of four types of flood control measures except for diversion channel of which the cost is extremely high.

(2) Examination of Combination of Flood Control Measure

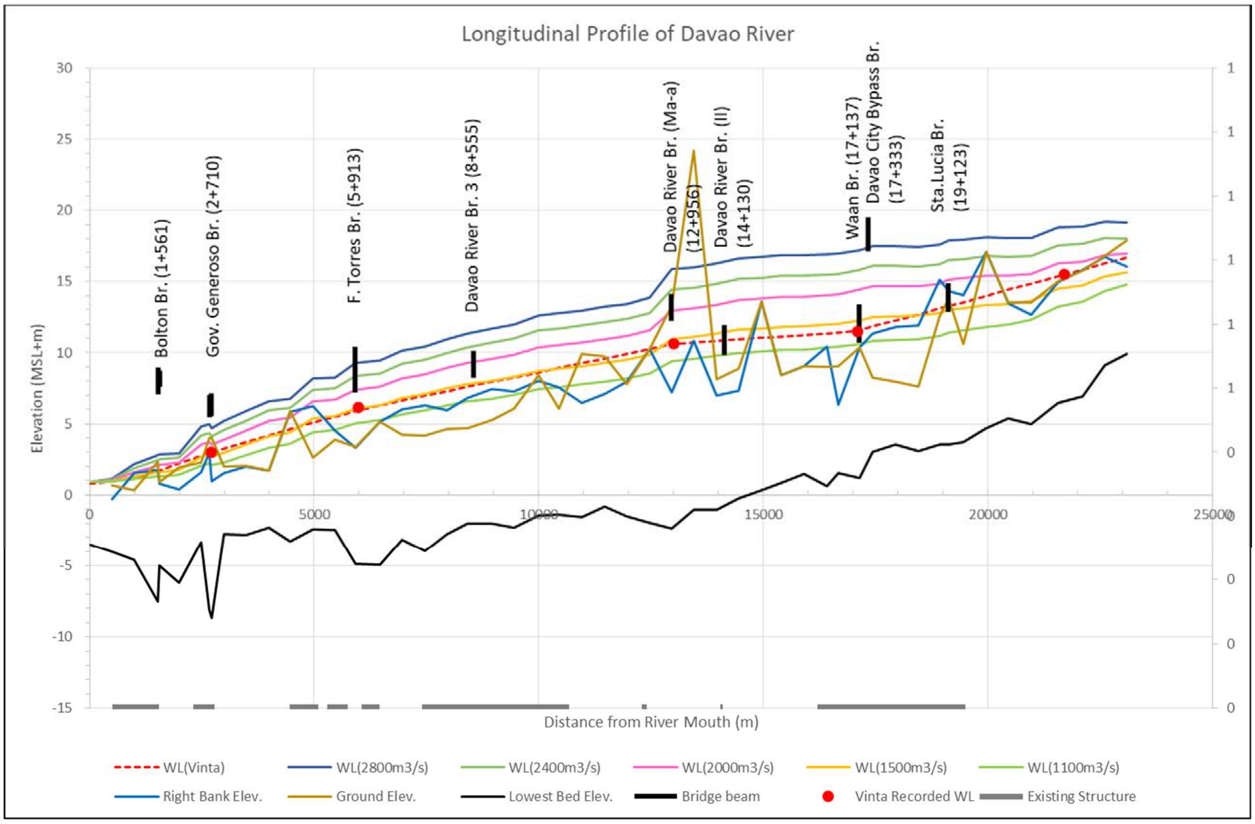
1) Examination of Restriction of Each Structural Measure for Examination of Combination

In the examining of the optimal combination of structural measures, the individual measures were re-examined based on the examination in the previous section.

A. Floodwall

The restriction of the flood wall height is examined. In the examination, the target water level is tried to set lower than the past flood water level so as not to increase the flood risk in the area, which means that the target water level is set to be less than or equal to the actual water level at Vinta, the largest flood in the Davao River since 2000.

Figure 3.4.14 shows a comparison between the calculated water level at the time of flood in case the flood wall is constructed along the river bank and the water level at Vinta at various discharge scales. The line connecting the red circles is the water level of Vinta which almost equals with the calculated water level at discharge amount of 1,500 m3/s. Therefore, the height of flood wall was decided to set to allocate the discharge amount of 1,500 m3/s at the maximum. In this case, the required flood wall height is 2.7m on average and 6.7m at maximum, including the free board (1.0m).



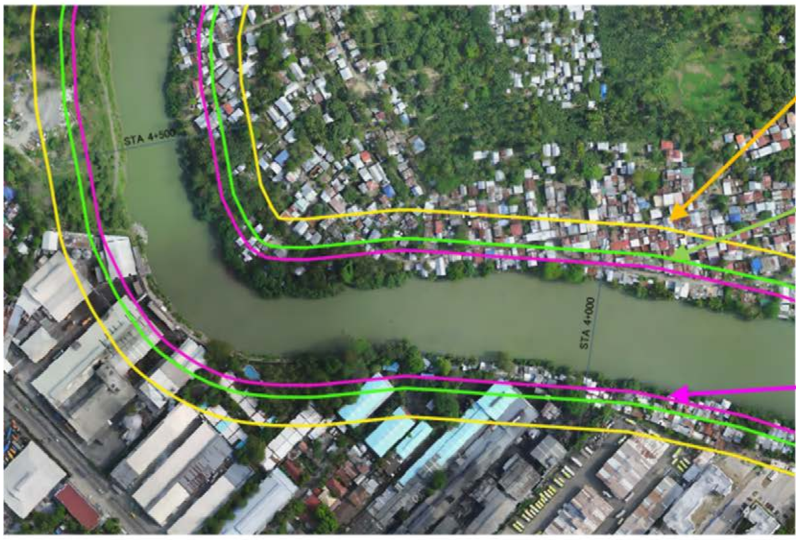
Source: Project Team

Figure 3.4.14 Comparison of Flood level with Various flood discharge after Dike / Floodwall construction and Actual Flood level in Vinta

B. River Improvement (Widening)

The required widening width is examined. As an preliminary examination, the required widening width and the number of affected buildings were estimated by the discharge scales of 2,800 m^3/s, 2,000 m^3/s, and 1,700 m^3/s in case of widening the river at the same distance from the center line of the current river channel to both banks. Figure 3.4.15 shows the required widening width (the required widening width for the current river width of about 80 m on average) and the number of affected buildings.

Considering the number of affected buildings and the easement width at the downstream of the Davao River specified in the Zoning Ordinance of Davao City being 30 m from the bank, the maximum widening width of the river for examination of combination will be set to 25 m on one side (2,000 m^3/s with an average river width of 130 m).



Source: Project Team

Figure 3.4.15 Preliminary Assessment of Necessary Channel Width and Number of Affected Buildings in case of Various Flood Scale of 2,800m^3/s, 2,000m^3/s and 1,700m^3/s

C. Retarding Pond

The analysis of the number of affected buildings, the presence or absence of a development plan, and the present development status in each of the 26 candidate site for retarding pond along the Davao River was conducted.

Regarding the presence or absence of a development plan, it was confirmed whether the candidate sites are classified as a residential or commercial area by using the future land use plan of 2045 and the CLUP 2019-2028 (draft version) of Davao City. Regarding the present status of development, a field survey was conducted at each candidate site to visually check whether or not a residential (sub-division) development activity is taking place. For selecting a specific development site for retarding pond, the priority will be lowered for locations where the number of affected buildings is large or where future development is expected.

Table 3.4.9 Analysis of Candidate Sites for Retarding Ponds in Davao River

No.	Distance from River Mouth of Pond *(km)	Side	Area (km^2)	Capacity (MCM)	Excavation Volume (MCM)	Affected Buidings (Number)	Buiding Density (Number /km^2)	Area to be developed: Laun Use Plan in 2045 by IM4Davao	Area to be developed: CLUP2019-28(draft)	Note
1	44.8	Left bank	0.42	2.10	7.77	21	50	No	No	
2	43.6	Right bank	0.22	1.10	11.00	3	14	No	No	
3	42.2	Right bank	0.39	1.95	19.31	4	10	No	No	
4	39.4	Left bank	0.37	1.85	6.48	16	43	No	Yes	
5	33.2	Left bank	2.93	14.65	83.51	221	75	No	No	
6	32.2	Right bank	2.19	10.95	38.33	117	53	No	No	
7	31.0	Left bank	0.44	2.20	6.38	3	7	No	No	
8	29.0	Right bank	0.85	4.25	11.90	12	14	No	No	
9	27.2	Left bank	0.39	1.95	4.88	1	3	No	No	
10	26.2	Right bank	0.07	0.35	0.84	3	43	No	No	
11	23.8	Left bank	0.76	3.80	11.40	32	42	No	No	
12	21.8	Right bank	1.03	5.15	17.00	25	24	No	No	
13	20.2	Right bank	0.31	1.55	4.96	14	45	No	No	
14	19.7	Left bank	0.43	2.15	6.45	12	28	Yes	Yes	Sub-division will be developed near future.
15	19.6	Right bank	0.33	1.65	5.61	5	15	No	Yes	Sub-division is under development.
16	19.2	Left bank	0.12	0.60	1.62	0	0	Yes	Yes	Sub-division will be developed near future.
17	18.5	Left bank	0.42	2.10	4.41	8	19	Yes	Yes	Sub-division is under development.
18	17.9	Right bank	0.05	0.25	0.45	3	60	No	Yes	
19	17.3	Right bank	0.37	1.85	4.63	12	32	Yes	Yes	Sub-division is under development.
20	15.4	Right bank	0.44	2.20	5.06	41	93	Yes	No	
21	15.7	Left bank	0.25	1.25	2.75	10	40	Yes	No	
22	14.5	Left bank	0.15	0.75	1.80	9	60	Yes	No	
23	14.0	Right bank	0.07	0.35	0.74	31	443	No	No	New road connecting on-going bridge will be constructed.
24	11.9	Left bank	0.04	0.20	0.50	5	125	Yes	Yes	
25	9.0	Left bank	0.32	1.60	4.32	30	94	No	No	
26	6.7	Right bank	0.50	2.50	6.75	110	220	No	No	Bridge & road will be constructed.
Total			13.86	69.30	268.81	748	-	-	-	-

Source: Project Team

D. Dam

The impact on the natural and social environment at the proposed dam site and ponding area was confirmed. As a result, it was confirmed that the ponding area includes restricted areas that may have serious environmental and social impacts.

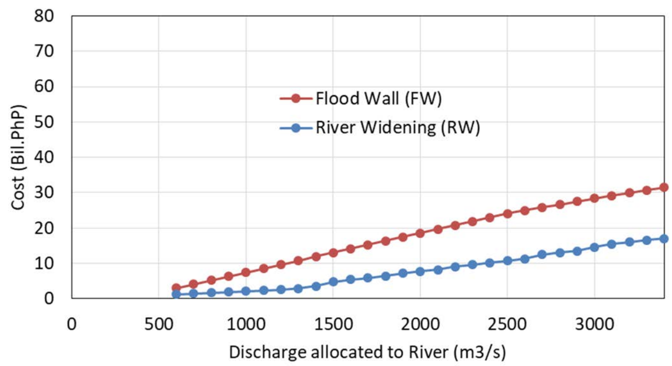
Regarding this restricted area, the introduction of structures will not be excluded for the purpose of flood control measures, but careful introduction and impact assessment will be required, and it might take considerable time in case the assessment results require measures to mitigate the impact.

2) General Examination of Tendency of Cost of Individual/Combined Implementation of Structural Measures

In the examination of the optimal combination of structural measures, the construction cost (direct construction cost, land acquisition cost, building compensation cost, bridge replacement cost (if necessary) was confirmed, and the tendency was analyzed.

A. Tendency of Measures for Increasing Flow Capacity of River Channel (Tendency for Flood wall and Widening)

Figure 3.4.16 shows the result of comparison of the construction cost by flood wall and river widening for each discharge scale indicated on the horizontal axis as "Discharge allocated to River". From this figure, it can be seen that the river widening is inexpensive in case the flood discharge is accommodate only by the river channel.

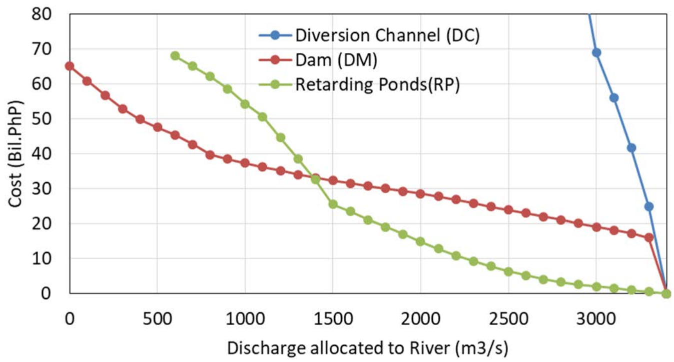


Source: Project Team

Figure 3.4.16 Comparison of Cost in case of Individual Implementation of Flood wall and River Widening with Various Scale in Davao River

B. Tendency of Measures for Flood Water Detention Facilities (Tendency of Retarding Pond and Dam (and Diversion Channel)

Figure 3.4.17 shows the result of comparing the construction cost of the retarding ponds, dam and diversion channel with the scale of each discharge amount. Figure 3.4.17 shows the cost of implementing the measures to cope with the remaining discharge amount (residual amount for 3,400 m^3/s) for each of the retarding ponds, dam, and diversion channel while the river channel is able to accommodate discharge amount indicated on the horizontal axis. From this figure, it can be seen that retarding ponds are inexpensive if the river channel has a flow capacity of 1,400 m^3/s or more and the remaining discharge amount is accommodated by the detention facility.



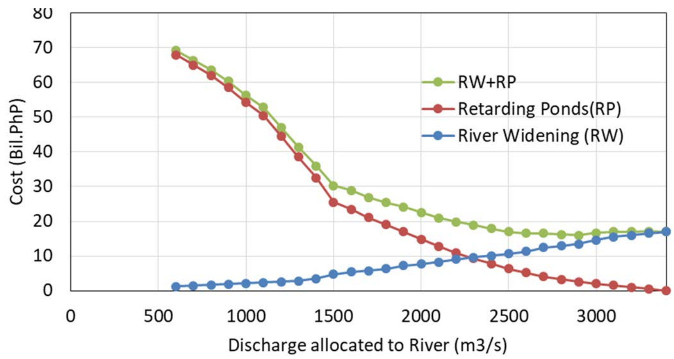
Source: Project Team

Figure 3.4.17 Comparison of Cost in case of Individual Implementation of Retarding Pond, Dam and Diversion Channel with Various Scale in Davao River

C. Tendency of Optimal Flood Discharge Distribution accommodated by River Channel and Flood Water Detention Facility

The optimal distribution of flood discharge by river channel and detention facilities was examined by combining the river widening which is lowest-cost measures among measures accommodated by river channel and the retarding ponds which are lowest-cost measures among detention facilities.

The green line in Figure 3.4.18 shows the cost in case of the combination of the river widening and the retarding ponds corresponding to the discharge amount of 3,400 m^3/s. In case the discharge allocated by the river channel is about 1700 m^3/s or more, the total value is gently constant (almost flat). From the viewpoint of cost, it is appropriate to make the river channel allocation more than about 1700 m^3/s.

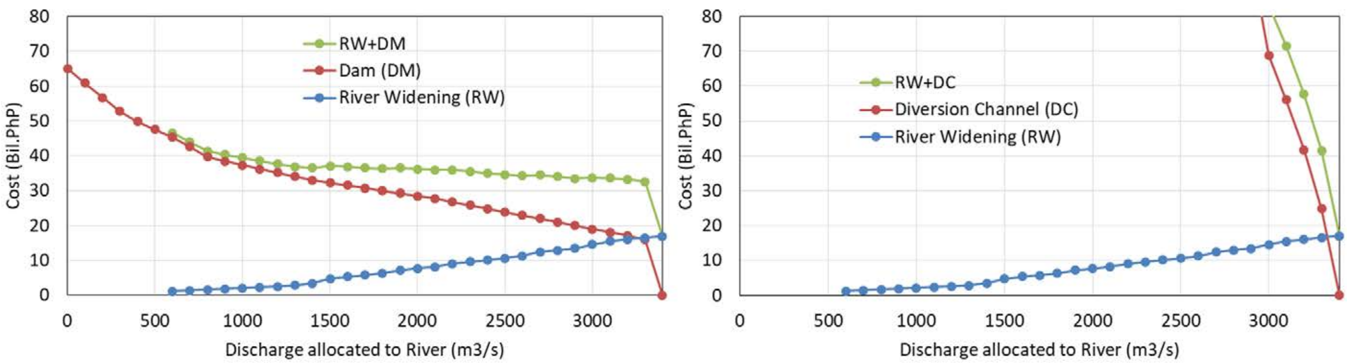


Source: Project Team

Figure 3.4.18 Comparison of Cost in case of Combined Implementation of River Widening and Retarding Pond with Various Scale in Davao River

D. Tendency of Optimal Flood Discharge Distribution accommodated by River Channel and Flood Water Detention Facilities (Other Facilities)

As a comparison, the cost of combining river channel and detention facility using dam or diversion channel was examined. As shown in Figure 3.4.19, if the entire discharge amount is allocated by the river channel, it is the cheapest compared to the accommodation by dam or diversion channel.



Source: Project Team

Figure 3.4.19 Comparison of Cost in case of Combined Implementation of River Widening and Dam / Diversion Channel with Various Scale in Davao River

3) Concept of Combination of Structural Measures

In the examination of the optimal combination of structural measures, the following three concepts were set and compared.

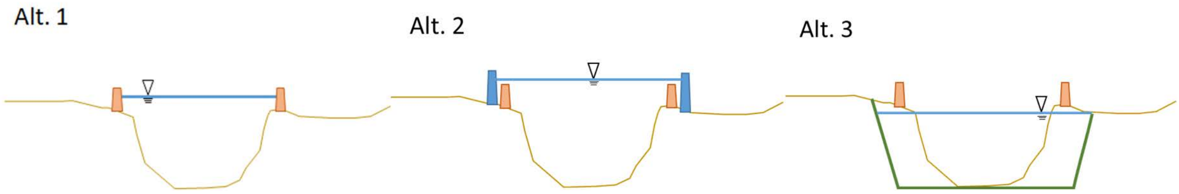
Alt.1: Considering present condition that land use is already highly advanced, priority should be given to minimizing land acquisition and resettlement and to allow floods to flow along present river channel (riverbanks).
By reinforcement works of present dike/revetment works, 3-5 year scale flood will be flowed down by river channel, and **flood water detention facilities** will be installed in the basin in order to secure the target flood control safety level that exceeds 3-5 year scale flood.
HWL is about present dike height or present river bank height.

Alt.2: Considering present condition that land use is already highly advanced, priority should be given to allow floods to flow along present river channel (river banks).
By increasing flow capacity by installation of new dike, 5-10 year scale flood will be flowed down by river channel, and **flood water detention facilities** will be installed in the basin in order to secure the target flood control safety level that exceeds 5-10 year scale flood.
HWL about 1.5 m higher than present dike height or present river bank height.

Alt.3: As land use is already highly advanced and its further advancement is expected in the future, priority should be given to maximizing the flow of floods by river channel and minimizing flood risk while keeping HWL low.
By widening width of river channel, 5-15 year scale flood will be flowed down by river channel, and **flood water detention facilities** will be installed in the basin in order to secure the target flood control safety level that exceeds 5-15 year scale flood.
HWL is about present ground level of inland area.

In any combination, dredging needs to be implemented for the purpose of rapid improving river flow capacity.

Figure 3.4.20 shows a comparison of the design cross sections of the above three policies. Looking at the planned high water level of the three policies, Alt.2 is the highest and Alt.3 is the lowest. The difference between them will be about 3m, which is depending on locations.



Source: Project Team

Figure 3.4.20 Comparison of Cross Section of Each Concept

4) Alt.1: Combination of Reinforcement of Present Dike and Flood Water Detention Facilities

For Alt.1, respecting the existing, ongoing and planned river works by DPWH DEO I (hereinafter referred to as "DEO works"), a certain level of flood control safety is ensured by reinforcement works in places where the flow capacity is insufficient due to the lack of DEO works, river channel dredging and introduction of water detention facilities.

For the target flood discharge of 3,400 m3/s, the flow capacity of the river channel will be increased up to 1,000 m3/s by the reinforcement work, and 200 m3/s will be secured by the dredging, then the remaining discharge amount 2,200 m3/s will be accommodated by the detention facilities. Table 3.4.10 shows the proposed combination of measures for Alt.1. Table 3.4.10 shows the construction cost (including direct construction cost, land acquisition cost, and building compensation cost) and the number of affected buildings. The number of affected buildings due to the construction of retarding ponds and dam is calculated using GIS data provided by Davao City. As for the dike reinforcement work, it is difficult to calculate the number of affected buildings due to the ongoing DEO work, therefore, it is assumed to be 50 buildings.

Table 3.4.10 Combination of Alternatives of Alt.1

No.	Combination of Structural Measures			Cost ** (Billion Php)	Affected buildings (Number)
	Dike / Flood wall +Dredging (Bridge Replacement)	Retarding Pond	Dam		
1-1	△ (1000m^3/s) + dredging (200m^3/s) (No bridge replacement)	○ (2200m^3s)	×	47 (1+1+45)	600
1-2	△ (1000m^3/s) + dredging (200m^3/s) (No bridge replacement)	×	○ (2200m^3/s)	37 (1+1+35)	700
1-3	△ (1000m^3/s) + dredging (200m^3/s) (No bridge replacement)	○ (1200m^3/s)	○ (1000m^3/s)	38 (1+1+11+25)	600
1-4	△ (1000m^3/s) + dredging (200m^3/s) (No bridge replacement)	○ (1800m^3/s)	○ (400m^3/s)	45 (1+1+24+19)	700

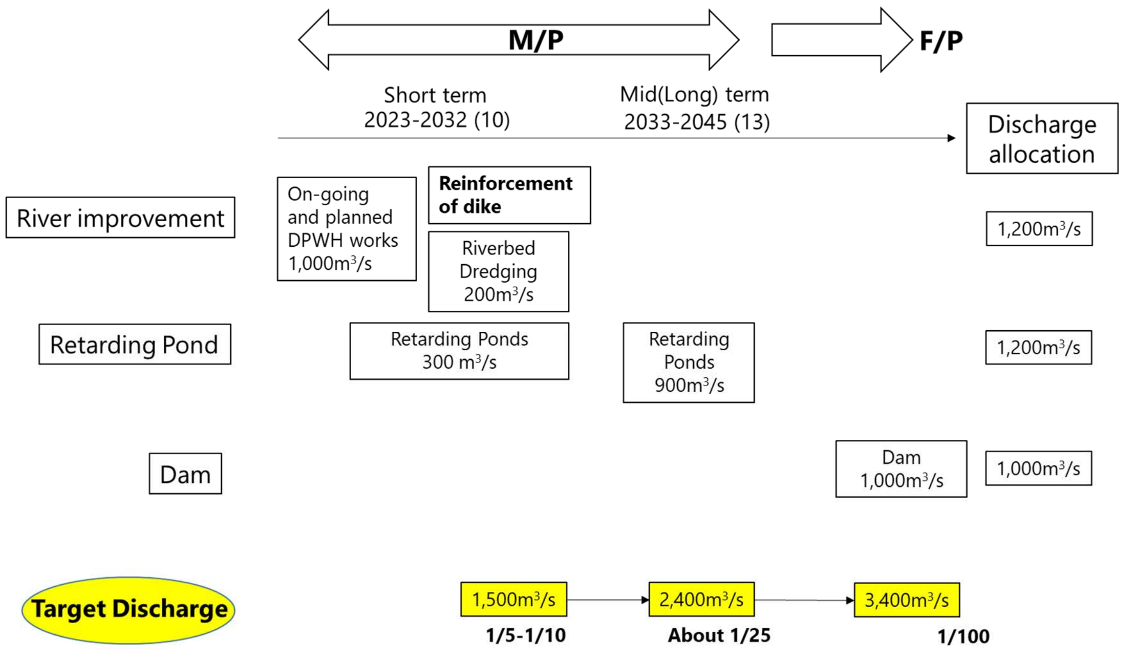
Note: ○: Necessary/Included, △: Partially necessary/included, ×: Unnecessary/Not included
**: Cost = Direct construction cost + land acquisition cost + compensation cost for building
Source: Project Team

In the combination of dike reinforcement, river channel dredging, and water detention facilities in Alt.1, No.1-2 of combination with dam only is the cheapest.

However, the dam has many disadvantageous conditions since it will take a long time to implement after the dredging work (after improvement of the discharge amount to 1,200 m^3/s) due to environmental and social considerations, and it is difficult to perform step-by-step work.

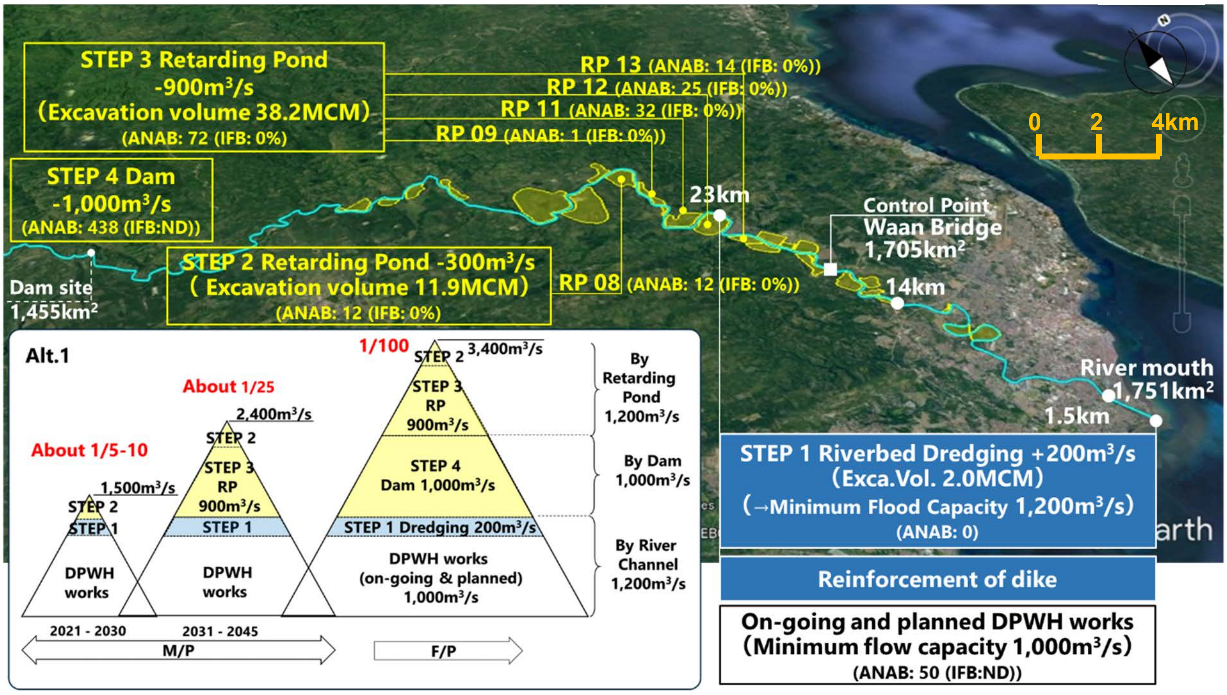
Therefore, from alternatives of Alt-1, No.1-3 is recommended, which is the second cheapest after No.1-2, has less affected buildings than No.1-2, and allows for gradual development.

Figure 3.4.21 and Figure 3.4.22 show the implementation schedule of No.1-3 in Alt.1 and the facility plan, respectively.



Source: Project Team

Figure 3.4.21 Preliminary Implementation Schedule of Alt.1



Note: ANAB: Assumed Number of Affected Buildings, IFB: Informal Building, ND: No data
Source: Project Team

Figure 3.4.22 Facility Plan of Alt.1

5) Alt.2: Combination of New Dike and Flood Water Detention Facilities

For Alt.2, a certain level of flood control safety is ensured by newly constructed flood wall, river channel dredging and water detention facilities.

The flow capacity of the river channel will be increased from the current capacity 600 m³/s to 1,500 m³/s by the newly constructed flood wall, and 200 m³/s will be secured by the dredging, then the remaining discharge amount 1,700 m³/s will be accommodated by the detention facilities. Table 3.4.11 shows the proposed combination of measures in Alt.2.

Table 3.4.11 Combination of Alternatives of Alt.2

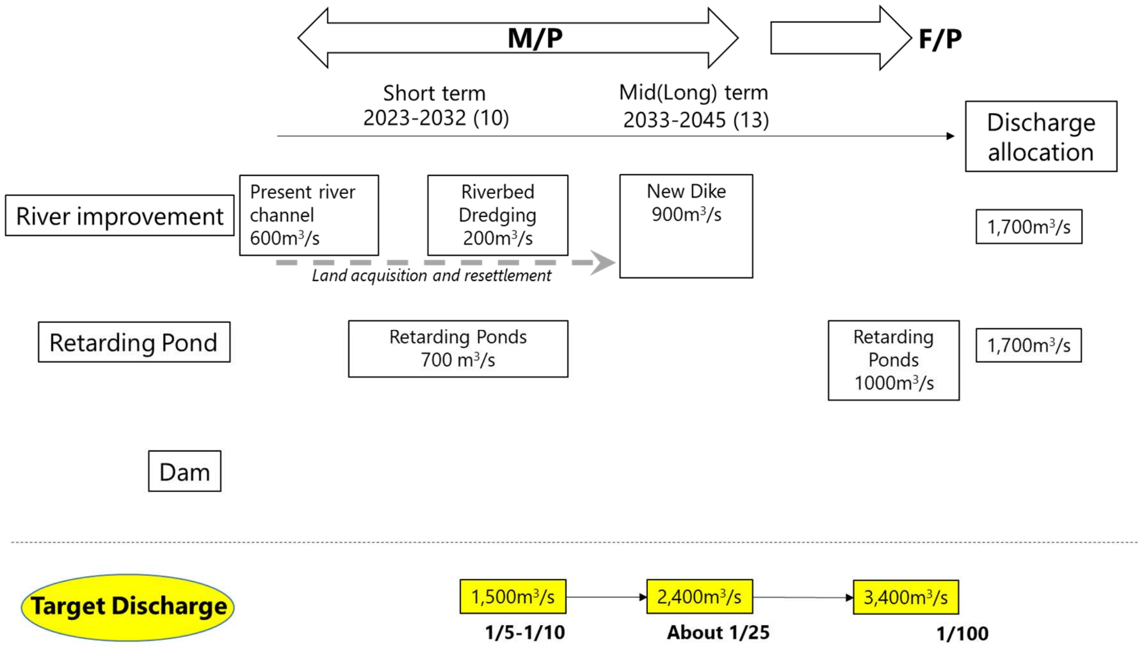
No.	Combination of Structural Measures			Cost ** (Billion Php)	Affected buildings (Number)
	Dike / Flood wall +Dredging (Bridge Replacement *)	Retarding Pond	Dam		
2-1	○ (1500m³/s) + dredging (200m³/s) (3 Bridges)	○ (1700m³s)	×	36 (13+1+22)	1,600
2-2	○ (1500m³/s) + dredging (200m³/s) (3 Bridges)	×	○ (1700m³/s)	45 (13+1+31)	1,900
2-3	○ (1500m³/s) + dredging (200m³/s) (3 Bridges)	○ (700m³/s)	○ (1000m³/s)	44 (13+1+5+25)	1,900
2-4	○ (1500m³/s) + dredging (200m³/s) (3 Bridges)	○ (1300m³/s)	○ (400m³/s)	47 (13+1+13+20)	1,900

Note: ○: Necessary/Included, △: Partially necessary/included, ×: Unnecessary/Not included
*: 3 bridges (Davao River bridge (II) (14k), Waan bridge (17k) & Sta. Lucia bridge (19k)))
**: Cost = Direct construction cost + land acquisition cost + compensation cost for building

Source: Project Team

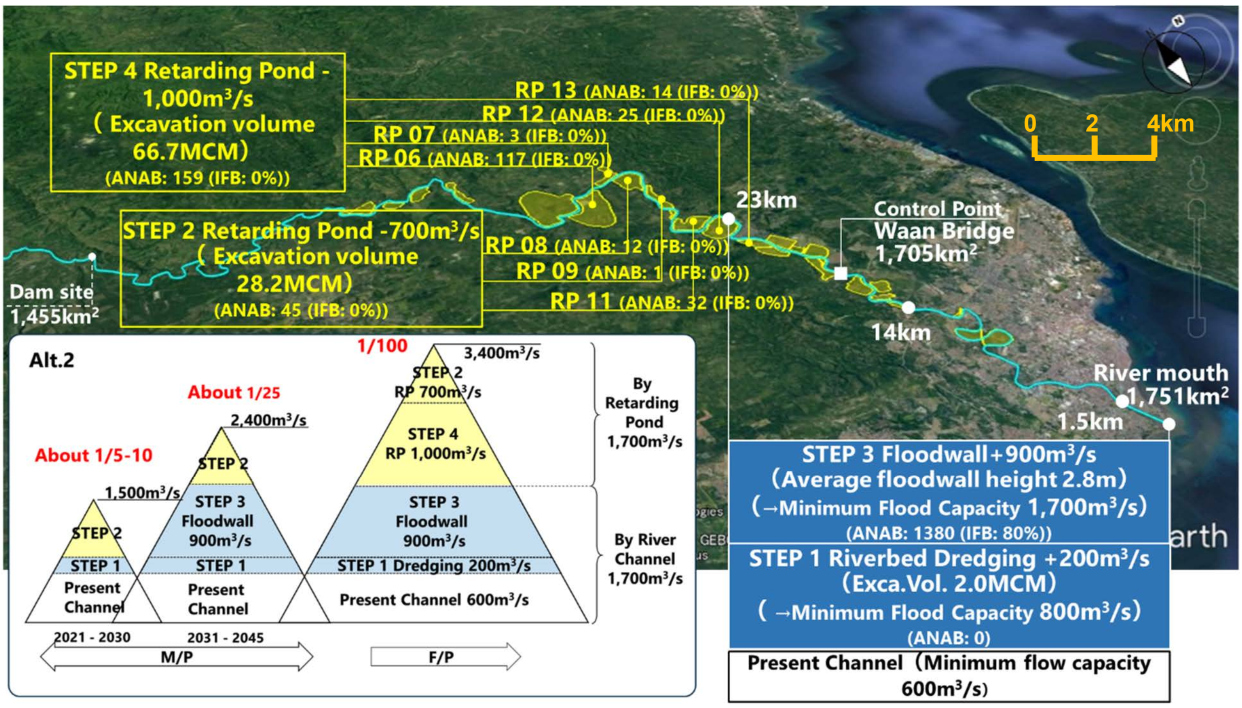
With regard to the combination of new flood wall construction, river channel dredging, and water detention facilities in Alt.2, the No. 2-1 of combination of retarding ponds only is the cheapest and minimizes the number of affected buildings. Stepwise construction is also possible. Therefore, from alternatives of Alt-2, No.2-1 is recommended.

Figure 3.4.23 and Figure 3.4.24 show the implementation schedule of No.2-1 in Alt.2 and the facility plan, respectively.



Source: Project Team

Figure 3.4.23 Preliminary Implementation Schedule of Alt.2



Note: ANAB: Assumed Number of Affected Buildings, IFB: Informal Building, ND: No data
Source: Project Team

Figure 3.4.24 Facility Plan of Alt.2

6) Alt.3: Combination of River Widening and Flood Water Detention Facilities

For Alt.3, a certain level of flood control safety is ensured by river widening, dredging and water detention facilities. The flow capacity of the river channel will be increased from the current capacity 600 m3/s to 1,700 or 2,000 m3/s by the river widening and dredging, and the remaining discharge amount 1,700 or 1,400 m3/s will be accommodated by the detention facilities. Table 3.4.12 shows the proposed combination of measures in Alt.3.

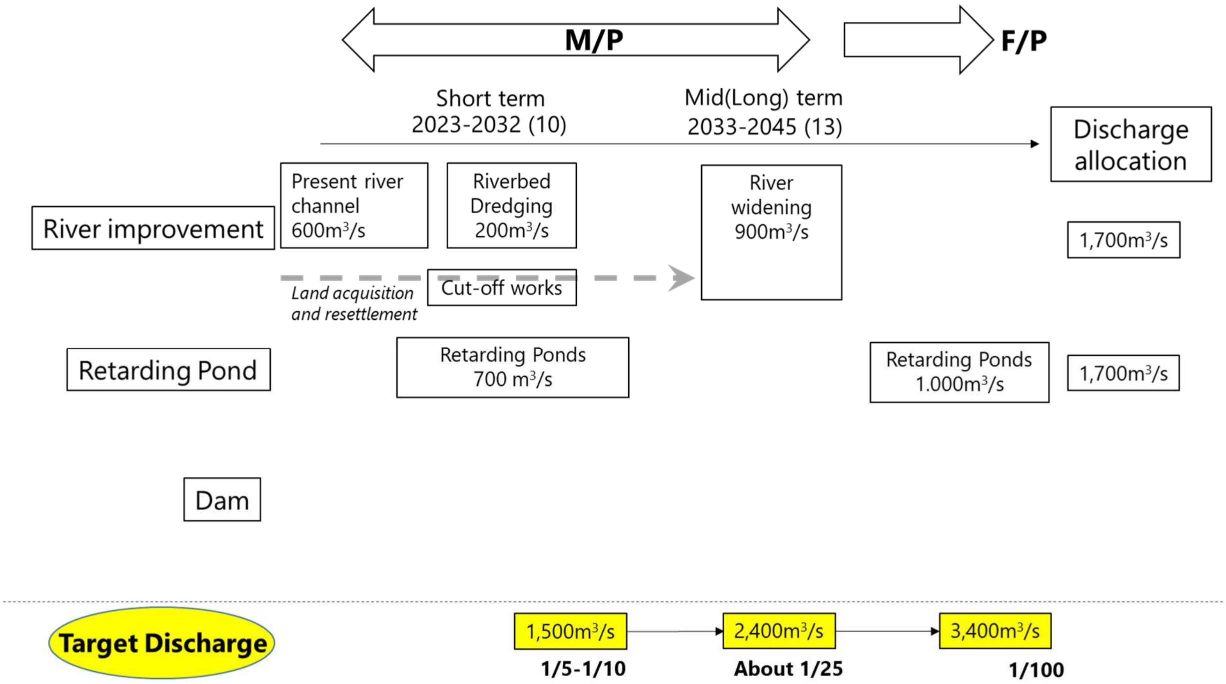
Table 3.4.12 Combination of Alternatives of Alt.3

No.	Combination of Structural Measures			Cost ** (Billion Php)	Affected buildings (Number)
	Dredging and Widening (Number of Bridge Replacement *)	Retarding Pond	Dam		
3-1	○ (1700m^3/s = 600 + 200 +900) (2 Bridge) (30m (15m each) widening)	○ (1700m^3/s)	×	28 ((1+5)+22)	1,600
3-2	○ (1700m^3/s = 600 + 200 +900) (2 Bridge) (30m (15m each) widening)	×	○ (1700m^3/s)	37 ((1+5)+31)	2,000
3-3	○ (2000m^3/s = 600 + 200 +1200) (3 Bridges) (50m (25m each) widening)	○ (1400m^3/s)	×	24 ((1+8)+15)	2,500
3-4	○ (2000m^3/s = 600 + 200 +1200) (3 Bridges) (50m (25m each) widening)	×	○ (1400m^3/s)	38 ((1+8)+29)	2,800

Note: ○: Necessary/Included, △: Partially necessary/included, ×: Unnecessary/Not included
*: 2 bridge (F. Torres bridge (6k) & Davao River bridge (13k)), 3 bridges (F. Torres bridge (6k), Davao River bridge (13k) & Waan bridge (17k))
**: Cost = Direct construction cost + land acquisition cost + compensation cost for building
Source: Project Team

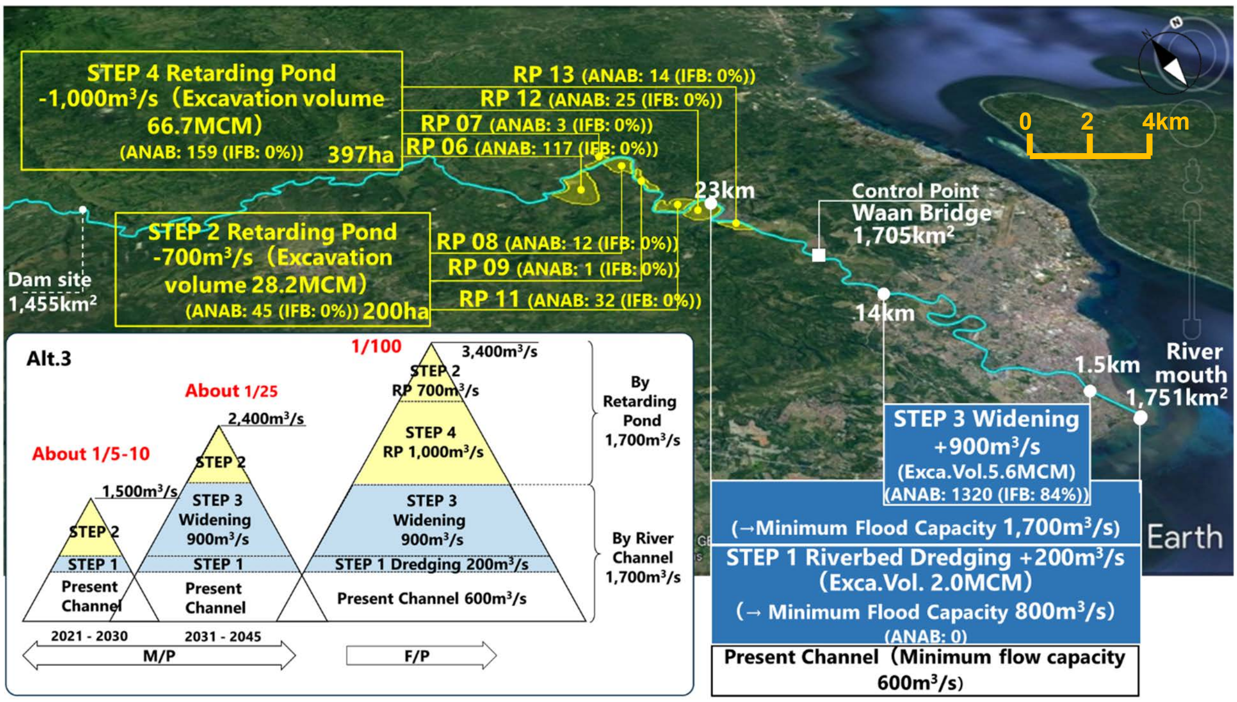
In the combination of river widening, dredging, and water detention facilities in Alt.3, the combination with the retarding ponds only becomes cheaper. In addition, the case making the width of widening larger, that is, the case making the allocation of the river channel larger, indicates lower cost. However, the widening to 2000 m3/s of No.3-3 has a large social impact since the average width from the existing river channel is about 50m and the number of affected buildings in the widening area will be about 2,500. Therefore, from alternatives of Alt-3, No.3-1 is recommended.

Figure 3.4.25 and Figure 3.4.26 show the implementation schedule of No.3-1 in Alt.3 and the facility plan, respectively.



Source: Project Team

Figure 3.4.25 Preliminary Implementation Schedule of Alt.3



Note: ANAB: Assumed Number of Affected Buildings, IFB: Informal Building, ND: No data
Source: Project Team

Figure 3.4.26 Facility Plan of Alt.3

7) Optimal Combination of Structural Measures for F/P

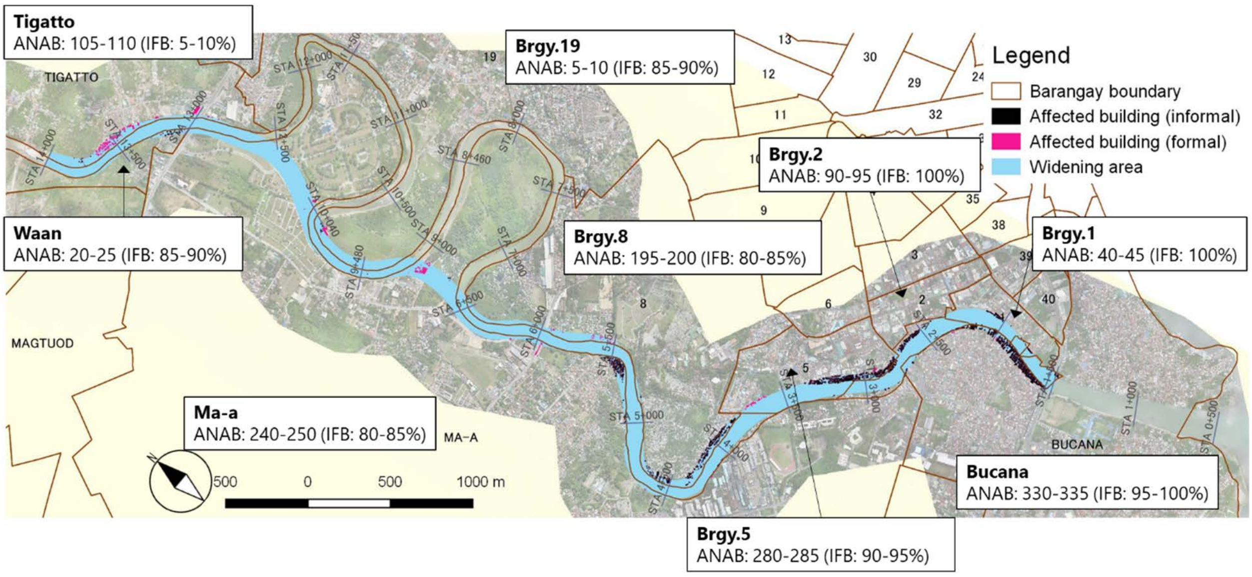
Comparing the recommendations of Alt.1 to Alt.3, the recommendation of Alt.3 is the cheapest. In addition, as for Alt.3, the river channel can accommodate 10-year flood, and in the unlikely event that large-scale floods occur continuously, it is more advantageous for river channels to have a large flow capacity. Furthermore, the risk (water level rise) at the time of flood occurrence including the worst case flood exceeding the target design level can be minimized, and the burden on operation and maintenance is reduced. Taking into account the above things, Alt.3 is recommended.

Regarding the river mouth, in any case of Alt.1 to Alt.3, the structure of MSL + 3.0m (design high tide level 1.53m + wave component about 1.0m + free board about 0.5m) as countermeasures against storm surge and waves (a flood wall along the river at the same height as the storm surge dike) is required.

For this dike at the river mouth, it was not included in the F/P since the construction of the dike and promenade downstream of the Bolton Bridge is currently being constructed by DPWH DEO (planned to be connected to the coastal road).

8) Detailed Examination for River Widening Works of Alt.3

In Alt.3, which is recommended as the optimal combination plan, relocation in urban areas will be a major issue. Distribution of affected buildings and assumed number of affected buildings by barangay are shown in Figure 3.4.27. A supplementary explanation of the content of the measures in Alt.3, and a measure to promote smooth relocation is described as below.



Note: ANAB: Assumed Number of Affected Buildings, IFB: Informal Building
Source: Project Team

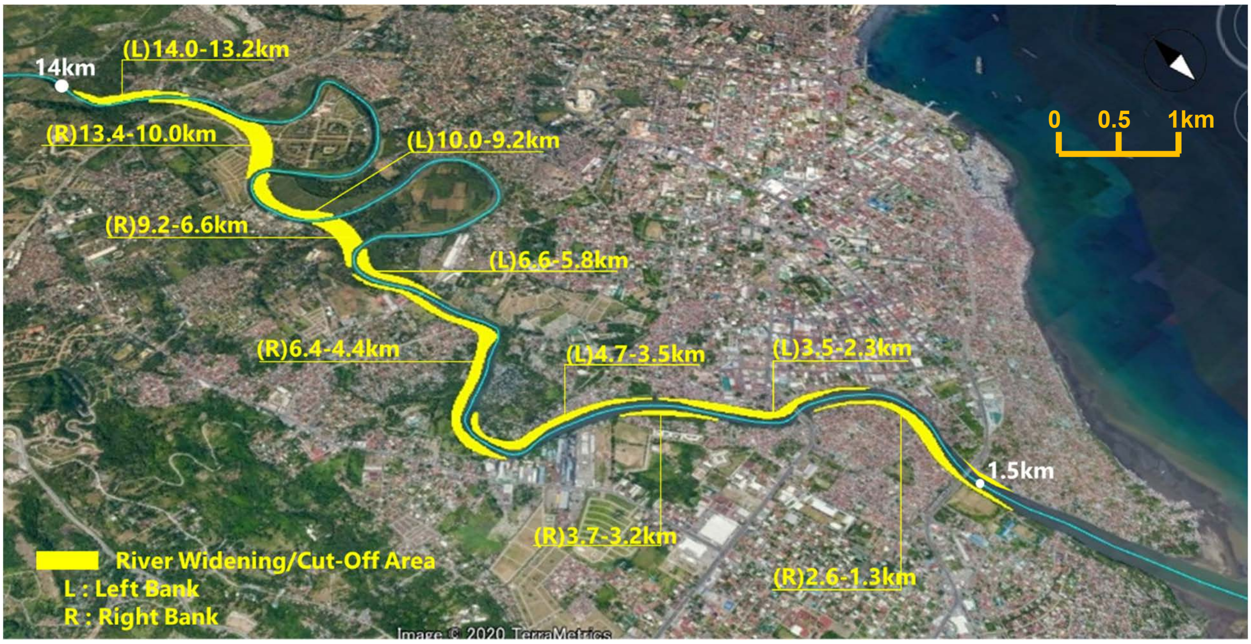
Figure 3.4.27 Distribution of Affected Buildings and Assumed Number of Affected Buildings by Barangay

A. Examination of River Alignment and Construction Method for River Widening Works

In the examination of the widening, the optimal alignment was examined by combining cut-off works, with reference to the Open space / Easement along the river tentatively indicated in CLUP 2019-2028, which is currently being prepared by Davao City.

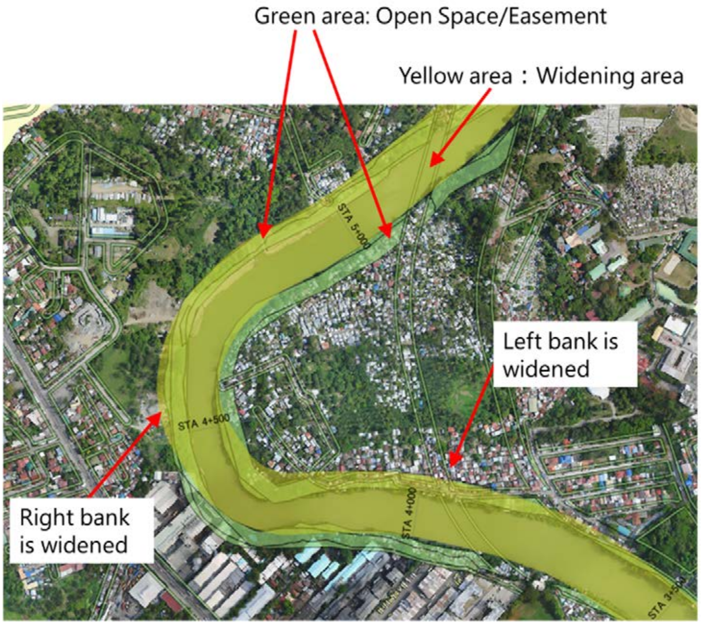
One-sided widening work is recommended considering minimization of the volume of works, utilization of the existing/ongoing dike and revetment, and reducing the number of affected buildings.

Figure 3.4.28 shows the layout of one-sided widening work, and Figure 3.4.29 shows an example of widening range and alignment for the section of 4-5 km from the river mouth.



Source: Project Team

Figure 3.4.28 Alignment of River Widening Works (Sections of Cut-off Works and One-sided Widening Works)



Source: Project Team

Figure 3.4.29 Example of Range and Alignment of Widening in Section of 4-5km from River Mouth

By the one-sided widening works, the widening area will be concentrated on the inner side of the curved part as much as possible, and the alignment of the channel after widening will be made as close to a straight line as possible. By them, the some of existing revetment can be used, and the length of new revetment installation can be shortened. Since the section where temporary coffering is not required becomes longer, it is more advantageous in terms of workability and economy than widening the both banks uniformly.

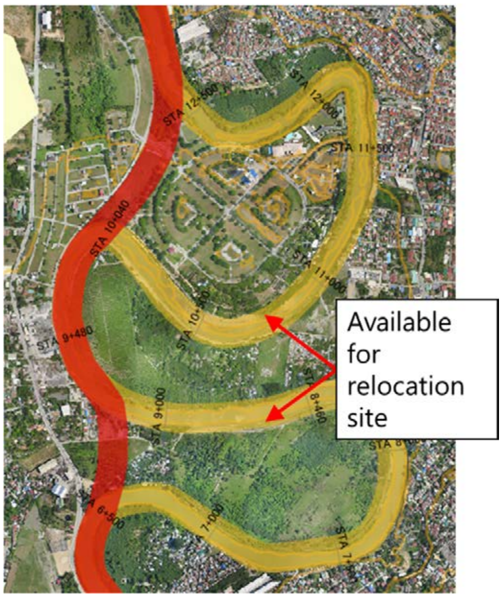
The main purpose of the cut-off works is to promote to discharge flood water, and further the present river channel (meandering part) after the cut-off works can be used as a new land, for example, as a resettlement site. The details are described as below.

B. Utilization of Present River Channel after Cut-off Works

The section from 6.5km to 12.5km from the river mouth which is located downstream side of the crocodile park is a meandering section. In the widening work, this section will be a cut-off section. By cutting off this section with the red line shown in Figure 3.4.30, the existing river channel can be used for other purposes. The current river channel shown in orange line in the figure is approximately 300,000 m^2 (30 ha) in area.

In this project, it is proposed that the existing river channel will be used as a relocation site for resettlements generated by the project implementation. The followings can be expected.

- Residents in the cut-off area (red area) can move to a place near the current place of residence (to the orange area after improvement work). Davao City can save the land acquisition cost.
- The area created by the cut-off works (orange area) is approximately 30 ha. In case the required area per building is estimated at 100 m^2 and all the land is used for residential area, 3,000 buildings can be relocated.
- In order to promote the implementation of the project, it is recommended to proceed with the cut off works in early stage of the Project in order to develop the relocation site.
- In addition, the number of affected buildings at the meandering section can be reduced by about 100 in case the cut-off works are made with the red alignment, compared to the case where the cut-off works is not made (the case widening is done along the orange alignment).



Source: Project Team

Figure 3.4.30 Cut-Off Area

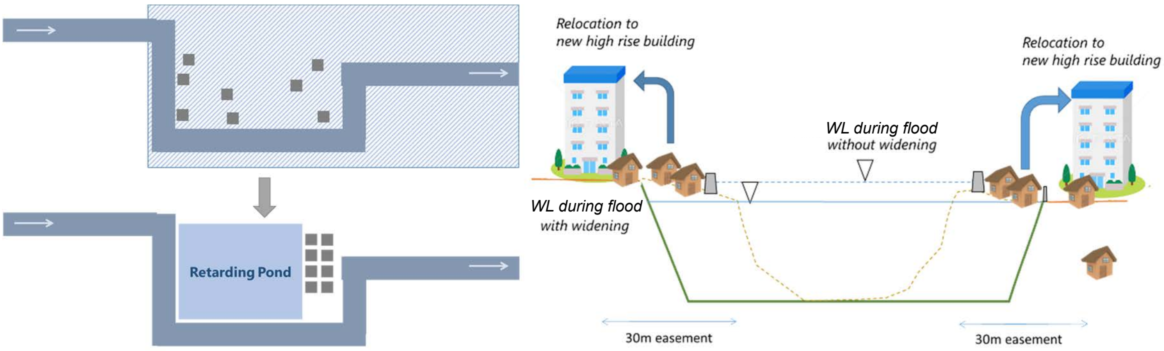
Further examination for the above-mentioned utilization of the existing river channel is described in Section 3.17.

In case that the cut-off work will be carried out in advance, it is estimated that the flow velocity will increase by about 20% just upstream of the section of the cut off works. The increase in flow velocity may cause the riverbed degradation and influence to the upstream bridges (Davao River bridge (13k)) and other structures like revetments. Although the Davao River bridge (13k) will be replaced at the time of the widening works and it is considered that there is not a high possibility that a sudden influence to the structures will occur during the period from the completion of the cut-off works to the replacement works, in order to ensure the safety of the bridge in such a period until the replacement works, it is recommended that regular monitoring of the riverbed around the bridge and reinforcement work (such as riverbed protection works by gabion works) when a serious riverbed deterioration that may affect the structure will be observed.

Also, considering the installation of gabions around the bridge as the reinforcement work (total thickness of 1 m and 5,000 m^2 in the upstream and downstream directions of the bridge), the project cost is roughly estimated to be approximately 0.02-0.03 billion Php.

C. Other Proposals for Promoting Resettlement

In order to promote relocation, group relocation to the vicinity of the proposed measures-implemented area and vertical relocation (construct multi-story residential buildings near the relocation site) can be considered as shown in Figure 3.4.31.



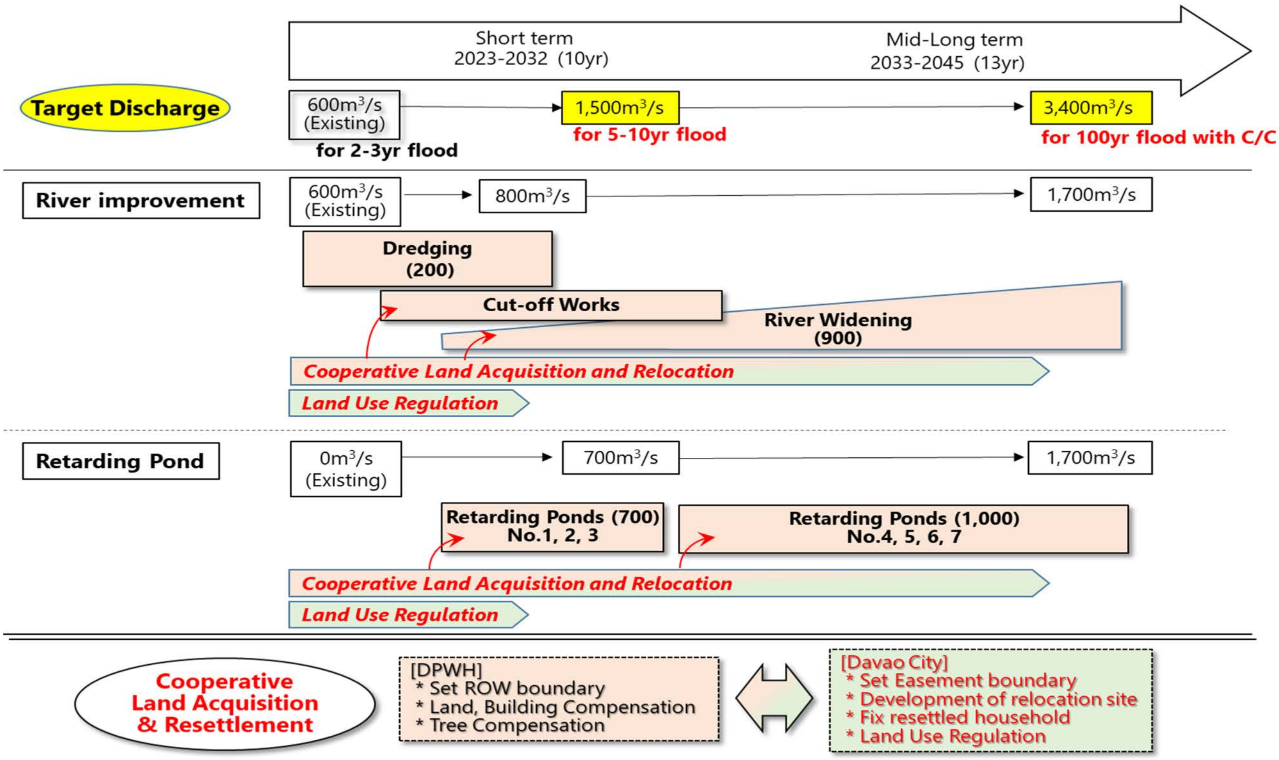
Source: Project Team

Figure 3.4.31 Proposals for Promoting Resettlement

If these measures allow for a smooth relocation, it is desirable to implement all the flood control measures as early as possible for rapid production of effect.

The implementation schedule is shown in Figure 3.4.32, as the short-term project, improvement of riverbeds (river dredging) and development of retarding ponds will be carried out while implementing measures related to resettlement such as the creation of resettlement sites by the cut-off works, and all related measures such as widening and the remaining retarding ponds projects will be implemented within the period of the master plan. The facility layout is the same as Figure 3.4.26.

If construction works can be carried out in the process shown in Figure 3.4.32, it will be possible to create a safe city that can cope with 100-year flood within the M/P stage. In this case, the target of F/P can be achieved within the target period of the M/P, that is, the M/P and the F/P will be the same.



Source: Project Team

Figure 3.4.32 Implementation Schedule of Alt.3 in case of Early-Stage Implementation of River Widening Works

3.4.2 Examination of Master Plan

Based on the examination in Section 3.4.1, structural measures for riverine flood control M/P in the Davao River will be a combination of widening (including dredging and cut-off works prior to widening) and retarding ponds, as shown in Table 3.4.13.

Table 3.4.13 Riverine Flood Control Master Plan in Davao River (Structural Measures)

	Short-Term Measures	Mid-Long Term Measures
Implementation Period (Target Year)	2023-2032 (2032)	2033-2045 (2045)
Design Level	5-10 year scale flood	100 year scale flood
Design Flood Discharge	1,500m^3/s	3,400m^3/s
Target Area	From river mouth to 23km	ditto
Measures	・Dredging (from river mouth to 23km ・Cut-off works ・Installation of retarding ponds	・River widening (from Bolton bridge to 14km) ・Installation of retarding ponds
Project Cost (Financial Cost)	11.58 billion Php	37.15 billion Php (including short-term measures)
Project Cost (Economic Cost)	10.54 billion Php	33.90 billion Php (including short-term measures)
Economic Evaluation (EIRR)	18.54%	15.55% (including short-term measures)
Economic Evaluation (ENPV) (Discount rate: 10%)	18.40 billion Php	17.44 billion Php (including short-term measures)
Economic Evaluation (B/C) (Discount rate: 10%)	2.042	1.509 (including short-term measures)

Source: Project Team

As described in Section 3.16, the short-term measures in Table 3.4.13 were selected as priority projects, and the detailed examination was conducted in the Stage 3: Feasibility study for Priority Projects mentioned in Chapter 4. As a result of the examination, the project cost and economic evaluation of the Short-Term Measures were reviewed, and the project cost and economic evaluation of the Mid-Long Term Measures were also reviewed with reference to the examination result of the Short-Term Measures. Table 3.4.14 shows the results of the review based on the examination of Stage 3.

Table 3.4.14 Riverine Flood Control Master Plan in Davao River (Structural Measures) (Revised)

	Short-Term Measures	Mid-Long Term Measures
Project Cost (Financial Cost)	21.60 billion Php	60.35 billion Php (including short-term measures)
Project Cost (Economic Cost)	20.24 billion Php	56.55 billion Php (including short-term measures)
Economic Evaluation (EIRR)	15.32 %	15.37 % (including short-term measures)
Economic Evaluation (ENPV) (Discount rate: 10%)	9.99 billion Php	12.98 billion Php (including short-term measures)
Economic Evaluation (B/C) (Discount rate: 10%)	1.895	1.728 (including short-term measures)

Source: Project Team

The details of the above measures in Table 3.4.14 are shown in Table 3.4.15.

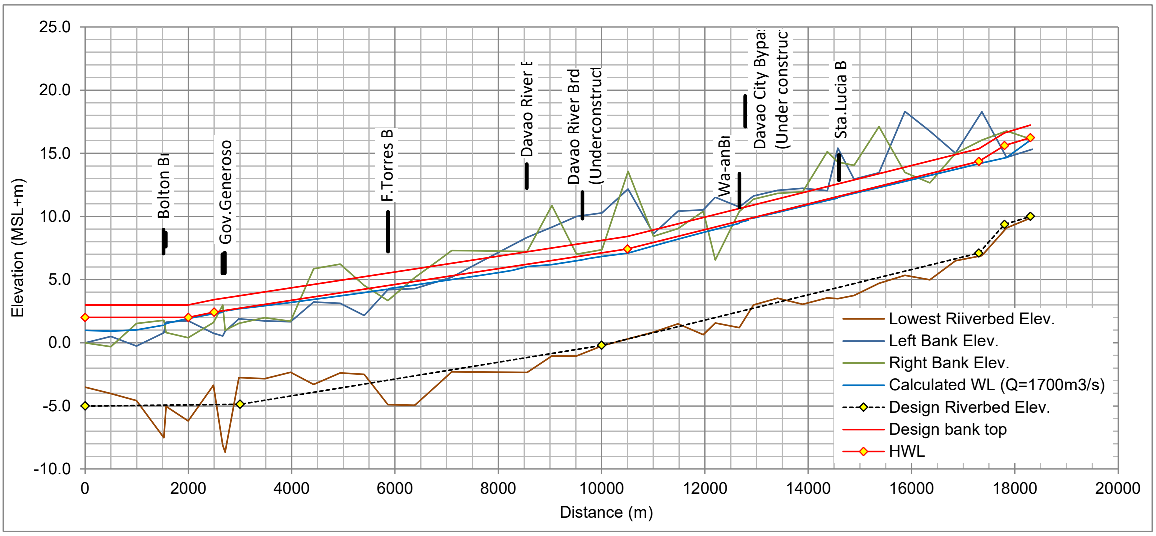
Table 3.4.15 Details of Structural Measures in Davao River

Item	Content
Short-Term Measures	
Dredging	Target Section: From river mouth to 23km Dredging Volume: 2 million m3
Cut-off works	Target Section: 6+500 – 12+700
Installation of Retarding Ponds	Number of Retarding Ponds to be Installed: 3 Location (Distance from river mouth & bankside): 29.0km (Right bank), 27.2km (Left bank), 23.8km (Left bank) Area: 200ha in total Excavation Volume: 28.2 million m3 in total
Mid-Long Term Measures	
River Widening	Target Section: From Bolton bridge to 14km Widening Width: Riverbed width 96.4m, Water depth about 7.2m, Width between top of riverbanks about 110.8m Shape of Cross Section: Inverted trapezoid with slope of 1:1 Excavation Volume: 5.6 million m^3 Number and Name of Bridges to be Replaced: 2 bridges (F. Torres bridge (6k), Davao river bridge (13.0k))
Installation of Retarding Ponds	Number of Retarding Ponds to be Installed: 4 Location (Distance from river mouth & bankside): 32.2km (Right bank), 31.0km (Left bank), 21.8km (Right bank), 20.2km (Right bank) Area: 397ha in total Excavation Volume: 66.7 million m3 in total

Source: Project Team

In order to facilitate the implementation of the proposed river widening works and installation of retarding ponds proposed in the M/P, it is expected that flood related ordinances and policies for the proposed measures shall be given emphasis by the Davao City as well as the proposed measures shall incorporate in the CLUP/CDP in order to avoid new construction of permanent building or newly development in the area.

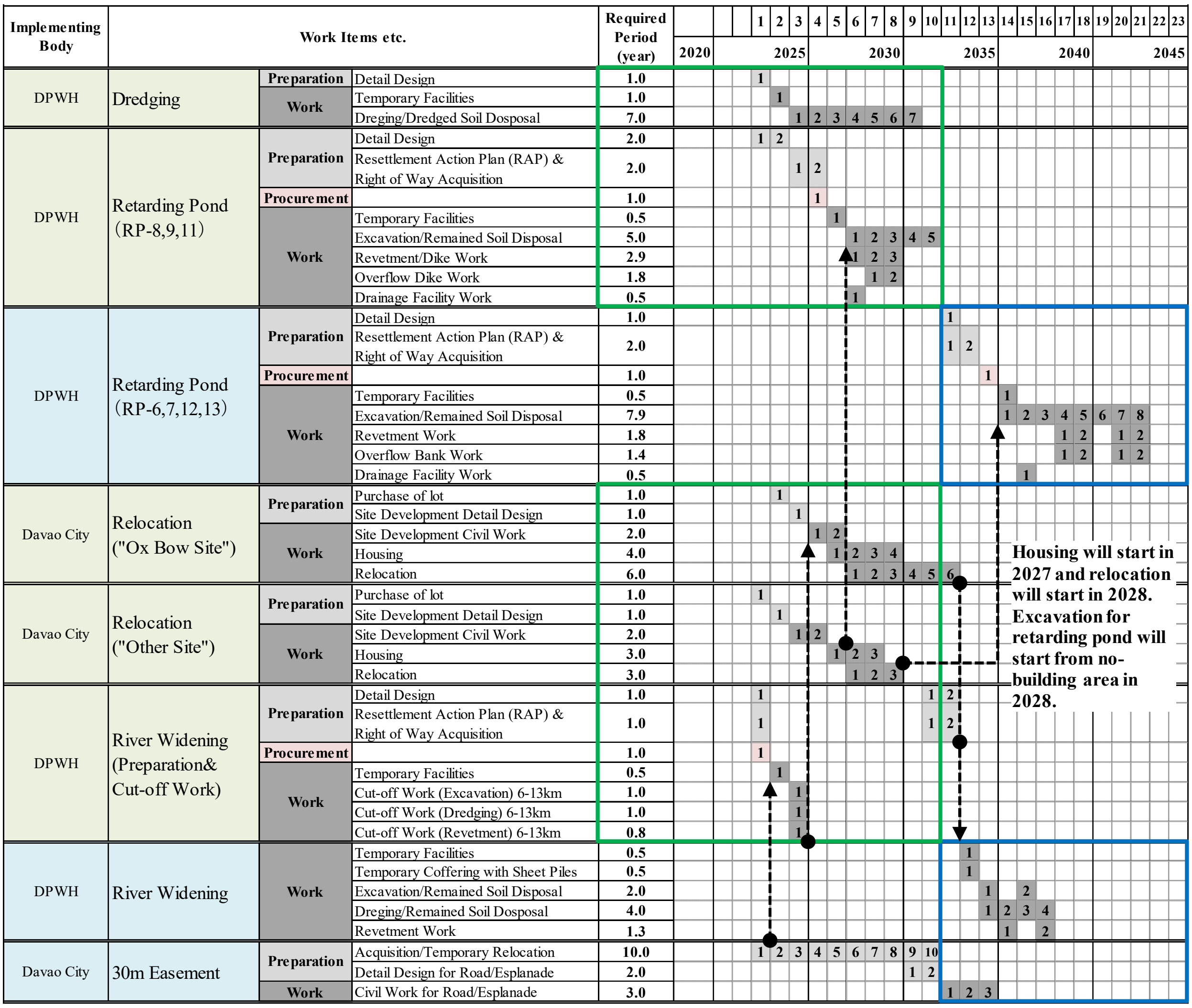
The design longitudinal profile of the Davao River (design riverbed elevation and HWL) is shown in Figure 3.4.33.



Source: Project Team

Figure 3.4.33 Longitudinal Profile of Davao River with Design Riverbed and HWL in M/P

Figure 3.4.34 shows the detailed implementation schedule for structural measures.



Source: Project Team

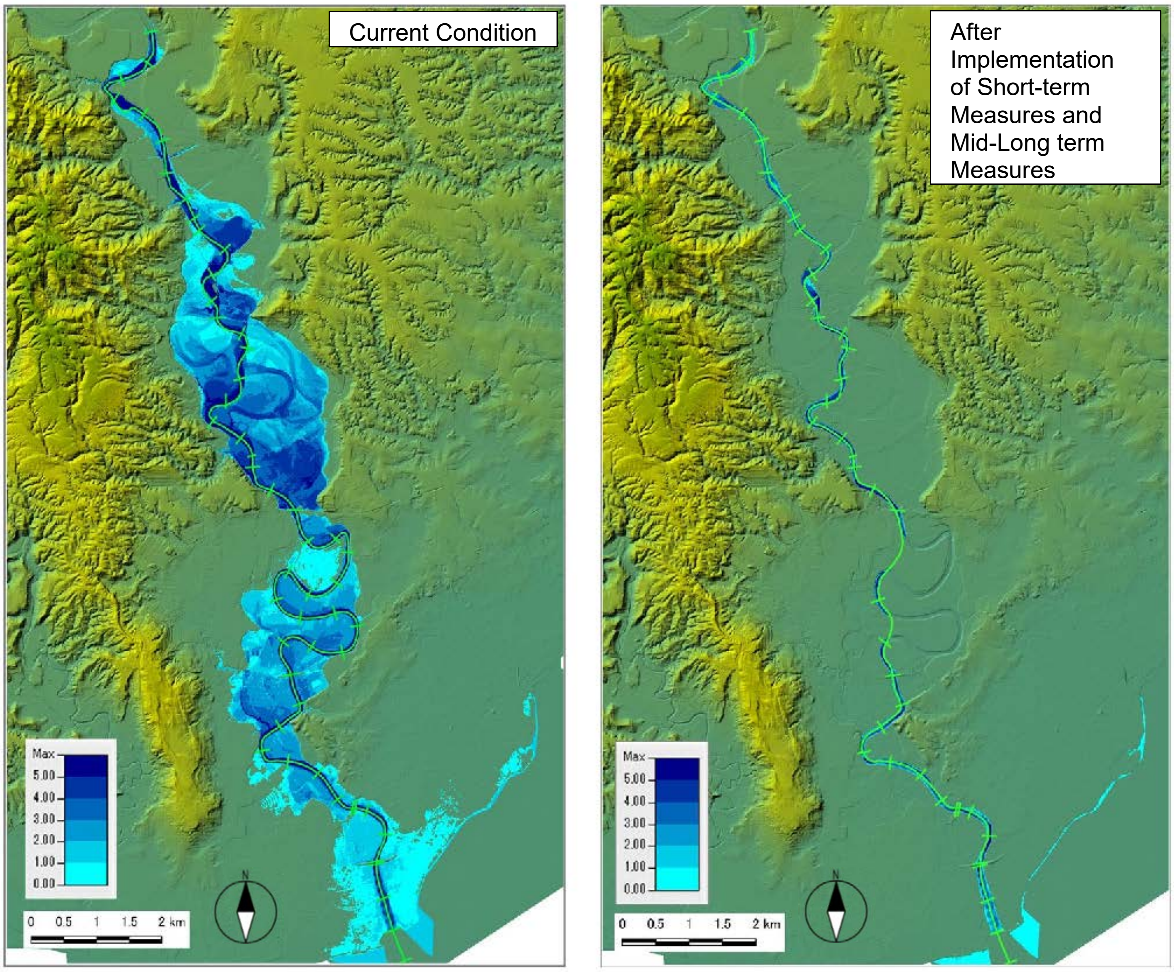
Figure 3.4.34 Detailed Implementation Schedule of M/P in Davao River

After the short-term measures and mid-long term measures shown in Table 3.4.13 are implemented, area to be protected in the Davao River can expect to become basically safe for 100 year scale flood as shown in Figure 3.4.35 and Table 3.4.16.

After only the short-term measures shown in Table 3.4.13 are implemented, area to be protected in the Davao River not only becomes basically safe for a flood discharge of 1,500 m^3/s (5-10 year scale flood), but also can expect a certain degree of damage reduction even in occurrence of higher scale floods.

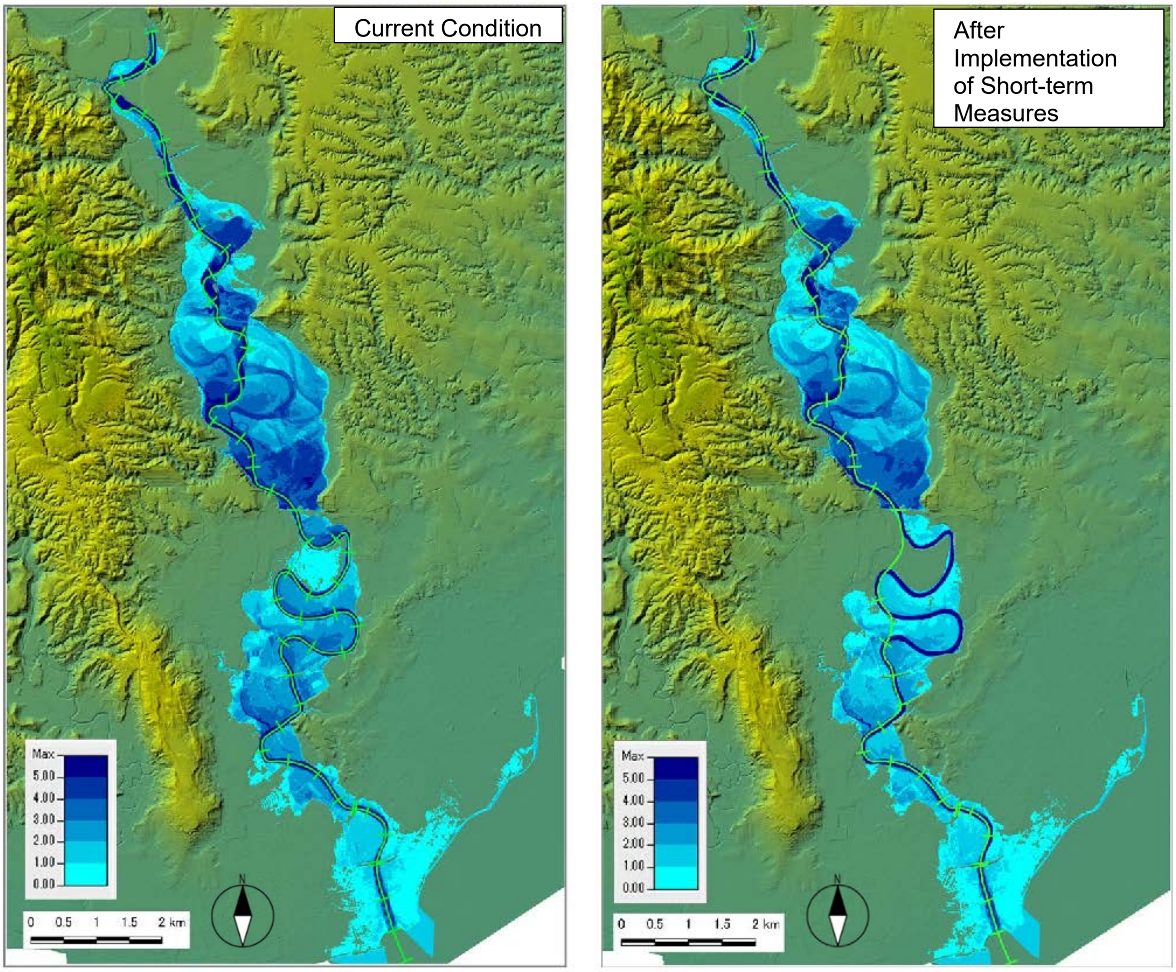
Figure 3.4.36 to Figure 3.4.39, Table 3.4.16, Figure 3.4.40 and Figure 3.4.41 show the inundation condition of the current condition and after implementation of short-term measures with various scale floods. Reduction of inundation area is more remarkable in case of the smaller scale floods such as the 10 year scale flood, whereas reduction of inundation area can be confirmed also in the case of 100 year scale flood.

It can be said that the areas where flooding has stopped after the implementation of the measures are where flood risk is greatly reduced. Although it is premised that the measures will be implemented, these areas can be prioritized from the viewpoint of flood risk when promoting regional development in the future. It is expected that the results of this study will be reflected and utilized in a development plan and a future plan in the Davao City.



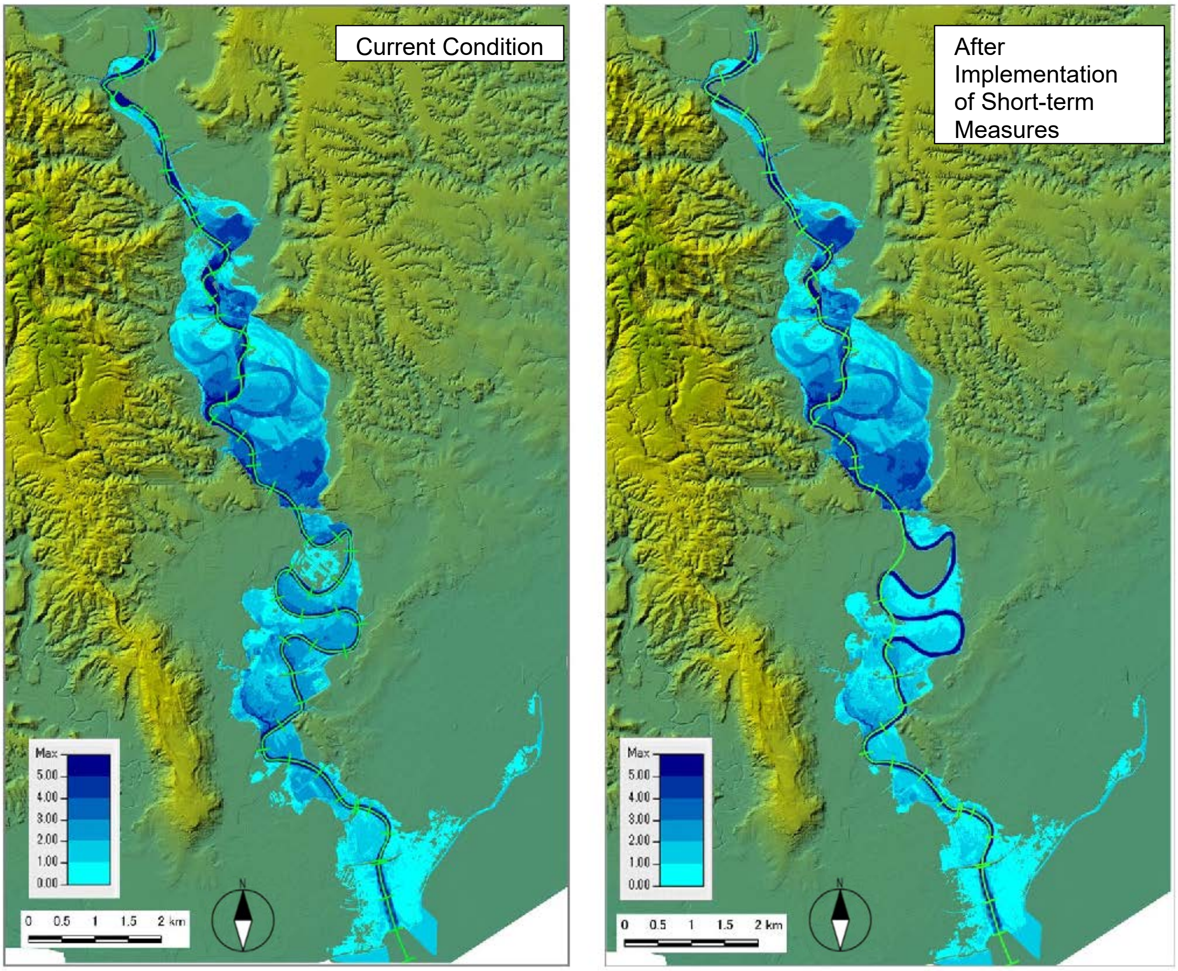
Source: Project Team

Figure 3.4.35 Comparison of Inundation Condition with 100 year Scale Flood between Current Condition and after Implementation of Short-Term Measures and Mid-Long Term Measures in Davao River



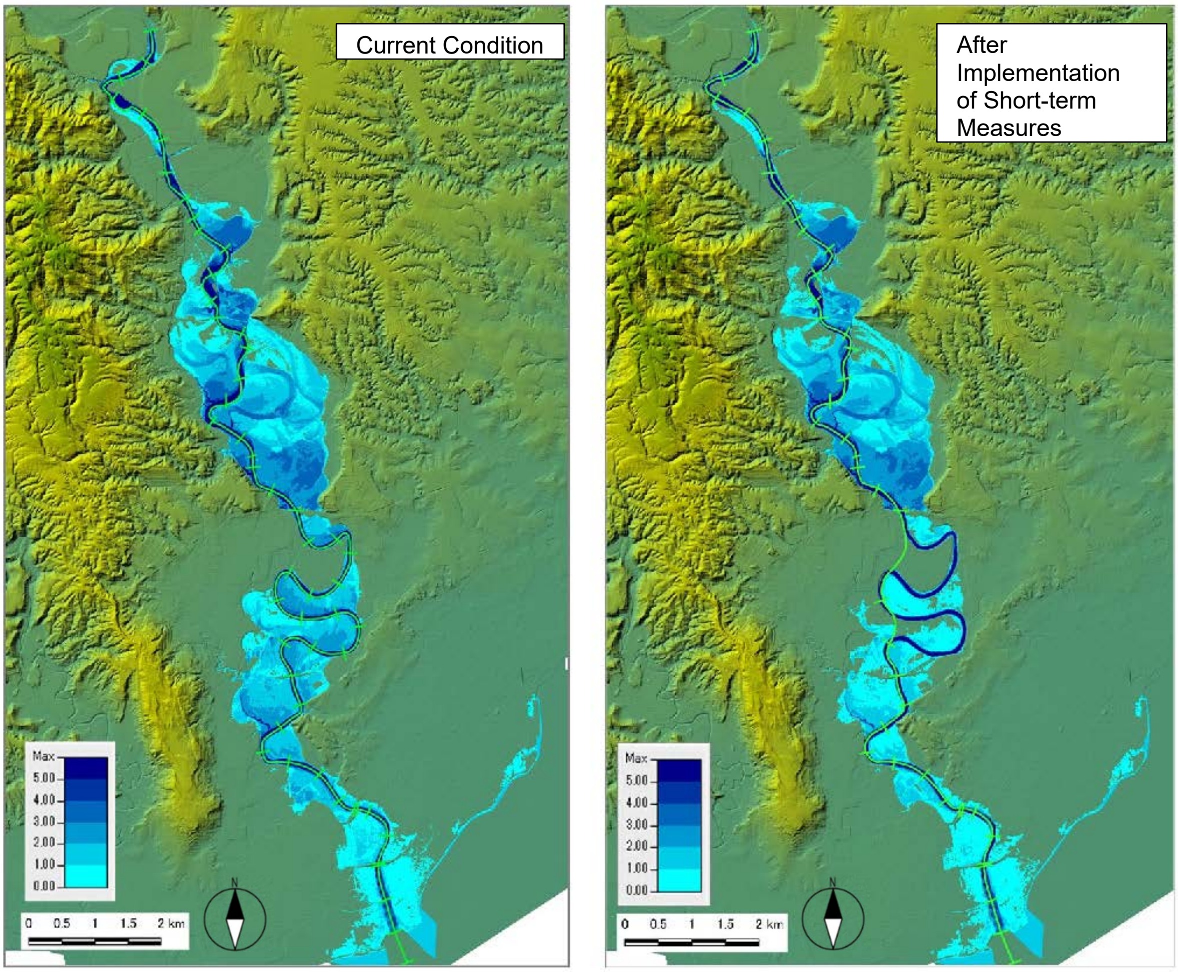
Source: Project Team

Figure 3.4.36 Comparison of Inundation Condition with 100 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Davao River



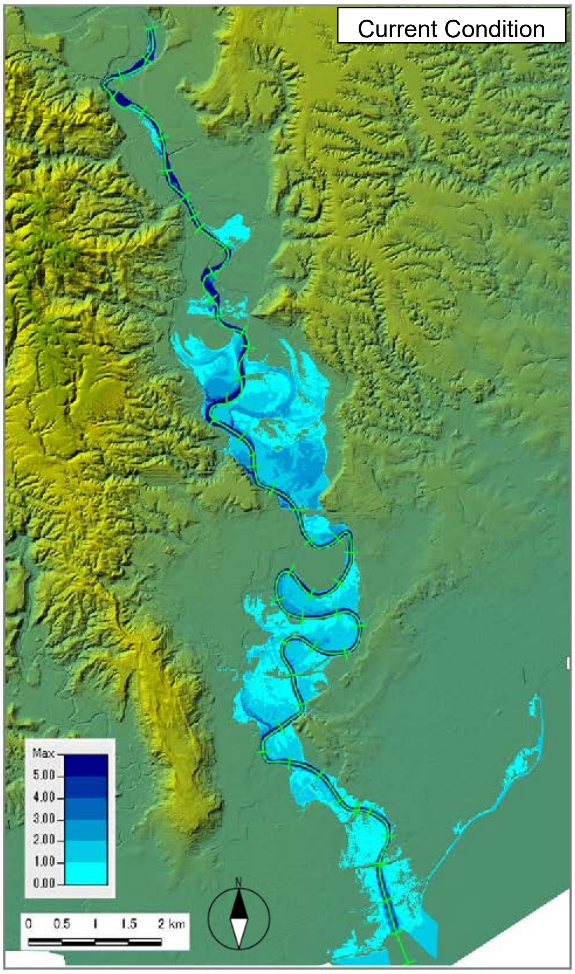
Source: Project Team

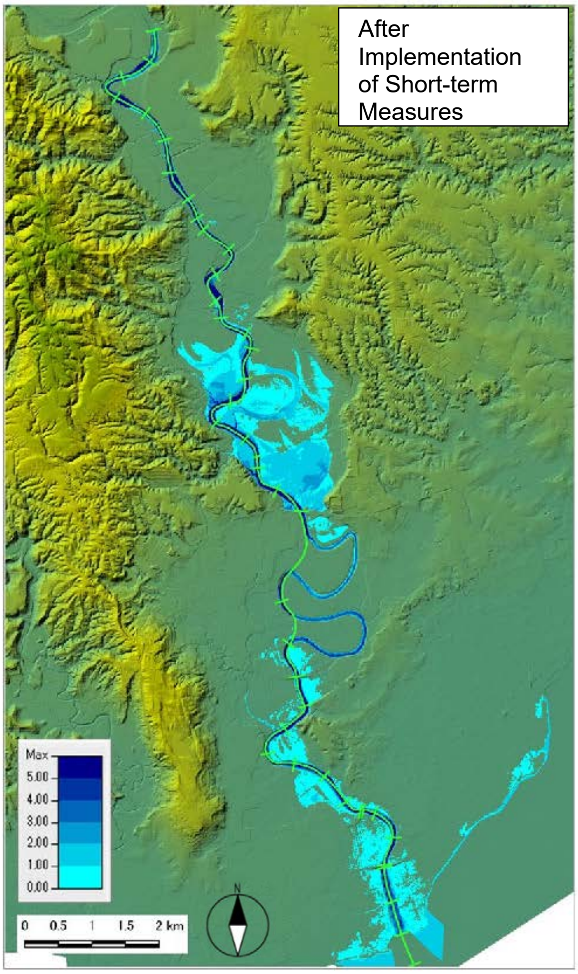
Figure 3.4.37 Comparison of Inundation Condition with 50 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Davao River



Source: Project Team

Figure 3.4.38 Comparison of Inundation Condition with 25 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Davao River





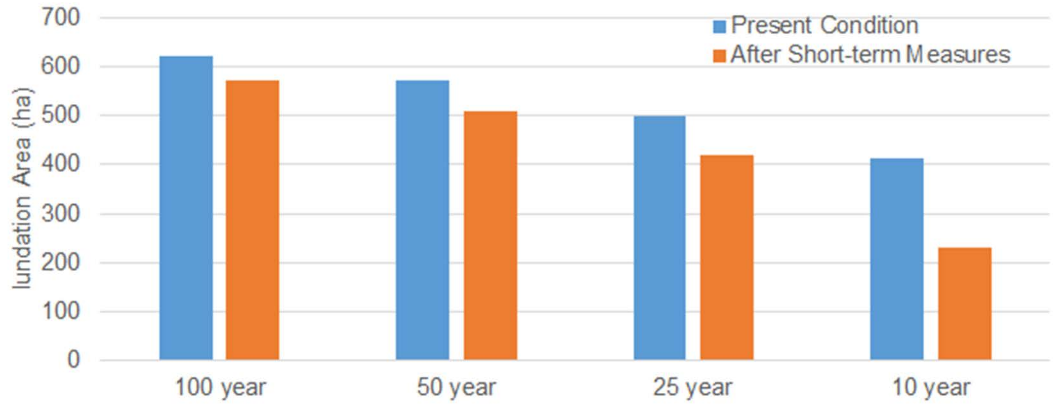
Source: Project Team

Figure 3.4.39 Comparison of Inundation Condition with 10 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Davao River

Table 3.4.16 Comparison of Inundation Condition between Current Condition and after Implementation of Short-Term Measures and Mid-Long Term Measures in Davao River (Inundation Area and Number of Inundated Buildings)

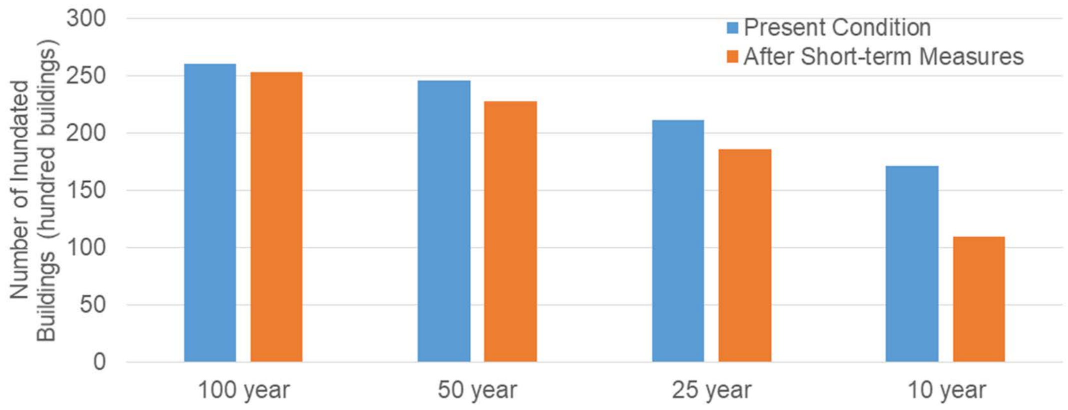
Flood scale	Inundation Area (ha) (more than 0.10m inundation depth)			Number of Inundated Buildings (hundred buildings) (more than 0.10m inundation depth)		
	Present Condition	After Short-term Measures	After Mid-Long term Measures	Present Condition	After Short-term Measures	After Mid-Long term Measures
100 year	624	571	0	260.6	253.3	0
50 year	573	508	0	246.0	228.1	0
25 year	500	418	0	211.5	186.3	0
10 year	413	232	0	171.0	109.4	0

Source: Project Team



Source: Project Team

Figure 3.4.40 Comparison of Inundation Condition between Current Condition and after Implementation of Short-Term Measures in Davao River (Inundation Area (ha) (more than 0.10m inundation depth))



Source: Project Team

Figure 3.4.41 Comparison of Inundation Condition between Current Condition and after Implementation of Short-Term Measures in Davao River (Number of Inundated Buildings (more than 0.10m inundation depth))

3.5 Structural Measures of Riverine Flood in Matina River

Examination of the structural measures for the Matina River will be implemented in the same manner as for the Davao River.

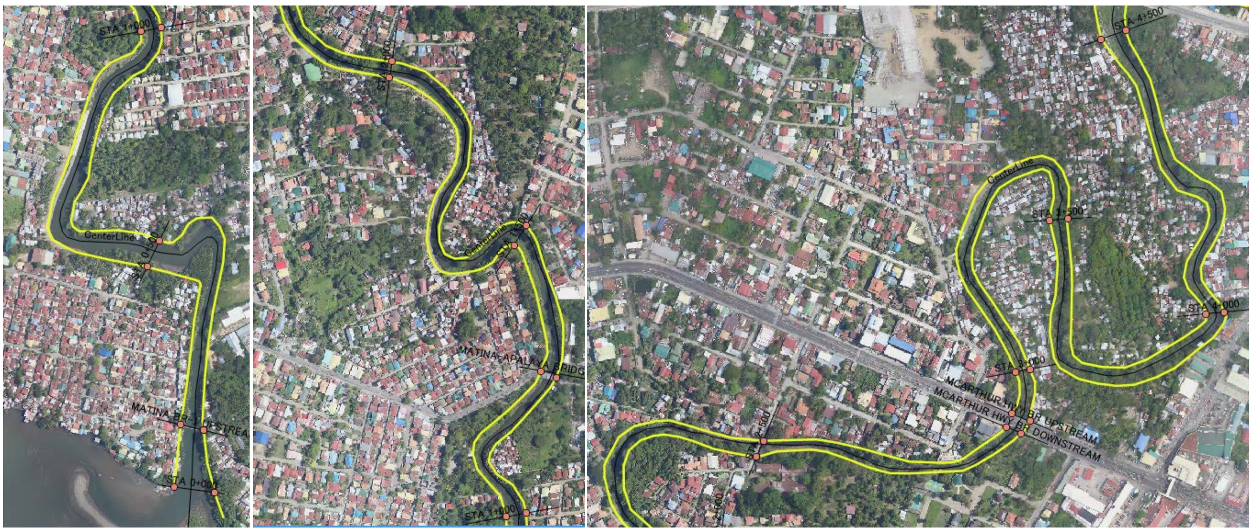
3.5.1 Examination of Alternatives of Structural Measures for Framework Plan in Matina River

(1) Examination of Individual Flood Control Measure

The examination of individual flood control measure of riverine flood in the Matina River focuses on four types of structural measures which are dike/flood wall, river channel improvement (widening), retarding pond and dam, excluding diversion channel (underground channel) which was obviously disadvantaged in terms of cost in consideration of the Davao River, targeting the 100-year flood. The details of each structural measures are described below.

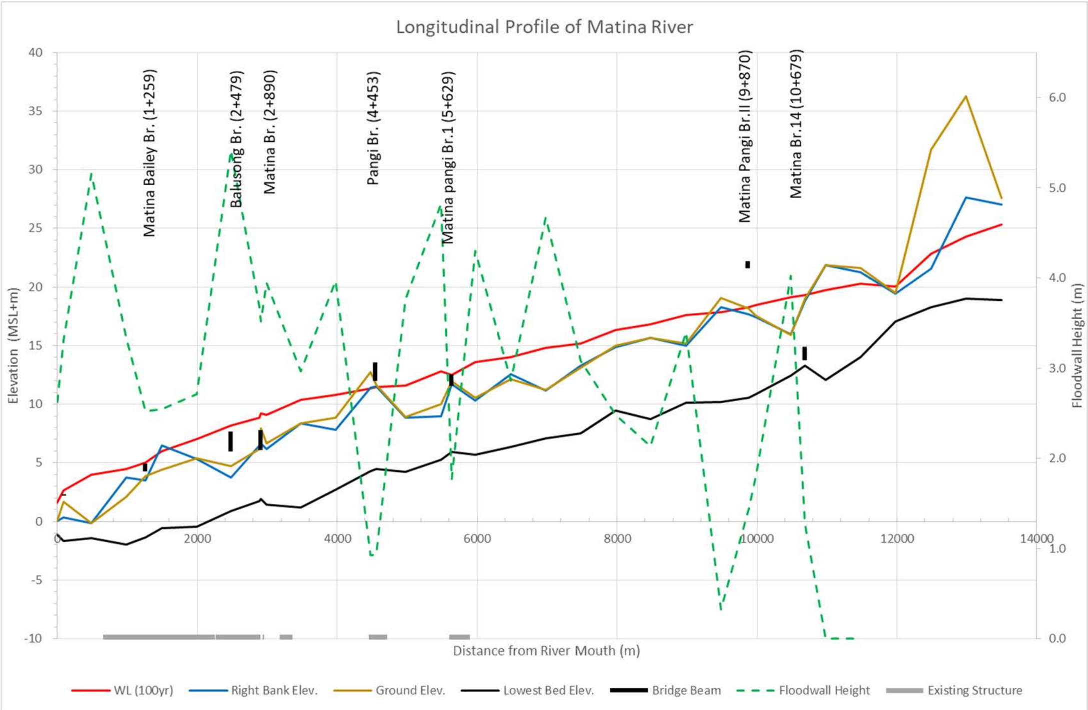
1) Dike / Flood wall

The alignment of newly proposed dike / flood wall was set on the current riverbank or behind the existing dike and/or revetment, and the necessary dike / flood wall height to be accommodated the design flood discharge amount with the river channel width between the dikes / flood walls was calculated by non-uniform flow calculation. Figure 3.5.1 shows an example of setting the alignment of dike / flood wall. Also, Figure 3.5.2 and Figure 3.5.3 show the water level and necessary dike / flood wall height for 100-year flood as a result of non-uniform flow calculation for each of the right and left banks. Figure 3.5.2 and Figure 3.5.3 show the present river bank elevation (dike elevation), the ground elevation, and the lowest riverbed elevation together. The necessary flood wall height including the free board (0.8 or 1.0 m) can be read from the axis on the right side of the figure. The necessary flood wall height is 2.6 m on average and 5.4 m at the maximum.



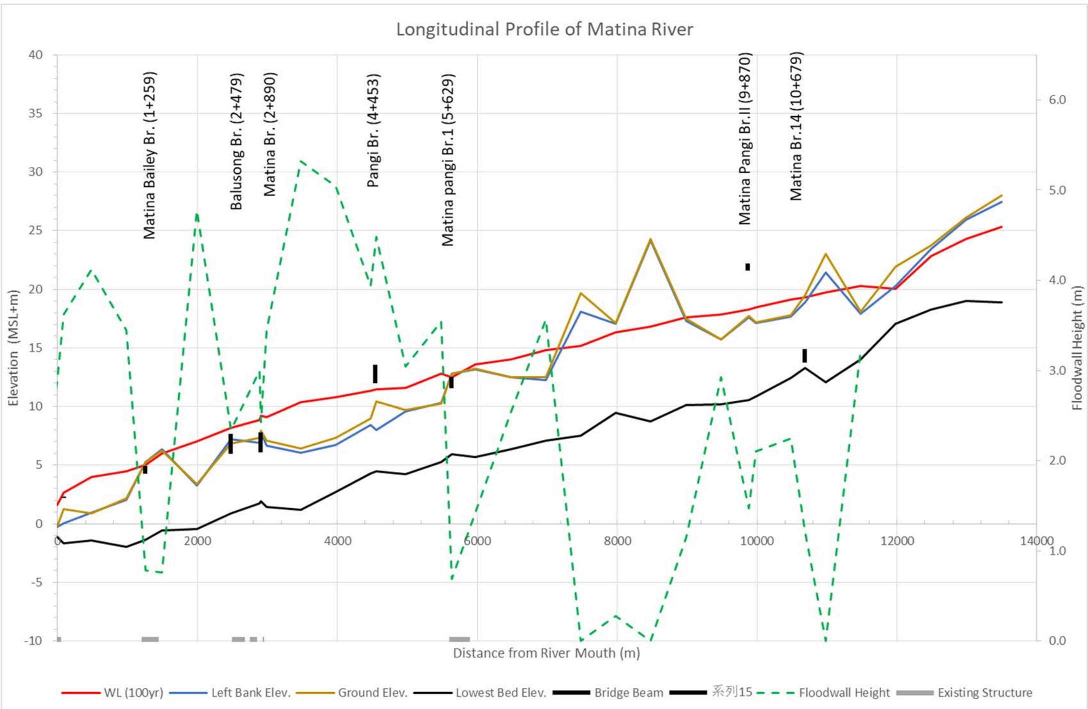
Source: Project Team

Figure 3.5.1 Example of Alignment of Dike in Matina River



Source: Project Team

Figure 3.5.2 Longitudinal Profile and Necessary Height of Dike / Flood wall in Matina River (Right bank)



Source: Project Team

Figure 3.5.3 Longitudinal Profile and Necessary Height of Dike / Flood wall in Matina River (Left bank)

In the examination of individual flood control measures, the required facility scale, available discharge amount, construction period, cost (direct construction cost, land acquisition cost, building compensation cost and bridge replacement cost (if necessary)), the number of affected buildings, period required for relocation (assuming that one year is required for every 100 affected buildings), and the disadvantages and restrictions, were confirmed. Table 3.5.1 summarizes the examination results for each item.

Table 3.5.1 Examination Result of Individual Implementation of Floodwall in Matina River

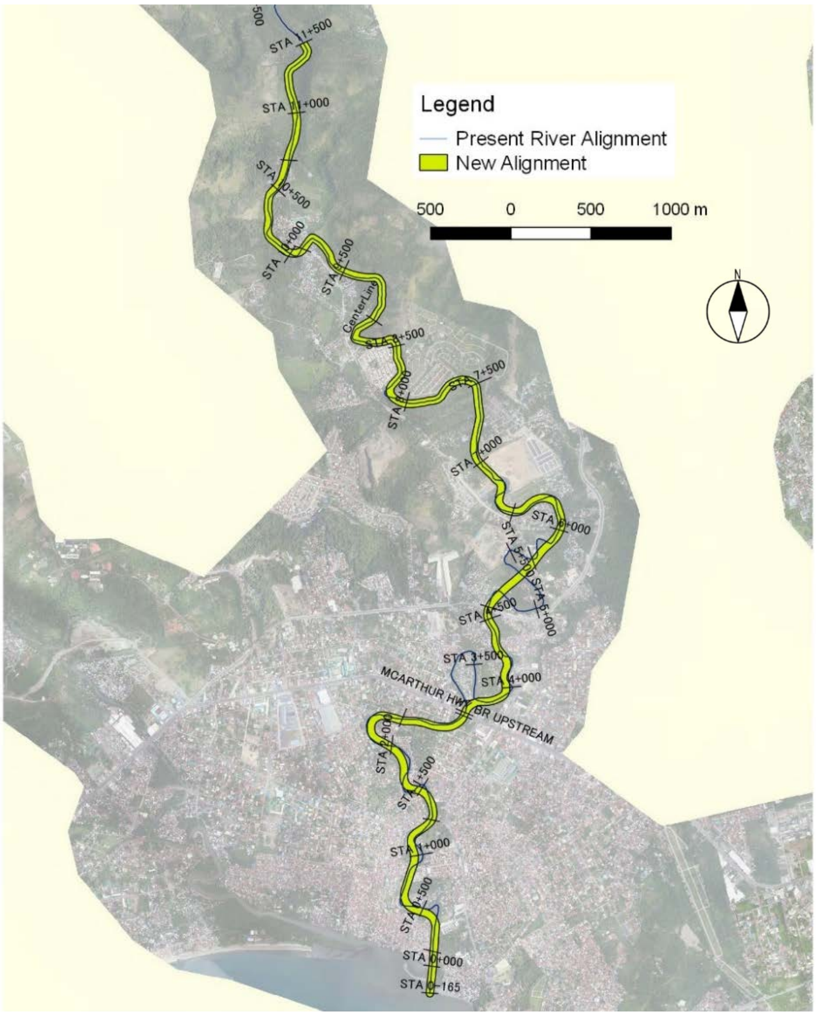
Outline of structure	- Concrete Wall + Pile Foundation - Average height: about 2.6m (with free board of 0.8m to 1.0m) - Maximum height: about 5.4m - Installed on both sides of the river from the river mouth to 11.5 km
Discharge amount to be accommodated	440 m^3/s at Matina Pangi Bridge II / 550 m^3/s at River mouth (100% of 100 year flood)
Construction period	Appox. 4 years
Direct construction cost + land acquisition cost + compensation cost for building + Bridge replacement	Appox. 5.9 billion Php
Number of affected buildings (Relocation required)	Appox. 670 buildings (Formal: 370, Informal: 300) (with 10m distance from proposed alignment)
Period required for relocation	Appox. 7 years
Disadvantages / restrictions	- Risk of housing collapse arises by break of dike with more than 2m height. - Existing 5 bridges replacement is necessary.

Source: Project Team

The structural type of the flood wall applied in the above examination is the same as the Davao River (see Table 3.4.3).

2) River Improvement (Widening)

In the examination of the proposed river widening, the river alignment was reviewed considering the cut-off works (see Figure 3.5.4), and the required widening width was confirmed for flowing the design flood discharge in the reviewed river alignment. Section for cut-off works was set considering present land use and number of affected buildings and with aims of 1) smooth runoff of flood discharge, 2) reduction of points of river bank erosion and scoring, and 3) shortening of length of river improvement and operation and maintenance. As a condition for the hydraulic analysis, the widened cross section will be a single cross section with slope of 1: 1, and the free board is set in the prescribed height (0.8m to 1m) according to the discharge amount. The shape of cross section in the downstream required for 100-year flood is an inverted trapezoidal with a riverbed width of 35.8m, a height of 5.5m and a width between the top of slope on both banks of 46.8m. And the shape of cross section in the upstream for 100-year flood is the same as the upstream, but a width between the top of slope on both banks is about 7m narrower than the downstream. Table 3.5.2 shows the results of the examination.



Source: Project Team

Figure 3.5.4 Comparison of Present River Alignment and Proposed River Alignment in Matina River

Table 3.5.2 Examination Result of Individual Implementation of Widening in Matina River

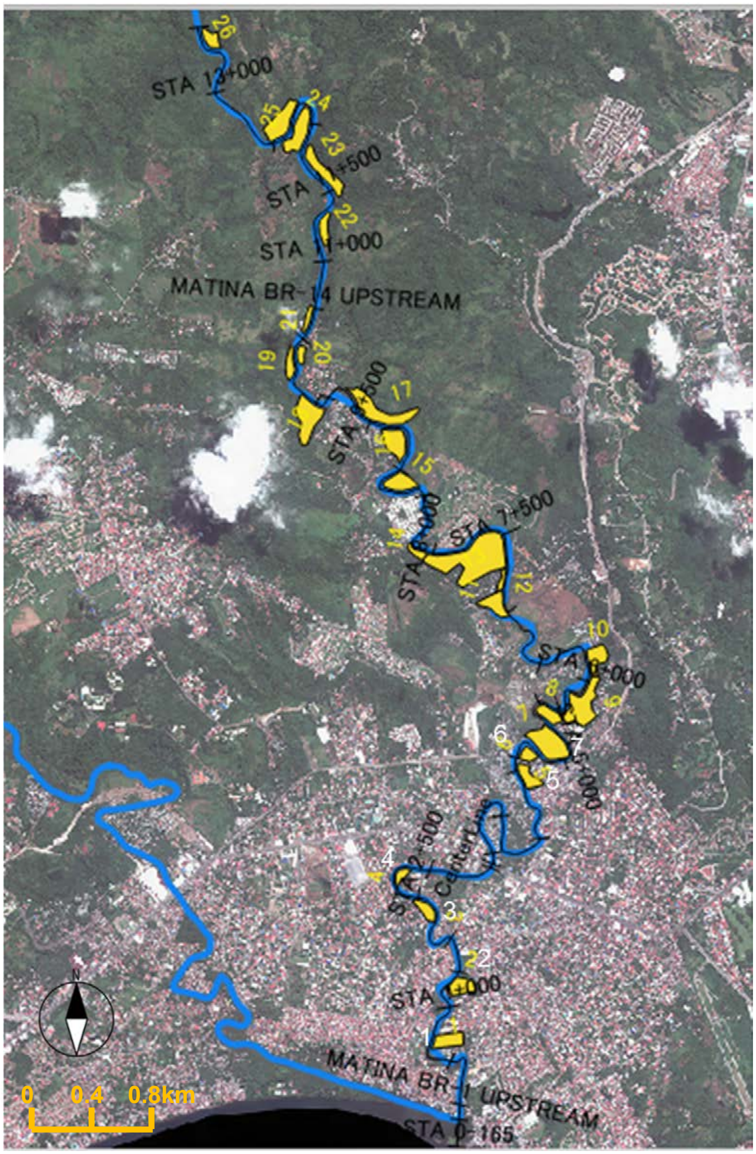
Outline of structure	Widening channel width from about 33m to about 47m in average (about 14m widening)
Discharge amount to be accommodated	440 m^3/s at Matina Pangi Bridge II / 550 m^3/s at River mouth (100% of 100 year flood)
Construction period	Appox. 5 years
Direct construction cost + land acquisition cost + compensation cost for building + Bridge replacement	Appox. 2.3 billion Php
Number of affected buildings (Relocation required)	Appox. 340 buildings (Formal: 170, Informal: 170)
Period required for relocation	Appox. 4 years
Disadvantages / restrictions	− Existing 6 Bridges replacement (lengthening) is necessary. − Cost for re-development of affected area (urbanized area) is required.

Source: Project Team

The structural type of the widening applied in the above examination is the same as the Davao River (see Figure 3.4.6).

3) Retarding Pond

In the examination of the proposed retarding pond, sites that could be used as retarding ponds were selected in the section from the river mouth to 14km upstream using the topographical and present land use data. The location and list of the selected candidate sites are shown in Figure 3.5.5 and Table 3.5.3, respectively.



Source: Project Team

Figure 3.5.5 Candidate Sites for Retarding Ponds in Matina River

Table 3.5.3 List of Candidate Sites for Retarding Ponds in Matina River

No.	Distance from River Mouth		Area	Capacity	No.	Distance from River Mouth		Area	Capacity	No.	Distance from River Mouth		Area	Capacity
	*(km)	Side	(km²)	(MCM)		*(km)	Side	(km²)	(MCM)		*(km)	Side	(km²)	(MCM)
1	0.7	Left bank	0.02	0.05	10	6.0	Left bank	0.02	0.08	19	10.2	Right bank	0.01	0.04
2	1.2	Left bank	0.01	0.07	11	7.0	Right bank	0.02	0.08	20	10.3	Left bank	0.01	0.03
3	1.8	Right bank	0.01	0.05	12	7.1	Right bank	0.00	0.02	21	10.5	Right bank	0.01	0.03
4	2.2	Left bank	0.01	0.02	13	7.8	Right bank	0.08	0.42	22	11.1	Left bank	0.01	0.05
5	4.4	Left bank	0.01	0.06	14	8.0	Right bank	0.01	0.03	23	11.4	Left bank	0.02	0.11
6	4.6	Left bank	0.01	0.03	15	8.5	Left bank	0.02	0.08	24	11.8	Right bank	0.02	0.12
7	4.7	Right bank	0.03	0.17	16	9.0	Right bank	0.02	0.10	25	12.2	Left bank	0.03	0.10
8	5.3	Left bank	0.01	0.05	17	9.8	Left bank	0.03	0.17	26	13.3	Left bank	0.01	0.05
9	5.6	Left bank	0.04	0.18	18	9.9	Right bank	0.03	0.15	Total			0.48	2.33

Source: Project Team

As an initial examination, the capacity that can be allocated in the retarding ponds was calculated by assuming that a 5m deep retarding pond would be developed at each candidate site (except, No. 1 was set to 3 m, and No. 4, 12, and 25 were set to 4 m due to topographical restrictions). The discharge amount that can be accommodated by the developed retarding ponds was calculated on the assumption that all the candidate sites would be developed for retarding ponds. Table 3.5.4 shows the results of the examination on the proposed retarding ponds. In case the current discharge amount in the target area of the Matina River to be protected by structural measures is 150m3/s, the individual measure by retarding ponds will not be able to cope with the 100-year flood even if all the candidate sites of retarding pond can be developed.

Table 3.5.4 Examination Result of Individual Implementation of Retarding Pond in Matina River

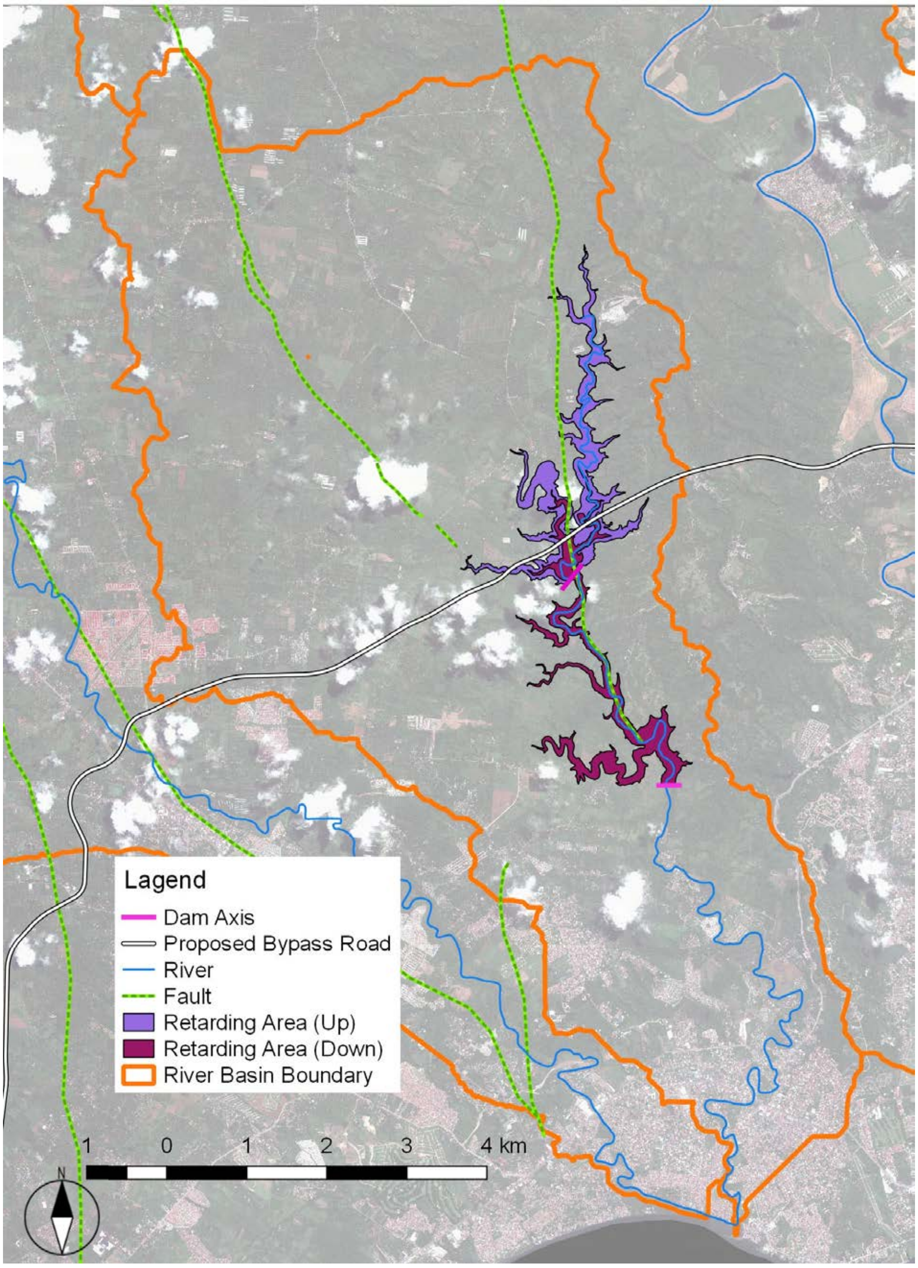
Outline of structure	Total area : 0.48 km² Gross Capacity: 2.33 million m³ (assumed average water depth of retarding pond is 5 m)
Discharge amount to be accommodated	Approx. 280m³/s (70% of remaining flood discharge (400 m³/s) of 100 year flood of 550 m³/s at River Mouth) in case that estimated present river capacity of protected area is 150m³/s
Construction period	Appox. 4 year
Direct construction cost + land acquisition cost + compensation cost for building	Appox. 0.7 billion Php
Number of affected buildings (Relocation required)	Appox. 83 buildings
Period required for relocation	Appox. 1 years
Disadvantages / restrictions	

Source: Project Team

The structural type of the retarding ponds applied in the above examination is the same as the Davao River (see Figure 3.4.8).

4) Dam

In the examination of the proposed dam, the candidate sites were selected by analyzing the topographic data, the existing/planned infrastructure information and fault information. For the Matina River, two candidate sites were selected using the topographic data as shown in Figure 3.5.6, but the candidate site on the upstream was excluded because it is assumed that the ponding area will include the alignment of the planned bypass road and the depth of inundation affects the road structure, and that a fault passes through the dam structure. Therefore, the candidate site on the downstream was examined.



Source: Project Team

Figure 3.5.6 Candidate Sites for Dam in Matina River

The dam site is located 11 km from the river mouth, and the assumed dam type is a fill dam.

The dam height is required to be 39 m to store the amount of the 100-year flood discharge, and the storage capacity including sedimentation capacity (sedimentation capacity + flood control capacity) is 8.6 million m^3. Table 3.5.5 shows the results of the examination.

Table 3.5.5 Examination Result of Individual Implementation of Dam in Matina River

Outline of structure	Fill dam with 39m height (detention capacity is 8.6 million m^3)
Discharge amount to be accommodated	Approx. 360 m^3/s (97% of flood discharge of 100 year flood of 370m^3/s at dam site)
Construction period	Appox. 10 years
Direct construction cost + land acquisition cost + compensation cost for building	Appox. 4.7 billion Php
Number of affected buildings (Relocation required)	Appox. 3 buildings
Period required for relocation	Appox. 1 years
Disadvantages / restrictions	Fault is located at about 600m away from dam axis. Alignment of planned bypass road crosses dam reservoir area but bridges and road will not be submerged.

Source: Project Team

The structural type of the dam applied in the above examination is the same as the Davao River (see Figure 3.4.11).

5) Examination Result of Individual Flood Control Measure

The results of the examination in case of implementation of four types of individual structural measures were summarized as shown in Table 3.5.6, focusing on the structural scale, cost, and number of affected buildings that can be dealt with individually.

Table 3.5.6 Examination Results of Individual Implementation in Matina River

No.	Measure (Number of Bridge Replacement)	Cost * (Billion Php)	Affected buildings (Number)
S1	Dike / Flood wall (All of 550m^3/s of 100 year flood discharge at River Mouth) (5 bridges, heightening)	5.9	670
S2	River improvement (Widening & Cut-off works) (All of 550m^3/s of 100 year flood discharge at River Mouth) (6 bridges, lengthening)	2.3	340
S3	Retarding Pond (430 m^3/s = 150m^3/s (present river capacity) + 280 m^3/s (Retarding Pond)) (No bridge replacement)	0.7	83
S4	Dam (510 m^3/s = 150m^3/s (present river capacity) + 360 m^3/s (Dam)) (No bridge replacement)	4.7	3

Source: Project Team

Challenges and evaluations for the individual flood control measures are summarized as follows.

- Dike / Flood wall:
  The cost is the largest among the four measures, and the number of affected buildings is also the largest.
- Widening:
  The number of affected buildings is more than half of the dike / flood wall, and the cost is about one third of the dike / flood wall.
- Retarding pond:
  The individual measure could not cope with 100-year flood even if all candidate sites could be developed.

- Dam:
  The individual measure could not cope with 100-year flood. The cost is about twice as the widening.

Based on the above, there are restrictions and limitations in any of the individual measures, and a combination of measures is required as examined in the below.

(2) Examination of Combination of Flood Control Measure

1) Examination of Restriction of Each Structural Measure for Examination of Combination

In the examining of the optimal combination of structural measures, the individual measures were re-examined based on the examination in the previous section.

A. Retarding pond

The analysis of the number of affected buildings and the presence or absence of a development plan in each of the 26 candidate site for retarding pond along the Matina River was conducted.

Regarding the presence or absence of a development plan, it was confirmed whether the candidate sites are classified as a residential or commercial area by using the future land use plan of 2045 and the CLUP 2019-2028 (draft version) of Davao City. It can be seen that almost all of the candidate sites on the Matina River are planned as development areas. For selecting a specific development site for retarding pond, since there is no significant difference in conditions, priority will be given to places where the area is large and where one project can be expected to have a high effect, and the upstream area where the expected effect is as large as possible.

Table 3.5.7 Analysis of Candidate Sites for Retarding Ponds in Matina River

No.	Distance from River Mouth of Pond		Area	Capacity	Excavation Volume	Affected Buidings	Buiding Density	Area to be developed		Note
	*(km)	Side	(km^2)	(MCM)	(MCM)	(Number)	(Number /ha)	Land Use Plan in 2045 by IM4Davao	CLUP2019-28(draft)	
1	0.7	Left bank	0.015	0.05	0.05	4	2.7	Yes	Yes	
2	1.2	Left bank	0.014	0.07	0.08	1	0.7	Yes	Yes	
3	1.8	Right bank	0.010	0.05	0.05	7	7.3	Yes	Yes	
4	2.2	Left bank	0.005	0.02	0.02	0	0.0	Yes	Yes	
5	4.4	Left bank	0.012	0.06	0.06	3	2.4	Yes	Yes	
6	4.6	Left bank	0.007	0.03	0.03	0	0.0	Yes	Yes	
7	4.7	Right bank	0.033	0.17	0.17	45	13.5	Yes	Yes	
8	5.3	Left bank	0.011	0.05	0.07	6	5.5	Yes	Yes	
9	5.6	Left bank	0.036	0.18	0.22	7	1.9	Yes	Yes	
10	6.0	Left bank	0.016	0.08	0.17	0	0.0	Yes	Yes	
11	7.0	Right bank	0.016	0.08	0.09	0	0.0	Yes	Yes	
12	7.1	Right bank	0.004	0.02	0.02	0	0.0	Yes	Yes	
13	7.8	Right bank	0.085	0.42	0.54	3	0.4	Yes	Yes	
14	8.0	Right bank	0.005	0.03	0.03	0	0.0	Yes	Yes	
15	8.5	Left bank	0.016	0.08	0.12	0	0.0	Yes	Yes	
16	9.0	Right bank	0.020	0.10	0.15	5	2.5	Yes	Yes	
17	9.8	Left bank	0.035	0.17	0.22	0	0.0	Yes	Yes	
18	9.9	Right bank	0.030	0.15	0.28	1	0.3	Yes	Yes	
19	10.2	Right bank	0.008	0.04	0.05	0	0.0	Yes	Yes	
20	10.3	Left bank	0.005	0.03	0.03	0	0.0	Yes	Yes	
21	10.5	Right bank	0.005	0.03	0.03	0	0.0	Yes	Yes	
22	11.1	Left bank	0.009	0.05	0.10	0	0.0	Yes	No	
23	11.4	Left bank	0.022	0.11	0.18	1	0.5	Yes	Yes	
24	11.8	Right bank	0.024	0.12	0.18	0	0.0	No	Yes	
25	12.2	Left bank	0.026	0.10	0.13	0	0.0	Yes	Yes	
26	13.3	Left bank	0.009	0.05	0.07	0	0.0	Yes	Yes	
Total			0.28	1.38	1.71	76	-	-	-	-

Source: Project Team

B. Dam

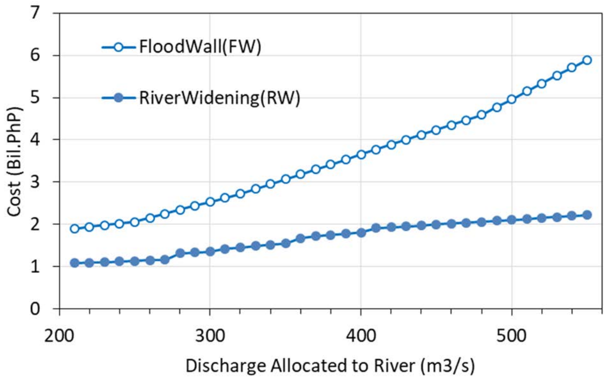
Through the examination of the impact on the natural and social environment at the dam site and ponding area, it was confirmed that restricted areas that could have serious social and environmental impacts are not included in the ponding area for the dam site in the Matina River basin.

2) General Examination of Tendency of Cost of Individual/Combined Implementation of Structural Measures

In the examination of the optimal combination of structural measures, the construction cost (direct construction cost, land acquisition cost, building compensation cost, bridge replacement cost (if necessary) was confirmed, and the tendency was analyzed.

A. Tendency of Measures for Increasing Flow Capacity of River Channel (Tendency for Flood wall and Widening)

Figure 3.5.7 shows the result of comparison of the construction cost by flood wall and river widening for each discharge scale indicated on the horizontal axis as "Discharge allocated to River". From this figure, it can be seen that the river widening is inexpensive about 1/3 to 1/2 in case the flood discharge is accommodated only by the river channel.

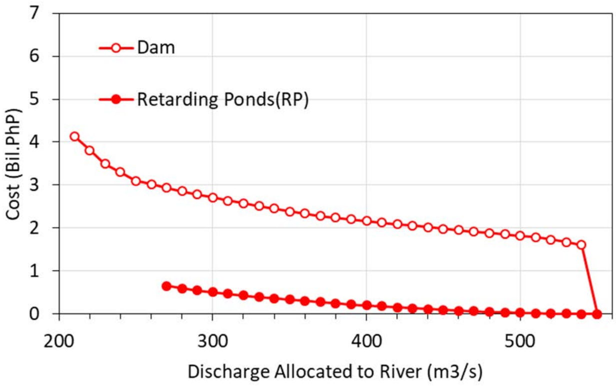


Source: Project Team

Figure 3.5.7 Comparison of Cost in case of Individual Implementation of Flood wall and River Widening with Various Scale in Matina River

B. Tendency of Measures for Flood Water Detention Facilities (Tendency of Retarding Pond and Dam)

Figure 3.5.8 shows the result of comparing the construction cost of the retarding ponds and dam with the scale of each discharge amount. Figure 3.5.8 shows the cost of implementing the measures to cope with the remaining discharge amount (residual amount for 550 m3/s) for each of the retarding ponds and dam while the river channel is able to accommodate discharge amount indicated on the horizontal axis. From this figure, it can be seen that retarding ponds are much inexpensive compared with dam as the detention facility.



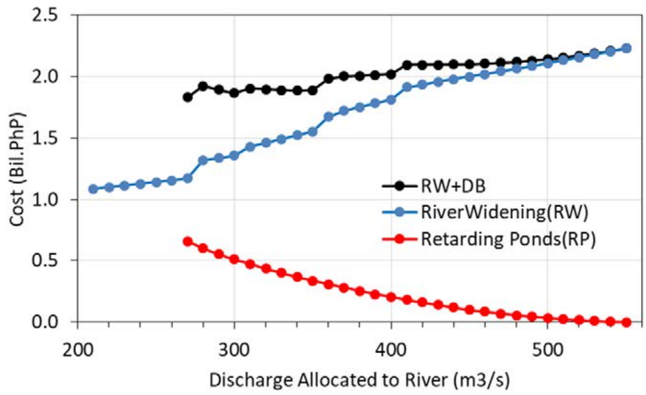
Source: Project Team

Figure 3.5.8 Comparison of Cost in case of Individual Implementation of Retarding Pond and Dam with Various Scale in Matina River

C. Tendency of Optimal Flood Discharge Distribution accommodated by River Channel and Flood Water Detention Facility

The optimal distribution of flood discharge by river channel and detention facilities was examined by combining the river widening which is lowest-cost measures among measures accommodated by river channel and the retarding ponds which are lowest-cost measures among detention facilities.

The black line in Figure 3.5.9 shows the cost in case of the combination of the river widening and the retarding ponds corresponding to the discharge amount of 550 m3/s. In case the discharge allocated by the river channel is about 270 to 350 m3/s, the total value is gently constant (almost flat).



Source: Project Team

Figure 3.5.9 Comparison of Cost in case of Combined Implementation of River Widening and Retarding Pond with Various Scale in Matina River

3) Concept of Combination of Structural Measures

In the examination of the Davao River, the combination of widening and retarding pond was the cheapest. In the unlikely event that large-scale floods occur continuously, it is more advantageous for river channels to have a large flow capacity. Furthermore, the risk (water level rise) at the time of flood occurrence including the worst case flood exceeding the target design level can be minimized, and the burden on operation and maintenance is reduced. Taking into account the above things, the combination of widening and retarding pond was recommended. All of the above conditions apply to the Matina River, so that the combination of widening and retarding pond is recommended for the structural measures in the Matina River.

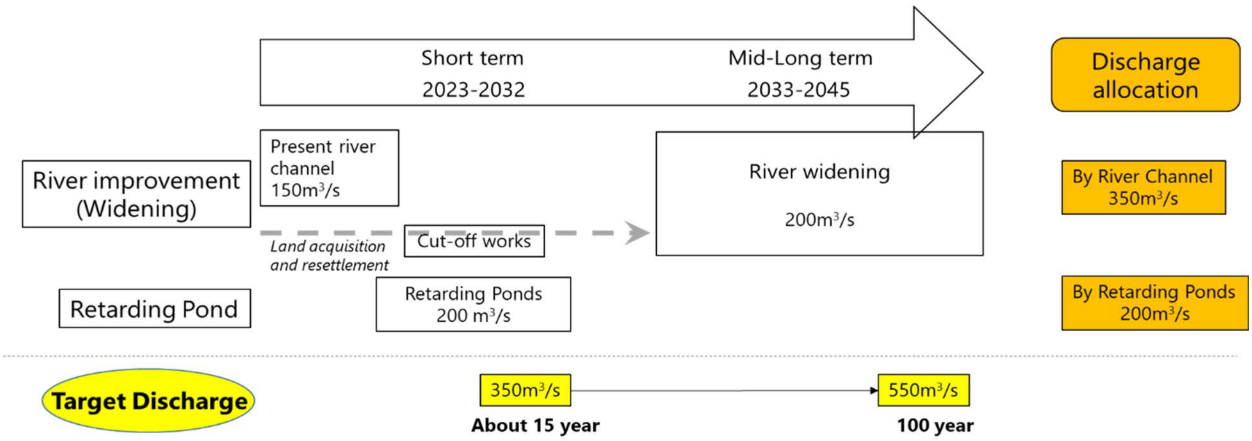
As described in the cost comparison in 2) above, in the combination of widening and retarding pond, it is advantageous to increase the flow capacity of the river channel to about 350 m3/s by widening, and to accommodate the rest at the retarding ponds.

Based on the scale of the required retarding ponds, the ease of inflow and outflow of the flood flow (long shape along the river channel), the inflow from the hinterland and tributaries, and the integration of the candidate retarding ponds, the optimal combination of widening and retarding ponds was examined. Table 3.5.8 shows the scale of the combination, cost and number of affected buildings. Figure 3.5.10 and Figure 3.5.11 show the implementation schedule and the facility plan. It will be possible to create a safe city that can cope with 100-year flood within the M/P stage by 2045. Therefore, the target of F/P can be achieved within the target period of the M/P, that is, the M/P and the F/P will be the same.

Table 3.5.8 Combination of Alternatives in Matina River

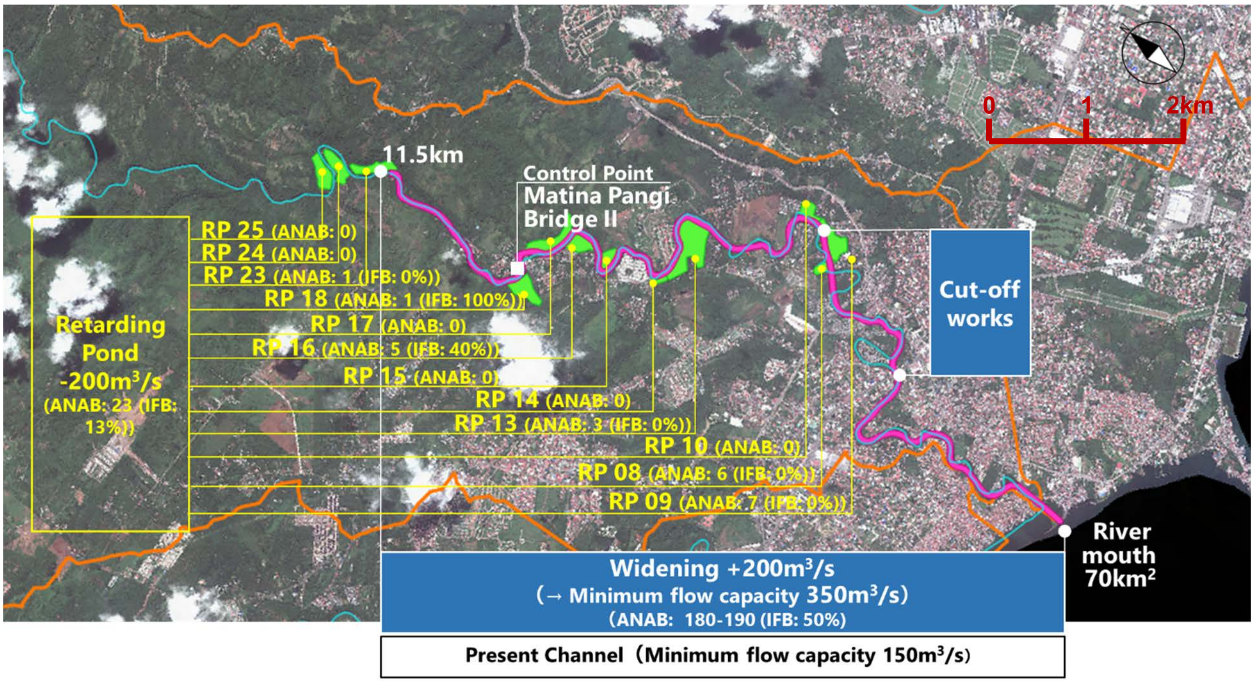
Combination of Structural Measures		Cost (Billion Php)	Affected buildings (Number)
Widening (Number of Bridge Replacement)	Retarding Pond		
$350 m^3/s$ = $150 m^3/s$ (present capacity) + $200 m^3/s$ (widening) (6 Bridges) (6m (3m each) widening in average)	$200 m^3/s$ (12 Regarding Ponds (No.8, 9, 10, 13, 14, 15, 16, 17, 18, 23, 24&25))	2.1 (1.6+0.5)	210

Source: Project Team



Source: Project Team

Figure 3.5.10 Preliminary Implementation Schedule in Matina River



Note: ANAB: Assumed Number of Affected Buildings, IFB: Informal Building
Source: Project Team

Figure 3.5.11 Facility Plan in Matina River

Regarding the river mouth, the structure of MSL+3.0m (design high tide level 1.53m + wave component about 1.0m + free board about 0.5m) as countermeasures against storm surge and waves (a flood wall along the river at the same height as the storm surge dike) is required.

This flood wall at the river mouth will be introduced in accordance with the widening work and will be installed on both banks for about 1 km from the river mouth. The cost is estimated at 0.4 Billion Php.

3.5.2 Examination of Master Plan

Based on the examination in Section 3.5.1, structural measures for riverine flood control M/P in the Matina River will be a combination of widening and retarding ponds, as shown in Figure 3.5.9.

Table 3.5.9 Riverine Flood Control Master Plan in Matina River (Structural Measures)

	Short-Term Measures	Mid-Long Term Measures
Implementation Period (Target Year)	2023-2032 (2032)	2033-2045 (2045)
Design Level	15 year scale flood	100 year scale flood
Design Flood Discharge	350m^3/s	550m^3/s
Target Area	From river mouth to 11.5km	ditto
Measures	・Cut-off works ・Installation of retarding ponds (Twelve locations)	・River widening (from river mouth to 11.5km) ・Flood wall at river mouth
Project Cost (Financial Cost)	1.26 billion Php	3.58 billion Php (including short-term measures)
Project Cost (Economic Cost)	1.15 billion Php	3.28 billion Php (including short-term measures)
Economic Evaluation (EIRR)	14.91%	11.06 % (including short-term measures)
Economic Evaluation (ENPV) (Discount rate: 10%)	2.35 billion Php	1.71 billion Php (including short-term measures)
Economic Evaluation (B/C) (Discount rate: 10%)	1.73	1.12 (including short-term measures)

Source: Project Team

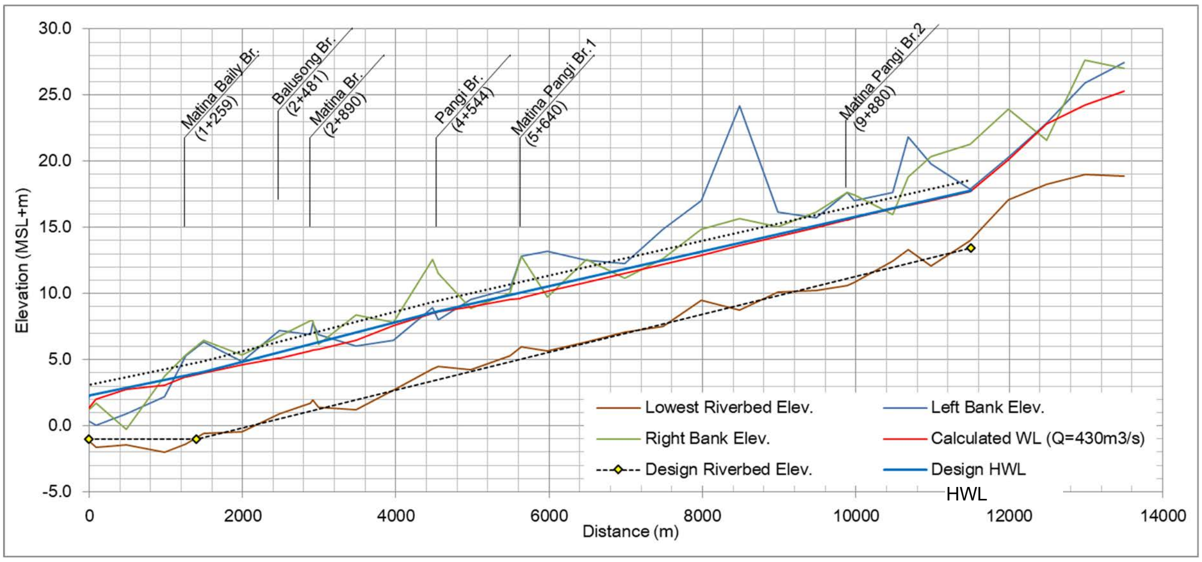
The details of the above measures are shown in Table 3.5.10.

Table 3.5.10 Details of Structural Measures in Matina River

Item	Content
Short-Term Measures	
Cut-off works	Target Section: 2+900 – 5+900
Installation of Retarding Ponds	Number of Retarding Ponds to be Installed: 12 Location (Distance from river mouth & bankside): 12.2km(Left bank), 11.8km (Right bank), 11.4km (Left bank), 9,9km (Right bank), 9.8km (Left bank), 9.0km (Right bank), 8.5km (Left bank), 8.0km (Right bank), 7.8km (Right bank), 6.0km (Left bank), 5.6km (Left bank), 5.3km (Left bank) Area：33ha in total Excavation Volume: 2.3 million m^3 in total
Mid-Long Term Measures	
River Widening	Target Section: From river mouth to 11.5km Widening Width: Riverbed width 22.8m, Water depth about 4.5m, Width between top of riverbanks about 33.4m Shape of Cross Section: Inverted trapezoid with slope of 1:1 Excavation Volume: 1.4 million m^3 Number and Name of Bridges to be Replaced: 3 bridges (Balusong Bridge (2.5k), Matina Br. (2.9k), Matina Pangi Br.2 (9.9k))
Installation of Flood Wall at river mouth	Target Distance: From river mouth to about 1.0km Height of Flood Wall: MSL+3.0m

Source: Project Team

The design longitudinal profile of the Matina River (design riverbed elevation and HWL) is shown in Figure 3.5.12.



Source: Project Team

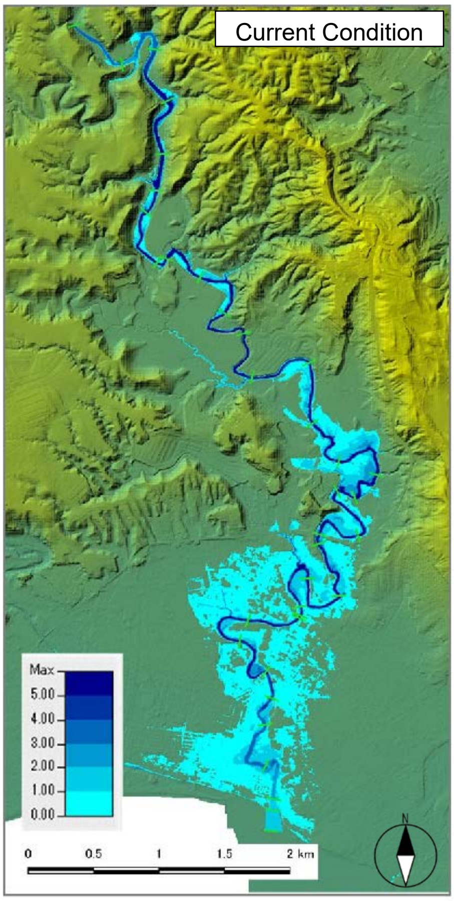
Figure 3.5.12 Longitudinal Profile of Matina River with Design Riverbed and HWL in M/P

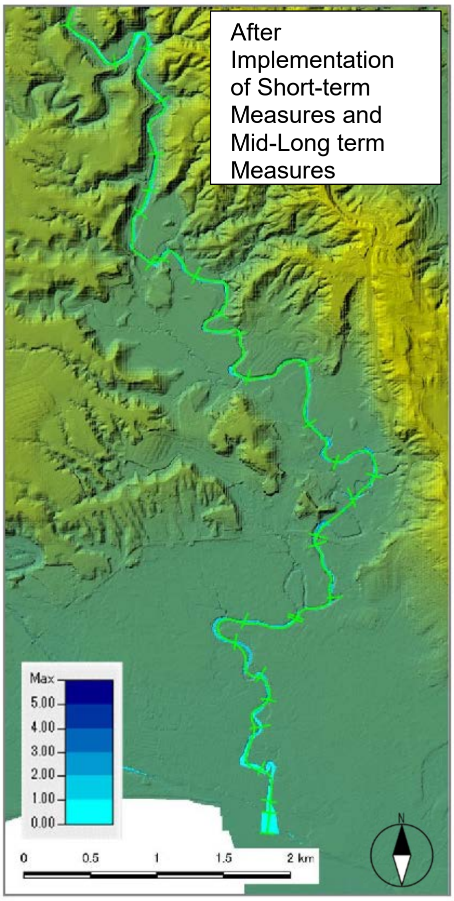
After the short-term measures and mid-long term measures shown in Figure 3.5.9 are implemented, area to be protected in the Matina River can expect to become basically safe for 100 year scale flood as shown in Figure 3.5.13 and Table 3.5.11.

After only the short-term measures shown in Figure 3.5.9 are implemented, area to be protected in the Matina River not only becomes basically safe for a flood discharge of 350 m3/s (about 15 year scale flood), but also can expect a certain degree of damage reduction even in occurrence of higher scale floods.

Figure 3.5.14 to Figure 3.5.16, Table 3.5.11, Figure 3.5.17 and Figure 3.5.18 show the inundation condition of the current condition and after implementation of short-term measures with various scale floods. Remarkable reduction of inundation area can be confirmed in all the cases.

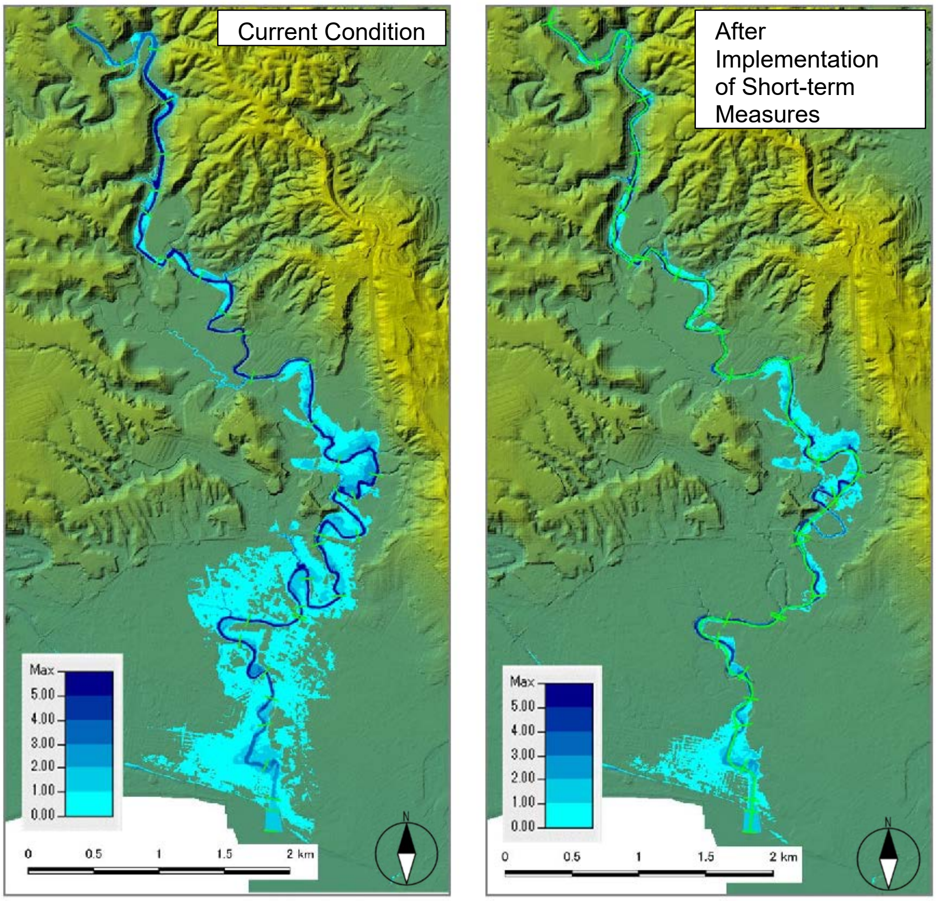
It can be said that the areas where flooding has stopped after the implementation of the measures are where flood risk is greatly reduced. Although it is premised that the measures will be implemented, these areas can be prioritized from the viewpoint of flood risk when promoting regional development in the future.





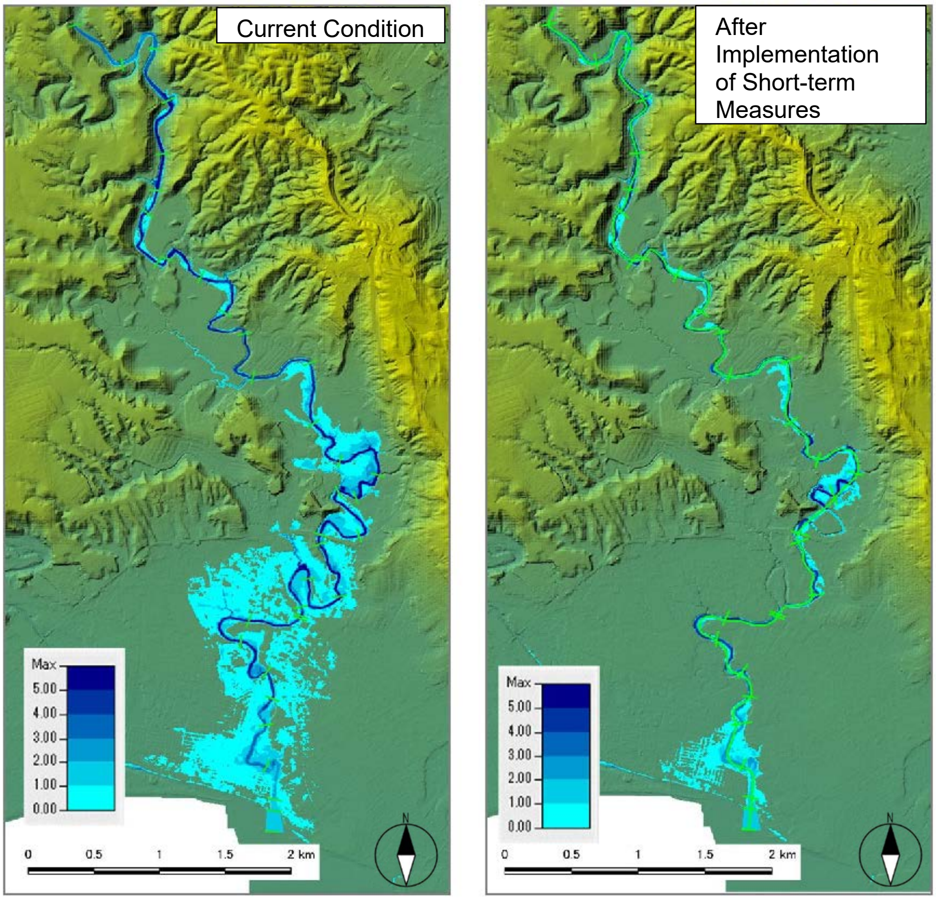
Source: Project Team

Figure 3.5.13 Comparison of Inundation Condition with 100 year Scale Flood between Current Condition and after Implementation of Short-Term Measures and Mid-Long Term Measures in Matina River



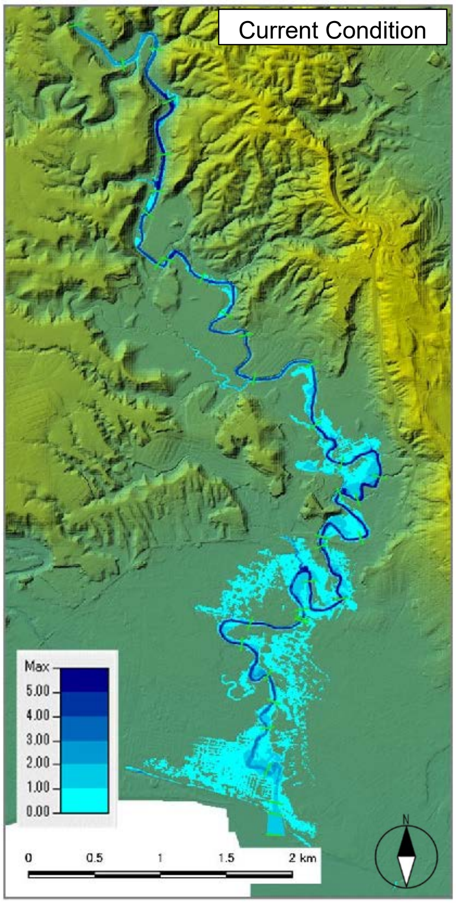
Source: Project Team

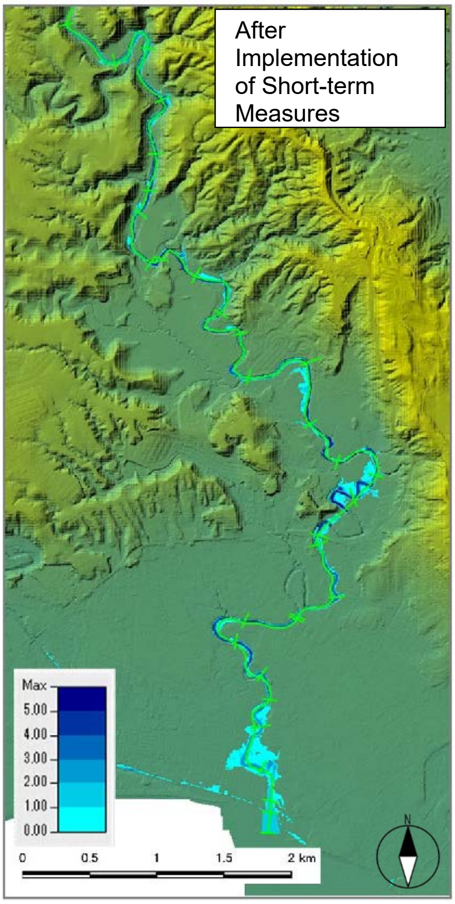
Figure 3.5.14 Comparison of Inundation Condition with 100 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Matina River



Source: Project Team

Figure 3.5.15 Comparison of Inundation Condition with 50 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Matina River





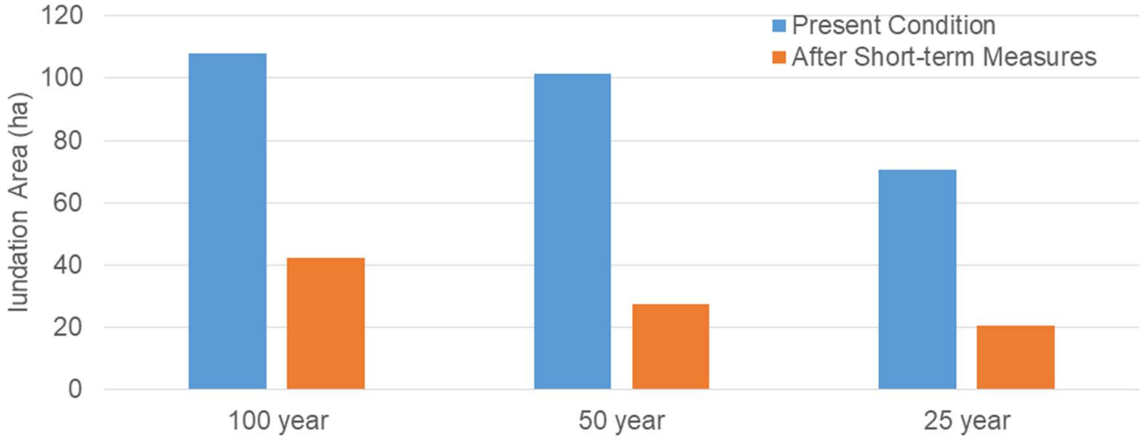
Source: Project Team

Figure 3.5.16 Comparison of Inundation Condition with 25 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Matina River

Table 3.5.11 Comparison of Inundation Condition between Current Condition and after Implementation of Short-Term Measures and Mid-Long Term Measures in Matina River (Inundation Area and Number of Inundated Buildings)

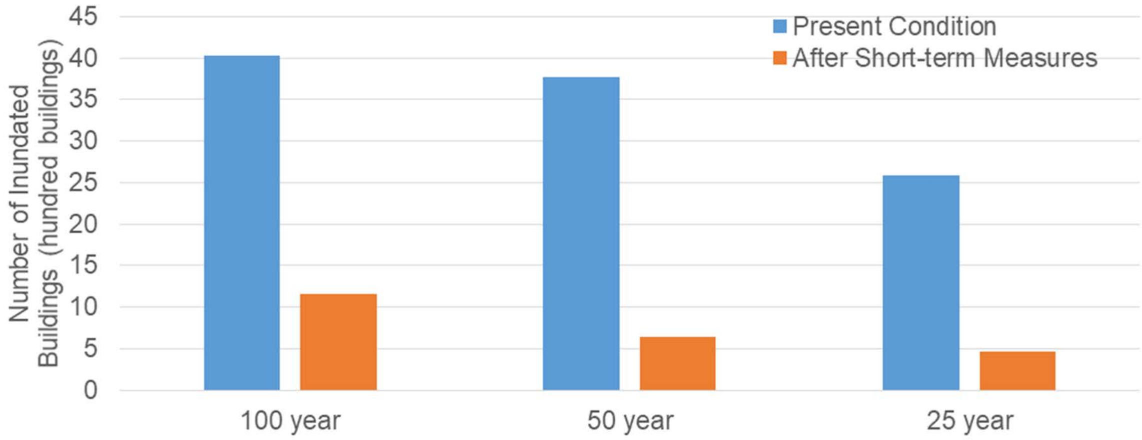
Flood scale	Inundation Area (ha) (more than 0.10m inundation depth)			Number of Inundated Buildings (hundred buildings) (more than 0.10m inundation depth)		
	Present Condition	After Short-term Measures	After Mid-Long term Measures	Present Condition	After Short-term Measures	After Mid-Long term Measures
100 year	108	42	0	40.3	11.5	0
50 year	101	28	0	37.7	6.4	0
25 year	71	20	0	25.8	4.7	0

Source: Project Team



Source: Project Team

Figure 3.5.17 Comparison of Inundation Condition between Current Condition and after Implementation of Short-Term Measures in Matina River (Inundation Area (ha) (more than 0.10m inundation depth))



Source: Project Team

Figure 3.5.18 Comparison of Inundation Condition between Current Condition and after Implementation of Short-Term Measures in Matina River (Number of Inundated Buildings (more than 0.10m inundation depth))

3.6 Structural Measures of Riverine Flood in Talomo River

Examination of the structural measures for the Talomo River will be implemented in the same manner as for the Davao River.

3.6.1 Examination of Alternatives of Structural Measures for Framework Plan in Talomo River

(1) Examination of Individual Flood Control Measure

The examination of individual flood control measure of riverine flood in the Talomo River focuses on four types of structural measures which are dike/flood wall, river channel improvement (widening), retarding pond and dam, excluding diversion channel (underground channel) which was obviously disadvantaged in terms of cost in consideration of the Davao River, targeting the 100-year flood. The details of each structural measures are described below.

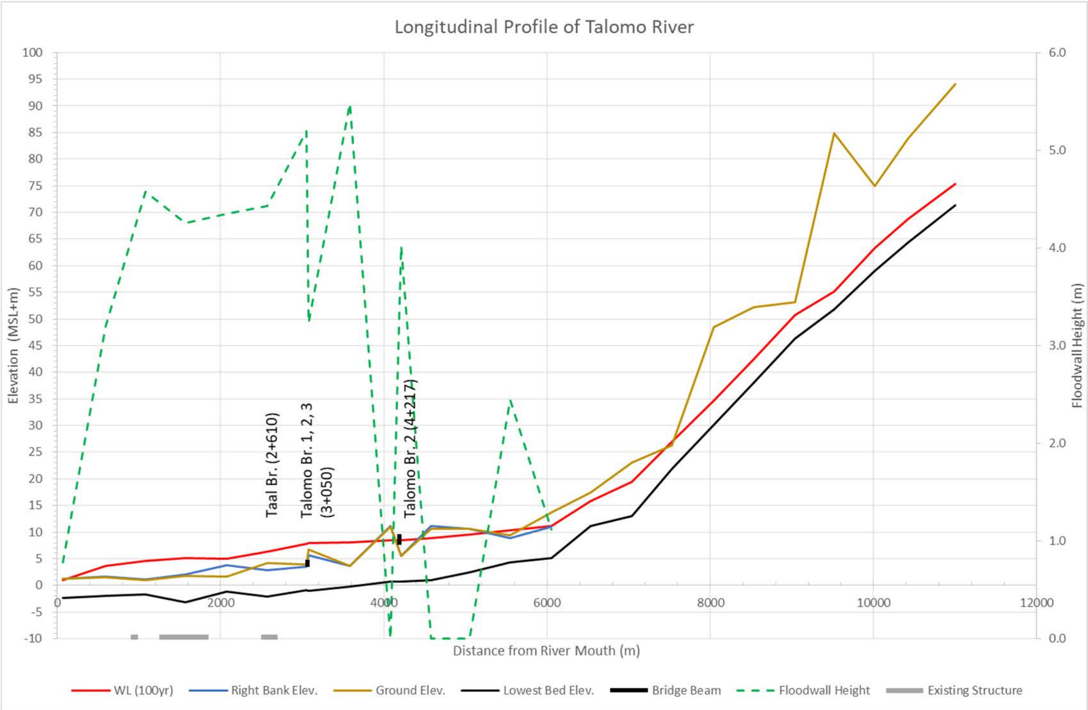
1) Dike / Flood wall

The alignment of newly proposed dike / flood wall was set on the current riverbank or behind the existing dike and/or revetment, and the necessary dike / flood wall height to be accommodated the design flood discharge amount with the river channel width between the dikes / flood walls was calculated by non-uniform flow calculation.

Figure 3.6.1 shows an example of setting the alignment of dike / flood wall. Also, Figure 3.6.2 and Figure 3.6.3 show the water level and necessary dike / flood wall height for 100-year flood as a result of non-uniform flow calculation for each of the right and left banks. Figure 3.6.2 and Figure 3.6.3 show the present river bank elevation (dike elevation), the ground elevation, and the lowest riverbed elevation together. The necessary flood wall height including the free board (1.0 m) can be read from the axis on the right side of the figure. The necessary flood wall height is 3.2 m on average and 5.5 m at the maximum.

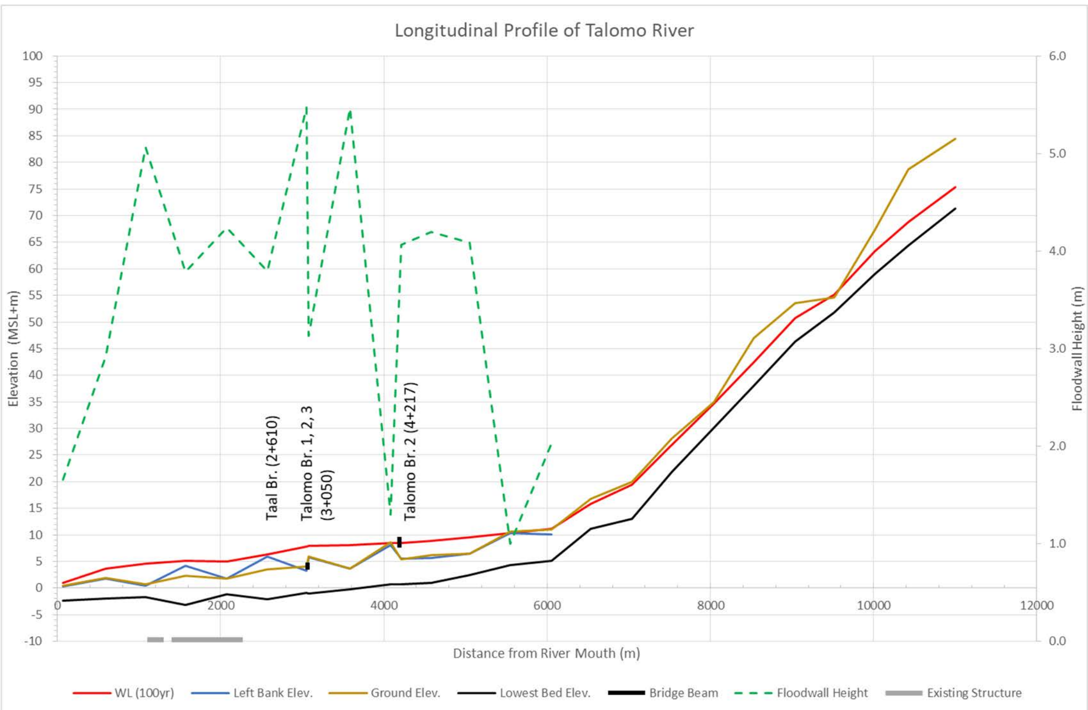
Source: Project Team

Figure 3.6.1 Example of Alignment of Dike in Talomo River



Source: Project Team

Figure 3.6.2 Longitudinal Profile and Necessary Height of Dike / Flood wall in Talomo River (Right bank)



Source: Project Team

Figure 3.6.3 Longitudinal Profile and Necessary Height of Dike / Flood wall in Talomo River (Left bank)

In the examination of individual flood control measures, the required facility scale, available discharge amount, construction period, cost (direct construction cost, land acquisition cost, building compensation cost and bridge replacement cost (if necessary)), the number of affected buildings, period required for relocation (assuming that one year is required for every 100 affected buildings), and the disadvantages and restrictions, were confirmed. Table 3.6.1 summarizes the examination results for each item.

Table 3.6.1 Examination Result of Individual Implementation of Floodwall in Talomo River

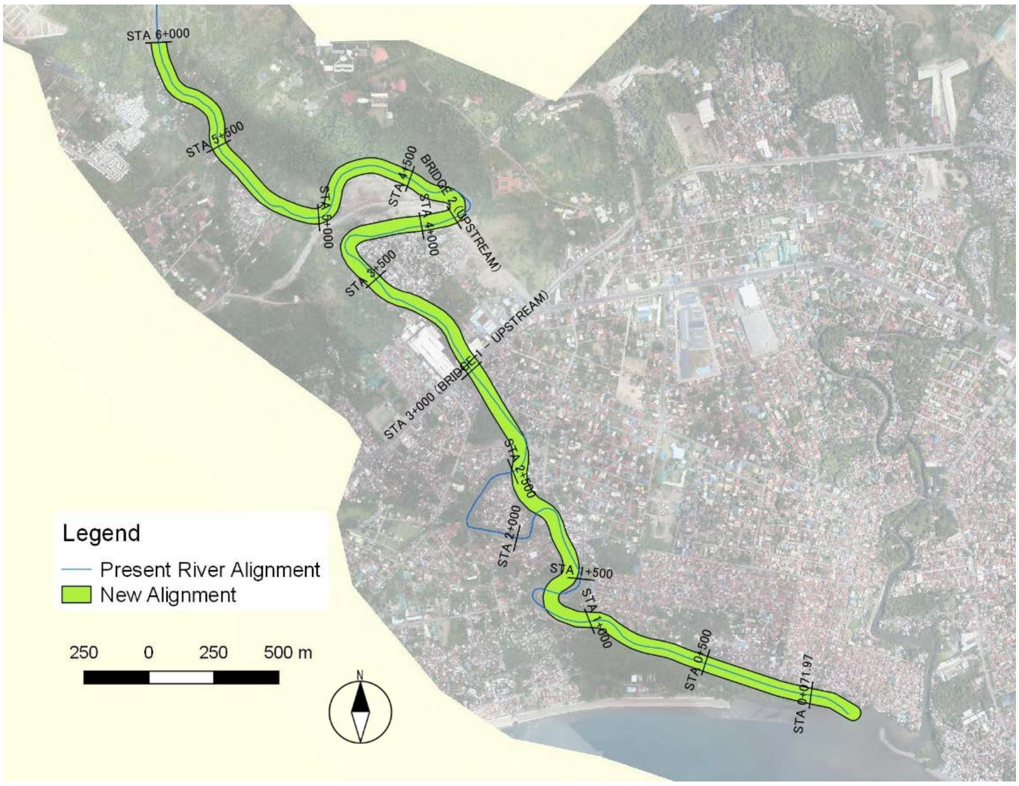
Outline of structure	- Concrete Wall + Pile Foundation - Average height: about 3.2m (with free board of 1.0m) - Maximum height: about 5.5m - Installed on both sides of the river from the river mouth to 6 km
Discharge amount to be accommodated	580 m^3/s at Mintal Bridge / 690 m^3/s at River mouth (100% of 100 year flood)
Construction period	Appox. 4 years
Direct construction cost + land acquisition cost + compensation cost for building + Bridge replacement	Appox. 3.7 billion Php
Number of affected buildings (Relocation required)	Appox. 430 buildings (Formal: 360, Informal: 70) (with 10m distance from proposed alignment)
Period required for relocation	Appox. 5 years
Disadvantages / restrictions	- Risk of housing collapse arises by break of dike with more than 2m height. - Existing 2 bridges replacement is necessary.

Source: Project Team

The structural type of the flood wall applied in the above examination is the same as the Davao River (see Table 3.4.3).

2) River Improvement (Widening)

In the examination of the proposed river widening, the river alignment was reviewed considering the cut-off work (see Table 3.6.4), and the required widening width was confirmed for flowing the design flood discharge in the reviewed river alignment. Section for cut-off works was set considering present land use and number of affected buildings and with aims of 1) smooth runoff of flood discharge, 2) reduction of points of river bank erosion and scoring, and 3) shortening of length of river improvement and operation and maintenance. As a condition for the hydraulic analysis, the widened cross section will be a single cross section with slope of 1: 1, and the free board is set in the prescribed height (1m) according to the discharge amount. The shape of cross section required for 100-year flood is an inverted trapezoidal with a riverbed width of 48.6m, a height of 5m and a width between the top of slope on both banks of 58.6m. Table 3.6.2 shows the results of the examination.



Source: Project Team

Figure 3.6.4 Comparison of Present River Alignment and Proposed River Alignment in Talomo River

Table 3.6.2 Examination Result of Individual Implementation of Widening in Talomo River

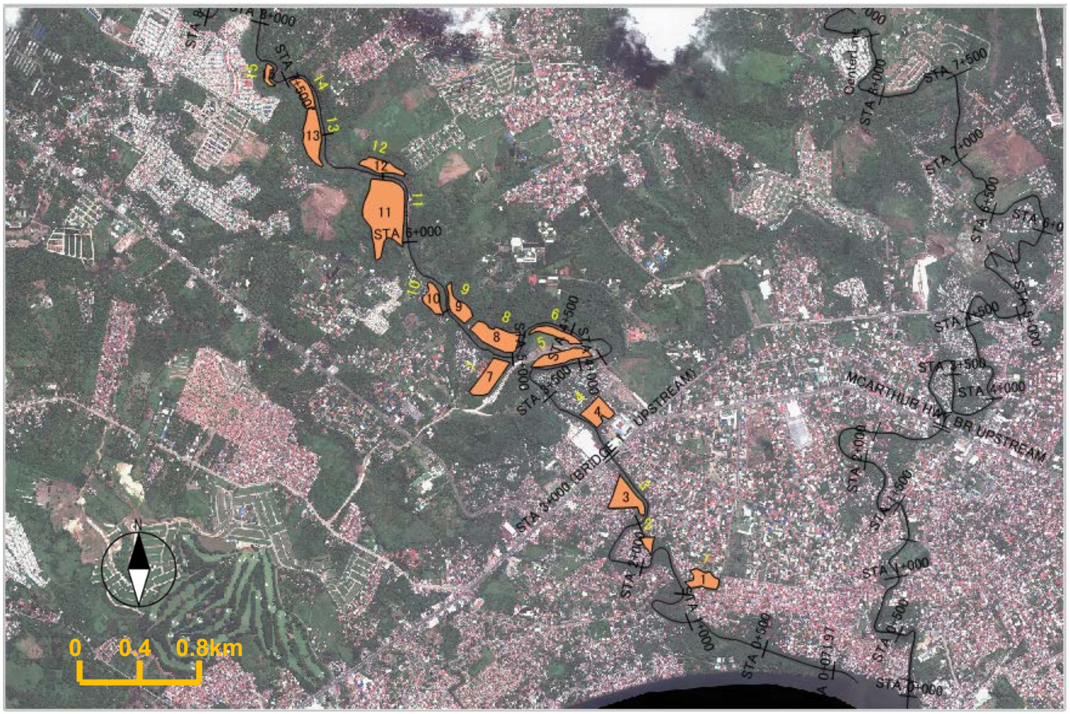
Outline of structure	Widening channel width from about 42m to about 59m in average (about 17m widening)
Discharge amount to be accommodated	580 m^3/s at Mintal Bridge / 690 m^3/s at River mouth (100% of 100 year flood)
Construction period	Appox. 5 years
Direct construction cost + land acquisition cost + compensation cost for building + Bridge replacement	Appox. 1.0 billion Php
Number of affected buildings (Relocation required)	Appox. 260 buildings (Formal: 190, Informal: 70)
Period required for relocation	Appox. 3 years
Disadvantages / restrictions	− Existing 1 Bridge replacement (lengthening) is necessary. − Cost for re-development of affected area (urbanized area) is required.

Source: Project Team

The structural type of the widening applied in the above examination is the same as the Davao River (see Figure 3.4.6).

3) Retarding Pond

In the examination of the proposed retarding pond, sites that could be used as retarding ponds were selected in the section from the river mouth to 8km upstream using the topographical and present land use data. The location and list of the selected candidate sites are shown in Figure 3.6.5 and Table 3.6.3, respectively.



Source: Project Team

Figure 3.6.5 Candidate Sites for Retarding Ponds in Talomo River

Table 3.6.3 List of Candidate Sites for Retarding Ponds in Talomo River

No.	Distance from River Mouth		Area	Capacity	No.	Distance from River Mouth		Area	Capacity
	*(km)	Side	(km^2)	(MCM)		*(km)	Side	(km^2)	(MCM)
1	1.6	Left bank	0.015	0.04	9	5.4	Left bank	0.015	0.07
2	1.9	Left bank	0.005	0.02	10	5.5	Right bank	0.013	0.06
3	2.6	Right bank	0.023	0.12	11	6.0	Right bank	0.081	0.40
4	3.2	Left bank	0.018	0.09	12	6.4	Left bank	0.014	0.07
5	3.8	Right bank	0.020	0.10	13	6.9	Right bank	0.027	0.13
6	4.5	Right bank	0.012	0.06	14	7.2	Right bank	0.013	0.07
7	5.1	Right bank	0.024	0.12	15	7.6	Right bank	0.005	0.02
8	4.9	Left bank	0.029	0.15	Total			0.31	1.53

Source: Project Team

As an initial examination, the capacity that can be allocated in the retarding ponds was calculated by assuming that a 5m deep retarding pond would be developed at each candidate site (except, No. 1 was set to 3 m, and No. 2 was set to 4 m due to topographical restrictions). The discharge amount that can be accommodated by the developed retarding ponds was calculated on the assumption that all the candidate sites would be developed for retarding ponds. Table 3.6.4 shows the results of the examination on the proposed retarding ponds. In case the current discharge amount in the target area of the Talomo

River to be protected by structural measures is 100 m^3/s, the individual measure by retarding ponds will not be able to cope with the 100-year flood even if all the candidate sites of retarding pond can be developed.

Table 3.6.4 Examination Result of Individual Implementation of Retarding Pond in Talomo River

Outline of structure	Total area : 0.31 km^2 Gross Capacity: 1.53 million m^3 (assumed average water depth of retarding pond is 5 m)
Discharge amount to be accommodated	Approx. 210m^3/s (35% of remaining flood discharge (590 m^3/s) of 100 year flood of 690 m^3/s at River Mouth) in case that estimated present river capacity of protected area is 100m^3/s
Construction period	Appox. 3 year
Direct construction cost + land acquisition cost + compensation cost for building	Appox. 0.6 billion Php
Number of affected buildings (Relocation required)	Appox. 60 buildings
Period required for relocation	Appox. 1 years
Disadvantages / restrictions	

Source: Project Team

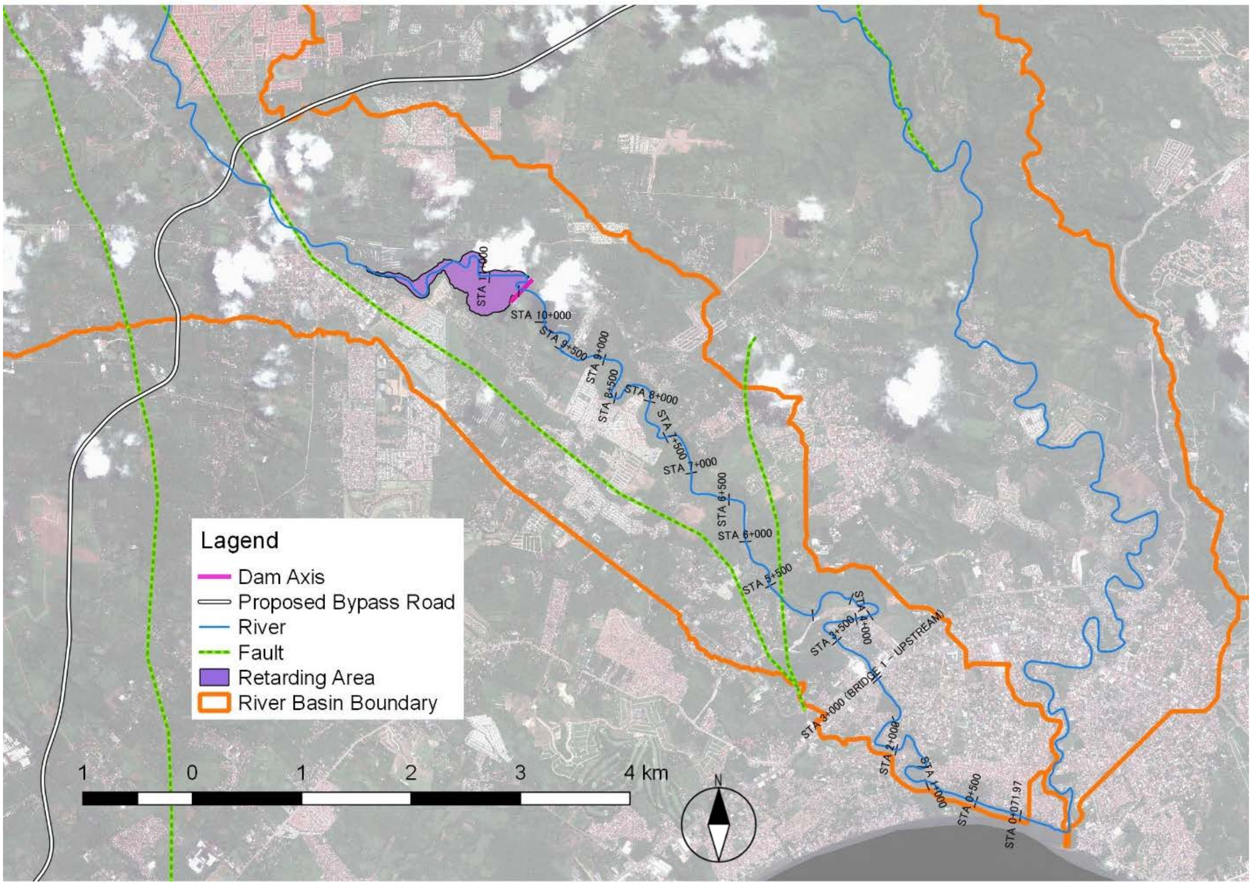
The structural type of the retarding ponds applied in the above examination is the same as the Davao River (see Figure 3.4.8).

4) Dam

In the examination of the proposed dam, the candidate sites were selected by analyzing the topographic data, the existing/planned infrastructure information and fault information.

For the Talomo River, the candidate site was selected as shown in Figure 3.6.6. The dam site is located 10.5 km from the river mouth. For the examination, dam type is assumed as a stream type concrete gravity dam.

The dam height is required to be 39 m, and the storage capacity excluding sedimentation capacity (flood control capacity) is 2.8 million m3. Table 3.6.5 shows the results of the examination.



Source: Project Team

Figure 3.6.6 Candidate Site for Dam in Talomo River

Table 3.6.5 Examination Result of Individual Implementation of Dam in Talomo River

Outline of structure	Concrete dry dam with 39m height (detention capacity is 2.8 million m^3)
Discharge amount to be accommodated	Approx. 220 m^3/s (38% of flood discharge of 100 year flood at dam site (580m^3/s))
Construction period	Appox. 10 years
Direct construction cost + land acquisition cost + compensation cost for building	Appox. 8.8 billion Php
Number of affected buildings (Relocation required)	Appox. 24 buildings
Period required for relocation	Appox. 1 years
Disadvantages / restrictions	Fault is located at about 700m away from edge of dam axis.

Source: Project Team

5) Examination Result of Individual Flood Control Measure

The results of the examination in case of implementation of four types of individual structural measures were summarized as shown in Table 3.6.6, focusing on the structural scale, cost, and number of affected buildings that can be dealt with individually.

Table 3.6.6 Examination Results of Individual Implementation in Talomo River

No.	Measure (Number of Bridge Replacement)	Cost * (Billion Php)	Affected buildings (Number)
S1	Dike / Flood wall (All of 690m^3/s of 100 year flood discharge at River Mouth) (2 bridges, heightening)	3.7	430
S2	River improvement (Widening & Cut-off works) (All of 690m^3/s of 100 year flood discharge at River Mouth) (1 bridges, lengthening)	1.0	260
S3	Retarding Pond (310 m^3/s = 100m^3/s (present river capacity) + 210 m^3/s (Retarding Pond)) (No bridge replacement)	0.6	60
S4	Dam (320 m^3/s = 100m^3/s (present river capacity) + 220 m^3/s (Dam)) (No bridge replacement)	8.8	24

Source: Project Team

Challenges and evaluations for the individual flood control measures are summarized as follows.

- Dike / Flood wall:
  The cost is about four times as the widening, and the number of affected houses is the largest among the four measures.
- Widening:
  The number of affected buildings is more than half of the dike / flood wall, and the cost is about a quarter of the dike / flood wall.
- Retarding pond:
  The individual measure could not cope with 100-year flood even if all candidate sites could be developed.
- Dam:
  The individual measure could not cope with 100-year flood. The cost is about nine times as the widening.

Based on the above, there are restrictions and limitations in any of the individual measures, and a combination of measures is required as examined in the below.

(2) Examination of Combination of Flood Control Measure

1) Examination of Restriction of Each Structural Measure for Examination of Combination

In the examining of the optimal combination of structural measures, the individual measures were re-examined based on the examination in the previous section.

A. Retarding Pond

The analysis of the number of affected buildings and the presence or absence of a development plan in each of the 15 candidate site for retarding pond along the Talomo River was conducted.

Regarding the presence or absence of a development plan, it was confirmed whether the candidate sites are classified as a residential or commercial area by using the future land use plan of 2045 and the CLUP 2019-2028 (draft version) of Davao City.

It can be seen that the candidate sites located in the upstream of area to be protected in the Talomo River aren't planned as development areas in the land use plan 2045, but all of the candidate sites are planned as development areas in the CLUP 2019-2028.

For selecting a specific development site for retarding pond, since there is no significant difference in conditions, priority will be given to places where the area is large and where one project can be expected to have a high effect, and the upstream area where the expected effect is as large as possible.

Table 3.6.7 Analysis of Candidate Sites for Retarding Ponds in Talomo River

No.	Distance from River Mouth of Pond		Area	Capacity	Excavation Volume	Affected Buidings	Buiding Density	Area to be developed		Note
	*(km)	Side	(km^2)	(MCM)	(MCM)	(Number)	(Number /ha)	Laun Use Plan in 2045 by IM4Davao	CLUP2019-28(draft)	
1	1.6	Left bank	0.015	0.04	0.06	11	7.4	Yes	Yes	
2	1.9	Left bank	0.005	0.02	0.02	3	6.4	Yes	Yes	
3	2.6	Right bank	0.023	0.12	0.14	2	0.9	Yes	Yes	
4	3.2	Left bank	0.018	0.09	0.14	14	8.0	Yes	Yes	
5	3.8	Right bank	0.020	0.10	0.16	2	1.0	Yes	Yes	
6	4.5	Right bank	0.012	0.06	0.12	0	0.0	Yes	Yes	
7	5.1	Right bank	0.024	0.12	0.20	3	1.3	Yes	Yes	
8	4.9	Left bank	0.029	0.15	0.26	6	2.0	No	Yes	
9	5.4	Left bank	0.015	0.07	0.11	9	6.1	No	Yes	
10	5.5	Right bank	0.013	0.06	0.09	2	1.6	No	Yes	
11	6.0	Right bank	0.081	0.40	0.91	3	0.4	Yes	Yes	
12	6.4	Left bank	0.014	0.07	0.09	2	1.4	No	Yes	
13	6.9	Right bank	0.027	0.13	0.26	3	1.1	No	Yes	
14	7.2	Right bank	0.013	0.07	0.11	0	0.0	No	Yes	
15	7.6	Right bank	0.005	0.02	0.03	0	0.0	No	Yes	
Total			0.31	1.53	2.69	60	-	-	-	-

Source: Project Team

B. Dam

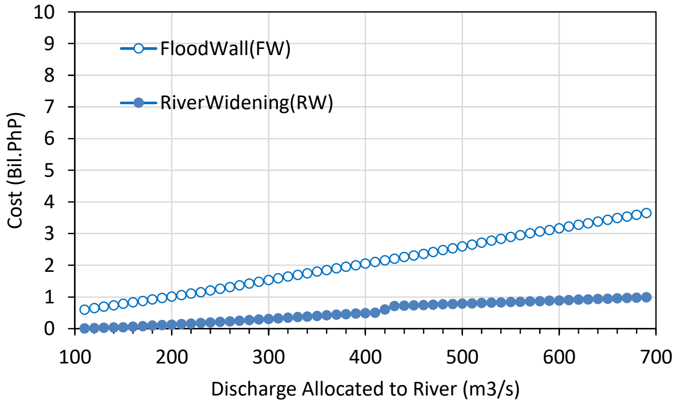
Through the examination of the impact on the natural and social environment at the dam site and ponding area, it was confirmed that restricted areas that could have serious social and environmental impacts are not included in the ponding area for the dam site in the Talomo River basin.

2) General Examination of Tendency of Cost of Individual/Combined Implementation of Structural Measures

In the examination of the optimal combination of structural measures, the construction cost (direct construction cost, land acquisition cost, building compensation cost, bridge replacement cost (if necessary) was confirmed, and the tendency was analyzed.

A. Tendency of Measures for Increasing Flow Capacity of River Channel (Tendency for Flood wall and Widening)

Figure 3.6.7 shows the result of comparison of the construction cost by flood wall and river widening for each discharge scale indicated on the horizontal axis as "Discharge allocated to River". From this figure, it can be seen that the river widening is inexpensive about 1/3 or less in case the flood discharge is accommodated only by the river channel.

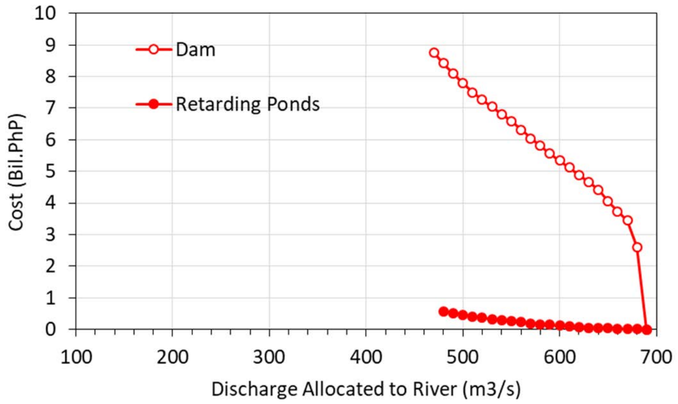


Source: Project Team

Figure 3.6.7 Comparison of Cost in case of Individual Implementation of Flood wall and River Widening with Various Scale in Talomo River

B. Tendency of Measures for Flood Water Detention Facilities (Tendency of Retarding Pond and Dam)

Figure 3.6.8 shows the result of comparing the construction cost of the retarding ponds and dam with the scale of each discharge amount. Figure 3.6.8 shows the cost of implementing the measures to cope with the remaining discharge amount (residual amount for 690 m^3/s) for each of the retarding ponds and dam while the river channel is able to accommodate discharge amount indicated on the horizontal axis. From this figure, it can be seen that retarding ponds are much inexpensive compared with dam as the detention facility.



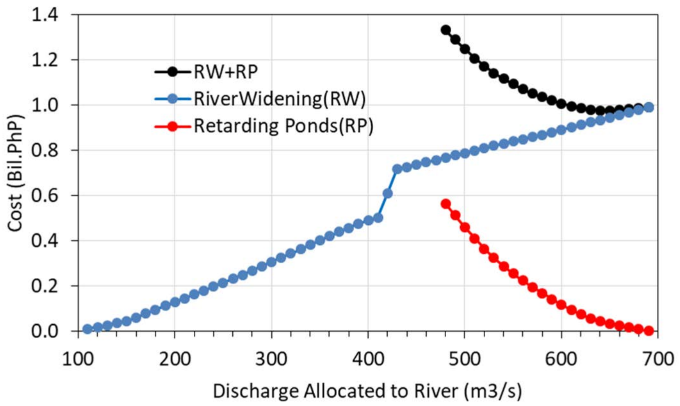
Source: Project Team

Figure 3.6.8 Comparison of Cost in case of Individual Implementation of Retarding Pond and Dam with Various Scale in Talomo River

C. Tendency of Optimal Flood Discharge Distribution accommodated by River Channel and Flood Water Detention Facility

The optimal distribution of flood discharge by river channel and detention facilities was examined by combining the river widening which is lowest-cost measures among measures accommodated by river channel and the retarding ponds which are lowest-cost measures among detention facilities.

The black line in Figure 3.6.9 shows the cost in case of the combination of the river widening and the retarding ponds corresponding to the discharge amount of 690 m3/s. In case the discharge allocated by the river channel is about 580 to 690 m^3/s, the total value is gently constant (almost flat), and the case of 650 m^3/s is the cheapest.



Source: Project Team

Figure 3.6.9 Comparison of Cost in case of Combined Implementation of River Widening and Retarding Pond with Various Scale in Talomo River

3) Concept of Combination of Structural Measures

In the examination of the Davao River, the combination of widening and retarding pond was the cheapest. In the unlikely event that large-scale floods occur continuously, it is more advantageous for river channels to have a large flow capacity. Furthermore, the risk (water level rise) at the time of flood occurrence including the worst case flood exceeding the target design level can be minimized, and the burden on operation and maintenance is reduced. Taking into account the above things, the combination of widening and retarding pond was recommended. All of the above conditions apply to the Talomo River, so that the combination of widening and retarding pond is recommended for the structural measures in the Talomo River.

As described in the cost comparison in 2) above, in the combination of widening and retarding pond, it is advantageous to increase the flow capacity of the river channel to about 580 m3/s by widening, and to accommodate the rest at the retarding ponds.

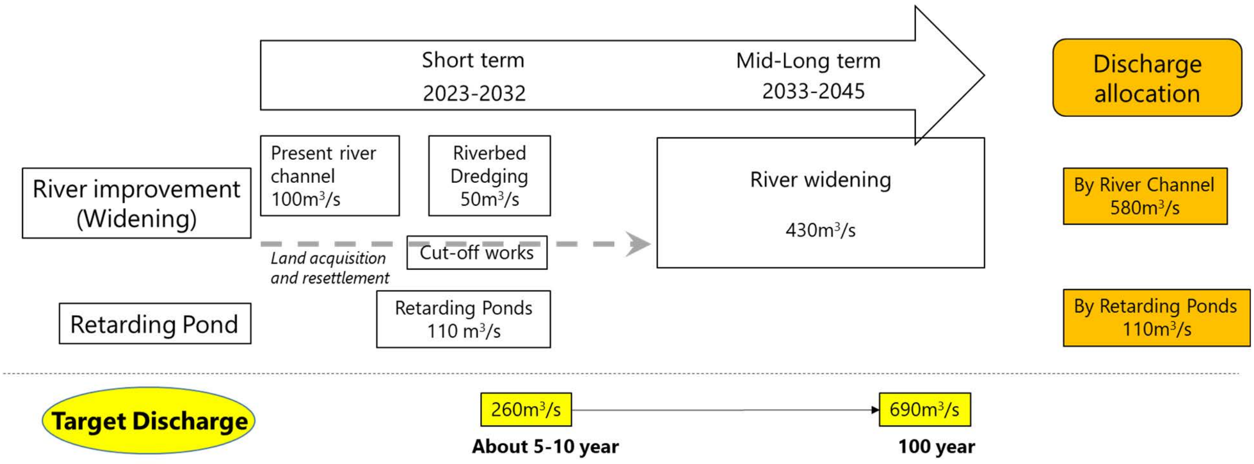
Based on the scale of the required retarding ponds, the ease of inflow and outflow of the flood flow (long shape along the river channel), the inflow from the hinterland and tributaries, and the integration of the candidate retarding ponds, the optimal combination of widening and retarding ponds was examined.

Table 3.6.8 shows the scale of the combination, cost and number of affected buildings. Figure 3.6.10 and Figure 3.6.11 show the implementation schedule and the facility plan. It will be possible to create a safe city that can cope with 100-year flood within the M/P stage by 2045. Therefore, the target of F/P can be achieved within the target period of the M/P, that is, the M/P and the F/P will be the same.

Table 3.6.8 Combination of Alternatives in Talomo River

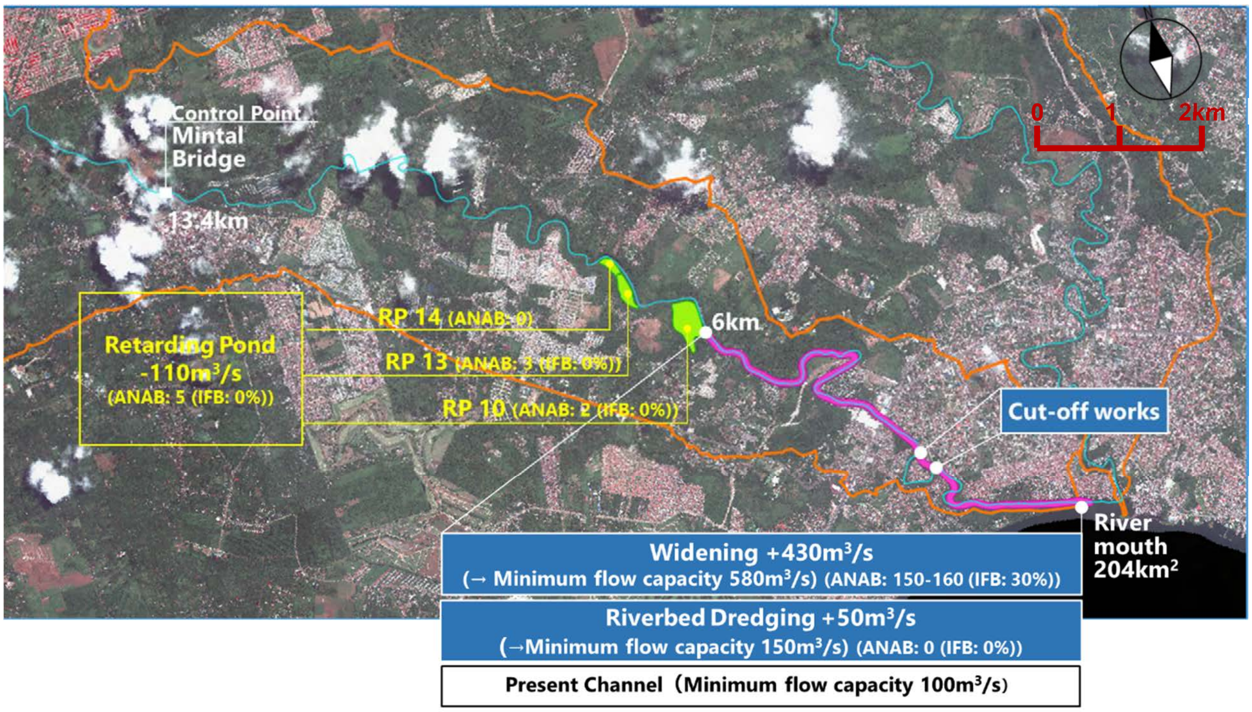
Combination of Structural Measures		Cost * (Billion Php)	Affected buildings (Number)
Widening (Number of Bridge Replacement)	Retarding Pond		
580m^3/s = 100 (present capacity) + 50 (dredging) + 430 (widening) (1 Bridges) (9m (4.5m each) widening in average)	110m^3/s (3 Regarding Ponds (No.11, 13&14))	1.3 ((0.1+0.9)+0.3)	160

Source: Project Team



Source: Project Team

Figure 3.6.10 Preliminary Implementation Schedule in Talomo River



Note: ANAB: Assumed Number of Affected Buildings, IFB: Informal Building
Source: Project Team

Figure 3.6.11 Facility Plan in Talomo River

Regarding the river mouth, the structure of MSL+3.0m as countermeasures against storm surge and waves is required. This flood wall at the river mouth will be introduced in accordance with the widening work and will be installed on both banks for about 2 km from the river mouth. The cost is estimated at 0.06 Billion Php.

3.6.2 Examination of Master Plan

Based on the examination in Section 3.6.1, structural measures for riverine flood control M/P in the Talomo River will be a combination of widening and retarding ponds, as shown in Table 3.6.9.

Table 3.6.9 Riverine Flood Control Master Plan in Talomo River (Structural Measures)

	Short-Term Measures	Mid-Long Term Measures
Implementation Period (Target Year)	2023-2032 (2032)	2033-2045 (2045)
Design Level	5-10 year scale flood	100 year scale flood
Design Flood Discharge	260m^3/s	690m^3/s
Target Area	From river mouth to 6.0km	ditto
Measures	・Dredging (from river mouth to 6.0km) ・Cut-off works ・Installation of retarding ponds (Three locations)	・River widening (from river mouth to 6.0km) ・Flood wall at river mouth
Project Cost (Financial Cost)	0.60 billion Php	1.66 billion Php (including short-term measures)
Project Cost (Economic Cost)	0.54 billion Php	1.52 billion Php (including short-term measures)
Economic Evaluation (EIRR)	16.52%	14.93% (including short-term measures)
Economic Evaluation (ENPV) (Discount rate: 10%)	0.99 billion Php	1.19 billion Php (including short-term measures)
Economic Evaluation (B/C) (Discount rate: 10%)	1.91	1.59 (including short-term measures)

Source: Project Team

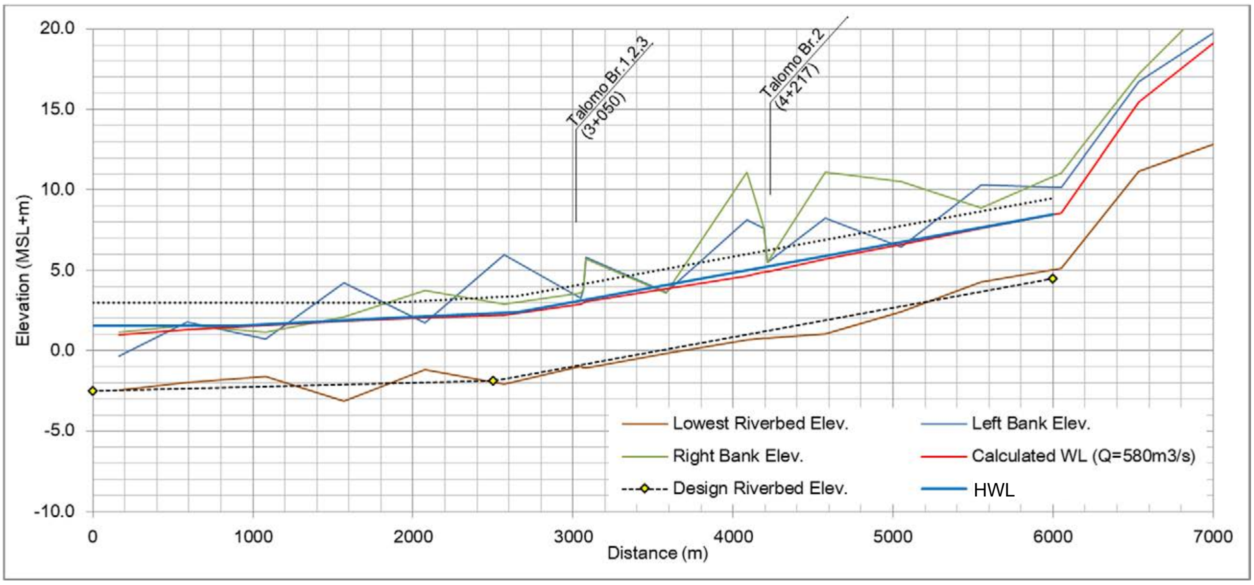
The details of the above measures are shown in Table 3.6.10.

Table 3.6.10 Details of Structural Measures in Talomo River

Item	Content
Short-Term Measures	
Dredging	Target Section: From river mouth to 6.0km Dredging Volume: 0.2 million m^3
Cut-off works	Target Section: 1+800 – 2+600
Installation of Retarding Ponds	Number of Retarding Ponds to be Installed: 3 Location (Distance from river mouth & bankside): 7.2km (Right bank), 6.9km (Right bank), 5.5km (Right bank) Area: 12ha in total Excavation Volume: 12.3 million m^3 in total
Mid-Long Term Measures	
River Widening	Target Section: From river mouth to 6.0km Widening Width: Riverbed width 41.0m, Water depth about 4.0m, Width between top of riverbanks about 51.0m Shape of Cross Section: Inverted trapezoid with slope of 1:1 Excavation Volume: 0.8 million m^3 Number and Name of Bridges to be Replaced: 1 bridge (Talomo Bridge 1,2,3 (3k))
Installation of Flood Wall at river mouth	Target Distance: From river mouth to about 2.0km Height of Flood Wall: MSL+3.0m

Source: Project Team

The design longitudinal profile of the Talomo River (design riverbed elevation and HWL) is shown in Figure 3.6.12.



Source: Project Team

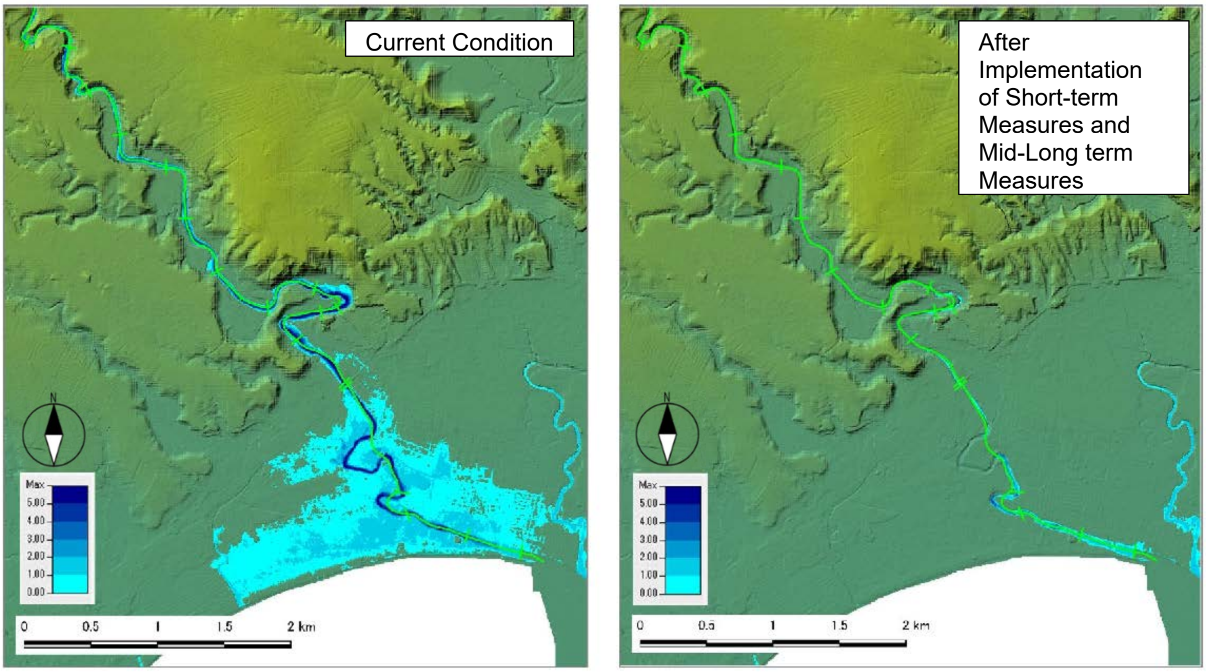
Figure 3.6.12 Longitudinal Profile of Talomo River with Design Riverbed and HWL in M/P

After the short-term measures and mid-long term measures shown in Table 3.6.9 are implemented, area to be protected in the Talomo River can expect to become basically safe for 100 year scale flood as shown in Figure 3.6.13 and Table 3.6.11.

After only the short-term measures shown in Table 3.6.9 are implemented, area to be protected in the Talomo River not only becomes basically safe for a flood discharge of 260 m3/s (5-10 year scale flood), but also can expect a certain degree of damage reduction even in occurrence of higher scale floods.

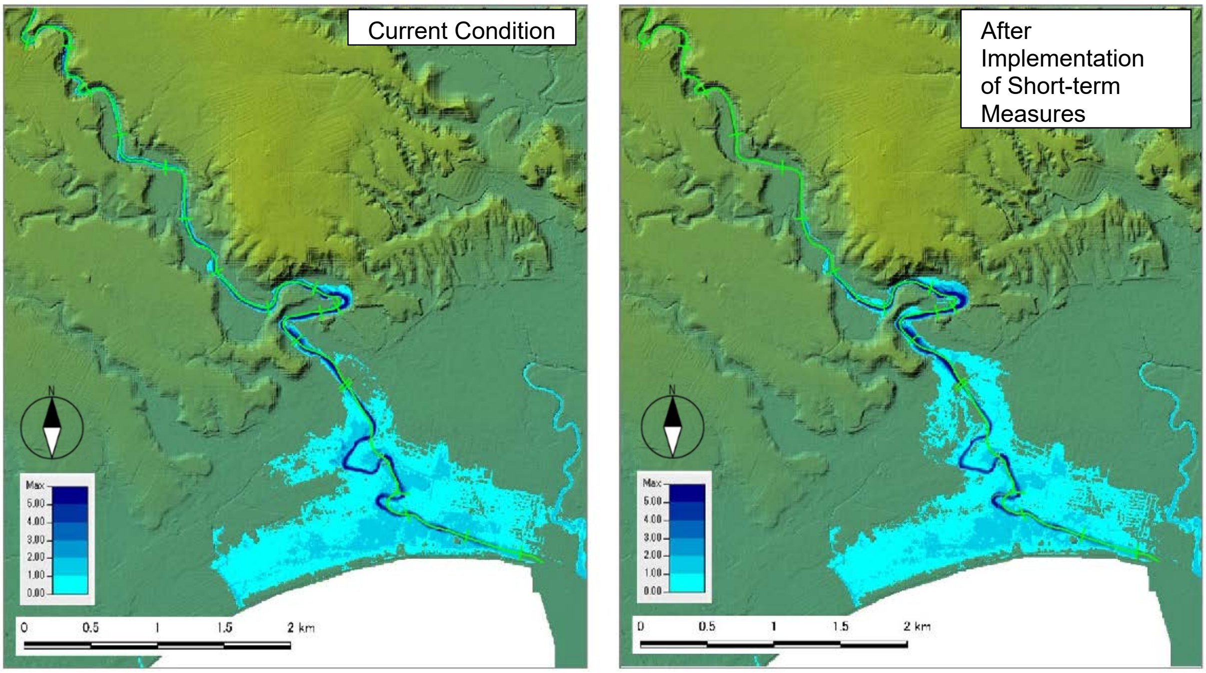
Figure 3.6.14 to Figure 3.6.17, Table 3.6.11, Figure 3.6.18 and Figure 3.6.19 show the inundation condition of the current condition and after implementation of short-term measures with various scale floods. Reduction of inundation area is more remarkable in case of the smaller scale floods such as the 10 year scale flood, whereas reduction of inundation area can be confirmed also in the case of 50 year scale flood.

It can be said that the areas where flooding has stopped after the implementation of the measures are where flood risk is greatly reduced. Although it is premised that the measures will be implemented, these areas can be prioritized from the viewpoint of flood risk when promoting regional development in the future.



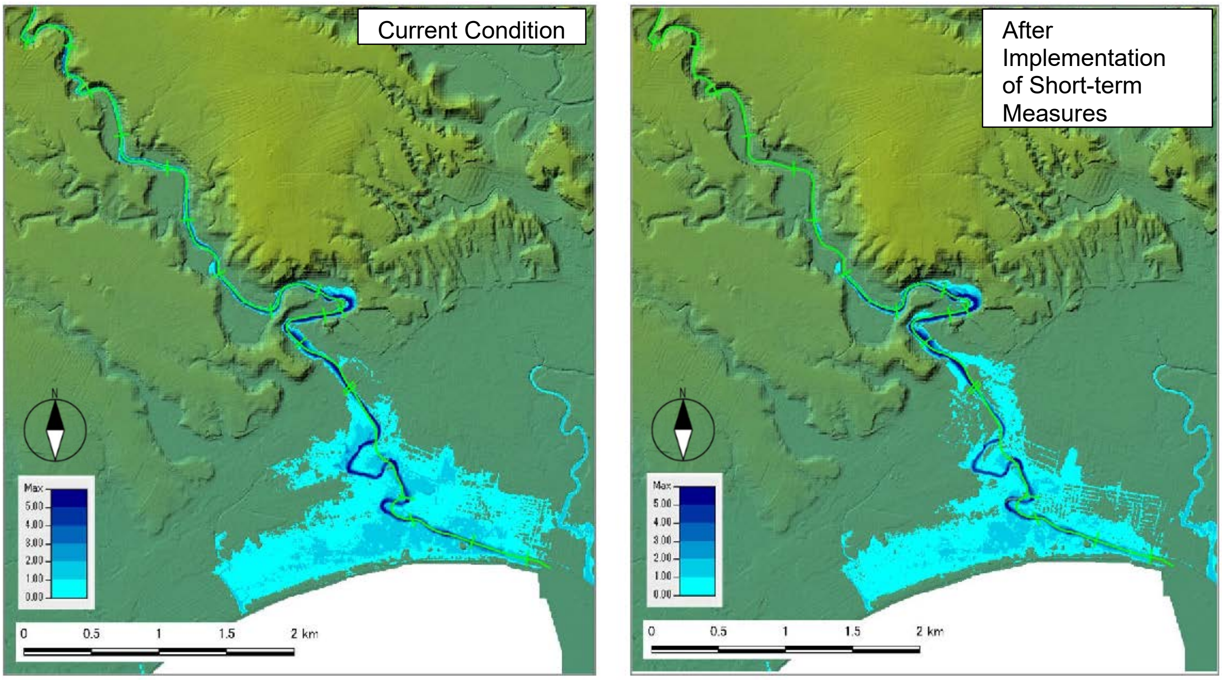
Source: Project Team

Figure 3.6.13 Comparison of Inundation Condition with 100 year Scale Flood between Current Condition and after Implementation of Short-Term Measures and Mid-Long Term Measures in Talomo River



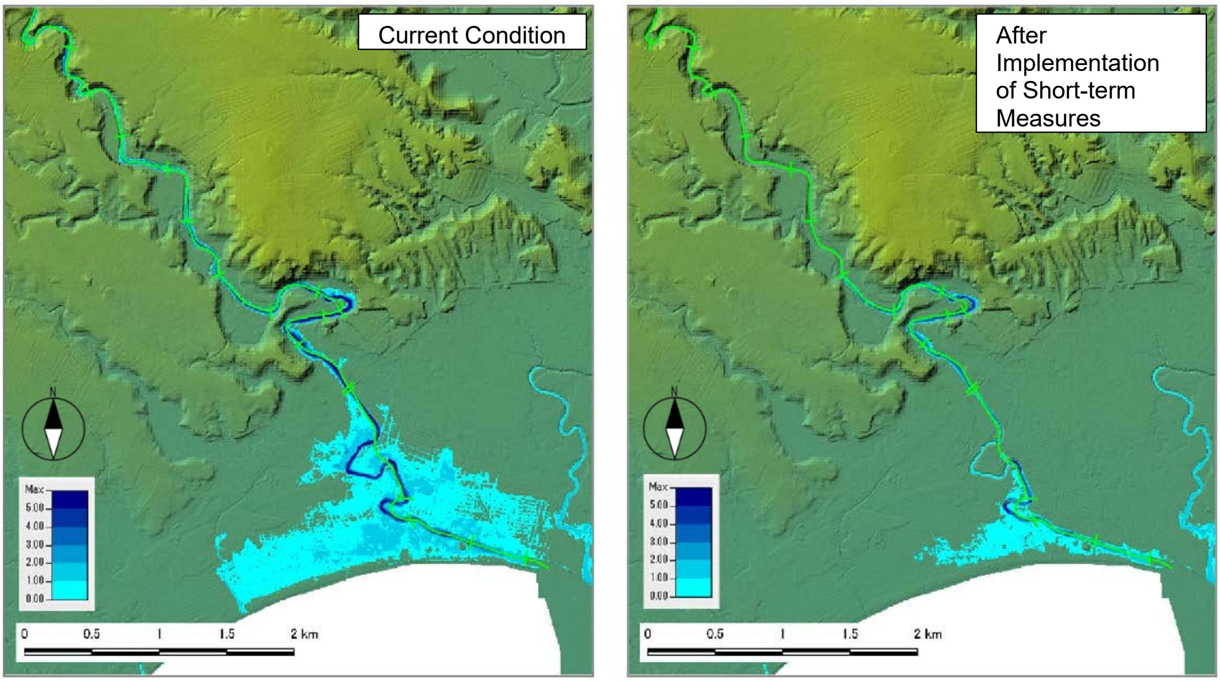
Source: Project Team

Figure 3.6.14 Comparison of Inundation Condition with 100 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Talomo River



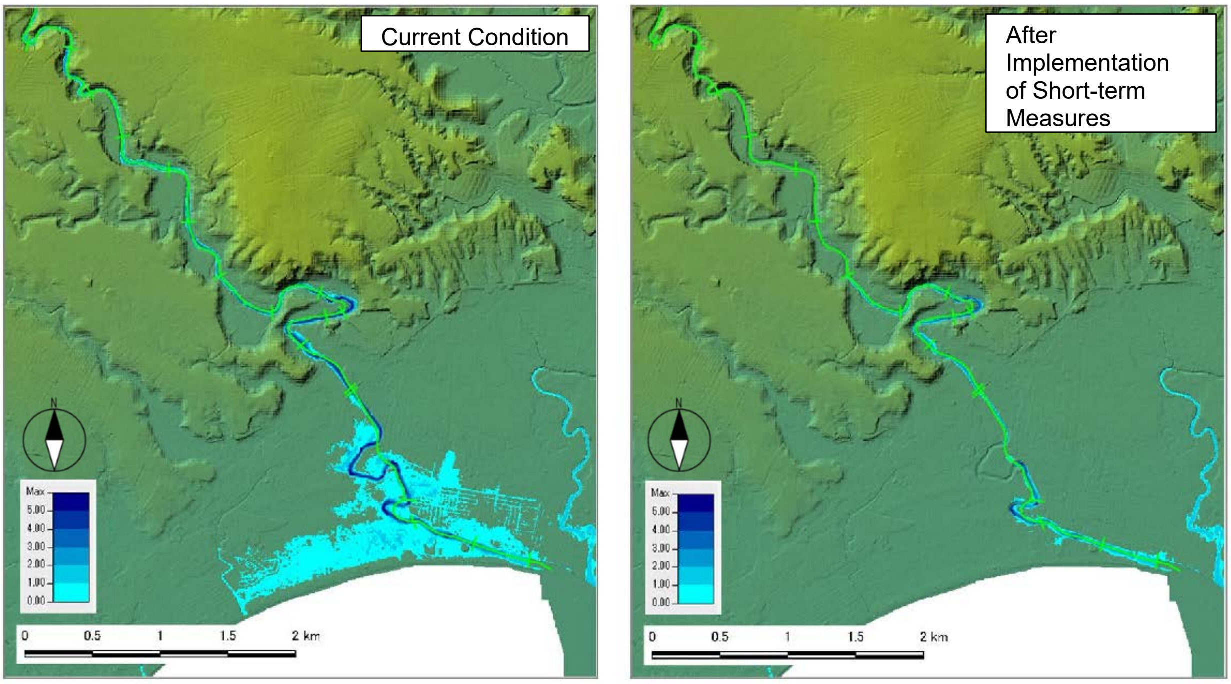
Source: Project Team

Figure 3.6.15 Comparison of Inundation Condition with 50 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Talomo River



Source: Project Team

Figure 3.6.16 Comparison of Inundation Condition with 25 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Talomo River



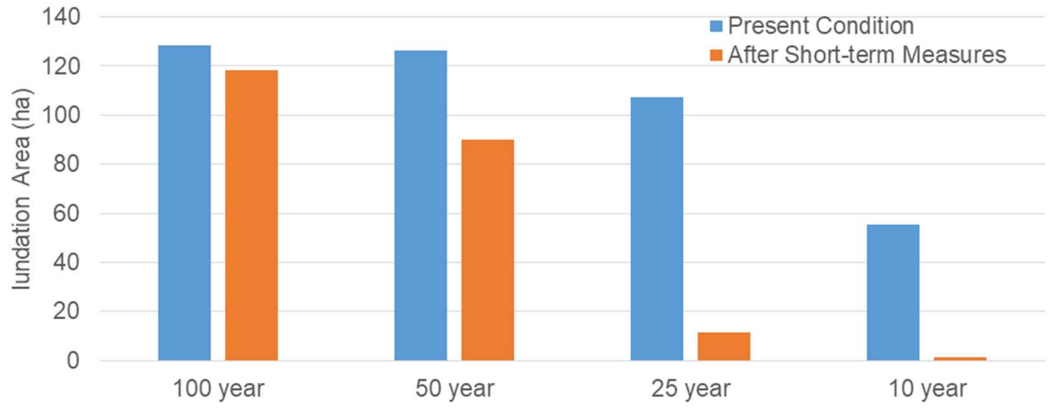
Source: Project Team

Figure 3.6.17 Comparison of Inundation Condition with 10 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Talomo River

Table 3.6.11 Comparison of Inundation Condition between Current Condition and after Implementation of Short-Term Measures and Mid-Long Term Measures in Talomo River (Inundation Area and Number of Inundated Buildings)

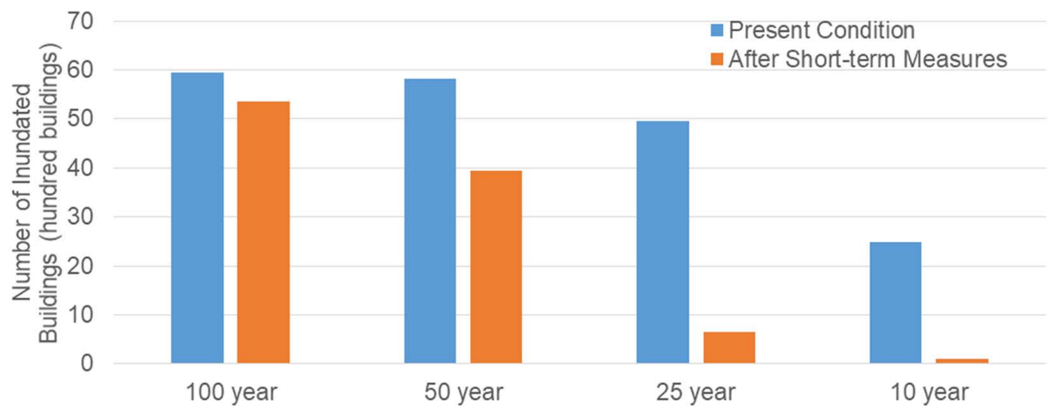
Flood scale	Inundation Area (ha) (more than 0.10m inundation depth)			Number of Inundated Buildings (hundred buildings) (more than 0.10m inundation depth)		
	Present Condition	After Short-term Measures	After Mid-Long term Measures	Present Condition	After Short-term Measures	After Mid-Long term Measures
100 year	128	118	0	59.5	53.7	0
50 year	126	90	0	58.3	39.3	0
25 year	107	11	0	49.6	6.5	0
10 year	56	1	0	24.8	1.1	0

Source: Project Team



Source: Project Team

Figure 3.6.18 Comparison of Inundation Condition between Current Condition and after Implementation of Short-Term Measures in Talomo River (Inundation Area (ha) (more than 0.10m inundation depth))



Source: Project Team

Figure 3.6.19 Comparison of Inundation Condition with 10 year Scale Flood between Current Condition and after Implementation of Short-Term Measures in Talomo River (Number of Inundated Buildings (more than 0.10m inundation depth))

3.7 Structural Measures of Storm Water Drainage Improvement

3.7.1 Outline of Structural Measures

(1) Menu of Structural Measures

1) General

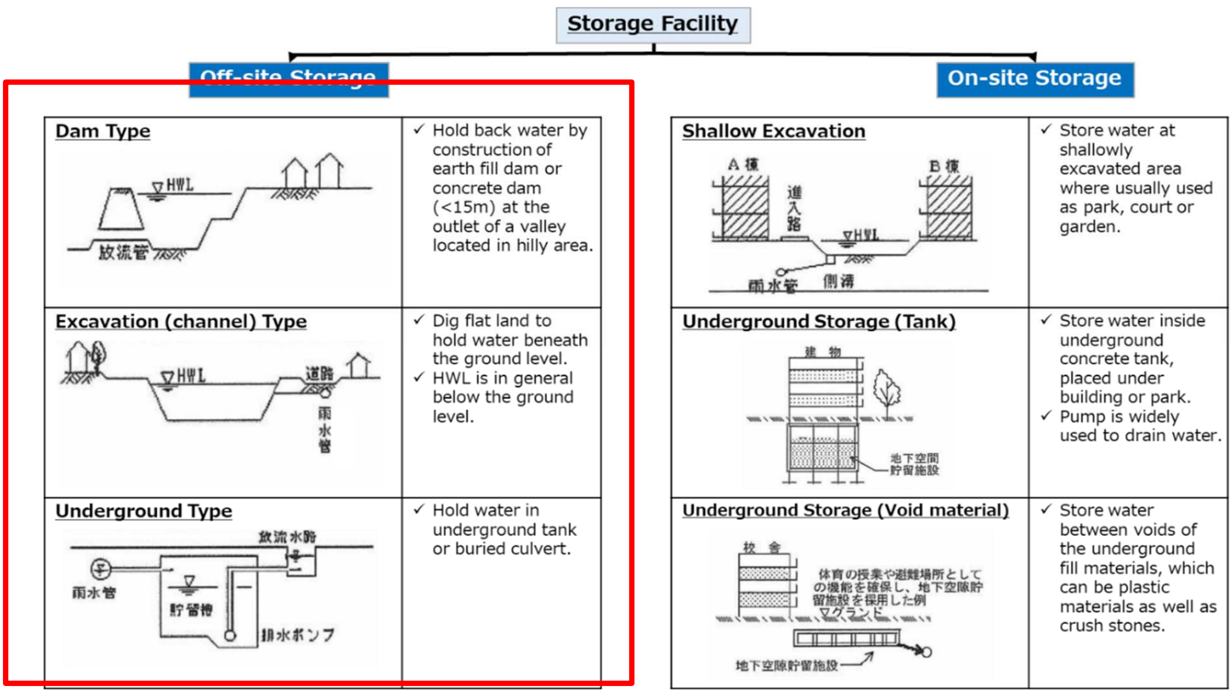
The storm water drainage improvement is largely divided into the following two categories; a) Measures to flow runoff faster by improving flow capacity of drainage channel, and b) Measures to reduce discharge in drainage channel by installing rainwater storage facilities along drainage channel and/or in catchment area.

As shown in Section 3.1.6, in the target area of the present project, although the drainage channel does not have enough capacity for severer extreme events, the space for channel widening is quite limited. In addition, the natural rainwater runoff retarding function is decreasing, and its recovery is an important task. Considering these, the strategy is set to upgrade drainage system mainly by securing and enhancing rainwater runoff retarding function.

The channel improvement is prioritized if it is available. However, the installation of rainwater storage facilities is considered in the case that the channel improvement is difficult though the existing capacity is not enough.

2) Outline of Rainwater Runoff Storage Facilities

The structure of the rainwater storage facilities is largely divided into on-site storage and off-site storage by the way of storing rainwater. The on-site storage catches rainwater at which rainfall occurs or with least movement of water after rainfall. On the other hand, the off-site storage stores the rainwater after runoff is concentrated to drainage channels. Typical on-site storage is constructed at around parks, houses and commercial facilities. The representative off-site storage is a retarding basin and an underground storage. Figure 3.7.1 shows the categorization of the rainwater storage facilities.



Source: Project Team

Figure 3.7.1 Categorization of Rainwater Storage Facilities

Among the above-mentioned facilities, the on-site storage which is installed at around houses and commercial facilities in green area, parking area or underground is usually planned with the development plan for residential and/or commercial area. Thus, this type is not the target of project implemented by DPWH RO/DCDEO. It is also difficult to install the storage facilities after the development works have been completed.

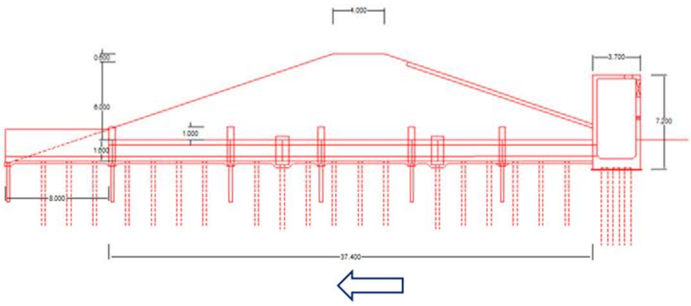
The application of the off-site storage facilities is examined as alternative structural measures for improving storm water drainage, in consideration of condition of catchment area of storm water drainage such as availability of vacant space, landuse along existing drainage channel and constrains for land acquisition. For all drainage areas, combination of different type of structure measures is examined, considering constrains in environment and available land space.

3) Retarding Basin (Dam Type)

There are valleys whose land area have not yet been utilized in hilly area of upper catchment in some drainage areas such as the Mamay Creek and Maa2. In such area, it is possible to install a retarding basin with dam type by filling up the outlet of a valley.

As shown in Figure 3.7.2, the fill dam with slope gradient of 1:3 is applied as the structure of the dam in general. An outlet for gravity drain is installed. The outlet structure should be free of clogging by deposition of sediment and so on. A tower structure for inflow is installed with a screen. The elevation of the inflow section is set higher than the planned maximum elevation of sedimentation. The outlet pipe is set in principle by excavation of the foundation which has enough strength.

The inside of the storage area should be properly maintained by excitation and land preparation in order to secure enough storage volume.

Site Image	Description / Structure Image
	✓ Reserve undeveloped valley in the upstream as retarding pond. ✓ Construction of dam (earth fill or concrete, H <5m) at the outlet, with installation of pump. 

Source: Project Team

Figure 3.7.2 Outline of Retarding Basin (Dam Type)

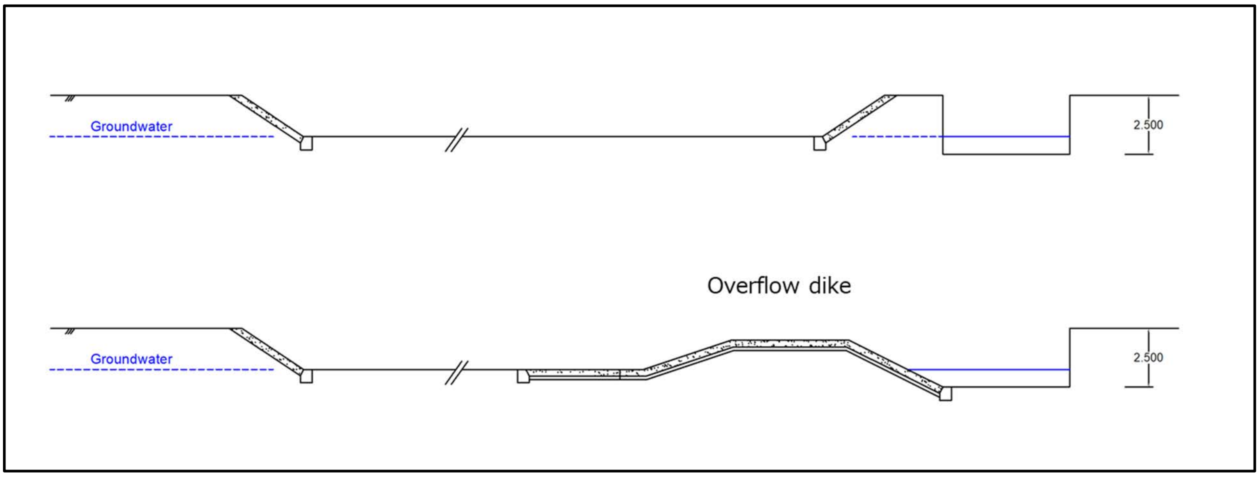
4) Retarding Basin (Excavation Type)

In some drainage areas, there are available land areas which have not yet been developed along the existing drainage channels. Such areas can be candidate sites for installing retarding basins with excavation type.

The excavation type of retarding basin can be further categorized into the following two types, deepening on required storage volume, available land area and so on.

① Shallow Excavation Type

- The relatively shallow retarding basin whose bottom elevation is almost equal or higher than the adjacent channel bed and groundwater level (Maximum depth of 2 to 3m is assumed.) In Figure 3.7.3, the reference drawing is presented.
- The bottom is kept as natural after excavation.
- No impermeable wall is installed, and the embankment is covered by blocks or concrete.
- An overflow weir along adjacent drainage channel and a drainage gate to secure gravity drain after flood are installed.

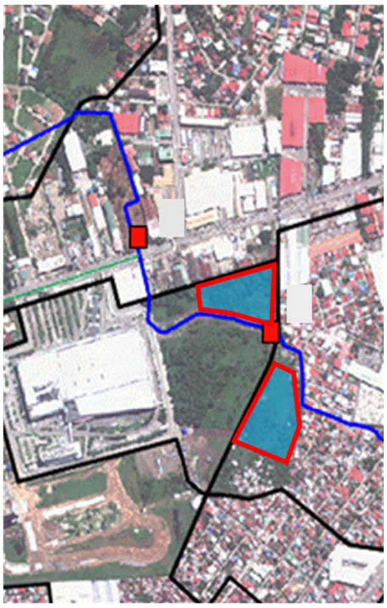
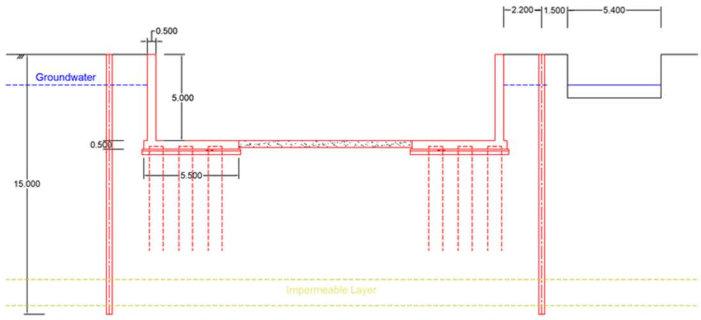


Upper: General Section, Lower: Overflow Section
Source: Project Team

Figure 3.7.3 Typical Drawing for Shallow Excavation Type of Retarding Basin

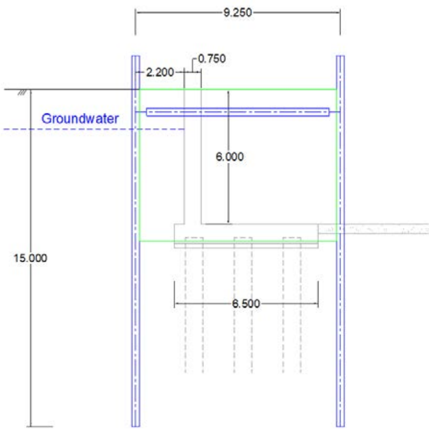
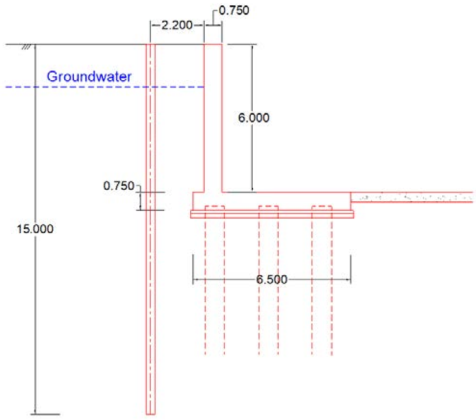
② Deep Excavation Type

- The relatively deep retarding basin whose bottom elevation is lower than the adjacent channel bed and groundwater level (Depth of 3 to 7m is assumed. Refer to Figure 3.7.4).
- Since waterproofing during and after construction is necessary, impermeable wall should be installed in addition to concrete retaining wall with necessary basement and floor slab. As shown in Figure 3.7.5, the temporary earth retaining work can act as the impermeable wall.
- An overflow weir along adjacent drainage channel and a drainage pump to drain the stored water after flood quickly are installed.

Site Image	Description / Structure Image
	✓ Reserve area along the existing drainage channel as retarding basin. ✓ Excavation of the site and construction of the retaining wall, overflow dike and pumping facilities will be needed. ✓ Due to the deep excavation depth, measures against groundwater to be considered both for permanent and temporary facilities. 

Source: Project Team

Figure 3.7.4 Outline of Deep Excavation Type of Retarding Basin

Temporary Structure	Permanent Structure
	

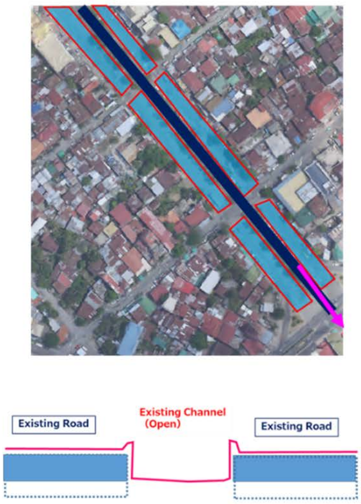
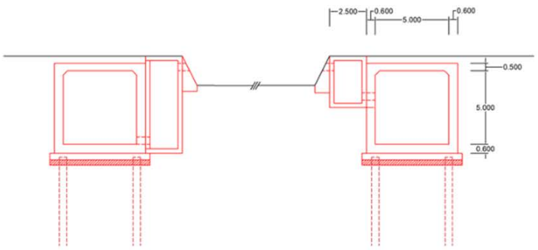
Source: Project Team

Figure 3.7.5 Typical Drawing for Deep Excavation Type of Retarding Basin

5) Retarding Basin (Closed Type under Ground, mainly under Road)

In some drainage areas such as the Agdao drainage area, the closed type of retarding basin which utilizes the underground space under public roads is considered. In case of the Agdao drainage area, both sides with about 10m width from the edge of the existing drainage channel can be available space to install the regarding basin under the road (refer to Figure 3.7.6).

The standard structure is box culvert, and the inlet/outlet structures are installed between the existing channel and the box culvert.

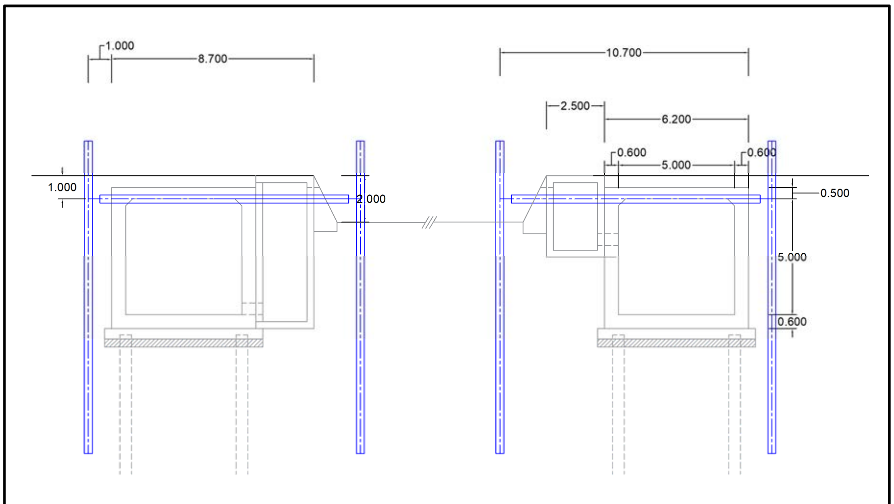
Site Image	Description / Structure Image
	✓ Install underground pond on both sides of the existing channel, under the road. ✓ Water intake from existing channel via overflow weir. ✓ Water is drained by a pump. 

Source: Project Team

Figure 3.7.6 Outline of Closed Type of Retarding Basin (Under Road)

For the construction of this type of structure, since it is necessary to excavate more than 5m in depth and the available space for construction is limited, earth retaining work utilizing cut beams is required refer to Figure 3.7.7). In case that the box culvert is constructed at the site, the minimum required space between the box culvert and the earth retaining work structure is about 2m. It can be reduced to about 1m in case of precast box culvert.

When the size of the box culvert is small (depth of the culvert is less than about 3m) and the excavation work without earth retaining structure can be implemented within the available space for construction, no earth retaining work is required.



Source: Project Team

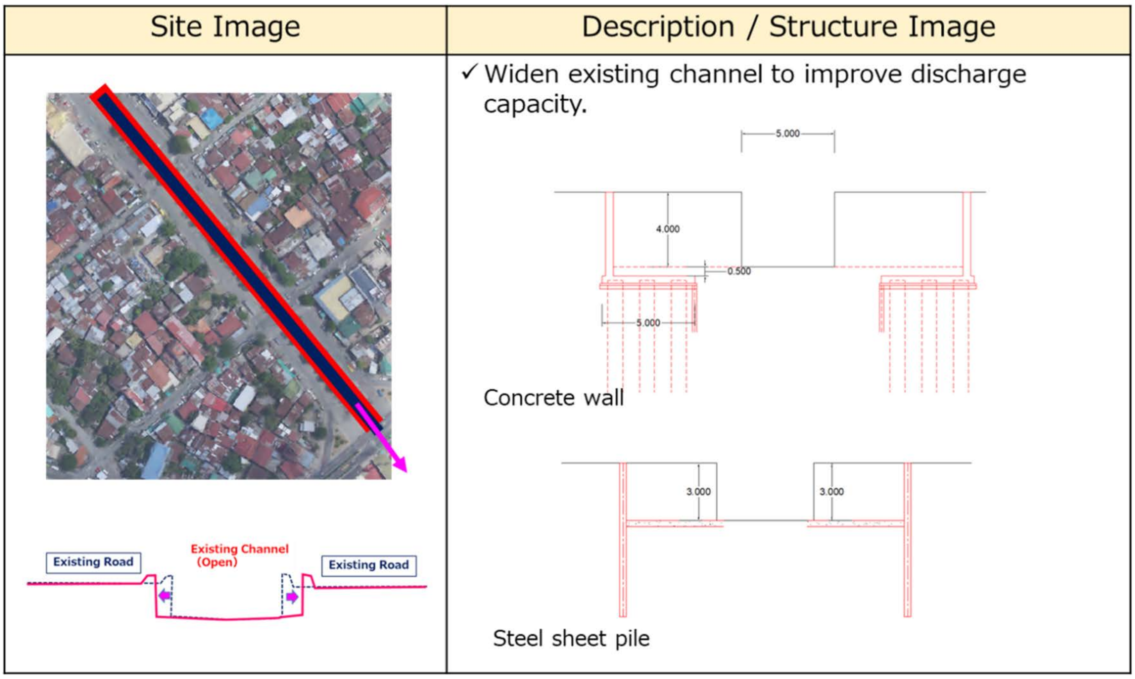
Figure 3.7.7 Typical Drawing for Temporary Structure for Construction of Closed Type of Retarding Basin (Under Road)

The tunnel structure with large diameter as one of possible closed type of retarding basin underground was also preliminary examined. However, the construction cost per storage volume is much higher than the other types (more than 1 order higher), this option was excluded from the alternative measures.

6) Channel Improvement

In order to improve the channel capacity with utilizing available space in the existing channel more efficiently, change to rectangular channel shape is considered. In case that there is available space along the existing channel, channel widening is also considered.

As shown in Figure 3.7.8, in case that channel depth is small (less than about 3m), revetment with steel sheet pile can be applied. For the deep channel, retaining wall with concrete is required. When the channel is widened, temporary bypass channel to drain flood flow during construction should be carefully considered.



Source: Project Team

Figure 3.7.8 Outline of Channel Improvement

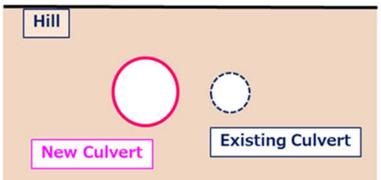
7) Bypass Channel (Culvert)

The installation of culvert as bypass channel considering the limited space for channel improvement is also examined in addition to the channel improvement. DPWH standard design can be applied for the culvert. When the upper part of the culvert is used as a road, the active load and pavement should be considered.

8) Underground Tunnel Diversion Channel

In principle, combination of the above-mentioned structure is examined as alternative structural measures. However, in the Sasa Creek drainage area, the improvement of the existing culvert with 300m in length cannot be done by open-cut method due to the topographical and surrounding condition. In this case, the underground tunnel diversion channel is installed beside the existing culvert.

In the Mamay Creek and Maa2 drainage areas, similar underground tunnel diversion channel is considered as alternative structural measures.

Site Image	Description / Structure Image
 	✓ Existing culver needs to be upgraded but open-cut excavation is not possible due to topography and surrounding environment. ✓ Water flow of existing culvert needs to be secured while upgrading works. ✓ Therefore construction of new culvert near the existing culvert without open-cut excavation, such as underground floodway by pipe-thrusting method is to be applied.

Source: Project Team

Figure 3.7.9 Outline of Underground Tunnel Diversion Channel

(2) Hydraulic Conditions for Structural Measures

The hydraulic conditions for examining alternative structural measures are as follows.

1) Design High Water Level for Main Drainage Channel

In order to minimize the backwater effect to lateral drainage channels, the design high water level is set at the bank level in principle, except for the portion where there is existing dykes.

The reach where extreme high tide and flood level in Davao River affect to the water level in the drainage channel, the influence is separately considered to set the design high water level.

2) Downstream Boundary Condition of Hydraulic Calculation

The downstream boundary condition for hydraulic calculation is given as follows.

- At Davao Gulf: MHHW=0.98m (Mean higher high water level relative to the mean sea level during 1970-1988 with climate change considered)
- At Davao River: Free flow with uniform flow assumption

3) Channel Roughness

The following Manning's coefficients for channel roughness are assumed.

- Improved Open Channel: 0.025
- Natural or Unimproved Open Channel: 0.03 – 0.04
- Closed channel and culvert: 0.015

3.7.2 Alternative Structural Measures for Framework Plan

The Framework Plan is a long term target without setting a target year. As the Framework Plan for the main drainage channel in the main drainage areas, the measures to prevent overflow from the main drainage channel for the extreme storm event with 25 year return period are examined.

The proposed structural measures as the Framework Plan for each of the main drainage areas are presented below.

(1) Roxas Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

The Roxas drainage area is located at the center of Poblacion district., and it drains to Davao Gulf. The drainage area is 1.40km^2. The characteristics of the Roxas drainage area are shown in Table 3.7.1.

Table 3.7.1 Characteristics of Roxas Drainage Area

Drainage Area (km^2)	1.40
Average Slope of Drainage Area (%)	0.60
Total Length of Main Drainage Channel (m)	860
Drainage Outlet	Davao Gulf
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	86
Runoff Coefficient (Existing Landuse (2017))	0.71
Runoff Coefficient (Future Landuse (2045))	0.73
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	36
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.059
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.059

[a]: Commercial, Industrial, Residential, Mixed use, and Road

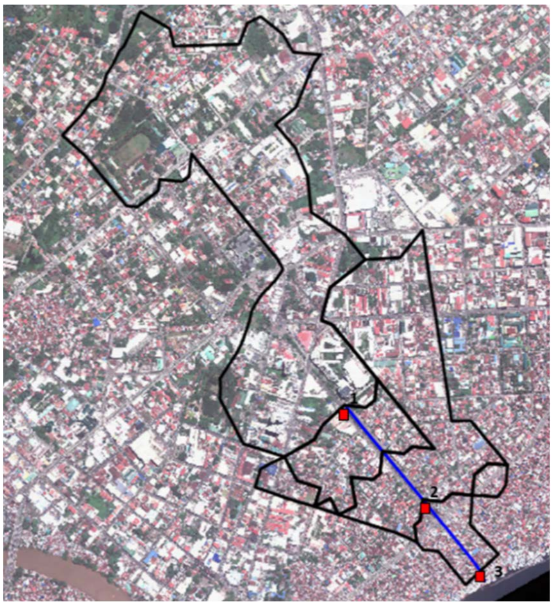
Source: Project Team

Figure 3.7.10 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.

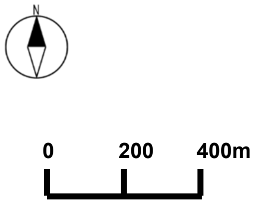
Figure 3.7.11 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period. The reach with about 300m in length from the outlet consists of box culverts and a covered open channel. Because the flow capacity in this reach is quite limited, it is expected that the wide area is inundated in the existing condition.

The coastal road project by DPWH is on-going. In this project, the connection road between the coastal road and Quezon Blvd. will be constructed along the existing Roxas drainage main channel. According to DPWH, together with the road construction, new box culverts which have enough flow capacity for 25 year return period (tentative dimension: W3.2m x H1.8m x 4 cells) will be installed under the road. With this new box culverts, it is expected that there will be no inundation due to overflow from the main drainage channel for 5 year return period.

Figure 3.7.12 shows the expected inundation area due to overflow from the main drainage channel for 25 year return period after the coastal road project will be completed. The measures to address the remaining inundation is examined in the following section.

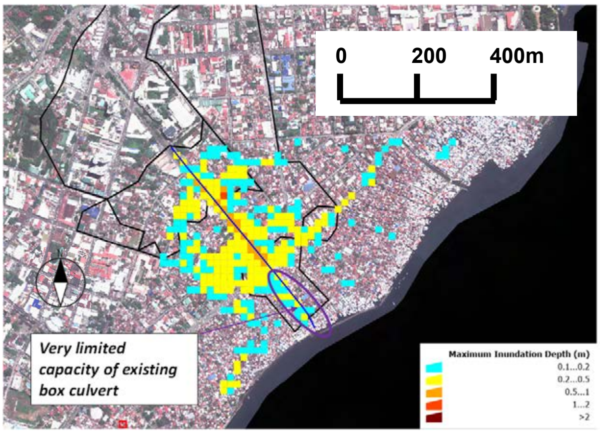


	1	2	3
Chainage (km)	0.86	0.38	0
Basic Design Flood Discharge (m^3/s)	22	25	36
ALT-1 : Design Flood Discharge (m^3/s)	22	25	36
ALT-2 : Design Flood Discharge (m^3/s)	22	14	36
ALT-3 : Design Flood Discharge (m^3/s)	22	13	32



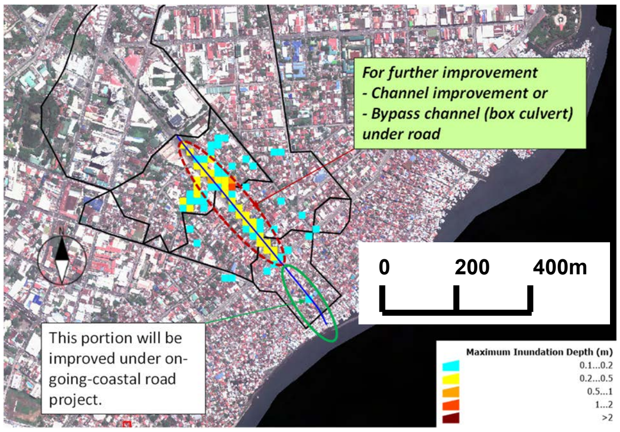
Source: Project Team

Figure 3.7.10 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Roxas Drainage Area



Source: Project Team

Figure 3.7.11 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period (Existing Condition) for Roxas Drainage Area



Source: Project Team

Figure 3.7.12 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period (After Completion of Coastal Road Project) for Roxas Drainage Area

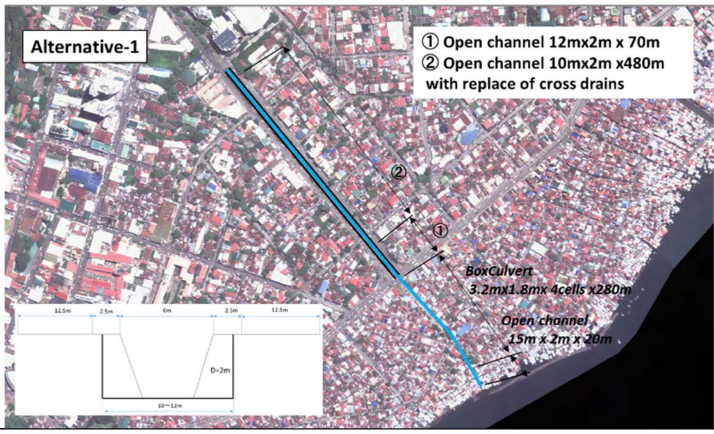
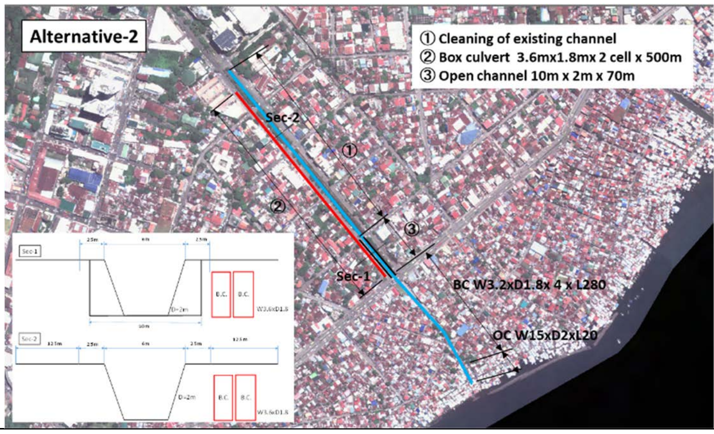
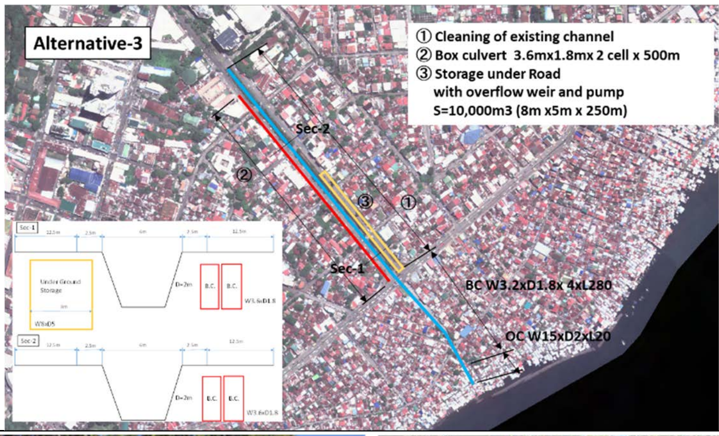
2) Alternative Measures

The following three alternatives are considered.

- Alternative-1: Drainage Channel Improvement
- Alternative-2: Bypass Channel (Culvert) and Partial Drainage Channel Improvement
- Alternative-3: Bypass Channel (Culvert) and Retarding Basin (Closed Type) under Road

Table 3.7.2 shows the conceptual layout of the proposed structures for each of the alternatives.

Table 3.7.2 Alternative Measures in Roxas Drainage Area

Alt.	Conceptual Layout of Structures	Menu of Measures
1		① Drainage Channel Improvement W12m x H2m x L70m ② Drainage Channel Improvement W10m x H2m x L480m Including improvement of cross drains 0 100 200m
2		① Dredging of Existing Channel ② Bypass Channel(Box Culverts) W3.6m x H1.8m x 2cells x L500m ③ Drainage Channel Improvement W10m x H2m x L70m 0 100 200m
3		① Dredging of Existing Channel ② Bypass Channel(Box Culverts) W3.6m x H1.8m x 2cells x L500m ③ Retarding Basin (Closed Type) under Road Storage Capacity=10,000m^3 W8m x H5m x L250m 0 100 200m
	 	Condition around Roxas Channel

Source: Project Team

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.3.

Table 3.7.3 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Roxas Drainage Area)

Alternative	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
1	0.109	0	0.109
2	0.088	0	0.088
3	0.385	0	0.385

Source: Project Team

Among the alternatives, the alternative-2 is recommended since the preliminary estimated cost (total of the construction and land acquisition / compensation cost) is the lowest.

The alternative-1 requires the removal of the existing trees along the Roxas channel, which may negatively affects to the landscape in the surrounding area. Furthermore, the total cost is higher than the alternative-2. Therefore, It is not recommended.

The total cost for alternative-3 is the highest among the alternatives. However, there is no impact on the existing trees along the Roxas channel. If the existing tress in the reach whose channel improvement is proposed in the alternative-2 are not allowed to be disturbed, the alternative-3 could be only available solution despite of its relatively high cost.

(2) Agdao Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

The Agdao drainage area is located at the center of Agdao area., and it drains to Davao Gulf. The drainage area is 5.15km^2. At Leon Garcia Street, the lower Agdao channel is divided into the Dacuado channel and the Old Agdao channel by the box culverts under the road. The Dacudao channel is connected to the Veloso channel which intercepts the runoff from hilly area along the Veloso street. The characteristics of the Agado drainage area are shown in Table 3.7.4.

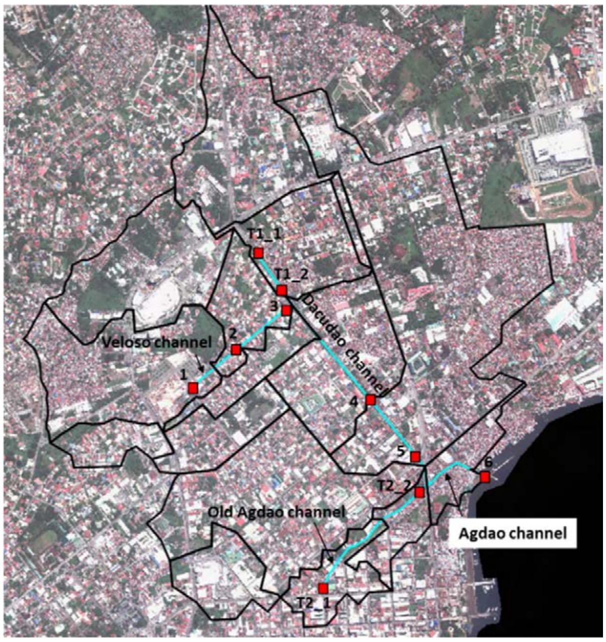
Table 3.7.4 Characteristics of Agdao Drainage Area

Drainage Area (km^2)	5.15
Average Slope of Drainage Area (%)	1.61
Total Length of Main Drainage Channel (m)	3,500
Drainage Outlet	Davao Gulf
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	88
Runoff Coefficient (Existing Landuse (2017))	0.69
Runoff Coefficient (Future Landuse (2045))	0.70
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	116
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.607
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.530

[a]: Commercial, Industrial, Residential, Mixed use, and Road

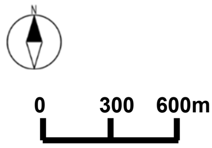
Source: Project Team

Figure 3.7.13 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.



	1	2	3	4	5	6	6D
Chainage (km)	2.29	1.96	1.6	0.97	0.5	0	Div.
Basic Design Flood Discharge (m^3/s)	16	16	33	68	92	116	-
ALT-1: Design Flood Discharge (m^3/s)	3	3	8	20	30	47	-
ALT-2: Design Flood Discharge (m^3/s)	3	3	8	20	30	44	12

	T1_1	T1_2	T2_1	T2_2	T2_n	TSD
Chainage (km)	0.36	0	0.85	0	-0.35	Div.
Basic Design Flood Discharge (m^3/s)	16	25	10	31	-	-
ALT-1: Design Flood Discharge (m^3/s)	8	18	9	15	15	-
ALT-2: Design Flood Discharge (m^3/s)	8	18	9	11	-	3



Source: Project Team

Figure 3.7.13 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Agdao Drainage Area

Figure 3.7.14 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period. The main causes of the inundation are considered as follows.

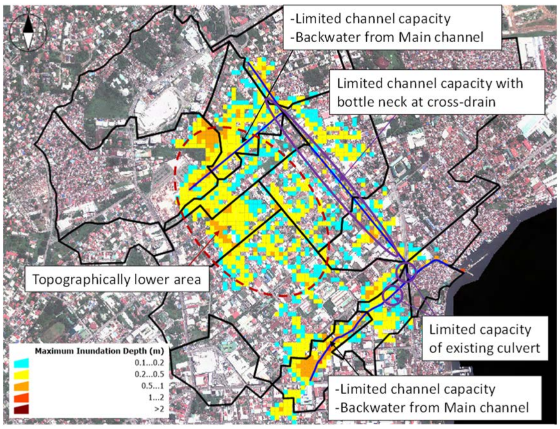
- Lack of flow capacity of the box culverts under Leon Garcia Street which are connected to the lower Agdao channel
- Lack of flow capacity of the Dacudao channel, especially at the cross drains
- Lack of flow capacity of the Veloso Channel and backwater effect from the Dacudao Channel
- Lack of flow capacity of the Old Agdao Channel and backwater effect from the Agdao Channel

The followings are being implemented as 2019-2020 projects by DPWH-DCDEO.

- Improvement of the Dacudao Channel (change to rectangular channel and improvement of cross drains)
- Installation of bypass channel along the Veloso Channel (Box culverts)
- Installation of bypass channel at surrounding area of the Veloso Channel (Pipe culvert)

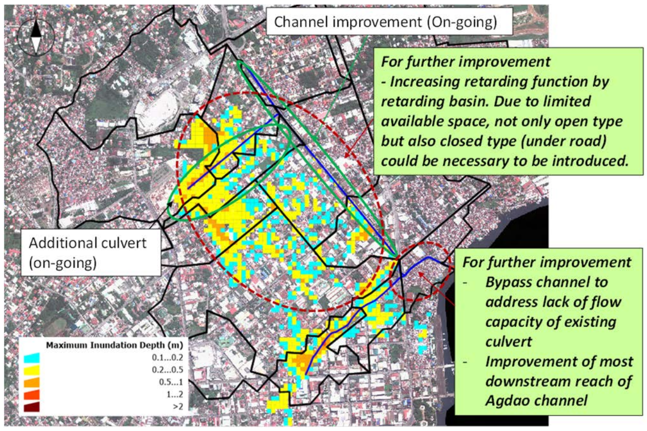
Figure 3.7.15 shows the expected inundation area due to overflow from the main drainage channel for 25 year return period after the completion of on-going DPWH-DCDEO projects. Although the inundation is reduced, there is still wide remaining inundation area. For further improvement, the following measures may be required.

- Mitigation of the backwater effect from the Dacudao Channel to the Veloso Channel by enhancing the retarding function around the Dacudao Channel
- Reduction of inflow from the catchment area of the Old Agdao Channel by enhancing the retarding function in the catchment
- Mitigation of the backwater effect from the Agdao Channel to the Old Agdao Channel



Source: Project Team

Figure 3.7.14 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period (Existing Condition) for Agdao Drainage Area



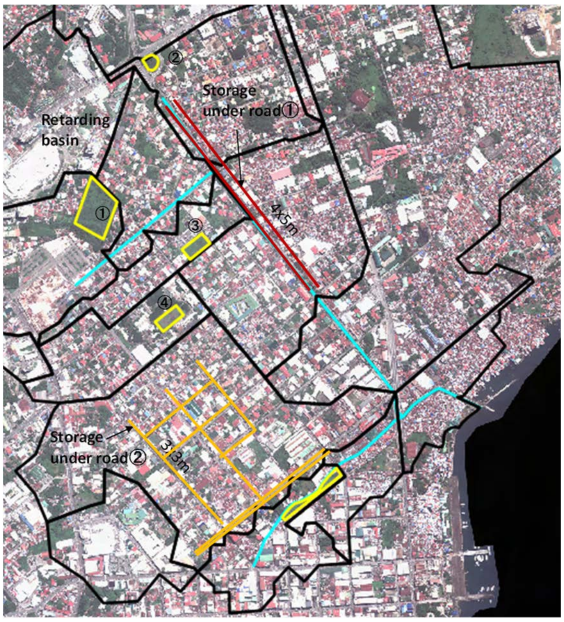
Source: Project Team

Figure 3.7.15 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period (After Completion of On-going DPWH Project) for Agdao Drainage Area

2) Alternative Measures

Our preliminary examination estimated that the necessary channel width in case that only channel widening is applied is two to four times as large as the existing one. The affected number of building is estimated at about 400, and many existing infrastructure such as road need to be reconstructed. Therefore, it is unrealistic to improve the drainage system only by the channel widening.

As for the enhancement of the retarding function, the installation of the retarding basins shown in Figure 3.7.16 is proposed, including the closed type of retarding basin under road in consideration with the limited space in the area around the Veloso Channel and the Dacudao Channel.



A. Retarding Basins
Total Storage Volume = 110x1,000m³

Retarding Basin	①	②	③	④
Type	Open	Closed	Open	Closed
Volume (1,000m³)	72	10	15	13
Area (1,000m²)	20	2.5	5	5
Depth (m)	3.6	4	3	2.6

B. Closed Type of Retarding Basin under Road
Total Storage Volume = 69.5x1,000m³

① Along the Dacudao Channel
Storage Volume =38x1,000m³
(Box Culvert W4mxH5mxL1,900m)

② Catchment Area of the Old Agdao Channel
Storage Volume =31.5x1,000m³
(Box Culvert W3mxH3mxL3,500m)

N 0 200 400m

Source: Project Team

Figure 3.7.16 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Agdao Drainage Area

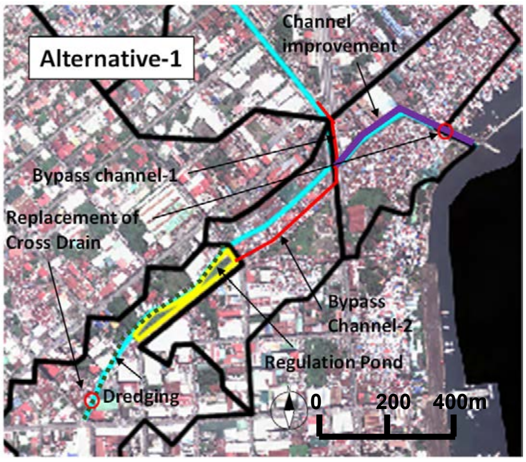
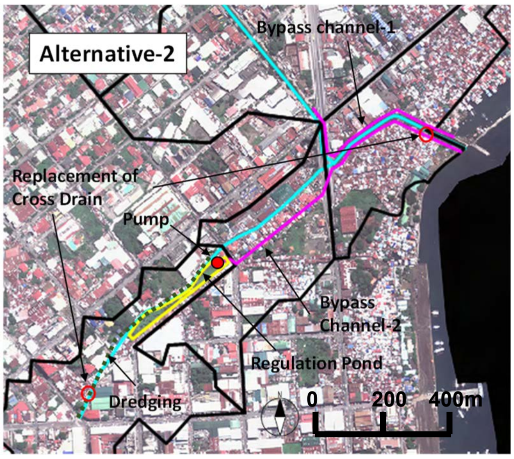
As for the mitigation of the backwater effect from the Agdao Channel to the Old Agdao Channel, the following two alternatives are considered.

- Alternative-1: Separation of the Agdao Channel with Improvement
  The inflow from the Dacudao Channel and that from the Old Agdao Channel is drained to the sea separately, by installing separation in the Agdao Channel. This can secure the gravity drain from the Old Agdao Channel without the influence from the water level rise in the Agdao Channel.
  It is necessary to widen and improve the Agdao Channel. In order to minimize the resettlement of the affected buildings, the channel widening and improvement is limited within the adjacent road area. Furthermore, the bypass channels are installed to supplement the lack of flow capacity of the existing box culverts to connect to the Agdao Chanel.

- Alternative-2: Pump Drainage from the Old Agdao Channel
  Pumps are installed in the Old Agdao Channel, and the water is drained by the pump when the water level of the Agdao Channel is high.
  No channel improvement is required in the Agdao Channel. Instead, the bypass channels under the road adjacent to the Agdao Channel are installed to increase the flow capacity of the existing box culverts to connect to the Agdao Chanel.

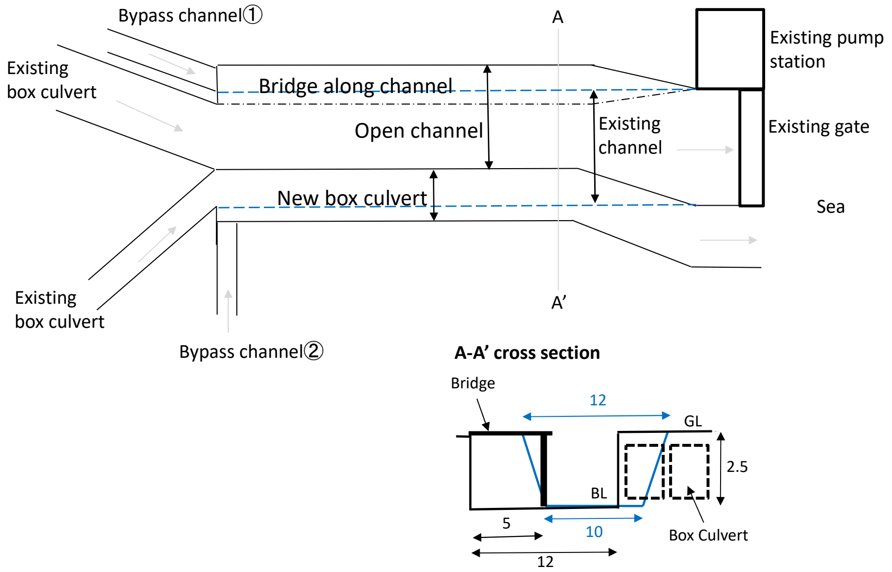
Table 3.7.5 shows the conceptual layout of the proposed structures for each of the alternatives.

Table 3.7.5 Alternative Measures to Mitigate Backwater Effect from the Agdao Channel to the Old Agdao Channel

Alt.	Conceptual Layout of Structures	Menu of Measures
1		① Improvement of the Agdao Channel Open Channel:W12m x H2-3m x L350m Box culverts W3m x H2.5m x 2cells x L350m Bridge along the channel:W5m x L350m ② Bypass Channel 1 Box Culvert W3m x H2.5m x 1cell x L150m ③ Bypass Channel 2 Box Culvert W3m x H2.4m x 1cell x L400m ④ Improvement of the Old Agdao Channel Regulation Pond:A5,000m^2 Dredging:L500m ⑤ Improvement of Cross Drains: 2places
2		① Bypass Channel 1 Box Culvert W2.5m x H2.5m x 1cell x L450m ② Bypass Channel 2 Pipe Culvert D1.83m x 1cell x L750m ③ Pumping Station Pump Capacity: 9m^3/s Regulation Pond: A5,000m^2 Dredging: L500m ④ Improvement of Cross Drains: 2places

Source: Project Team

Figure 3.7.17 presents the conceptual layout of the improvement of the Agdao Channel for the alternative-1.



Source: Project Team

Figure 3.7.17 Conceptual Layout of Improvement

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.6. In the table, the cost for the case that only channel widening is applied is also shown as a reference.

Table 3.7.6 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Agdao Drainage Area)

Alternative	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
1	3.385	0.409	3.794
2	3.739	0.409	4.148
Ref [a]	2.312	2.474	4.786

a: The case that only channel widening is applied
Source: Project Team

Among the alternatives, the alternative-1 is recommended since the preliminary estimated cost (total of the construction and land acquisition / compensation cost) is the lowest.

The alternative-2 requires to operate and maintain the pumps forever, which is less sustainable. The cost is also higher than the alternative-1. It is thus not recommended. However, if the improvement of the Agdao Channel is not possible by some reasons, the alternative-2 may be the possible measures to be applied.

(3) Jerome Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

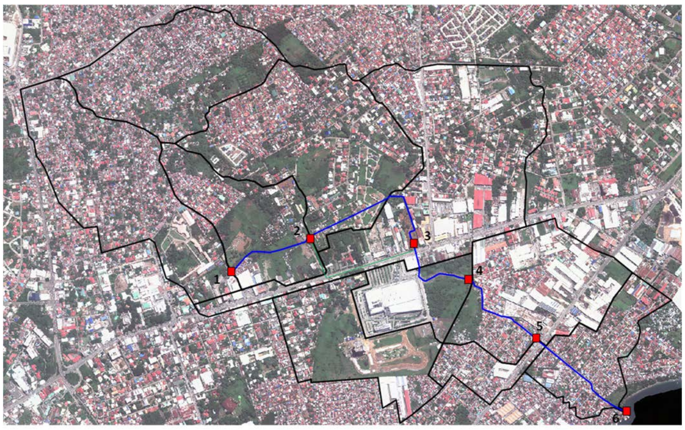
The Jerome drainage area is located at the eastern part of Agdao district., and it drains to Davao Gulf. The drainage area is 4.21km^2. The characteristics of the Jerome drainage area are shown in Table 3.7.7.

Table 3.7.7 Characteristics of Jerome Drainage Area

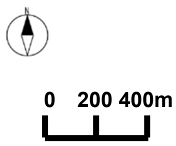
Drainage Area (km^2)	4.21
Average Slope of Drainage Area (%)	2.52
Total Length of Main Drainage Channel (m)	2,900
Drainage Outlet	Davao Gulf
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	86
Runoff Coefficient (Existing Landuse (2017))	0.63
Runoff Coefficient (Future Landuse (2045))	0.72
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	100
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.641
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.733

[a]: Commercial, Industrial, Residential, Mixed use, and Road
Source: Project Team

Figure 3.7.18 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.



	1	2	3	4	5	6
Chainage (km)	2.92	2.48	1.59	1.14	0.62	0
Basic Design Flood Discharge (m^3/s)	15	25	70	74	95	100
ALT-1: Design Flood Discharge (m^3/s)	18	12	18	12	7	20
ALT-2: Design Flood Discharge (m^3/s)	18	12	18	20	10	25



Source: Project Team

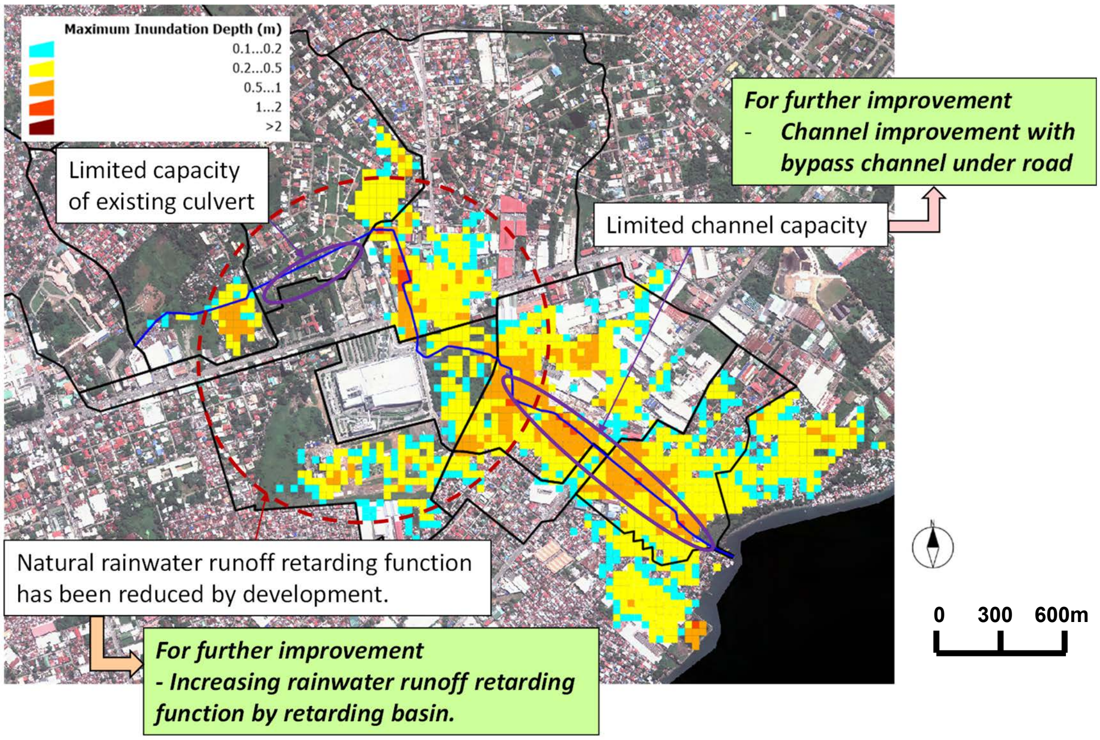
Figure 3.7.18 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Jerome Drainage Area

Figure 3.7.19 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period. The main causes of the inundation are considered as follows.

- Reduction of natural rainwater runoff retarding function due to development
- Lack of flow capacity of the existing box culverts
- Lack of flow capacity of the lower reach of the main drainage channel and limited space for improvement of the channel

For improvement of the drainage system, the following measures may be required.

- Improvement of channel and installation of bypass channel under the adjacent road for the enhancement of flow capacity
- Enhancement of rainwater runoff retarding function by installing retarding basins



Source: Project Team

Figure 3.7.19 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period for Jerome Drainage Area

2) Alternative Measures

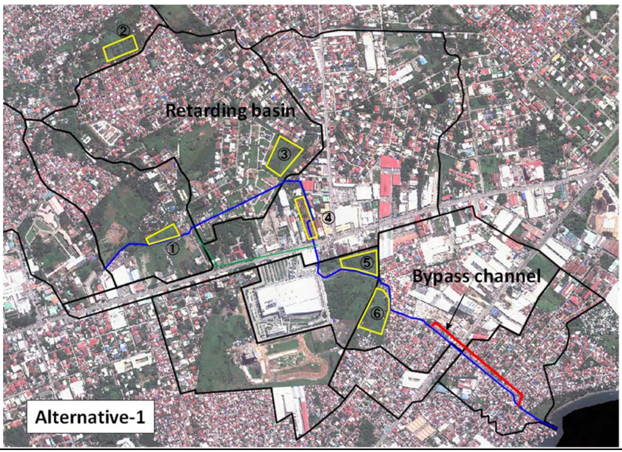
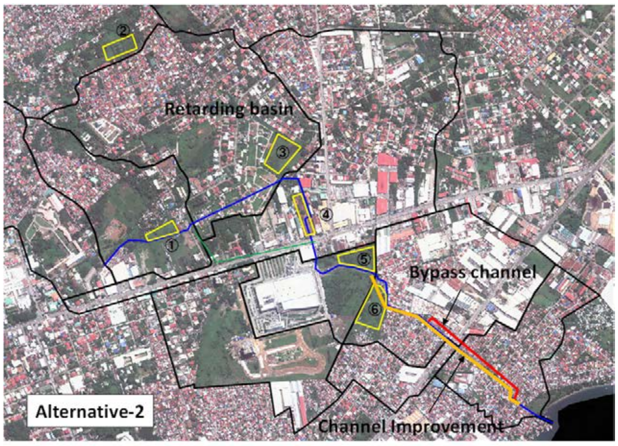
Our preliminary examination estimated that the necessary channel width in case that only channel widening is applied is two to four times as large as the existing one. The affected number of building is estimated at about 350, and many existing infrastructure such as road need to be reconstructed. Therefore, it is unrealistic to improve the drainage system only by the channel widening.

The following two alternatives are considered.

- Alternative-1: Retarding Basins and Bypass Channel (Culvert)
- Alternative-2: Retarding Basins, Channel Improvement and Bypass Channel (Culvert)

Table 3.7.8 shows the conceptual layout of the proposed structures for each of the alternatives.

Table 3.7.8 Alternative Measures in Jerome Drainage Area

<table>
<tr><th>Alt.</th><th>Conceptual Layout of Structures</th><th>Menu of Measures</th></tr>
<tr><td>1</td><td>
</td><td>A. Retarding Basins
Total Storage Volume = 336x1,000m³
<table>
<tr><th></th><th>①</th><th>②</th><th>③</th><th>④</th><th>⑤</th><th>⑥</th></tr>
<tr><td>Volume (1,000m3)</td><td>33</td><td>40</td><td>64</td><td>48</td><td>58</td><td>93</td></tr>
<tr><td>Area (1,000m2)</td><td>6</td><td>9</td><td>15</td><td>8</td><td>10</td><td>16</td></tr>
<tr><td>Depth (m)</td><td>5.5</td><td>4.5</td><td>4.3</td><td>6</td><td>5.8</td><td>5.8</td></tr>
</table>
B. Bypass Channel
Box Culvert
W3m x H1.7m x 1cell x L610m
N 0 200 400m</td></tr>
<tr><td>2</td><td>
</td><td>A. Retarding Basins
Total Storage Volume = 288x1,000m³
<table>
<tr><th></th><th>①</th><th>②</th><th>③</th><th>④</th><th>⑤</th><th>⑥</th></tr>
<tr><td>Volume (1,000m3)</td><td>33</td><td>40</td><td>64</td><td>48</td><td>15</td><td>88</td></tr>
<tr><td>Area (1,000m2)</td><td>6</td><td>9</td><td>15</td><td>8</td><td>3</td><td>16</td></tr>
<tr><td>Depth (m)</td><td>5.5</td><td>4.5</td><td>4.3</td><td>6</td><td>5</td><td>5.5</td></tr>
</table>
B. Channel Improvement
W5m x H2.5-3m x L1,000m
C. Bypass Channel
Box Culvert
W3m x H2.3m x 1cell x L610m
N 0 200 400m</td></tr>
</table>

Source: Project Team

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.9. In the table, the cost for the case that only channel widening is applied is also shown as a reference.

Table 3.7.9 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Jerome Drainage Area)

Alternative	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
1	2.492	1.144	3.636
2	2.516	0.860	3.377
Ref [a]	1.455	1.943	3.399

a: The case that only channel widening is applied
Source: Project Team

Among the alternatives, the alternative-2 is recommended since the preliminary estimated cost (total of the construction and land acquisition / compensation cost) is the lowest.

The alternative-2 maximizes the flow capacity of the existing channel under the condition with limited space. If the channel improvement is not possible by some reasons, the alternative-1 may be the possible measures to be applied despite of the higher cost.

(4) Mamay Creek Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

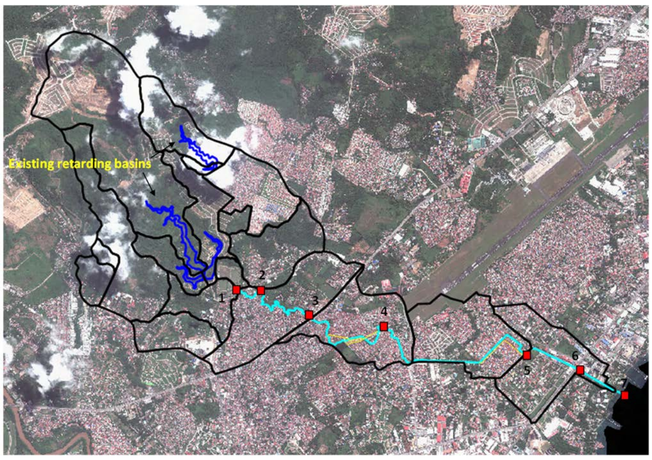
The Mamay Creek drainage area has a catchment from the hilly area in the north of the Diversion Road to the western part of the Davao International Airport, and it drains to Davao Gulf. The drainage area is 8.91km^2. The characteristics of the Mamay Creek drainage area are shown in Table 3.7.10.

Table 3.7.10 Characteristics of Mamay Creek Drainage Area

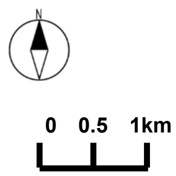
Drainage Area (km^2)	8.91
Average Slope of Drainage Area (%)	11.04
Total Length of Main Drainage Channel (m)	6,000
Drainage Outlet	Davao Gulf
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	63
Runoff Coefficient (Existing Landuse (2017))	0.56
Runoff Coefficient (Future Landuse (2045))	0.63
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	186
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.305
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.455

[a]: Commercial, Industrial, Residential, Mixed use, and Road
Source: Project Team

Figure 3.7.20 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.



	1	2	3	4	5	6	7
Chainage (km)	6.00	5.68	4.52	3.42	1.23	0.58	0.00
Basic Design Flood Discharge (m^3/s)	65	107	137	150	157	177	186
Flood Discharge with existing Retarding Basin (m3/s)	28	54	76	86	102	121	130
Alt-1: Design Flood Discharge (m^3/s)	10	15	22	12	31	42	53
Alt-2: Design Flood Discharge (m^3/s)	0	0	27	10	29	39	49
Alt-3: Design Flood Discharge (m^3/s)	10	15	22	15	48	60	70



Source: Project Team

Figure 3.7.20 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Mamay Creek Drainage Area

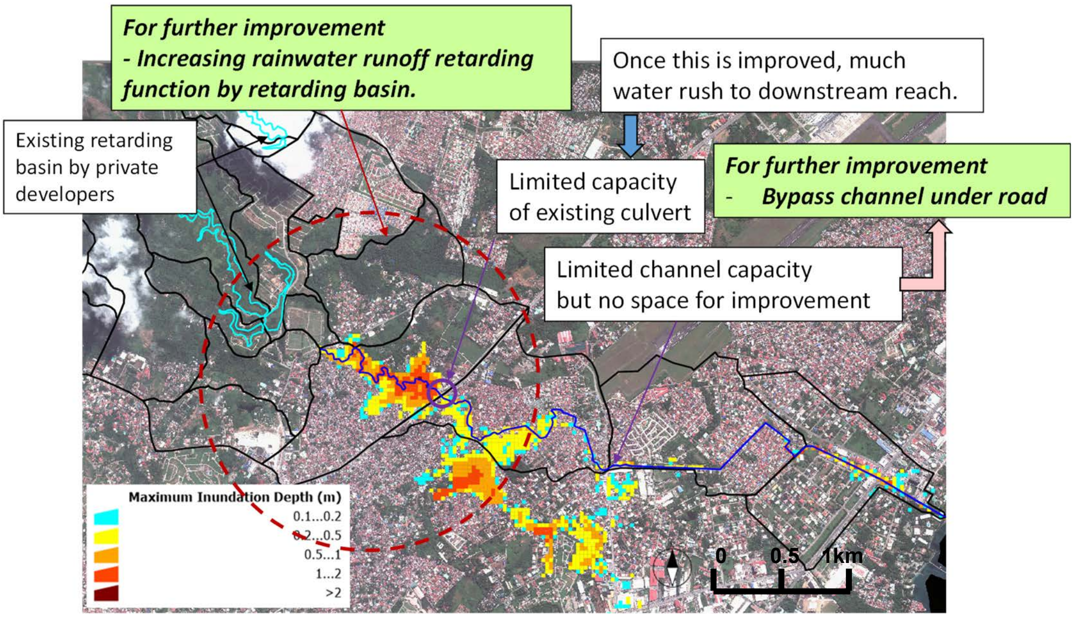
There is the retarding basins which were installed by private developers when sub-divisions were developed in the upper catchment of the Mamay Creek. It is expected that about 50m^3/s of the peak discharge for 25 year retune period is reduced by these retarding basins. It is recommended that the existing retarding basins be conserved. In the present plan, it is assumed that the existing retarding basins and their function will be kept in future.

Figure 3.7.21 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period. The main causes of the inundation are considered as follows.

- Increase in runoff due to development of the upper catchment
- Backwater due to lack of flow capacity of the existing box culvert at the Diversion Road
- Lack of flow capacity of the existing box culverts
- Lack of flow capacity of the lower reach of the main drainage channel and limited space for improvement of the channel

For improvement of the drainage system, the following measures may be required.

- If the flow capacity of the exiting box culvert at the Diversion Road is improved, higher peak discharge can occur at the downstream reach. However, it is difficult to increase the flow capacity there, since the available space for channel improvement is quite limited. Therefore, the enhancement of rainwater runoff retarding function by installing retarding basins should be considered.
- Improvement of channel or installation of bypass channel under the adjacent road for the enhancement of flow capacity



Source: Project Team

Figure 3.7.21 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period for Mamay Creek Drainage Area

2) Alternative Measures

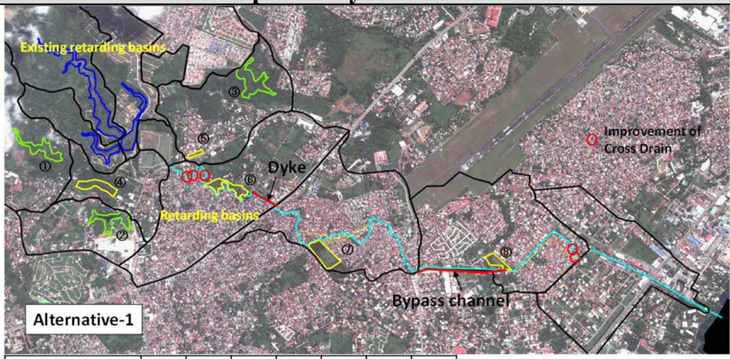
Our preliminary examination estimated that the necessary channel width in case that only channel widening is applied is two to five times as large as the existing one. The affected number of building is estimated at about 1,000, and many existing infrastructure such as road need to be reconstructed. Therefore, it is unrealistic to improve the drainage system only by the channel widening.

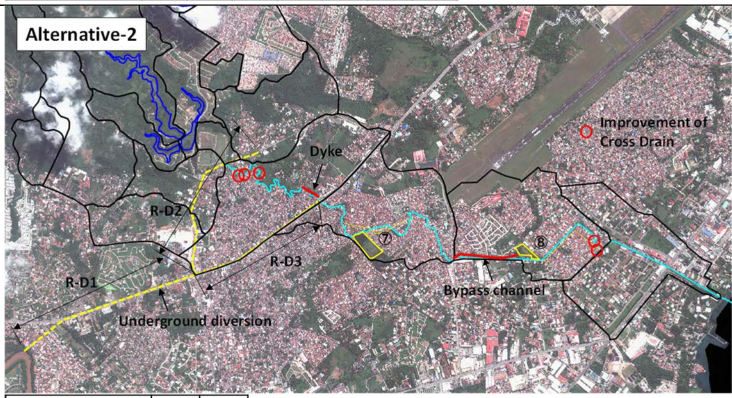
The following three alternatives are considered.

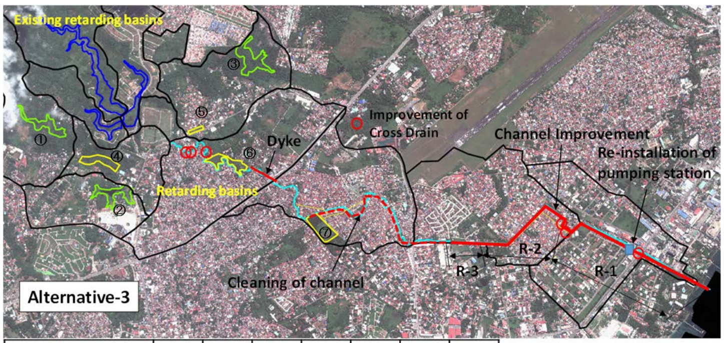
- Alternative-1: Retarding Basins, Bypass Channel and Dyke
- Alternative-2: Underground Diversion Tunnel, Retarding Basins, Bypass Channel and Dyke
- Alternative-3: Retarding Basins, Channel Improvement and Dyke

Table 3.7.11 shows the conceptual layout of the proposed structures for each of the alternatives.

Table 3.7.11 Alternative Measures in Mamay Creek Drainage Area

<table>
<tr><th>Alt.</th><th>Conceptual Layout of Structures</th><th>Menu of Measures</th></tr>
<tr><td>1</td><td>


<table>
<tr><td>Retarding Basins</td><td>①</td><td>②</td><td>③</td><td>④</td><td>⑤</td><td>⑥</td><td>⑦</td></tr>
<tr><td>Type</td><td colspan="3">dam</td><td colspan="4">open</td></tr>
<tr><td>Volume (1,000m3)</td><td>41</td><td>26</td><td>68</td><td>33</td><td>15</td><td>24</td><td>92</td></tr>
<tr><td>Area (1,000m2)</td><td>20</td><td>22</td><td>30</td><td>15</td><td>3</td><td>16</td><td>22</td></tr>
<tr><td>Dam height/ Depth (m)</td><td>6</td><td>2</td><td>5</td><td>2.2</td><td>5</td><td>1.5</td><td>4.2</td></tr>
</table>
0 0.5 1km
</td><td>A. Retarding Basins (Dam Type)
Total Storage Volume
=135x1,000m3
B. Retarding Basins (Excavation Type)
Total Storage Volume
= 217x1,000m^3
C. Dyke
H2m x L220m
D. Bypass Channel
Box Culvert
W3.3mxH1.7mx1cellxL660m
E. Improvement of Cross Drains 5places</td></tr>
<tr><td>2</td><td>


<table>
<tr><td>Retarding Basins</td><td>⑦</td><td>⑧</td></tr>
<tr><td>Type</td><td colspan="2">open</td></tr>
<tr><td>Volume (1,000m3)</td><td>6</td><td>15</td></tr>
<tr><td>Area (1,000m2)</td><td>4</td><td>10</td></tr>
<tr><td>Depth (m)</td><td>1.5</td><td>1.5</td></tr>
</table>
0 0.5 1km
</td><td>A. Retarding Basins (Excavation Type)
Total Storage Volume
=21x1,000m^3
B. Underground Diversion Tunnel
R-D1: D7.2m x L1,500m
R-D2: D4.7m x L1,350m
R-D3: D4.3m x L1,200m
C. Dyke
H2m x 220m
D. Bypass Channel
Box Culvert
W3.3mxH1.7mx1cellxL660m
E. Improvement of Cross Drains 5places</td></tr>
<tr><td>3</td><td>


<table>
<tr><td>Retarding Basins</td><td>①</td><td>②</td><td>③</td><td>④</td><td>⑤</td><td>⑥</td><td>⑦</td></tr>
<tr><td>Type</td><td colspan="3">dam</td><td colspan="4">open</td></tr>
<tr><td>Volume (1,000m3)</td><td>41</td><td>26</td><td>68</td><td>33</td><td>15</td><td>24</td><td>92</td></tr>
<tr><td>Area (1,000m2)</td><td>20</td><td>22</td><td>30</td><td>15</td><td>3</td><td>16</td><td>22</td></tr>
<tr><td>Dam height/ Depth (m)</td><td>6</td><td>2</td><td>5</td><td>2.2</td><td>5</td><td>1.5</td><td>4.2</td></tr>
</table>
0 0.5 1km
</td><td>A. Retarding Basins (Dam Type)
Total Storage Volume
=135x1,000m^3
B. Retarding Basins (Excavation Type)
Total Storage Volume
= 164x1,000m^3
C. Dyke
H2m x L220m
D. Channel Improvement L2,400m
E. Dredging L1,600m
F. Improvement of Cross Drains 6places
G. Replacement of Existing Pumping Station</td></tr>
</table>

Source: Project Team

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.12. In the table, the cost for the case that only channel widening is applied is also shown as a reference.

Table 3.7.12 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Mamay Creek Drainage Area)

Alternative	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
1	1.136	0.404	1.540
2	13.112	0.104	12.216
3	1.703	0.317	2.020
Ref [a]	2.073	1.926	4.000

a: The case that only channel widening is applied
Source: Project Team

Among the alternatives, the alternative-1 is recommended since the preliminary estimated cost (total of the construction and land acquisition / compensation cost) is the lowest.

The alternative-2 is not recommended because the construction cost is almost one order higher than the others despite the land acquisition / compensation cost is the lowest.

The alternative-3 maximizes the flow capacity of the existing channel under the condition with limited space. However, it is necessary to replace the existing pumping station which has just been installed. The cost is also higher than the alternative-1. Therefore, it is not recommended.

(5) Sasa Creek Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

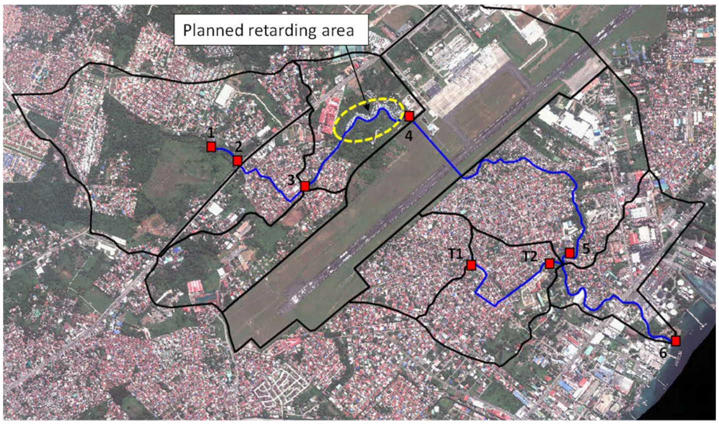
The Sasa Creek drainage area has a catchment from the hilly area in the north of the Diversion Road to the Davao International Airport, and it drains to Davao Gulf. The drainage area is 5.97km^2. The characteristics of the Sasa Creek drainage area are shown in Table 3.7.13.

Table 3.7.13 Characteristics of Sasa Creek Drainage Area

Drainage Area (km^2)	5.97
Average Slope of Drainage Area (%)	4.85
Total Length of Main Drainage Channel (m)	6,000
Drainage Outlet	Davao Gulf
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	66
Runoff Coefficient (Existing Landuse (2017))	0.57
Runoff Coefficient (Future Landuse (2045))	0.63
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	141
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.100
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.191

[a]: Commercial, Industrial, Residential, Mixed use, and Road
Source: Project Team

Figure 3.7.22 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.



	1	2	3	4	5	6
Chainage (km)	5.00	4.82	4.25	3.25	1.27	0.00
Basic Design Flood Discharge (m³/s)	42	42	65	79	108	141
Design Flood Discharge (m³/s)	42	6	16	12	51	86

	T1	T2
Chainage (km)	0.95	0.00
Basic Design Flood Discharge (m³/s)	11	22
Design Flood Discharge (m³/s)	11	22

Source: Project Team

Figure 3.7.22 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Sasa Creek Drainage Area

Figure 3.7.23 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period.

There are box culverts across the Davao International Airport. The upstream area of the box culverts was originally planned as a retarding basin. Although it is the high risk area for flood damage due to deep inundation, there are currently many informal settlers. According to officers of Davao City, this area will be secured as the retarding basin by resettlement of the existing informal settlers.

The main causes of the inundation in the Sasa Creek drainage area are considered as follows.

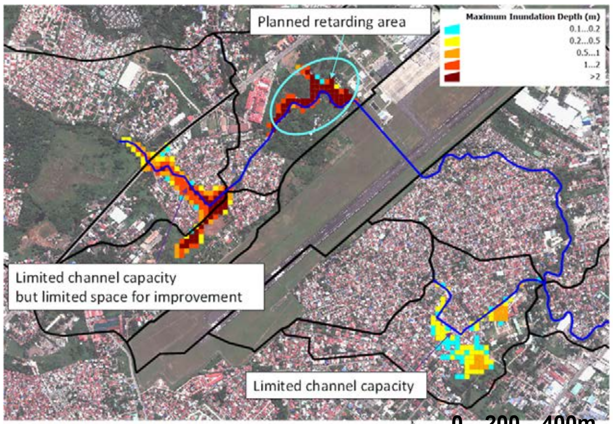
- Lack of flow capacity of the main drainage channel in La Verna area and limited space for improvement of the channel
- Lack of flow capacity of the drainage channel in Pampanga area

Since there is severe inundation around La Verna area, which disturbs the traffic from the central area of Davao City to the Davao International Airport, the following improvements are being implemented by DPWH-DCDEO.

- Dredging of existing drainage channel
- Improvement of cross drains
- Installation of pumping station (capacity =2m^3/s)
- Installation of retarding basin (storage capacity = 65,000m^3) (Partially implemented)
- Installation of underground diversion tunnel (D3m x L300m)
- Improvement of drainage channel downstream of the underground diversion tunnel

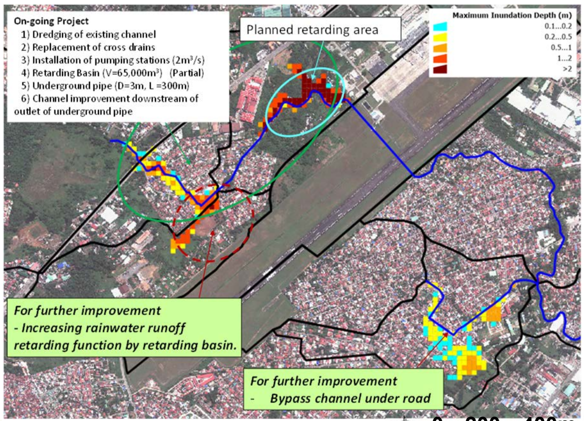
Figure 3.7.24 shows the expected inundation area due to overflow from the main drainage channel for 25 year return period after the completion of on-going DPWH-DCDEO projects. Although the inundation is reduced, there is still wide remaining inundation area. For further improvement, the following measures may be required.

- Completion of the remaining portion of the retarding basin (storage capacity = 65,000m^3)
- Further enhancement of rainwater runoff retarding function
- Installation of bypass channel under the adjacent road for the enhancement of flow capacity in Pampanga area



Source: Project Team

Figure 3.7.23 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period (Existing Condition) for Sasa Creek Drainage Area



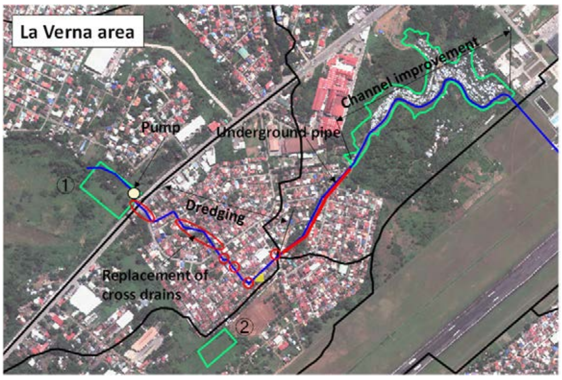
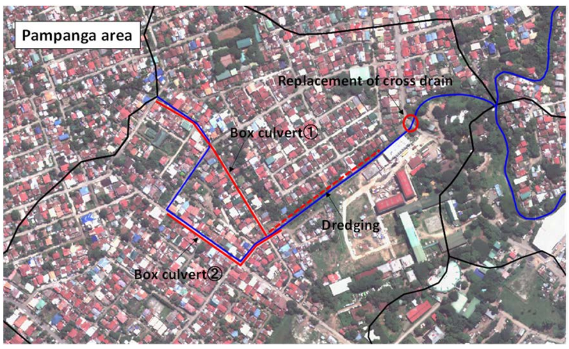
Source: Project Team

Figure 3.7.24 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period (After Completion of On-going DPWH Project) for Sasa Creek Drainage Area

2) Supplemental Measures

Table 3.7.14 shows the conceptual layout of the proposed structures for La Verna and Pampanga areas to supplement the on-going Projects by DPWH to prevent the overflow from the main drainage channel for 25 year return period.

Table 3.7.14 Measures in Sasa Creek Drainage Area

Area	Conceptual Layout of Structures	Menu of Measures
La Veran		A. Retarding Basins (Excavation Type) ① Retarding Basin (Uncompleted portion) Storage Capacity =65x1,000m³ ② Retarding Basin Storage Capacity =20x1,000m³ 0 150 300m
Pampanga		A. Bypass Channels Box Culvert① W2m x H1.5m x 1cell x L310m Box Culvert② W2 x H1.3m x 1cell x L250m B. Improvement of Cross Drains 1place C. Dredging L210m 0 100 200m

Source: Project Team

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.15.

Table 3.7.15 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Sasa Creek Drainage Area)

Area	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
La Verna	0.447	0.033	0.480
Pampanga	0.027	0	0.026
Total	0.474	0.033	0.507

Source: Project Team

(6) Emars Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

The Emars drainage area is located at the eastern part of Matina-Aplaya area., and it drains to Davao Gulf. The drainage area is 2.42km^2. The characteristics of the Emars drainage area are shown in Table 3.7.16.

Table 3.7.16 Characteristics of Emars Drainage Area

Drainage Area (km^2)	2.42
Average Slope of Drainage Area (%)	3.22
Total Length of Main Drainage Channel (m)	2,000
Drainage Outlet	Davao Gulf
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	76
Runoff Coefficient (Existing Landuse (2017))	0.59
Runoff Coefficient (Future Landuse (2045))	0.70
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	46
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.085
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.319

[a]: Commercial, Industrial, Residential, Mixed use, and Road
Source: Project Team

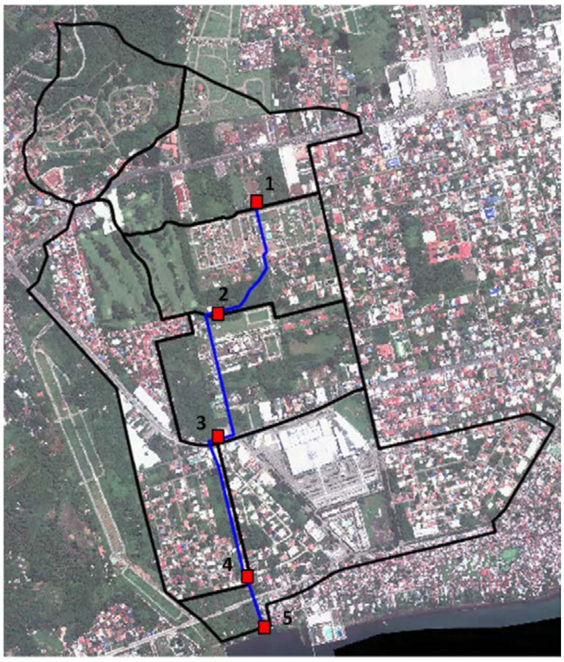
Figure 3.7.25 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.

Figure 3.7.26 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period. The main causes of the inundation are considered as follows.

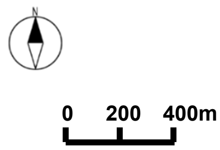
- Reduction of natural rainwater runoff retarding function due to development
- The proposed main drainage channel in M/P1998 has not yet been constructed. The storm water in the drainage area is drained by the channel connected by culverts. Although the capacity of the culverts is not enough, the space for installing channel is quite limited.

For improvement of the drainage system, the following measures may be required.

- Enhancement of rainwater runoff retarding function by installing retarding basins
- Installation of bypass channel for the enhancement of flow capacity

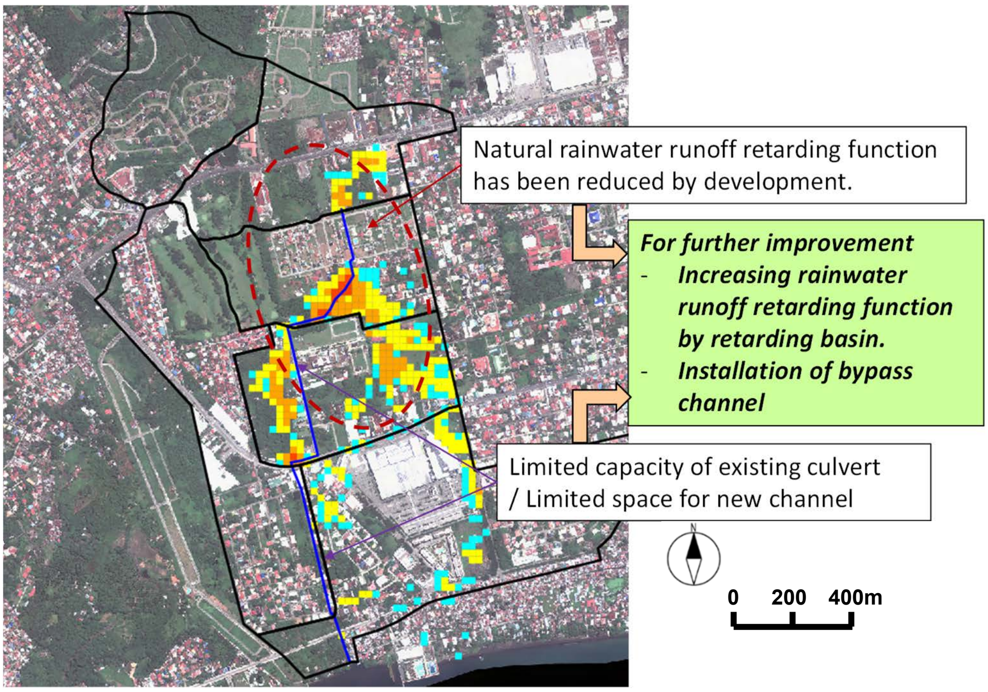


	1	2	3	4	5
Chainage (km)	1.94	1.36	0.75	0.17	0
Basic Design Flood Discharge (m3/s)	20	20	28	34	46
ALT-1: Design Flood Discharge (m3/s)	2	1.5	2.5	15	32
ALT-2: Design Flood Discharge (m3/s)	2	1.5	2.5	15	40



Source: Project Team

Figure 3.7.25 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Emars Drainage Area



Source: Project Team

Figure 3.7.26 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period for Emars Drainage Area

2) Alternative Measures

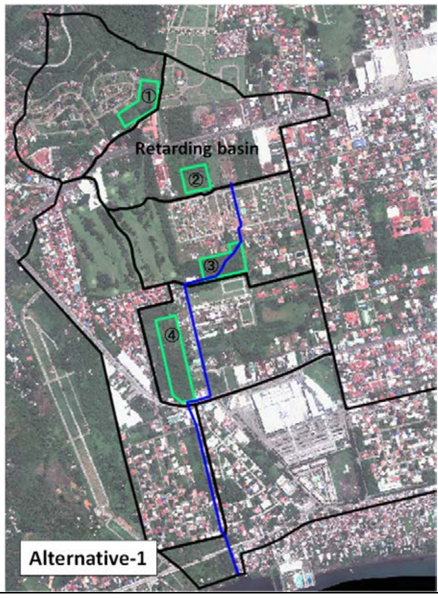
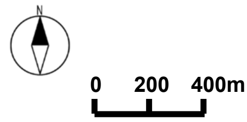
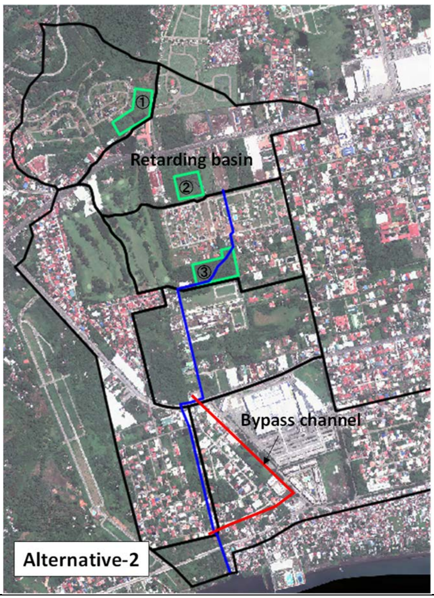
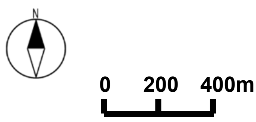
Our preliminary examination estimated that the necessary channel width in case that only channel widening is applied is about 7m. The affected number of building is estimated at about 40, and many existing infrastructure such as road need to be reconstructed. Therefore, it is unrealistic to improve the drainage system only by the channel widening.

The following two alternatives are considered.

- Alternative-1: Retarding Basins
- Alternative-2: Retarding Basins and Bypass Channel (Culvert)

Table 3.7.17 shows the conceptual layout of the proposed structures for each of the alternatives.

Table 3.7.17 Alternative Measures in Emars Drainage Area

<table>
<tr><th>Alt.</th><th>Conceptual Layout of Structures</th><th>Menu of Measures</th></tr>
<tr><td>1</td><td>
</td><td>A. Retarding Basins
Total Storage Volume = 236x1,000m³
<table>
<tr><th></th><th>①</th><th>②</th><th>③</th><th>④</th></tr>
<tr><td>Type</td><td>Open</td><td>Open</td><td>Open</td><td>Open</td></tr>
<tr><td>Volume (1,000m3)</td><td>30</td><td>20</td><td>36</td><td>150</td></tr>
<tr><td>Area (1,000m2)</td><td>15</td><td>10</td><td>18</td><td>30</td></tr>
<tr><td>Depth (m)</td><td>2</td><td>2</td><td>2</td><td>5</td></tr>
</table>

</td></tr>
<tr><td>2</td><td>
</td><td>B. Retarding Basins
Total Storage Volume = 86x1,000m³
<table>
<tr><th></th><th>①</th><th>②</th><th>③</th></tr>
<tr><td>Type</td><td>Open</td><td>Open</td><td>Open</td></tr>
<tr><td>Volume (1,000m3)</td><td>30</td><td>20</td><td>36</td></tr>
<tr><td>Area (1,000m2)</td><td>15</td><td>10</td><td>18</td></tr>
<tr><td>Depth (m)</td><td>2</td><td>2</td><td>2</td></tr>
</table>
A. Bypass Channel
Box Culvert
W2m x H2m x 1cell x L1,060m

</td></tr>
</table>

Source: Project Team

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.18. In the table, the cost for the case that only channel widening is applied is also shown as a reference.

Table 3.7.18 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Emars Drainage Area)

Alternative	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
1	0.848	0.921	1.768
2	0.113	0.483	0.595
Ref [a]	0.480	0.356	0.836

a: The case that only channel widening is applied
Source: Project Team

Among the alternatives, the alternative-2 is recommended since the preliminary estimated cost (total of the construction and land acquisition / compensation cost) is the lowest.

(7) Shanghai Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

The Shanghai drainage area is located at the western part of Matina-Aplaya area., and it drains to Davao Gulf. The drainage area is 1.60km^2. The characteristics of the Shanghai drainage area are shown in Table 3.7.19.

Table 3.7.19 Characteristics of Shanghai Drainage Area

Drainage Area (km^2)	1.60
Average Slope of Drainage Area (%)	1.12
Total Length of Main Drainage Channel (m)	310
Drainage Outlet	Davao Gulf
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	65
Runoff Coefficient (Existing Landuse (2017))	0.55
Runoff Coefficient (Future Landuse (2045))	0.65
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	39
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.068
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.113

[a]: Commercial, Industrial, Residential, Mixed use, and Road
Source: Project Team

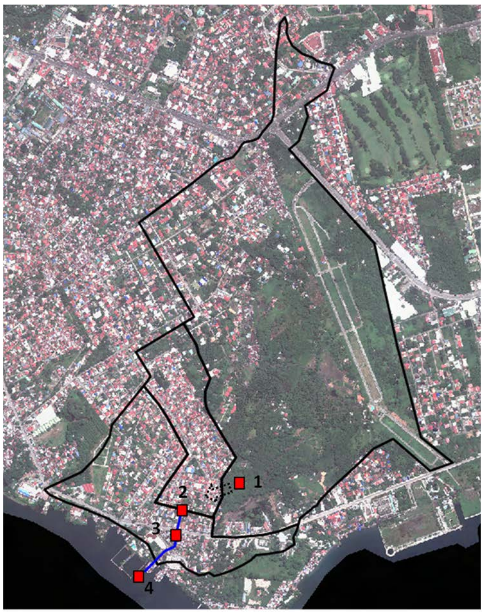
Figure 3.7.27 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.

Figure 3.7.28 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period. The main causes of the inundation are considered as follows.

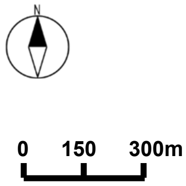
- Reduction of natural rainwater runoff retarding function due to development
- The proposed main drainage channel which drains from the upper catchment to the sea in M/P1998 has not yet been constructed. The severe inundation occurs at the connection point to the existing culvert without enough capacity.

For improvement of the drainage system, the following measures may be required.

- Enhancement of rainwater runoff retarding function by installing retarding basins
- Installation of diversion channel which connects the upper catchment area and the sea

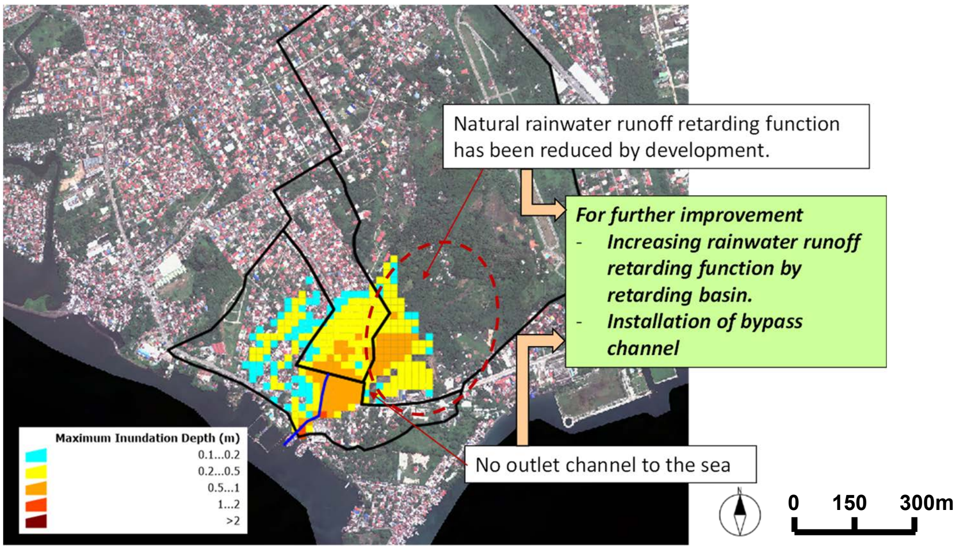


	1	2	3	4	Div.
Chainage (km)		0.31	0.21	0	0
Basic Design Flood Discharge (m3/s)	30	31	31	39	-
Alt 1: Design Discharge (m3/s)	30	5	5	13	30
Alt 2: Design Discharge (m3/s)	30	5	5	13	13



Source: Project Team

Figure 3.7.27 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Shanghai Drainage Area



Source: Project Team

Figure 3.7.28 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period for Shanghai Drainage Area

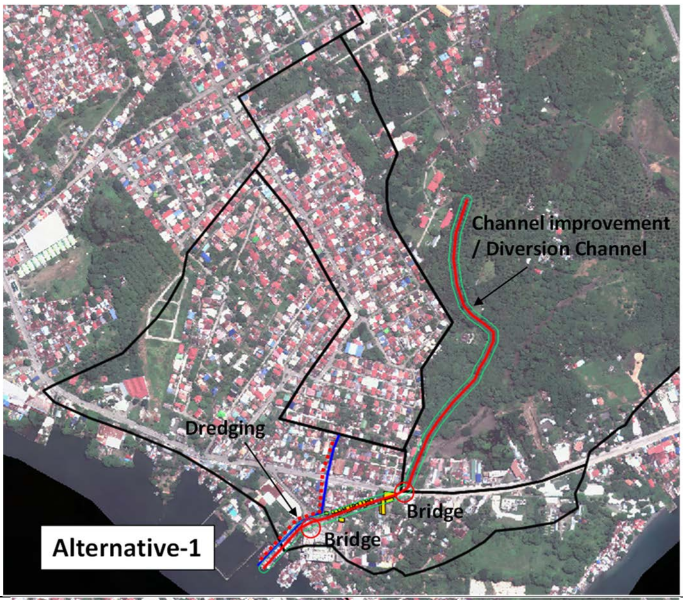
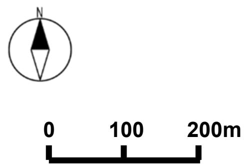
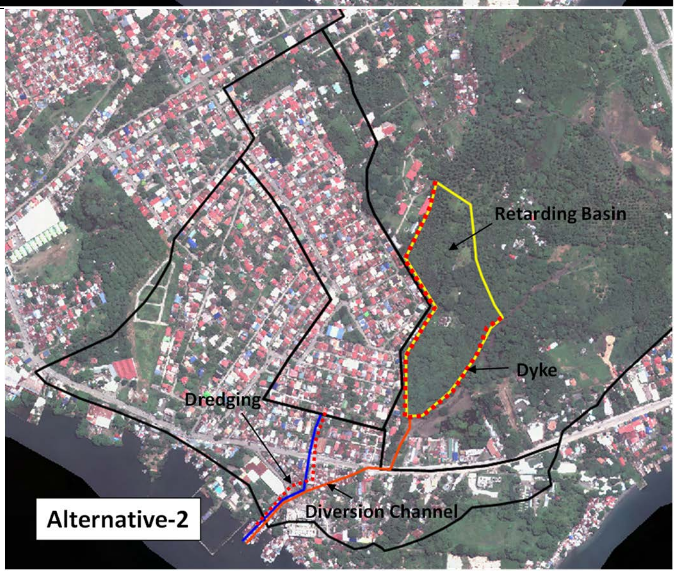
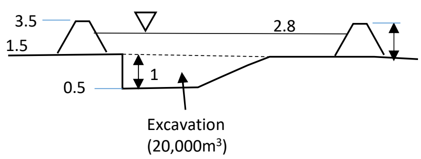
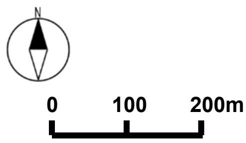
2) Alternative Measures

The following two alternatives are considered.

- Alternative-1: Channel Improvement and Installation of Diversion Channel
- Alternative-2: Retarding Basins and Bypass Channel (Culvert)

Table 3.7.20 shows the conceptual layout of the proposed structures for each of the alternatives.

Table 3.7.20 Alternative Measures in Shanghai Drainage Area

Alt.	Conceptual Layout of Structures	Menu of Measures
1		A. Channel Improvement / Diversion Channel Open Channel W8m x D2m x L1,000m Replacement of Bridges 2places B. Dredging L300m 
2		A. Retarding Basin Total Storage Volume=50x1,000m^3 Area：A50,000m^2 Dyke：H2m x L800m Exavation：20,000m^3 (H1m xA20,000m^2) B. Bypass Channel Box Culvert W3m x H1.7m x 1cell x L450m C. Dredging L300m 

Source: Project Team

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.21.

Table 3.7.21 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Shanghai Drainage Area)

Alternative	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
1	0.194	0.041	0.235
2	0.055	0.129	0.184

Source: Project Team

Among the alternatives, the alternative-2 is recommended since the preliminary estimated cost (total of the construction and land acquisition / compensation cost) is the lowest.

The alternative-1 requires the resettlement of about 30 buildings for the construction of the diversion channel. The cost is also higher than the alternative-2. Therefore, the alternative-1 is not recommended.

(8) Maa 1 Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

The Maa 1 drainage area is located at the eastern part of Maa area., and it drains to the Davao River. The drainage area is 1.41km^2. The characteristics of the Maa 1 drainage area are shown in Table 3.7.22.

Table 3.7.22 Characteristics of Maa1 Drainage Area

Drainage Area (km^2)	1.41
Average Slope of Drainage Area (%)	1.75
Total Length of Main Drainage Channel (m)	1,400
Drainage Outlet	Davao River
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	72
Runoff Coefficient (Existing Landuse (2017))	0.57
Runoff Coefficient (Future Landuse (2045))	0.69
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	36
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.039
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.185

[a]: Commercial, Industrial, Residential, Mixed use, and Road
Source: Project Team

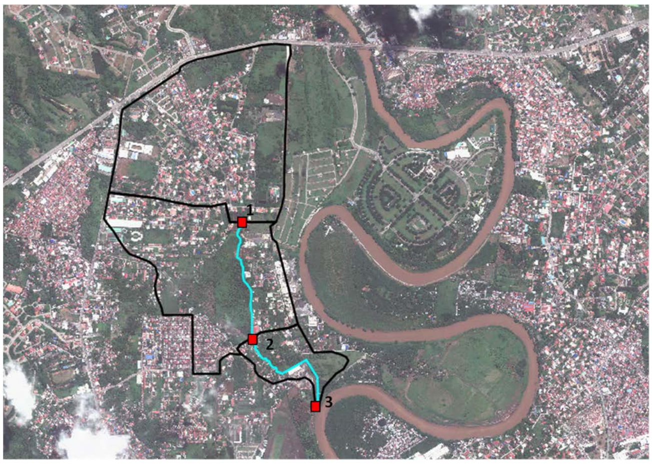
Figure 3.7.29 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.

Figure 3.7.30 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period. The main causes of the inundation are considered as follows.

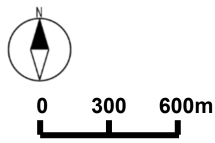
- Lack of flow capacity of drainage channel

For improvement of the drainage system, the following measures may be required.

- Enhancement of rainwater runoff retarding function by installing retarding basins
- Channel improvement for the enhancement of flow capacity

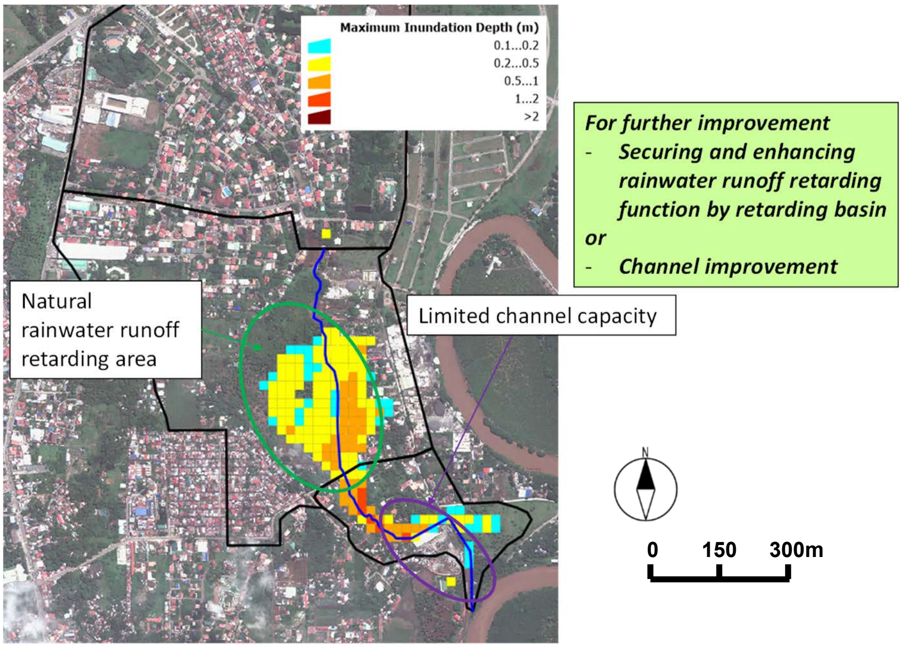


	1	2	3
Chainage (km)	1.37	0.71	0
Basic Design Flood Discharge (m3/s)	21	35	36
ALT-1: Design Flood Discharge (m3/s)	21	35	36
ALT-2: Design Flood Discharge (m3/s)	14	13	17



Source: Project Team

Figure 3.7.29 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Maa1 Drainage Area



Source: Project Team

Figure 3.7.30 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period for Maa1 Drainage Area

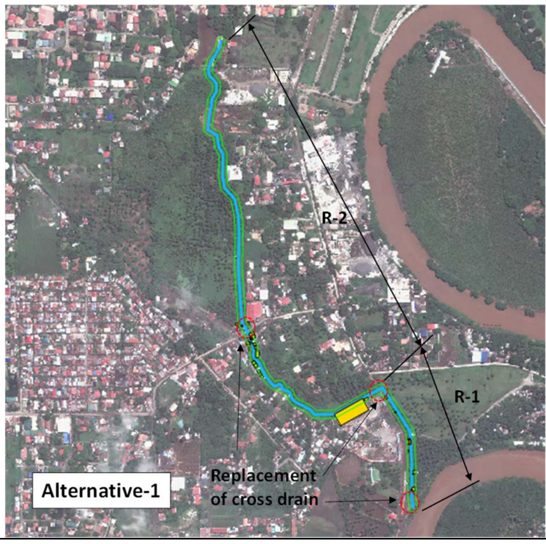
2) Alternative Measures

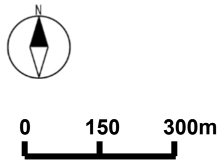
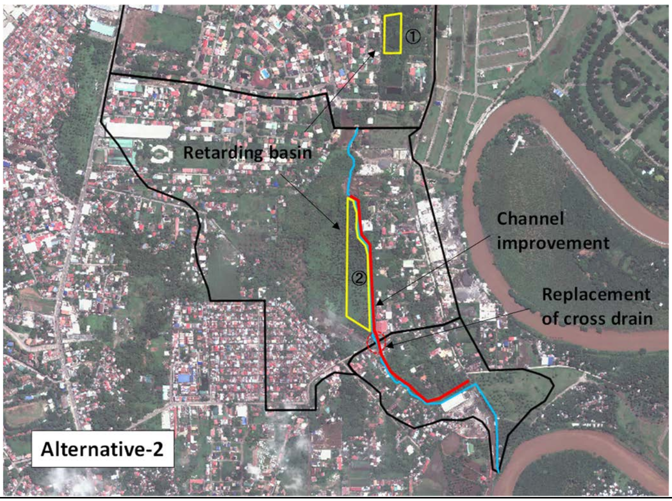
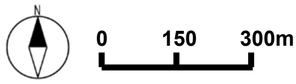
The following two alternatives are considered.

- Alternative-1: Channel Improvement
- Alternative-2: Retarding Basins and Channel Improvement

Table 3.7.23 shows the conceptual layout of the proposed structures for each of the alternatives.

Table 3.7.23 Alternative Measures in Maa1 Drainage Area

<table>
<tr><th>Alt.</th><th>Conceptual Layout of Structures</th><th>Menu of Measures</th></tr>
<tr><td>1</td><td>
</td><td>A. Chanel Improvement
W7-8m x D2.5-3m x L1,400m

B. Improvement of Cross Drains
3places

</td></tr>
<tr><td>2</td><td>
</td><td>A. Retarding Basins
Total Storage Volume=46x1,000m³
<table>
<tr><th></th><th>①</th><th>②</th></tr>
<tr><td>Type</td><td>Open</td><td>Open</td></tr>
<tr><td>Volume (1,000m3)</td><td>10</td><td>36</td></tr>
<tr><td>Area (1,000m2)</td><td>5</td><td>18</td></tr>
<tr><td>Depth (m)</td><td>2</td><td>2</td></tr>
</table>
B. Chanel Improvement
W4m x D2.5m x L810m
C. Improvement of Cross Drains
1place

</td></tr>
</table>

Source: Project Team

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.24.

Table 3.7.24 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Maa1 Drainage Area)

Alternative	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
1	0.315	0.048	0.363
2	0.200	0.040	0.240

Source: Project Team

Among the alternatives, the alternative-2 is recommended since the preliminary estimated cost (total of the construction and land acquisition / compensation cost) is the lowest.

The alternative-1 requires the resettlement of about 30 buildings for the construction of the diversion channel. The cost is also higher than the alternative-2. Therefore, the alternative-1 is not recommended.

(9) Maa 2 Drainage Area

1) Characteristics of Drainage Area and Causes of Inundation

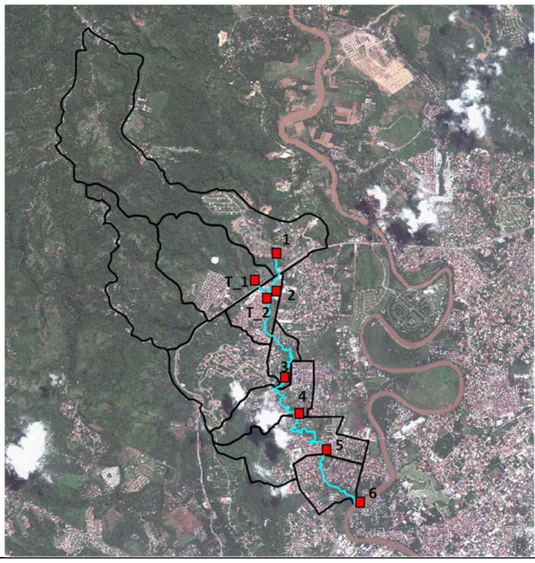
The Maa 2 drainage area is located at the western part of Maa area., and it drains to the Davao River. The drainage area is 9.03km^2. The characteristics of the Maa 2 drainage area are shown in Table 3.7.25.

Table 3.7.25 Characteristics of Maa2 Drainage Area

Drainage Area (km^2)	9.03
Average Slope of Drainage Area (%)	16.38
Total Length of Main Drainage Channel (m)	5,700
Drainage Outlet	Davao River
Ratio of Occupation of Urban Type Landuse[a] for Existing Condition (%)	39
Runoff Coefficient (Existing Landuse (2017))	0.50
Runoff Coefficient (Future Landuse (2045))	0.60
Basic Design Flood Discharge for 25 Year Return Period (Under Future Landuse (2045) with Climate Change Considered) (m^3/s)	132
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Existing Landuse (2017)) (Billion Php)	0.194
Expected Annual Damage by Inundation due to Overflow from Main Drainage Channel (Future Landuse (2045)) (Billion Php)	0.224

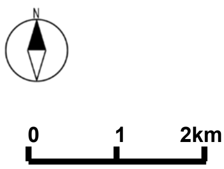
[a]: Commercial, Industrial, Residential, Mixed use, and Road
Source: Project Team

Figure 3.7.31 shows the delineation of sub-drainage areas, and the design flood discharge for the alternatives explained later as well as the basic design discharge that assumes no overflow from the channel at the representative points along the main drainage channel, under the future landuse condition with the climate change considered.



	1	2	3	4	5	6
Chainage (km)	5.35	4.86	3.1	1.98	0.96	0
Basic Design Flood Discharge (m^3/s)	55	55	82	112	128	132
Alt 1: Design Discharge (m3/s)	20	20	41	46	74	86
Alt 2: Design Discharge (m3/s)	20	20	340	45	72	84

	T_1	T_2
Chainage (km)	0.32	0
Basic Design Flood Discharge (m^3/s)	29	29
Alt 1: Design Discharge (m3/s)	35	12
Alt 2: Design Discharge (m3/s)	20	10



Source: Project Team

Figure 3.7.31 Delineation of Sub-Drainage Areas, Basic Design Flood Discharge and Design Flood Discharge for Maa2 Drainage Area

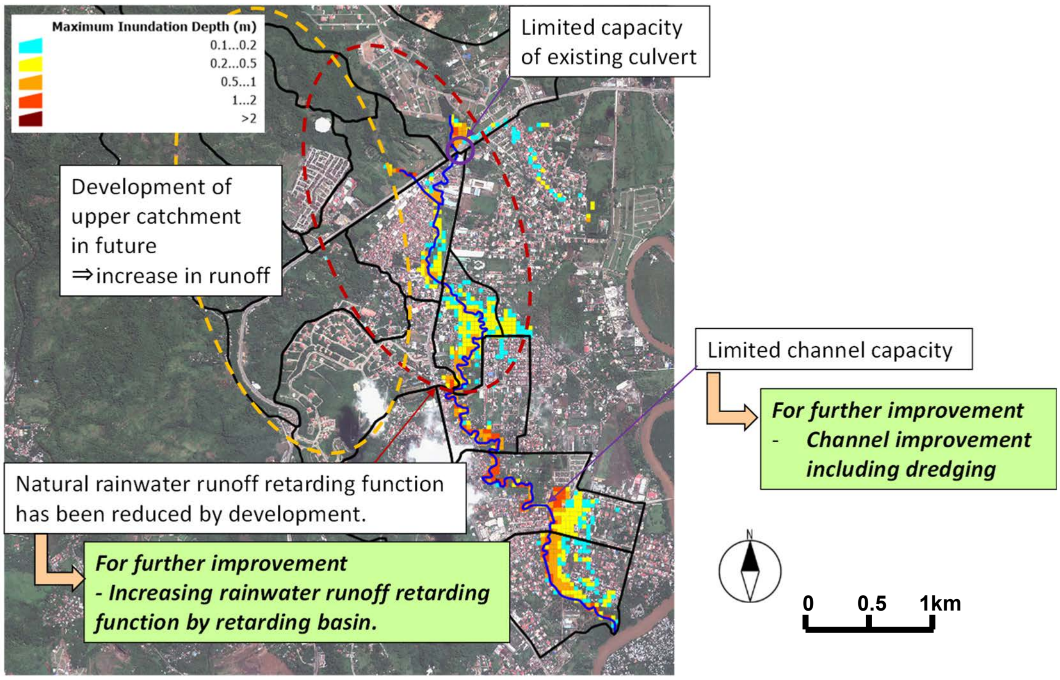
Figure 3.7.32 presents the expected inundation area due to overflow from the main drainage channel for 25 year return period. The main causes of the inundation are considered as follows.

- Reduction of natural rainwater runoff retarding function due to development
- Increase in runoff due to development of upper catchment area

- Backwater due to lack of flow capacity of the existing box culvert at the Diversion Road
- Lack of flow capacity of drainage channel

For improvement of the drainage system, the following measures may be required.

- If the flow capacity of the exiting box culvert at the Diversion Road is improved, higher peak discharge can occur at the downstream reach. However, it is difficult to increase the flow capacity there, since the available space for channel improvement is quite limited. Therefore, the enhancement of rainwater runoff retarding function by installing retarding basins should be considered.
- Enhancement of rainwater runoff retarding function by installing retarding basins
- Channel improvement for the enhancement of flow capacity



Source: Project Team

Figure 3.7.32 Expected Inundation Area due to Overflow from Main Drainage Channel for 25 Year Return Period for Maa2 Drainage Area

2) Alternative Measures

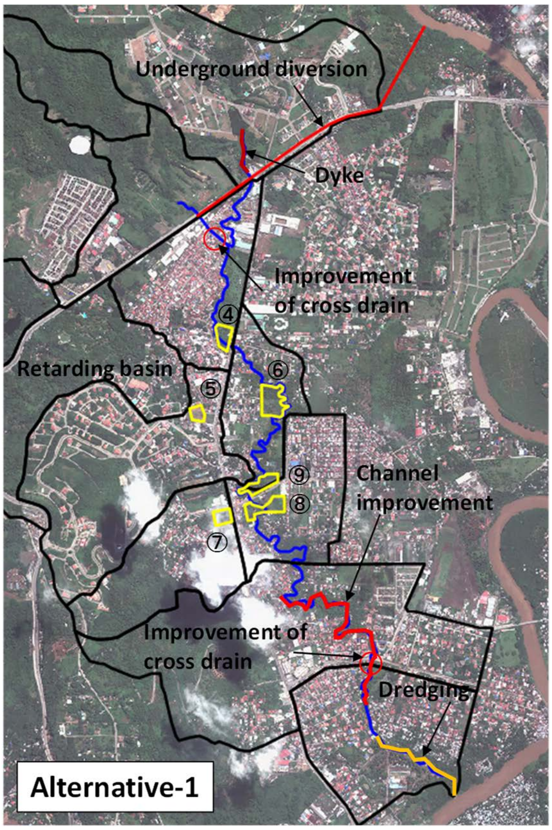
Our preliminary examination estimated that the necessary channel width in case that only channel widening is applied is one to three times as large as the existing one. The affected number of building is estimated at about 350, and many existing infrastructure such as road need to be reconstructed. Therefore, it is unrealistic to improve the drainage system only by the channel widening.

The following two alternatives are considered.

- Alternative-1: Underground Diversion Tunnel (Larger Scale), Retarding Basins and Channel Improvement
- Alternative-2: Underground Diversion Tunnel (Smaller Scale), Retarding Basins and Channel Improvement

Table 3.7.26 shows the conceptual layout of the proposed structures for each of the alternatives.

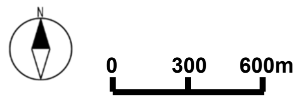
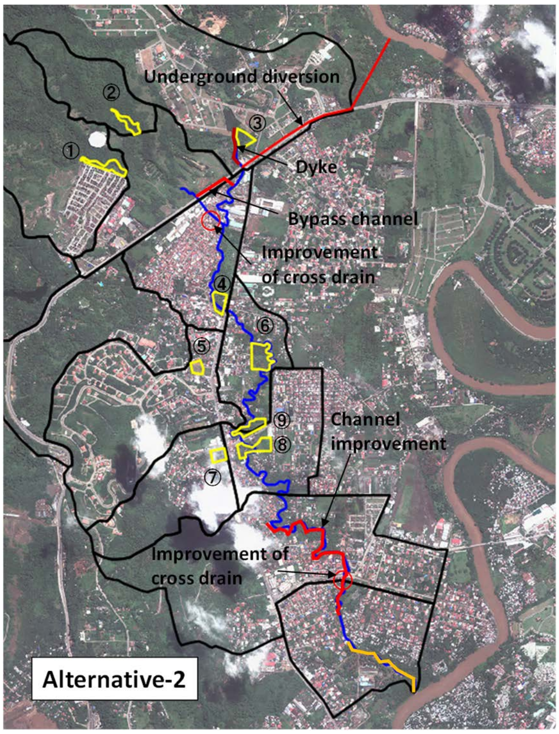
Table 3.7.26 Alternative Measures in Maa2 Drainage Area

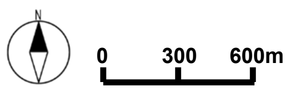
<table>
<tr><th>Alt.</th><th>Conceptual Layout of Structures</th><th>Menu of Measures</th></tr>
<tr><td>1</td><td>
</td><td>A. Underground Diversion Tunnel
D3.7m x L1,500m

B. Retarding Basins
Total Storage Volume=123x1,000m^3
<table>
<tr><th></th><th>④</th><th>⑤</th><th>⑥</th><th>⑦</th><th>⑧</th><th>⑨</th></tr>
<tr><td>Type</td><td colspan="6">Open</td></tr>
<tr><td>Volume (1,000m3)</td><td>8</td><td>8</td><td>28</td><td>11</td><td>20</td><td>48</td></tr>
<tr><td>Area (1,000m2)</td><td>4</td><td>4</td><td>14</td><td>5</td><td>10</td><td>8</td></tr>
<tr><td>Dam Height/ Depth (m)</td><td>2</td><td>2</td><td>2</td><td>2.2</td><td>2</td><td>6</td></tr>
</table>
C. Dyke
H2m x L200m

D. Channel Improvement
W9m x D3m x L1,300m

E. Dredging L500m

F. Improvement of Cross Drains 2places

</td></tr>
<tr><td>2</td><td>
</td><td>A. Underground Diversion Tunnel
D2.6m x L1,200m

B. Retarding Basins
Total Storage Volume =179x1,000m^3
<table>
<tr><th></th><th>①</th><th>②</th><th>③</th><th>④</th><th>⑤</th><th>⑥</th><th>⑦</th><th>⑧</th><th>⑨</th></tr>
<tr><td>Type</td><td colspan="2">Dam</td><td colspan="7">Open</td></tr>
<tr><td>Volume (1,000m3)</td><td>15</td><td>11</td><td>36</td><td>12</td><td>8</td><td>26</td><td>11</td><td>20</td><td>40</td></tr>
<tr><td>Area (1,000m2)</td><td>8</td><td>6</td><td>6</td><td>6</td><td>4</td><td>13</td><td>5</td><td>10</td><td>8</td></tr>
<tr><td>Dam Height/ Depth (m)</td><td>5</td><td>5</td><td>6</td><td>2</td><td>2</td><td>2</td><td>2.2</td><td>2</td><td>5</td></tr>
</table>
C. Dyke
H2m x L200m
D. Bypass Channel
W9m x H2m x 1cell x L260
E. Channel Improvement
W9m x D3m x L1,300m
F. Dredging L500m
G. Improvement of Cross Drains 2places

</td></tr>
</table>

Source: Project Team

The construction cost and land acquisition / compensation cost are preliminary estimated for each of the alternatives as shown in Table 3.7.27.

Table 3.7.27 Preliminary Estimated Cost for Construction and Land Acquisition / Compensation (Maa2 Drainage Area)

Alternative	Preliminary Estimated Cost (Billion Php)		
	Construction Cost	Land Acquisition /Compensation Cost	Total
1	2.946	0.149	3.095
2	2.036	0.246	2.282
Ref [a]	1.676	0.800	2.476

a: The case that only channel widening is applied
Source: Project Team

Among the alternatives, the alternative-2 is recommended since the preliminary estimated cost (total of the construction and land acquisition / compensation cost) is the lowest.

If the installation of the retarding basins in the upper catchment area is not possible by some reasons, the alternative-1 may be the possible measures to be applied despite of the higher cost.

3.7.3 Structural Measures for Master Plan

(1) Improvement of Main Drainage Channels

1) Scale and Economic Aspect of Full Menu of Framework Plan

The total project cost for implementing the full menu of the Framework Plan which is examined in Section 3.7.2 is estimated at 1bout 17 Billion Php.

The simple economic analysis, which assumes that the initial investment concentrates in the first year and the benefit appears in the rest of project period (50years are assumed), shows that B/C=1.17 for the entire projects in case that the social discount rate is 10%. The investment to the full menu of the Framework Plan is thus economically viable. Table 3.7.28 presents the project cost and B/C for each of the main drainage areas. In the analysis, the present landuse condition to estimate the annual damage reduction is assumed.

Table 3.7.28 Project Cost and B/C for Each of Main Drainage Areas in Case that Full Menu of Framework Plan is implemented

		Annual Damage Reduction (Billion Php)	Cost (Billion Php)					Annualized Cost (Economic) (Billion Php)	B/C
			Const-ruction Cost	Land Acquisition/ Compen-sation Cost	Project Cost (Financial)	Project Cost (Economic)	Annual O& M Cost		
1	Roxas	0.003	0.088	0	0.124	0.113	0.4	0.012	0.29
2	Agdao	0.469	3.385	0.409	5.203	4.749	16.9	0.496	0.95
3	Jerome	0.641	2.516	0.860	4.451	4.086	12.6	0.425	1.51
4	Mamay Creek	0.303	1.136	0.404	2.026	1.860	5.7	0.193	1.57
5	Sasa Creek	0.084	0.474	0.033	0.703	0.641	2.4	0.067	1.25
6	Emars	0.085	0.113	0.482	0.665	0.627	0.6	0.064	1.33
7	Shanghai	0.068	0.055	0.129	0.213	0.200	0.3	0.020	3.33
8	Maa1	0.039	0.200	0.040	0.324	0.296	1.0	0.031	1.26
9	Maa2	0.194	2.036	0.246	3.129	2.856	10.2	0.298	0.65
	Total	**1.886**	**10.003**	**2.603**	**16.839**	**15.427**	**50.0**	**1.606**	**1.17**

Remark: It is assumed that the annual O&M cost is 0.5% of the construction cost.
Source: Project Team

Assuming that the full menu of the Framework Plan will be implemented by 2045 which is the target year of the Master Plan, it is required to invest 17/23=0.74 Billion Php annually in average. It is about 1.5 times as large as the average annual budget for the projects for storm water drainage improvement by DPWH-DCDEO in the last 5years.

2) Master Plan

As shown in 1), the investment to the full menu of the Framework Plan is economically viable. The required annual investment in average to implement the full menu of the framework plan by 2045 is not unrealistic, since it is about 1.5 times as large as the average annual budget for the projects for storm water drainage improvement by DPWH-DCDEO in the last 5years.

Considering the above-mentioned condition, the Master Plan is set as same as the Framework Plan, which targets to achieve the safety level of 25 year return period for the main drainage channels by 2045.

3) Step-wide Implementation

As for the implementation of the Master Plan, the proposed projects are divided into the short term (2023-2032) and the long-term (2033-2045).

The short-term projects are selected so as to prevent overflow from main drainage channels for the extreme event with 5 year return period among the full menu of the Framework Plan.

As for the deep excavation type of retarding basin whose construction cost is high, the following set-wise implementation is considered.

- Phase-1: Acquisition of necessary land area and construction of shallow excavation type of retarding basin
- Phase-2: Upgrade to deep excavation type of retarding basin which has enough storage volume to meet the requirement of the Framework Plan

When the implementation of the Phase-1 can achieve the safety level of 5 year return period, only Phase-1 is implemented in the short-term.

For the implementation of the proposed retarding basins, it is necessary to secure the land for the construction and to prevent land development. It is highly recommended to reflect the proposed retarding basins into the land use plan and regulation in Davao City as early as possible.

The total project cost for the selected short-term projects is about 8.8 Billion Php. The simple economic analysis, which assumes that the initial investment concentrates in the first year and the benefit appears in the rest of project period (50years are assumed), shows that B/C=2.15 for the short-term projects in case that the social discount rate is 10%. The B/C for all main drainage areas exceeds 1. Table 3.7.29 presents the project cost and B/C for each of the main drainage areas. In the analysis, the present landuse condition to estimate the annual damage reduction is assumed.

Table 3.7.29 Project Cost and B/C for Each of Main Drainage Areas for Short-Term Projects

		Annual Damage Reduction (Billion Php)	Cost (Billion Php)					Annualized Cost (Economic) (Billion Php)	B/C
			Const-ruction Cost	Land Acquisition/ Compen-sation Cost	Project Cost (Financial)	Project Cost (Economic)	Annual O& M Cost		
1	Roxas	0	0	0	0	0	0.0	0	N/A
2	Agdao	0.440	1.176	0.409	2.088	1.917	5.9	0.199	2.21
3	Jerome	0.621	1.520	0.860	3.046	2.809	7.6	0.291	2.13
4	Mamay Creek	0.289	0.198	0.316	0.611	0.570	1.0	0.059	4.94
5	Sasa Creek	0.084	0.286	0.015	0.419	0.382	1.4	0.040	2.10
6	Emars	0.085	0.113	0.482	0.665	0.627	0.6	0.064	1.33
7	Shanghai	0.068	0.055	0.129	0.213	0.200	0.3	0.020	3.33
8	Maa1	0.038	0.196	0.001	0.277	0.252	1.0	0.026	1.44
9	Maa2	0.182	0.874	0.246	1.491	1.366	4.4	0.142	1.28
	Total	**1.807**	**4.418**	**2.458**	**8.811**	**8.122**	**22.1**	**0.841**	**2.15**

Remark: It is assumed that the annual O&M cost is 0.5% of the construction cost.
Source: Project Team

(2) Improvement of Local Inundation in the Central Area of Davao City

The proper maintenance and removal of deposition in the existing drainage channel are fundamental measures to mitigate the local inundation due to the lack of flow capacity of lateral drainage channel. These are discussed in the section of "Non-Structural Measures" as one of non-structural measures.

For further improvement of drainage capacity, it is necessary to upgrade the lateral drainage channels.

In the present project, the priority areas for the upgrade of the lateral drainage channels are identified, considering the hot spots where the expected inundation depth exceeds the allowable depth during the extreme event with 25 year return period even after the main drainage channels are improved.

The allowable depth is set as follows, in order to avoid severe damage and secure proper urban function.

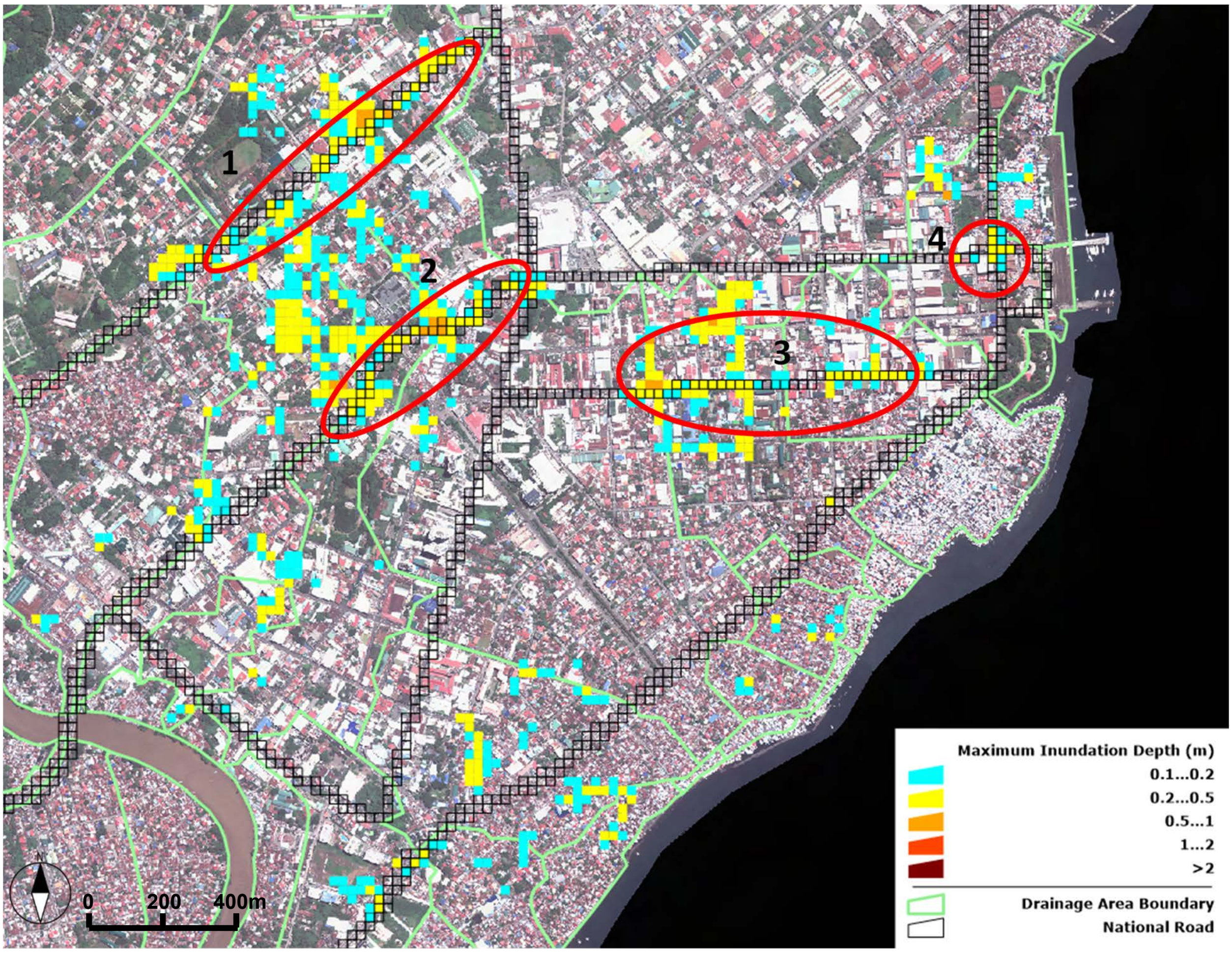
- National Road: 0.2m (Vehicle can pass the inundation area)
- Other areas except open space and agricultural areas: 0.5m

In the Poblacion district, there are not only the Roxas drainage area, one of main drainage areas, but also a lot of other small drainage areas. By utilizing the numerical simulation model based on the drainage inventory data, the expected inundation area during the extreme event with 25 year return period after the removal of deposition in the drainage channel and the completion of the improvement of main drainage channels is examined. Figure 3.7.33 shows the expected inundation area. In the figure, the mesh with national road is also shown.

There is no inundation around the Roxas Channel because of the improvement of the main drainage channel. However, there are still remaining inundation in the upper catchment of Roxas drainage area and some small drainage areas. Especially in four areas indicated with the red colour, the inundation depth in national roads exceeds 0.2m in many places, and is more than 0.5m in some places. On the basis of this result, the following four areas are identified as the priority areas for the countermeasures against local inundation in the Poblacion district.

- 1.F. Torres Street (Roxas and Quirino_L_B drainage area)
- 2.Elpido Quirino Avenue (Roxas and Anda drainage area)
- 3.Ramon Magsaysay Avenue (Roxas, Ponce and Magsaysay drainage area)
- 4. Corner of Leon Garcia Street and St. Ana Street (St. Ana drainage area)

The countermeasures are installation of storage pipe under road and/or small-scale closed type of retarding basin spot by spot in order to reduce the inundation depth.



Source: Project Team

Figure 3.7.33 Expected Inundation Area for 25 Year Return Period after Removal of Deposition and Completion of Improvement of Main Drainage Channels

(3) Implementation Scheme

The following types for implementation scheme on the proposed structural measures are considered, depending on the level of construction and project cost.

- Type-1: The project which is expected to be implemented by DPWH-DCDEO
  The project in which the standard design of DPWH is basically applicable or DPWH-DCDEO has experiences on the similar projects.
  In case that the total project cost exceeds the limitation that DPWH-DCDEO can handle (0.1Billion Php per project), the project is divided to several projects which are implemented in multiple year.
- Type-2: The project which is expected to be implemented by DPWH-DCDEO with technical support by other organizations
  The project in which DPWH-DCDEO does not have enough experiences on the similar projects.
  In case that the total project cost exceeds the limitation that DPWH-DCDEO can handle (0.1Billion Php per project), the project is divided to several projects which are implemented in multiple year.
- Type-3: The project which is expected to be implemented by DPWH-RO/CO
  The project which requires relatively high technical level or budget which far exceeds s the limitation that DPWH-DCDEO can handle.

(4) Operation and Maintenance for Proposed Structural Measures

Table 3.7.30 shows the items to be considered for operation and maintenance for proposed structural measures.

Table 3.7.30 Items to be Considered for Operation and Maintenance for Proposed Structural Measures

Type of Structure	Items	
	Ordinary time	During/After flood events
Retarding basin	✓ Periodical inspection of structures such as riprap, concrete wall, gates and overflow weir ✓ Periodical inspection of drainage pumps in case of closed type and deep open type retarding basin ✓ Periodical cleaning of retarding basin including removal of sediment and garbage ✓ Prevention of illegal activities inside the retarding basin	During flood event ✓ Sharing information of status of retarding basin with relevant organizations in real time After flood event ✓ Operation of gates and pumps and monitoring of drainage of stored water by gravity or pumps just after the flood event ✓ Checking the status of structures and pumps ✓ Urgent removal of deposited sediment and garbage, especially around the gates and pumps to ensure their proper function
Open channel	✓ Periodical inspection of structures such as riprap, concrete wall and cross drain. ✓ Prevention of illegal activities along the channel ✓ Periodical cleaning of deposited sediment and garbage	During flood event ✓ Sharing information of status of channel with relevant organizations in real time After flood event ✓ Checking the status of structures
Closed channel including diversion tunnel	✓ Periodical inspection of manhole, inlet structure and overflow weir ✓ Periodical cleaning of deposited sediment and garbage inside the channel	During flood event ✓ Sharing information of status of channel with relevant organizations in real time After flood event ✓ Checking the status of structures and pumps ✓ Urgent removal of deposited sediment and garbage, especially around the overflow weir to ensure their proper function

Source: Project Team

(5) Project List

The project list for the structural measures on storm water drainage improvement in the Master Plan is presented in Table 3.7.31.

(6) Implementation Schedule

The implementation schedule for the structural measures on storm water drainage improvement in the Master Plan is presented in Figure 3.7.34.

Table 3.7.31 Project List for Structural Measures on Storm Water Drainage Improvement in the Master Plan

Project			Work Item	Project Cost (Billion Php)	Short Term 2023-2032	Long Term 2033-2045	Imp. Type
A	Main Drainage Improvement			16.839	8.811	8.028	
	A-1	Roxas Drainage Area		0.124	0	124	
	A-1-1	Channel Improvement and Installation of Bypass Channel	Dredging (L480m) Box Culvert (W3.6mxH1.8mx2cellsxL500m) Channel Improvement (W10m x H2m x L70m)	0.124		x	①
	A-2	Agdao Drainage Area		5.203	2.088	3.115	
	A-2-1	Installation of Retarding Basin① (Phase-1)	Retarding basin (shallow open) (V=40,000m^3, A=20,000m^2, H=2m)	0.336	x		①
	A-2-2	Upgrading of Retarding Basin① (Phase-2)	Retarding basin (deep open) (V=72,000m^3, A=20,000m^2, H=3.6m)	0.575		x	②
	A-2-3	Installation of Retarding Basin②	Retarding basin (closed) (V=10,000m^3, A=2,500m^2, H=4m)	0.440		x	③
	A-2-4	Installation of Retarding Basin③ (Phase-1)	Retarding basin (shallow open) (V=8,000m^3, A=5,000m^2, H=1.6m)	0.057	x		①
	A-2-5	Upgrading of Retarding Basin③ (Phase-2)	Retarding basin (deep open) (V=15,000m^3, A=5,000m^2, H=3m)	0.213		x	②
	A-2-6	Installation of Retarding Basin④	Retarding basin (closed) (V=13,000m^3, A=5,000m^2, H=2.6m)	0.571		x	③
	A-2-7	Installation of Underground Rainwater Storage along Dacudao Creek (Phase-1)	Retarding basin (closed) (V=10,000m^3, W4mxH5mxL500m)	0.398	x		③
	A-2-8	Installation of Underground Rainwater Storage along Dacudao Creek (Phase-2)	Retarding basin (closed) (V=28,000m^3, W4mxH5mxL1,400m)	1.111		x	③
	A-2-9	Installation of Underground rainwater storage in catchment area of Old Agdao Channel (Phase-1)	Retarding basin (closed) (V=22,500m^3, W3mxH3mxL2,500m)	0.513	x		②
	A-2-10	Installation of Underground rainwater storage in catchment area of Old Agdao Channel (Phase-2)	Retarding basin (closed) (V=9,000m^3, W3mxH3mxL1,000m)	0.204		x	②
	A-2-11	Improvement of Lower Agdao Channel	Open channel (W12mxH2-3mxL350m) Box culvert (W3mxH2.5mx2cellsxL350m) Bridge along channel (W5mxL350m) Improvement of cross drain (1place) Box culvert (W3mxH2.5mx1cellxL150m)	0.647	x		③
	A-2-12	Improvement of Old Agdao Channel	Dredging (L500m) Regulation Pond (A=5,000m^2) Improvement of cross drain (1place) Box culvert (W3mxH2.4mx1cellxL400m)	0.136	x		①
	A-3	Jerome Drainage Area		4.451	3.046	1.405	
	A-3-1	Installation of Retarding Basin① (Phase-1)	Retarding basin (shallow open) (V=6,000m^3, A=6,000m^2, H=1m)	0.221	x		①
	A-3-2	Upgrading of Retarding Basin① (Phase-2)	Retarding basin (deep open) (V=33,000m^3, A=6,000m^2, H=5.5m)	0.432		x	②
	A-3-3	Installation of Retarding Basin② (Phase-1)	Retarding basin (shallow open) (V=18,000m^3, A=9,000m^2, H=2m)	0.057	x		①
	A-3-4	Upgrading of Retarding Basin② (Phase-2)	Retarding basin (deep open) (V=40,000m^3, A=9,000m^2, H=4.5m)	0.433		x	②
	A-3-5	Installation of Retarding Basin③ (Phase-1)	Retarding basin (shallow open) (V=30,000m^3, A=15,000m^2, H=2m)	0.227	x		①
	A-3-6	Upgrading of Retarding Basin③ (Phase-2)	Retarding basin (deep open) (V=64,000m^3, A=15,000m^2, H=4.3m)	0.540		x	②
	A-3-7	Installation of Retarding Basin④	Retarding basin (deep open) (V=48,000m^3, A=8,000m^2, H=6m)	0.874	x		③
	A-3-8	Installation of Retarding Basin⑤	Retarding basin (deep open) (V=15,000m^3, A=3,000m^2, H=5m)	0.371	x		③
	A-3-9	Installation of Retarding Basin⑥	Retarding basin (deep open) (V=88,000m^3, A=16,000m^2, H=5.5m)	0.781	x		③
	A-3-10	Improvement of Lower Jerome Channel	Box Culvert (W3mxH2.3mx1cellxL610m) Chanel Improvement (W5mxH2.5-3mxL1,000m) Improvement of cross drain (14places)	0.516	x		①
	A-4	Mamay Creek Drainage Area		2.026	0.611	1.415	
	A-4-1	Installation of Retarding Basin①	Retarding basin (dam) (V=41,000m^3, A=20,000m^2, H=6m)	0.089	x		②
	A-4-2	Installation of Retarding Basin②	Retarding basin (dam) (V=26,000m^3, A=22,000m^2, H=2m)	0.089	x		②
	A-4-3	Installation of Retarding Basin③	Retarding basin (dam) (V=68,000m^3, A=30,000m^2, H=5m)	0.083	x		②
	A-4-4	Installation of Retarding Basin④	Retarding basin (shallow open) (V=33,000m^3, A=15,000m^2, H=2.2m)	0.068	x		①
	A-4-5	Installation of Retarding Basin⑤ (Phase-1)	Retarding basin (shallow open) (V=6,000m^3, A=3,000m^2, H=2m)	0.015	x		①
	A-4-6	Upgrading of Retarding Basin⑤ (Phase-2)	Retarding basin (deep open) (V=15,000m^3, A=3,000m^2, H=5m)	0.286		x	②
	A-4-7	Installation of Retarding Basin⑥	Retarding basin (shallow open) (V=24,000m^3, A=16,000m^2, H=1.5m)	0.049	x		①
	A-4-8	Installation of Retarding Basin⑦ (Phase-1)	Retarding basin (shallow open) (V=33,000m^3, A=22,000m^2, H=1.5m)	0.123	x		①
	A-4-9	Upgrading of Retarding Basin⑦ (Phase-2)	Retarding basin (deep open) (V=130,000m^3, A=22,000m^2, H=6m)	0.942		x	③
	A-4-10	Installation of Retarding Basin⑧	Retarding basin (shallow open) (V=15,000m^3, A=10,000m^2, H=1.5m)	0.108		x	②
	A-4-11	Channel Improvement	Dyke (H2mxL220m) Improvement of cross drain (5places)	0.094	x		①
	A-4-12	Instalation of Bypass Channel in Middle Mamay Creek	Box Culvert (W3.3mxH1.7mx1cellxL660m)	0.079		x	①

Project			Work Item	Project Cost (Billion Php)	Short Term 2023-2032	Long Term 2033-2045	Imp. Type
	A-5	**Sasa Creek Drainage Area**		**0.703**	**0.419**	**0.284**	
	A-5-1	Completion of Remaining Portion of Retarding Basin① in La Verna Area	Retarding basin (deep open) (V=65,000m^3, A=13,000m^2, H=5m)	**0.381**	x		②
	A-5-2	Installation of Retarding Basin② in La Verna Area	Retarding basin (deep open) (V=20,000m^3, A=5,000m^2, H=4m)	**0.284**		x	②
	A-5-3	Channel Imrovement and Instalation of Bypass Channel in Pampanga Area	Dredging (L320m) Improvement of cross drain (1place) Box Culvert (W2mxH1.5mx1cellxL310m) Box Culvert (W2mxH1.3mx1cellxL230m)	**0.038**	x		①
	A-6	**Emars Drainage Area**		**0.665**	**0.665**	**0.000**	
	A-6-1	Installation of Retarding Basin①	Retarding basin (shallow open) (V=30,000m^3, A=15,000m^2, H=2m)	**0.274**	x		①
	A-6-2	Installation of Retarding Basin②	Retarding basin (shallow open) (V=20,000m^3, A=10,000m^2, H=2m)	**0.110**	x		①
	A-6-3	Installation of Retarding Basin③	Retarding basin (shallow open) (V=36,000m^3, A=18,000m^2, H=2m)	**0.192**	x		①
	A-6-4	Instalation of Bypass Channel	Box Culvert (W2mxH2mx1cellxL1,060m)	**0.090**	x		①
	A-7	**Shanghai Drainage Area**		**0.213**	**0.213**	**0.000**	
	A-7-1	Installation of Retarding Basin	Storage Volume=50,000m^3 Dyke (H2mxL800m) Excavation (V=20,000m^3)	**0.164**	x		①
	A-7-2	Channel Imrovement and Instalation of Bypass Channel	Box Culvert (W3mxH1.7mx1cellxL450m) Dredging (L300m)	**0.049**	x		①
	A-8	**Maa1 Drainage Area**		**0.324**	**0.277**	**0.047**	
	A-8-1	Installation of Retarding Basin① (Phase-1)	Retarding basin (shallow open) (V=4,000m^3, A=2,000m^2, H=2m)	**0.008**	x		①
	A-8-2	Completionof of Remaining Portion of Retarding Basin① (Phase-2)	Retarding basin (shallow open) (V=10,000m^3, A=5,000m^2, H=2m)	**0.047**		x	①
	A-8-3	Installation of Retarding Basin②	Retarding basin (shallow open) (V=20,000m^3, A=10,000m^2, H=2m)	**0.029**	x		①
	A-8-4	Improvement of Channel	Chanel Improvement (W4mxH2.5mxL810m) Improvement of cross drain (1place)	**0.240**	x		①
	A-9	**Maa2 Drainage Area**		**3.129**	**1.491**	**1.639**	
	A-9-1	Installation of Retarding Basin①	Retarding basin (dam) (V=15,000m^3, A=8,000m^2, H=5m)	**0.036**	x		②
	A-9-2	Installation of Retarding Basin②	Retarding basin (dam) (V=11,000m^3, A=6,000m^2, H=5m)	**0.048**	x		②
	A-9-3	Installation of Retarding Basin③	Retarding basin (deep open) (V=36,000m^3, A=6,000m^2, H=6m)	**0.504**	x		③
	A-9-4	Improvement of Upper Maa2 Channel①	Dyke (H2mxL200m)	**0.071**	x		①
	A-9-5	Improvement of Upper Maa2 Channel②	Box Culvert (W3mxH1.7mx1cellxL450m) Improvement of cross drain (1place)	**0.034**	x		①
	A-9-6	Installation of Underground Diversion Channel	Tunnel Channel (D2.6mxL1,200m)	**1.122**		x	③
	A-9-7	Installation of Retarding Basin④	Retarding basin (shallow open) (V=12,000m^3, A=6,000m^2, H=2m)	**0.016**	x		①
	A-9-8	Installation of Retarding Basin⑤	Retarding basin (shallow open) (V=8,000m^3, A=4,000m^2, H=2m)	**0.036**	x		①
	A-9-9	Installation of Retarding Basin⑥	Retarding basin (shallow open) (V=26,000m^3, A=13,000m^2, H=2m)	**0.057**	x		①
	A-9-10	Installation of Retarding Basin⑦	Retarding basin (shallow open) (V=11,000m^3, A=5,000m^2, H=2.2m)	**0.049**	x		①
	A-9-11	Installation of Retarding Basin⑧	Retarding basin (shallow open) (V=20,000m^3, A=10,000m^2, H=2m)	**0.051**	x		①
	A-9-12	Installation of Retarding Basin⑨ (Phase-1)	Retarding basin (shallow open) (V=16,000m^3, A=8,000m^2, H=2m)	**0.041**	x		①
	A-9-13	Upgrading of Retarding Basin⑨ (Phase-2)	Retarding basin (deep open) (V=40,000m^3, A=8,000m^2, H=5m)	**0.516**		x	②
	A-9-14	Improvement of Lower Maa2 Channel	Chanel Improvement (W9mxH3mxL1,300m) Improvement of cross drain (1place) Dredging (L500m)	**0.547**	x		①

Source: Project Team

		Project	Imp. Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
								2027					2032					2037					2042			2045
A	Main Drainage Improvement																									
	A-1	**Roxas Drainage Area**																								
	A-1-1	Channel Imrovement and Instalation of Bypass Channel	①															(2)								
	A-2	**Agdao Drainage Area**																								
	A-2-1	Installation of Retarding Basin① (Phase-1)	①					(4)																		
	A-2-2	Upgrading of Retarding Basin① (Phase-2)	②															(6)								
	A-2-3	Installation of Retarding Basin②	③															(2)								
	A-2-4	Installation of Retarding Basin③ (Phase-1)	①					(1)																		
	A-2-5	Upgrading of Retarding Basin③ (Phase-2)	②															(3)								
	A-2-6	Installation of Retarding Basin④	③															(2)								
	A-2-7	Installation of Underground Rainwater Storage along Dacudao Creek (Phase-1)	③					(2)																		
	A-2-8	Installation of Underground Rainwater Storage along Dacudao Creek (Phase-2)	③															(3)								
	A-2-9	Installation of Underground rainwater storage in catchment area of Old Agdao	②					(6)																		
	A-2-10	Installation of Underground rainwater storage in catchment area of Old Agdao	②															(2)								
	A-2-11	Improvement of Lower Agdao Channel	③					(3)																		
	A-2-12	Improvement of Old Agdao Channel	①					(2)																		
	A-3	**Jerome Drainage Area**																								
	A-3-1	Installation of Retarding Basin① (Phase-1)	①					(3)																		
	A-3-2	Upgrading of Retarding Basin① (Phase-2)	②															(5)								
	A-3-3	Installation of Retarding Basin② (Phase-1)	①					(1)																		
	A-3-4	Upgrading of Retarding Basin② (Phase-2)	②															(5)								
	A-3-5	Installation of Retarding Basin③ (Phase-1)	①					(3)																		
	A-3-6	Upgrading of Retarding Basin③ (Phase-2)	②															(6)								
	A-3-7	Installation of Retarding Basin④	③					(2)																		
	A-3-8	Installation of Retarding Basin⑤	③					(2)																		
	A-3-9	Installation of Retarding Basin⑥	③					(2)																		
	A-3-10	Improvement of Lower Jerome Channel	①					(6)																		
	A-4	**Mamay Creek Drainage Area**																								
	A-4-1	Installation of Retarding Basin①	②					(1)																		
	A-4-2	Installation of Retarding Basin②	②					(1)																		
	A-4-3	Installation of Retarding Basin③	②					(1)																		
	A-4-4	Installation of Retarding Basin④	①					(1)																		
	A-4-5	Installation of Retarding Basin⑤ (Phase-1)	①					(1)																		
	A-4-6	Upgrading of Retarding Basin⑤ (Phase-2)	②															(3)								
	A-4-7	Installation of Retarding Basin⑥	①					(1)																		
	A-4-8	Installation of Retarding Basin⑦ (Phase-1)	①					(2)																		
	A-4-9	Upgrading of Retarding Basin⑦ (Phase-2)	③															(2)								
	A-4-10	Installation of Retarding Basin⑧	②															(1)								
	A-4-11	Channel Imrovement	①					(1)																		
	A-4-12	Instalation of Bypass Channel in Middle Mamay Creek	①															(1)								
	A-5	**Sasa Creek Drainage Area**																								
	A-5-1	Completion of Remaining Portion of Retarding Basin① in La Verna Area	②					(4)																		
	A-5-2	Installation of Retarding Basin② in La Verna Area	②															(3)								
	A-5-3	Channel Imrovement and Instalation of Bypass Channel in Pampanga Area	①					(1)																		
	A-6	**Emars Drainage Area**																								
	A-6-1	Installation of Retarding Basin①	①					(3)																		
	A-6-2	Installation of Retarding Basin②	①					(1)																		
	A-6-3	Installation of Retarding Basin③	①					(2)																		
	A-6-4	Instalation of Bypass Channel	①					(1)																		
	A-7	**Shanghai Drainage Area**																								
	A-7-1	Installation of Retarding Basin	①					(2)																		
	A-7-2	Channel Imrovement and Instalation of Bypass Channel	①					(1)																		
	A-8	**Maa1 Drainage Area**																								
	A-8-1	Installation of Retarding Basin① (Phase-1)	①					(1)																		
	A-8-2	Completionof of Remaining Portion of Retarding Basin① (Phase-2)	①															(1)								
	A-8-3	Installation of Retarding Basin②	①					(1)																		
	A-8-4	Improvement of Channel	①					(3)																		
	A-9	**Maa2 Drainage Area**																								
	A-9-1	Installation of Retarding Basin①	②					(1)																		
	A-9-2	Installation of Retarding Basin②	②					(1)																		
	A-9-3	Installation of Retarding Basin③	③					(2)																		
	A-9-4	Improvement of Upper Maa2 Channel①	①					(1)																		
	A-9-5	Improvement of Upper Maa2 Channel②	①					(1)																		
	A-9-6	Installation of Underground Diversion Channel	③															(3)								
	A-9-7	Installation of Retarding Basin④	①					(1)																		
	A-9-8	Installation of Retarding Basin⑤	①					(1)																		
	A-9-9	Installation of Retarding Basin⑥	①					(1)																		
	A-9-10	Installation of Retarding Basin⑦	①					(1)																		
	A-9-11	Installation of Retarding Basin⑧	①					(1)																		
	A-9-12	Installation of Retarding Basin⑨ (Phase-1)	①					(1)																		
	A-9-13	Upgrading of Retarding Basin⑨ (Phase-2)	②															(6)								
	A-9-14	Improvement of Lower Maa2 Channel	①					(6)																		

Remarks: (*) in the bar in the figure indicates expected project duration in year.

Source: Project Team

Figure 3.7.34 Implementation Schedule