G. Structural Measures

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G. STRUCTURAL MEASURES

1. GENERAL

1.1 Basic Procedure

Basic procedure for the formulation of the flood mitigation plan for structural measures is described below.

1.1.1 Additional Basic Analysis

The additional basic analysis consists of (1) hydrologic analysis and (2) flood inundation analysis, as described below:

(1) Hydrologic Analysis

The hydrologic analysis is carried out in order to estimate the design flood discharges. The specific discharge method is applied in principle. However, if the preceding studies are available for certain river basins, the design flood discharges of the preceding studies are referred.

(2) Flood Inundation Analysis

Hydraulic analysis is conducted based on the non-uniform flow method, for which Hec-RAS model is adopted. In this analysis, the newly surveyed river cross-sections are utilized. By this analysis, the following items are calculated:

- Calculation of the existing flow capacity of river channel
- Calculation of design high water level of river channel

Based on the results of the hydraulic analysis, the flood inundation analysis is carried out in order to estimate flood damage areas. The flood damage areas are estimated with HEC-RAS and Hec-GeoRAS models in principle. However, if the preceding studies are available for certain river basins, the flood damage areas of the preceding studies are referred.

1.1.2 Formulation of Plan of Structural Measures

The plan of structural measures is formulated considering (1) applicable structural measures and (2) selection of optimum structural measures, as follows:

(1) Applicable Structural Measures

The applicable structural measures are studied based on the flood type in due consideration of the field survey results and existing reports.

(2) Selection of Optimum Structural Measures

For the structural measures, the optimum case is selected through cost comparison study for several alternatives prepared by the combination of the structural measures in principle.

1.2 Basic Conditions

1.2.1 Objective River Basins

The plan of the structural measures is formulated for the six (6) model river basins, the Ilog-Hilabangan, Dungcaan, Meycauayan, Kinanliman, Tuganay and Dinanggasan River Basins.

1.2.2 Safety Level

In principle, the safety level of the plan is 20-year return period. However, if the preceding plans are available for certain river basins, the safety levels of the preceding plans are adopted. The safety level of the respective river basin is shown below.

Table G.1.1 Safety Levels of the River Basins

River Basin	Safety Level (Return Period)	Preceding Plan
1. Ilog-Hilabangan	25	Master Plan Report, Ilog-Hilabangan River Basin Flood Control Project, July 1991
2. Dungcaan	20	None
3. Meycauayan	30 (O) 10 (I)	Feasibility Study on Valenzuela - Obando - Meycauayan (VOM) Area Drainage System Improvement Project, 2001
4. Kinanliman	25	Detailed Design Report for the Pilot Project for Kinanliman River, Real, Quezon, 2007
5. Tuganay	25	Report on Preliminary Design of Liboganon River Dike Extension, 1998
6. Dinanggasan	20	Basic Study on Disaster Prevention and Reconstruction Project for Camiguin Island, Mindanao, Philippines, 2003*

Note) O: Over Flow, I: Inland Flooding.
**: This Basic Study did not refer to the project scale for flood control.*

1.2.3 Accuracy of the Study

The plan for the respective model river basins is formulated within the very limited time (three months), therefore, the accuracy of this Study is very rough and the level of the Study seems to be a pre-master plan. Therefore, for the implementation of the projects for the river basins, further studies such as master plan and feasibility study are indispensable.

1.2.4 Applicable Structural Measures and Selection of Optimum Structural Measures

(1) Classification of Structural Measures

The applicable structural measures are classified into:

- River channel improvement
- Dam and reservoir/Sabo dam

- Retarding basin
- Diversion channel
- Drainage facilities

In principle, the applicable structural measures for each flood type are, as follows:

Table G.1.2 Applicable Structural Measures for Each Flood Type

Flood Type	Applicable Measures				
	River Channel Improvement	Dam and Reservoir and/or Sabo dam	Retarding Basin	Diversion Channel	Drainage Facilities
Lahar/Debris Flow	O	O			
Flash Flood	O	O			
Over Flow	O	O	O	O	O
Bank Erosion	O				
Inland Flooding	O				O

(2) Selection of Optimum Structural Measures

In principle, the optimum structural measures are selected based on the cost comparison among the possible alternative cases, which are formulated considering the combinations of the applicable structural measures.

1.2.5 Responsible Agencies and O/M Plan

(1) Responsible Agencies for Implementation, Maintenance and Operation

The proposed structural measures shall be implemented, maintained and operated properly in order to realize the expected benefits. In this regards, the following agencies cover the works for the implementation, maintenance and operation of the proposed measures in principle, referring to the National Flood Mitigation Framework Plan (DPWH), the Manual on Maintenance of Flood Control and Drainage Structure (DPWH) and the Local Government Code of 1991 (RA 7160), as summarized in Table G.1.3.

Table G.1.3 Responsible Agencies for Implementation, Maintenance and Operation

Proposed Measures		Major Responsible Agency
Structural Measures	River Channel Improvement	DPWH and LGUs
	Retarding Basin	DPWH and LGUs
	Sabo Dam	DPWH and LGUs

(2) O/M Plan

1) Maintenance

The primary objective of the Manual on Maintenance of Flood Control and Drainage Structures is to serve as reference to guide the DPWH engineers and staff in the effective implementation of their maintenance works and activities. This manual shows the step-by-step procedure of the maintenance activities for the structural measures. The gist of the manual is summarized below:

a) Preparation and Submission of Inventory List

Each DEO/PMO (District Engineering Office/Project Management Office) prepares and submits inventory list of all the existing flood control and drainage structures under their responsibility to BOM (Bureau of Maintenence) every year.

b) Monitoring

DEO/PMO conducts monitoring of the structures using the recording sheet. If the damage/irregularity of a structure is found, necessary countermeasure shall be ranked into three levels (A, B and C) based on the urgency.

c) Emergency Measures

When the damage is judged to be Urgency A, DEO/PMO shall issue the Flood Information to the related agencies, such as MDCC(s) and/or CDCC(s). When it is judged that portion of the structure has a high possibility of overflow/breach during the coming flood event, DEO/PMO shall issue the Flood Information on Flood Fighting to the related MDCC(s) and/or CDCC(s).

d) Damage Investigation and Status Report

Just after finding damage, DEO/PMO shall conduct damage investigation for the damaged structures ranked as Urgency A and B. The results of the investigation are recorded on the forms of damage investigation.

e) Priority List

DEO/PMO shall submit the priority list form to BOM, which describes the selected flood control structures. The BOM approves the implementation of repair/rehabilitation of the selected structures, if the structures are included in the inventory list.

f) Implementation of Repair and/or Rehabilitation

The implementation of repair and/or rehabilitation of damaged flood control structures are being undertaken by the construction group within the DEO/PMO organization structure.

2) Operation

In principle, the retarding basins including auxiliary equipments should have their respective standard operation procedures. Therefore, these facilities are operated based on the established or prescribed operation rule. For the other structures (river channel and sabo dams), their operation is not required in principle.

2. ILOG-HILABANGAN RIVER BASIN

2.1 Basin Conditions

2.1.1 Natural Conditions

(1) Topography

The Ilog-Hilabangan River Basin is enclosed by three clusters of mountains; namely, Negros Central Mountains to the north, Negros Cordillera to the east, Southern Negros Mountains to the southwest. It faces Panay Gulf to the northwest. The Ilog-Hilabangan Plain is situated in the middle part of the Basin. It is characterized by irregularly shaped depression and dissected plateau that has an alluvial flat land and gently sloping hills. The highland of this plain has an elevation of less than 300 meters above mean sea level. In the northwestern part of the plain, the delta along the Ilog River faces Panay Gulf. From the micro-topographical viewpoint, the delta has a very gentle slope as it comes to the seashore. The topography of the Basin is shown in Figure G.2.1.

(2) Existing River System and Structures

The Ilog-Hilabangan River system is composed mainly of two major rivers; Ilog River with a length of about 120 km, and Hilabangan River with a length of 35 km. The Hilabangan River merges to Ilog River at around 17 km from the river mouth. Ilog River diversifies into Old Ilog River and other several branch rivers in the lower reaches. The basin has the total area of 2,162 km^2. The riverbed gradient of Ilog River (1/140 to 1/3,100) is relatively gentle compared with that of Hilabangan River (1/80 to 1/240).

During 1970-1990, the present Ilog River became the main outlet stream and the Municipality of Ilog was in danger of possible floods. In order to change this situation, Old Ilog River was dredged and utilized as a diversion channel with the construction of the diversion facilities. However, the facilities were destroyed with Typhoon Nanang in 2001. The existing river system of the Ilog-Hilabangan River Basin is shown in Table G.2.1 and Figure G.2.1.

Table G.2.1 Rivers in the Ilog-Hilabangan River Basin

River	Catchment Area (km^2)	Length (km)	Remarks
Ilog	1,709	120.0*	*Excluding Hilabangan
Hilabangan	453	35.0	

The major river structures relating to flood control are, as follows:

- Revetment works have been constructed mainly around bridges.

- The construction of modular steel bridge has started at barangay 8 and 9 of the Kabankalan City with an 80 m revetment wall.
- The flow capacity of Old Ilog River was increased with dredging with 19 million pesos in 1999, so that the floods flow down through Old Ilog River. In order to change the direction of a part of flood flow from Ilog River to Old Ilog River, diversion facilities were constructed at the diversion point, but the facilities were destroyed with Typhoon Nanang in 2001.

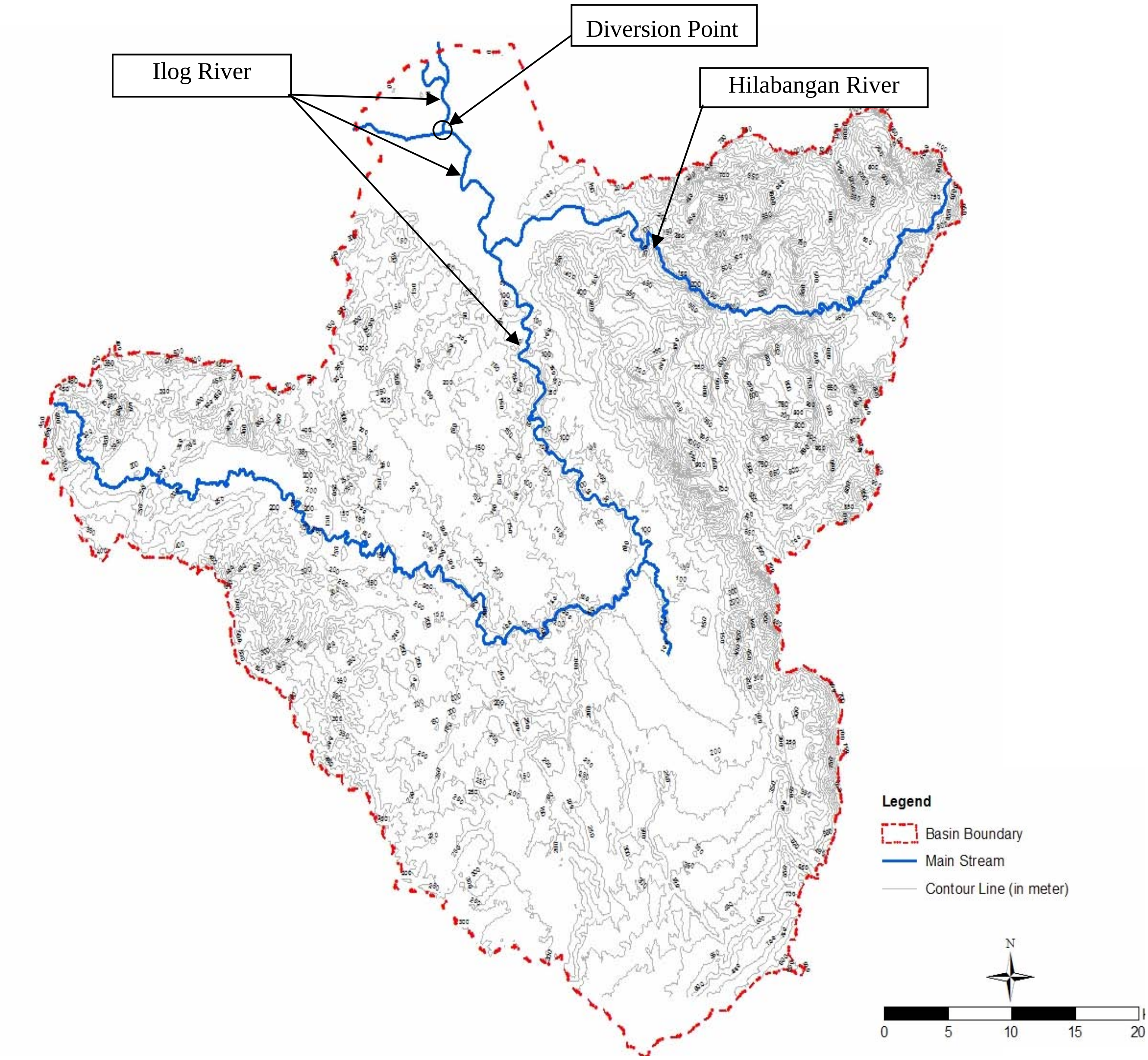


Figure G.2.1 Topographic Map of the Ilog-Hilabangan River Basin

(3) Meteorology and Hydrology

The Ilog-Hilabangan River Basin falls in Type I and Type III of the modified Corona's climate classification. Type III, in which the large part of the basin excluding the upstream reach of Ilog River lies, is characterized by not very pronounced seasons, relatively dry from November to April. While, Type I is characterized as two pronounced seasons, dry and wet. Monthly rainfall distribution at Kabankalan City is shown in Figure G.2.2.

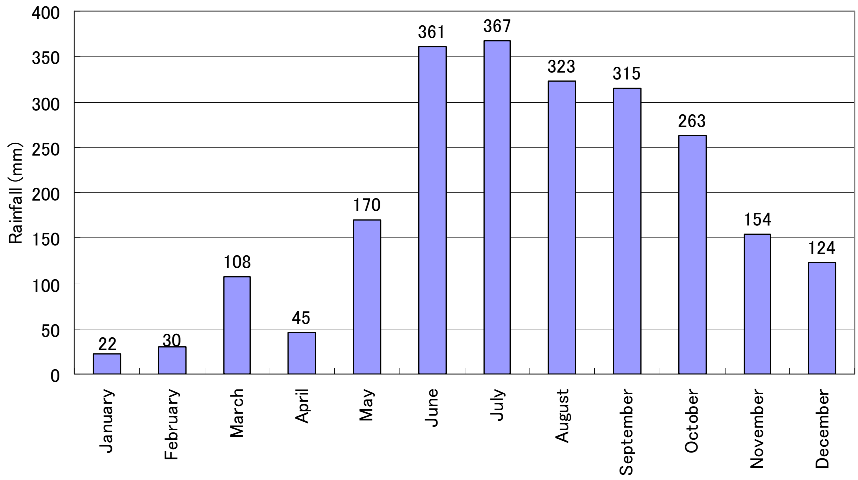


Figure G.2.2 Monthly Rainfall Distribution at Hacienda Clementina, Kabankalan, 2000-2005

(4) Regional Geology

Old volcanic rocks, partly covered by later sedimentary rocks and young volcanic rocks, are exposed in the interior of the Negros Central Mountains and the Negros Cordillera. The front and foothills are generally covered by these sedimentary rocks, which include sandstone, siltstone, conglomerate, shale and limestone.

At the Southern Negros Mountain region, there is a series of old sedimentary rocks with younger sedimentary rocks and volcanic rocks. The region is dominated by old volcanic rocks with the basement complex of metamorphosed igneous and sedimentary rocks.

The Ilog-Hilabangan Plain is formed of young and old sedimentary rocks, volcanic rocks and limestone.

Numerous faults and folds are found in the river basin. The main trend of the faults strikes northwest-southeast and northeast-southwest. Folds generally exist in older sedimentary rocks. The Ilog-Hilabangan plain and Negros Central Mountains are bordered by faults having NNE-SSW strike and SSE dip.

2.1.2 Social and Economic Conditions

(1) Population and its Growth

The total population of the Kabankalan City based on the 2000 NSO Census is 149,769, and 77.8% of the populace is found in the rural areas. The average annual growth rate from 1995 to 2000 is 1.46%. The average population density for the entire City is 215 persons/km^2.

On the other hand, for the Municipality of Ilog, the total population is 46,525 based on the 2000 NSO Census, and 27.3% of the population is in the urban areas. The average annual growth rate from 1995 to 2000 is 1.17%. The average population density for the entire Municipality is 152 persons/km^2.

(2) Land Use

1) Existing Land Use

The City of Kabankalan covers a total land area of 69,735 ha. More than half of the land area is devoted to agriculture, while a little more than one-fourth is utilized for forest areas.

On the other hand, the Municipality of Ilog covers a total land area of 30,596 ha. More than half of the land area of the Municipality is devoted to agriculture, and nearly a third of the total land area is forest areas. Fishponds occupy a significant portion of the land use, which occupy nearly a tenth of the land. Figure G.2.3 shows the existing land use map of the basin (2002/03).

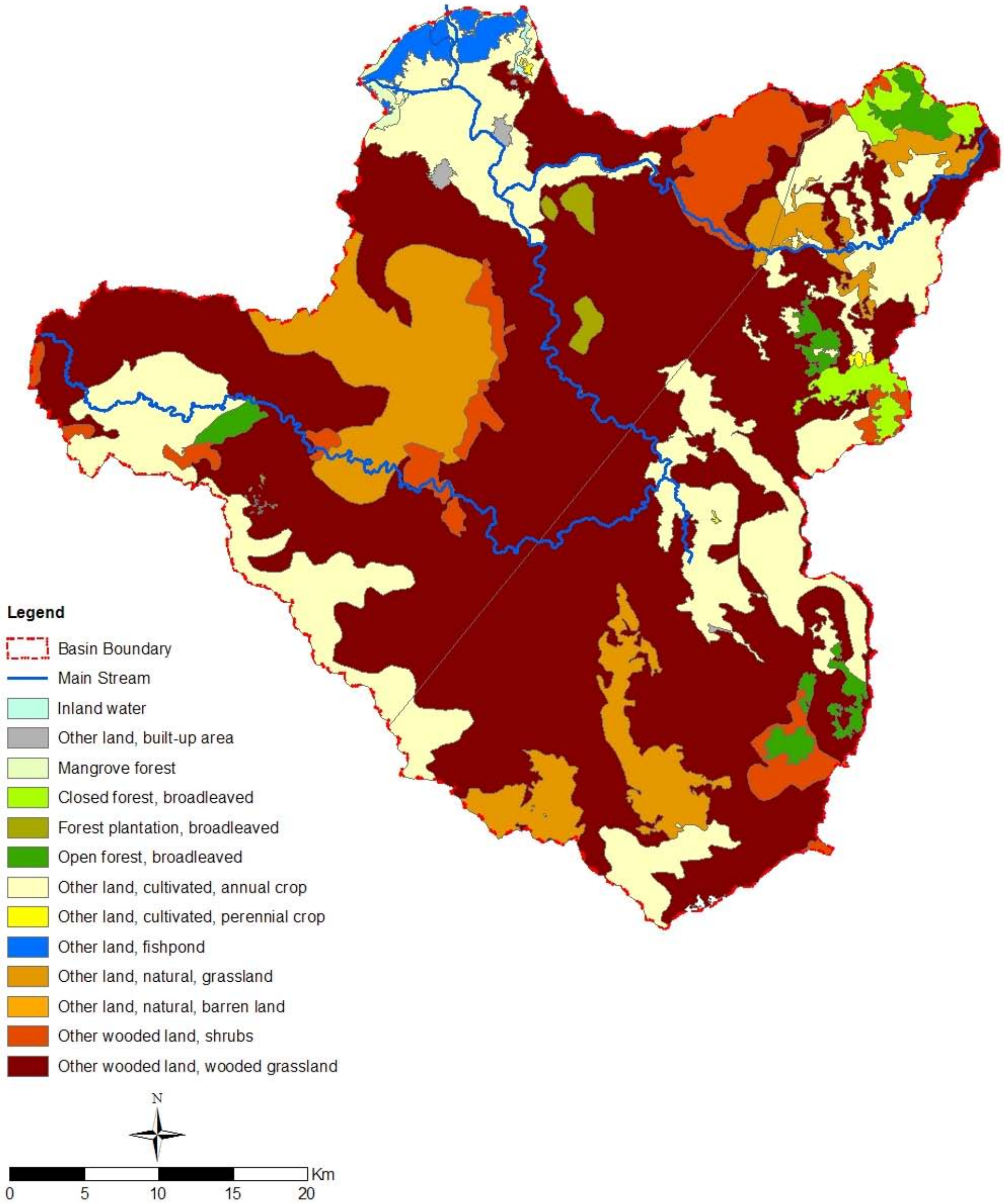


Figure G.2.3 Existing Land Use in the Ilog-Hilabangan River Basin

2) Projected Land Use

The year of projection for the City of Kabankalan is 2014. The major changes in the land use are; increase of forestland (3,412 ha), built-up (302 ha) and infrastructure/utilities (89 ha): and decrease of open grassland (3,457 ha), agricultural (202 ha) and industrial (143 ha).

On the other hand, the year of projection for the Municipality of Ilog is 2010. Significant increase is expected for built-up area (106 ha), buffer zone (71 ha) and mineral zone (13 ha). On the other hand, only agricultural area will be decreased (234 ha).

Table G.2.2 and Table G.2.3 show the existing and projected land use of Kabankalan City and Ilog Municipality.

Table G.2.2 Existing and Projected Land Use in Kabankalan City

Land Use	Existing (2004)		Projected (2014)		Area Change (has)
	Area (has)	Percent to Total (%)	Area (has)	Percent to Total (%)	
Built-up	2,512.68	3.6	2,814.64	4.0	+301.96
Open Grassland/Cogonal	9,438.96	13.5	5,982.06	8.6	-3,456.90
Fishpond	802.94	1.2	802.94	1.2	0
Forest Land	18,035.00	25.9	21,446.67	30.8	+3,411.67
Industrial	1,869.27	2.7	1,725.85	2.5	-143.42
Rivers/Creeks	505.59	0.7	505.59	0.7	0
Infrastructure/Utilities	752.04	1.1	840.90	1.2	+88.86
Agricultural	35,819.01	51.4	35,616.83	51.1	-202.18
TOTAL	69,735.49	100.0	69,735.49	100.00	0

Source) Comprehensive Local Development Plan, 2005-2014, City of Kabankalan

Table G.2.3 Existing and Projected Land Use in Ilog Municipality

Land Use	Existing (2000)		Projected (2010)		Area Change (has)
	Area (has)	Percent to Total (%)	Area (has)	Percent to Total (%)	
Built-up	302.48	1.0	407.99	1.3	+105.51
Industrial	1.02	0.0	5.00	0.0	+3.98
Agricultural	17,156.36	56.1	16,922.75	55.3	-233.61
Open Grassland/Cogonal	781.00	2.6	791.37	2.6	+10.37
Socialized Housing Site	0.00	0.0	7.02	0.0	+7.02
Cemetery	6.10	0.0	7.62	0.0	+1.52
Dumping Site	0.00	0.0	2.40	0.0	+2.40
Mangroves	291.80	1.0	291.80	1.0	0
Fishpond	2,618.71	8.6	2,618.71	8.6	0
Timberland	8,940.02	29.2	8,940.02	29.2	0
Tourist Zone	-	-	7.99	0.0	+7.99
Mineral Zone	-	-	12.50	0.0	+12.50
Roads	38.67	0.1	50.28	0.2	+11.61
Rivers/Creeks	459.84	1.5	459.84	1.5	0
Buffer Zone	-	-	70.71	0.2	+70.71
TOTAL	30,596.00	100.0	30,596.00	100	0

Source) Comprehensive Land Use Plan, CY 2000-2010, Municipal Planning and Development Office, Municipality of Ilog

(3) Local Economy

1) Agriculture

The agriculture plays an important role in the economy of the City of Kabankalan. The sugarcane (15,187 ha) is leading and followed by cereals such as rice (3,861 ha), corn and livestock industries. The area of the brackish water fishpond is covering an area of 521 ha. In the coastal areas, fishing becomes the major source of livelihood.

The Municipality of Ilog is also considered as an agricultural municipality. Sugarcane (6,605 ha) is the leading and followed by corn (2,725 ha) and rice (1,176 ha). Ilog has a total fishpond area of 2,108.5 ha with an estimate production of 4,421 metric tons.

2) Commerce and Trade

Commercial establishments of the City of Kabankalan include department stores, appliance centers, drugstores, pawnshops/jewelry stores and sari-sari stores which are located in the urban area occupying 102 ha. In order to accommodate the increasing demand for a bigger commercial area, the City has allocated 107 ha.

The Municipality of Ilog has four public markets, two of which located at the urban center. The public markets being the center of commercial activities have an area of approximately 3 ha. Commercial activities in the Municipality considerably increased for the last five years.

3) Industry

The NEDA has identified the City of Kabankalan as the growth center and the site of People's Industrial Estate, an agro-industrial center of Southern Negros. The agro-industries include sugar mills, rice mills, corn mills, repair shops and other small and medium agro-based industries. A big percentage of the population is dependent on the sugar industry for their means of income and livelihood.

In the Municipality of Ilog, industrial activities are fast growing. In 1995 there were 14 registered establishments. These establishments are rice and corn mills, CHB making, saw mills (coco lumber), food processing (bakery) and machine shops (welding and repair shop).

2.1.3 Floods and Flood Damage

(1) Floods and Flood Damage

The Ilog-Hilabangan River Basin experienced severe floods by typhoons in 1949, Nitang-1984, Ruping-1990, Nanang-2001 and Ursula-2003. In the 1949 flood, the landside was inundated for 4 days causing 730 dead and 5.1 million pesos damage (1954 price level). On the other hand, by the 1984 flood, the Municipalities of Kabankalan and Ilog including the surrounding flat land were inundated resulting in 48 dead and 29 missing. The flood inundation area in 1984 flood roughly covered 125 km^2 in the lower reaches. By 1990 flood, rehabilitation costs of infrastructure in Regions VI and VII were estimated at 220 million pesos and 184 million pesos, respectively.

(2) Major Causes of Floods

Heavy rainfall in the lower reaches of Negros Occidental as well as in the upstream of Negros Oriental causes flash floods in the tributaries and overflow in the lower reaches. These tributaries and main stream are lack of flow capacity. In addition, severe bank erosion in the lower reaches causes heavy siltation, and the shallow rivers and estuarine areas are also one of the factors of the flooding.

Up to the present, the basin has been changed in accordance with the economic and population growth, and correspondingly land use has been changed from agricultural and forestal to residential, commercial and industrial. These changes in the land use substantially increased the runoff discharge and thereby peak discharge. On the other hand, the urbanization in the lower reaches has taken place, and this increased the flood damages.

2.1.4 Previous Related Study

Based on the severe floods in 1949, 1984 and 1990, the necessity of providing more effective countermeasures was recognized, and the "Study on Ilog-Hilabangan River Basin Flood Control Project, July 1991, JICA (the Master Plan)" was commenced to formulate a master plan of flood control, as follows:

(1) Master Plan

The project scale for the Master Plan was 100-year return period. Based on the alternative study, a river channel improvement plan along the present river channel was selected. The major features of the river improvement works are summarized below.

Table G.2.4 Major Works of River Improvement Proposed in the Master Plan for the Ilog-Hilabangan River Basin

River	Design Discharge (m^3/s)	Length (km)	Width (m)	Major Structures
Ilog	5,450	20.0	160-300	Embankment

(2) Selected Urgent Project

The urgent project was selected within the framework of the Master Plan by narrowing down the area to be protected and/or by lowering the project scale. The project scale for the Urgent Project was 25-year return period. The proposed project was a river channel improvement for the same river stretch as the Master Plan.

2.2 Hydrologic Analysis

The design discharge is set with reference to the Master Plan. Distribution of the design discharge for 25-year return period is shown in Figure G.2.4.

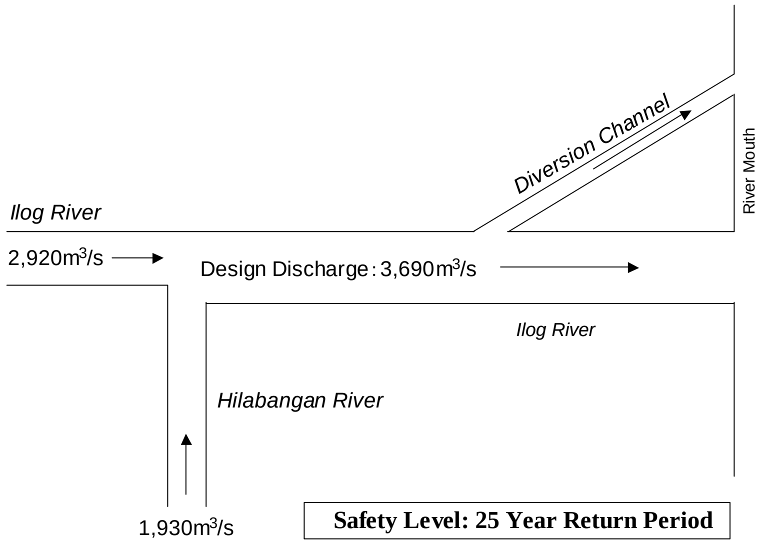


Figure G.2.4 Design Discharge Distribution in the Ilog-Hilabangan River Basin

2.3 Flood Inundation Analysis

2.3.1 Flow Capacity

Flow capacity of the existing river channel is analyzed with HEC-RAS. In the analysis, the newly obtained river cross sections are utilized. The flow capacities of the existing river channel are estimated as shown below.

Table G.2.5 Flow Capacity of Existing River Channel in the Ilog-Hilabangan River Basin

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

2.3.2 Flood Inundation Area

The flood inundation area is estimated with reference to the Master Plan. The flood inundation area is distributed over the whole low flat ground including built-up areas of Kabankalan and Ilog, fishpond area and annual crop area. The total inundation area is estimated at 10,402 ha with 25-year return period flood, as shown below. The flood inundation area is shown in Figure G.2.5.

Table G.2.6 Area of Flood Inundation of the Ilog-Hilabangan River Basin

(Unit:ha)

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

2.4 Basic Layout of Main Structural Measures

2.4.1 Applicable Structural Measures

The flood type of the Ilog-Hilabangan River Basin is F+O+B/F+B (Group 1). Comparing with the flood type of this basin, the following structural measures are considered as the applicable ones:

Table G.2.7 Basic Applicable Structural Measures for Flood Type in the Ilog-Hilabangan River Basin

Flood Type	Applicable Measures				
	River Channel Improvement	Dam and Reservoir and/or Sabo dam	Retarding Basin	Diversion Channel	Drainage Facilities
Flash Flood (F)	O	O			
Over Flow (O)	O	O	O	O	O
Bank Erosion (B)	O				

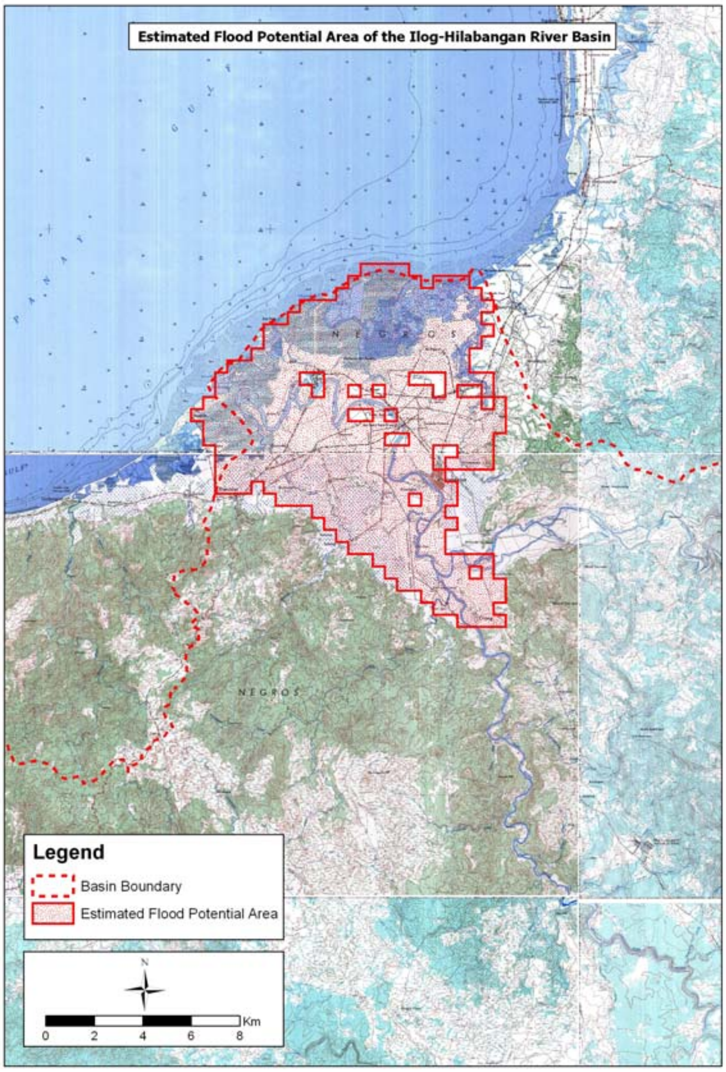


Figure G.2.5 Flood Inundation Area of the Ilog-Hilabangan River Basin

In the Master Plan, several alternatives including dam and reservoir, retarding basin and drainage facilities were examined and the Ilog river channel improvement was selected as the optimum structural measures. Since then, flooding conditions have not changed so much except that the Old Ilog River was improved as the diversion channel of the Ilog River. Therefore, as the applicable structural measures for the flood damage mitigation, two (2) measures, river channel improvement and diversion channel, are studied for the basin.

(1) River Channel Improvement

Based on the Master Plan, the river channel improvement following existing river alignment is adopted for the river channel improvement.

(2) Diversion Channel

The old Ilog River is applicable as a diversion channel by expanding its river width and dredging riverbed.

Based on the above, the applicable structural measures are recommended as summarized below:

Table G.2.8 Applicable Structural Measures in the Ilog-Hilabangan River Basin

Flood Type	Applicable Measures				
	River Channel Improvement	Dam and Reservoir and/or Sabo Dam	Retarding Basin	Diversion Channel	Drainage Facilities
F+O+B/F+B	O			O	

2.4.2 Target Area of Flood Mitigation

The target area of flood mitigation is a potential flood area along Ilog and Hilabangan Rivers, as shown in Figure G.2.5. The target reach has been set at 3 km and 2 km upstream from the confluence of the Ilog River and Hilabangan River, respectively.

2.4.3 Basic Idea of Layout

At present, the floods flow through Ilog River and Old Ilog River. Based on this present condition, the basic layout is considered, as follows:

(1) Utilizing Ilog River Only after the Diversion Point

In this case, closing facilities are to be constructed in Old Ilog River, but maintenance flow is released to Old Ilog River through the facilities.

(2) Utilizing the Old Ilog River Only after the Diversion Point

In this case, closing facilities are to be constructed in Ilog River, but maintenance flow is released to Ilog River through the facilities.

(3) Utilizing the Both Rivers after the Diversion Point

In this case, diversion facilities are required at the diversion point in order to control the discharges of the flood flows for the both rivers. For Old Ilog River, only bank protection works are considered without increasing its existing flow capacity.

2.4.4 Possible Alternative Cases

Corresponding to the above idea, three alternative cases are conceivable as shown in Table G.2.9 and Figure G.2.6.

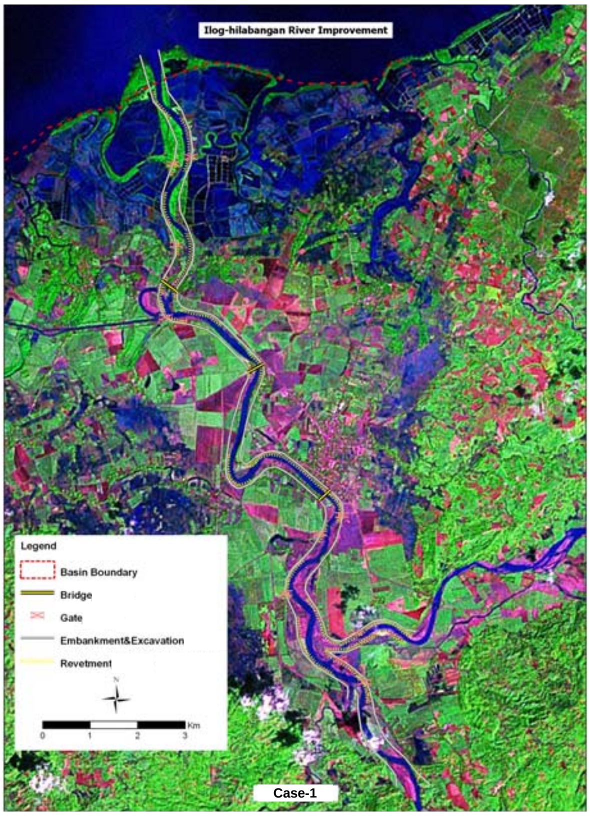
Table G.2.9 Alternative Cases in the Ilog-Hilabangan River Basin

Alternative Cases	Basic Layout of Main Structural Measures
Case-1	• River channel improvement of Ilog River after the diversion point
Case-2	• River channel improvement of Old Ilog River after the diversion point as a diversion channel
Case-3	• River channel improvement of Ilog River and Old Ilog River after the diversion point

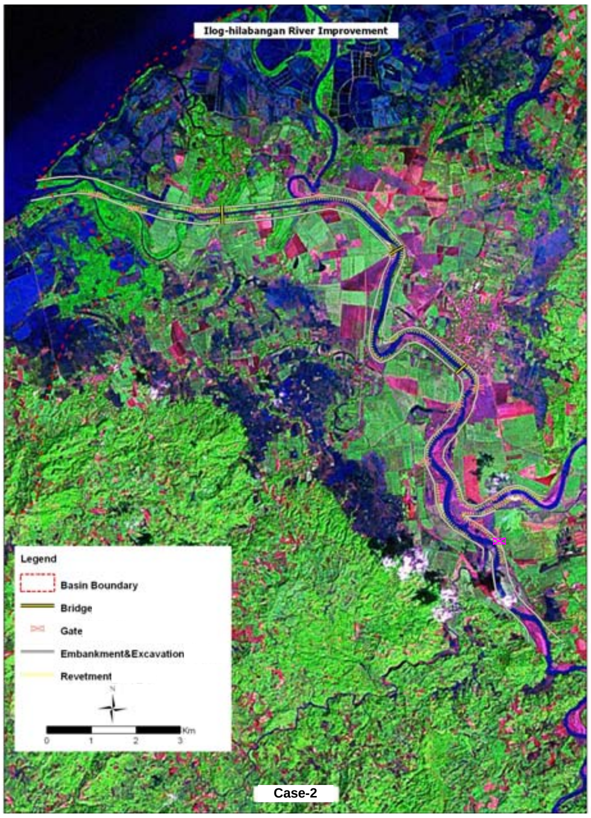
2.4.5 Recommended Structural Measures

(1) Optimum Case

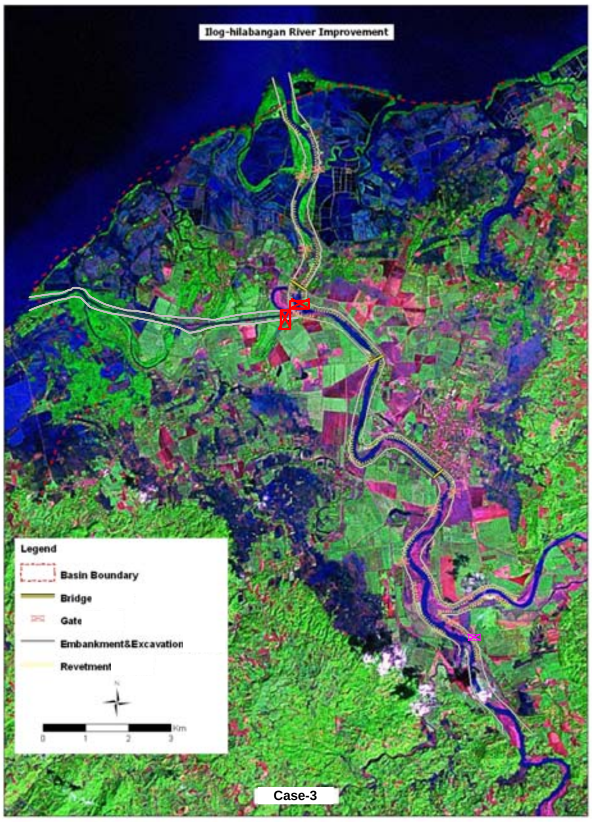
The optimum case is determined based on the cost comparison, assuming the benefit accrued from each alternative is the same. In line with this idea, cost for each alternative case is roughly estimated as shown in Table G.2.10. Based on the estimation results, the cost difference between Case-1 and Case-2 is only 184 million pesos, around 9% of the Case-1 cost. Therefore, Case-1 is preliminarily recommended as the structural measures, which comprises the river channel improvement of Ilog and Hilabangan Rivers.



Case-1



Case-2



Case-3

Figure G.2.6 Comparison of Alternative Cases in the Ilog–Hilabangan River Basin

Table G.2.10 Result of Cost Comparison of Alternative Cases in the Ilog-Hilabangan River Basin

Alternative Cases	Cost (mil. Pesos)
Case-1	2,106
Case-2	2,290
Case-3	12,944

With the recommended structural measures, the design discharge of 25-year return period will be distributed as shown in Figure G.2.7.

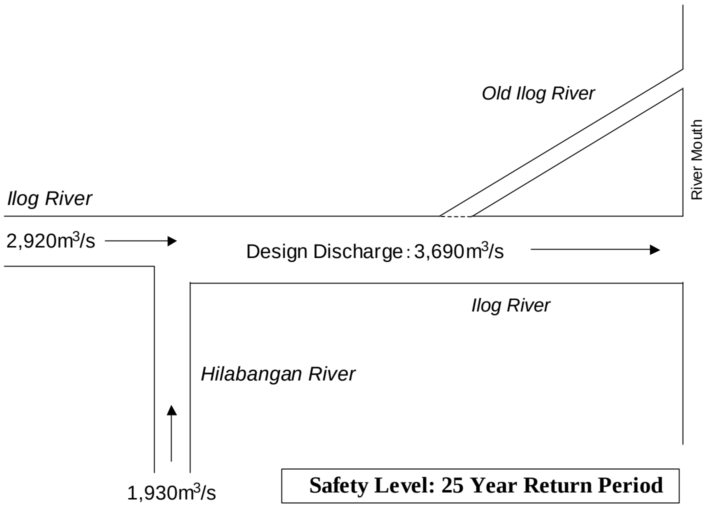


Figure G.2.7 Design Discharge Distribution with Optimum Structural Measures in the Ilog-Hilabangan River Basin

3. DUNGCAAN RIVER BASIN

3.1 Basin Conditions

3.1.1 Natural Conditions

(1) Topography

The Dungcaan River Basin is generally mountainous on the south-eastern portion and it sloped down west towards the shoreline of Baybay City. The City proper of Baybay is approximately 15.5 meters above mean sea level and is surrounded by the mountain ranges of Mt. Cayoguiocan, Mt. Mabajon and Mt. Balao in the south; Mt. Hiluguiran to the east; and Mt. Maganjan to the northeast of the River Basin.

The southern Dungcaan River drains the areas covered by Mt. Cayoguiocan and it meanders northeast passing through Barangay Ciabo before draining the Gubang, Cantognos and Igang Barangays at the foot of Mt. Maganjan. The topography of the Basin is shown in Figure G.3.1.

(2) Existing River System and Structures

The Dungcaan River system is composed of three major rivers; Dungcaan River with a length of about 37.9 km (the principal drainage of this basin), the Pawonyan River with a length of 26.3 km (the right side main tributary), and the Tabayagon River with a length of 16.1km (the left side main tributary). The Dungcaan River Basin has the total area of 176 km^2. The riverbed gradient of Dungcaan River, ranging from 1/40 to 1/240, is relatively gentle compared with that of the Pawonyan (1/14 to 1/130) and Tabayagon River (1/8 to 1/80).

Dungcaan River flows through two channels in the downstream of the Baybay Bridge, the northern main stream and the southern sub-stream. The southern sub-stream was once closed with the concrete wall at the diversion point, and this concrete wall was broken in 2006. The existing river system of Dungcaan River is shown in Table G.3.1 and Figure G.3.1.

Table G.3.1 Rivers in the Dungcaan River Basin

River	Catchment Area (km^2)	Length (m)	Remarks
Dungcaan	176	37,900*	* Excluding tributaries
Pawonyan	52	26,300	Tributary
Tabayagon	30	16,100	Tributary

The major river structures relating to flood control are, as follows:

- Concrete wall was constructed at the entrance of the southern sub-stream in the downstream of the Baybay Bridge. The purpose of this wall was prevention of flood damages to the Poblacion of Baybay from entering the floods into this sub-stream. However, this concrete wall was destroyed after continuous rainfall in December 2006.

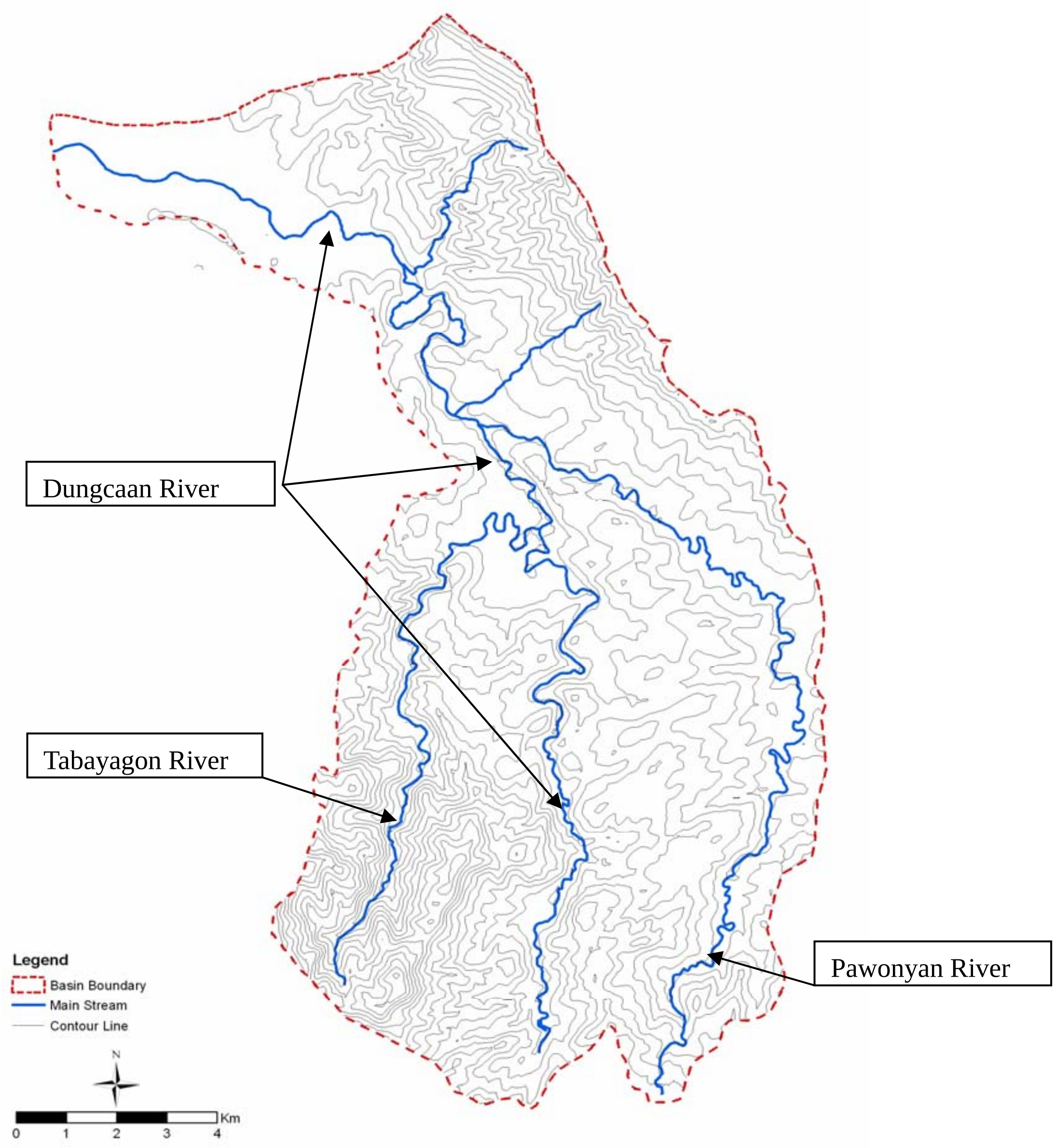


Figure G.3.1 Topographic Map of the Dungcaan River Basin

(3) Meteorology and Hydrology

The climate of the basin falls under Type IV of the modified Corona's climate classification, which is generally characterized as no dry season but with a pronounced maximum rainfall from September to January. For this type of climate, rainfall is more or less evenly distributed throughout the year.

The frequency of tropical cyclones are rated 7% for the area of Baybay. Monthly rainfall distribution at Baybay City is shown in Figure G.3.2.

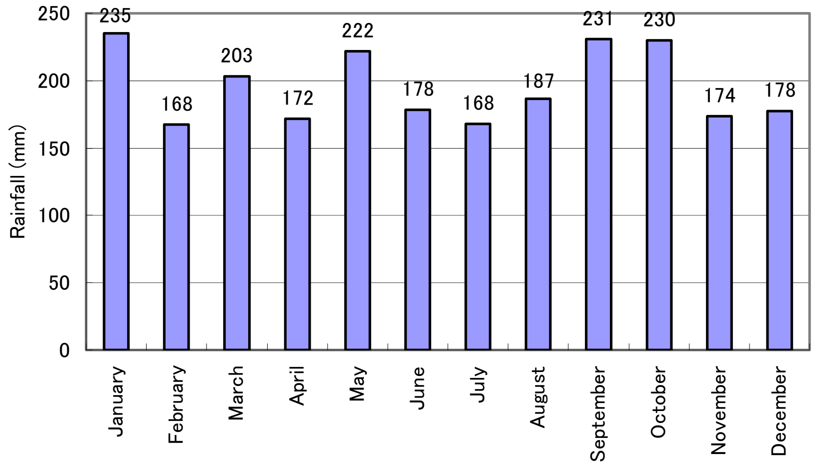


Figure G.3.2 Monthly Rainfall Distribution at PAGASA, Baybay, 1994-2000

(4) Regional Geology

Geologic map around Baybay reveals two major rock foundations; limestone and poorly consolidated sediments with an area of 1,316 hectares (2.9%): and the metamorphosed rocks, volcanic rocks and highly crystallized rocks with an area of 44,734 hectares (97.1%).

3.1.2 Social and Economic Conditions

(1) Population and its Growth

Based on the 2002 NCSO report, Baybay registered a total population of 99,689. Its Poblacion retains 17,391 in population. Population density of Baybay is 207.67 persons/km^2. On the other hand, the average annul growth rate from 1995 to 2000 is 2.10%. It is noteworthy that the increase in population from 1995 to 2000 is nearly three-fold of the increase from 1990 to 1995. It is not far-fetched to surmise that further acceleration in the growth of population will speed up considering the recent upgrading of Baybay from a 1st-Class City to a full-fledged city (January 2007).

(2) Land Use

The City of Baybay covers a total land area of 46,050 ha. Nearly half of the land area is utilized for agriculture while more than two-fifths is considered forest areas. Land use projection is under preparation. Figure G.3.3 shows the land use map of the basin. The details of the land use of the Baybay City are shown in Table G.3.2.

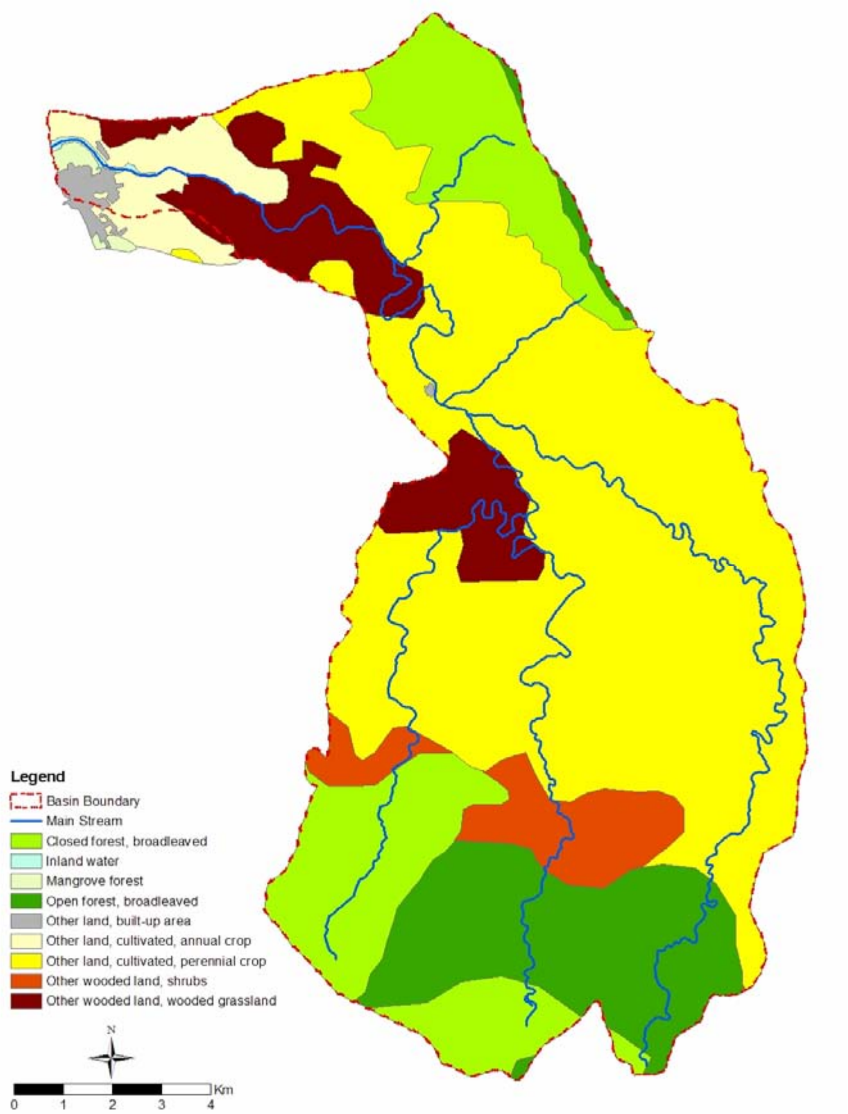


Figure G.3.3 Existing Land Use in the Dungcaan River Basin

Table G.3.2 Existing Land Use in Baybay City

Land Use	Land Area (has)	Percent of Total (%)
Built-up	352	0.8
Agriculture	22,412	48.7
Forest	21,790	47.3
Fishponds/ Swamps/ Mangroves	47	0.1
Grassland/ Pastureland	180	0.4
Agri-industrial (rice and corn mills, etc.)	167	0.4
Institutional	1,053	2.3
Roads/ Bridges	30	0.7
Open Water Space	13	0.0
Dump Site	1	0.0
Cemetery/ Burial Ground	6	0.0

(3) Local Economy

1) Agriculture

Agriculture is one of the most important economic activities in the Baybay City. Coconut farming occupies the largest area of agricultural land with 16,176 ha, followed by irrigated rice farming with 1,540 ha, rainfed rice with 441 ha and corn with 250 ha.

2) Commerce and Trade

There is a Central Business District in the Poblacion of the City where most of the commercial establishments are located. More than 700 establishments operate in the Poblacion. Commercial activities include the wholesale and sari-sari, eatery, rice and corn retailer, cold/snack bar/refreshment, hollow block makers and others.

3) Industry

The City of Baybay is basically agricultural town. Hence, the industries in the City are mostly agri-base operating at the Poblacion and in outlying rural barangays. Various cottage industries can also be found in the City such as bamboo and rattan craft, ceramics, dress making, fiber craft food preservation, metal craft and other related activities.

3.1.3 Floods and Flood Damage

(1) Floods and Flood Damage

The Dungcaan River Basin experienced severe floods in 1972, 1994 and 2006. In the 1972 floods, the flood depth was 1-2 m and the flood duration was from 3 hr to 1 day. On the other hand, in the 1994 floods, the flood depth was around 1.5 m and the flood duration was from 6 hr to 2 days. The flood flows were very fast with thousand of up rooted coconut trees including heavy sediment discharges. Severe bank erosion is observed in the downstream of Dungcaan River.

In the 1972 flood, thousand of up rooted coconut trees caused damming at the upstream and at the Baybay Bridge, and they breached. As a result, the floodwater flowed into the Poblacion and remarkable damages were occurred, i.e., number of affected people was around 10,000 persons and the number of completely damaged houses was 250 (based on the questionnaire survey). The 2006 flood was caused by continuous rainfall, and the concrete wall at the entrance of the southern sub-stream was destroyed as fore mentioned.

(2) Major Causes of Floods

Heavy rainfall in the upstream of the basin causes overflow in the lower reaches in where the river is lack of flow capacity. In addition, severe bank erosion is observed especially in the lower reaches of Dungcaan River. Rapid change in land use seems not to be the major cause of floods in the basin. However, rapid increase of the population in the Poblacion of Baybay contributes to the increase of flood damages.

3.1.4 Previous Related Study

The City of Baybay is preparing land use plan, etc. at present.

3.2 Hydrologic Analysis

3.2.1 Specific Discharge Formula

The design discharge of Dungcaan River is computed with the Specific Discharge Formula, as follows:

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

Where, q = specific discharge ($m^3/s/km^2$)

c = constant (11.59, decided by region and return period)

A = catchment area (km^2)

3.2.2 Design Discharge Distribution

Distribution of design discharge for 20-year return period is shown in Figure G.3.4.

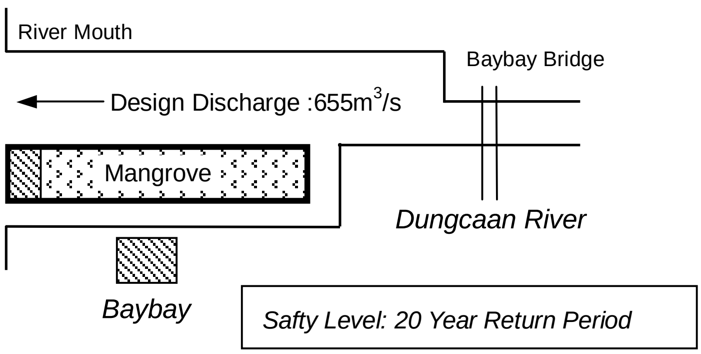


Figure G.3.4 Design Discharge Distribution in the Dungcaan River Basin

3.3 Flood Inundation Analysis

3.3.1 Flow Capacity

The flow capacity of the existing river channel is analyzed with HEC-RAS using the river cross sections newly obtained in the survey. The flow capacity of Dungcaan River at the Bridge is estimated as shown below.

Table G.3.3 Flow Capacity of Existing River Channel in the Dungcaan River Basin

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

3.3.2 Flood Inundation Area

Flood inundation area is analyzed with HEC-RAS and HEC-GeoRAS using the river cross sections newly obtained. In the analysis, the altitude data of SRTM is adjusted by comparison with the river cross sectional survey data. As a result, the flood inundation area consists of mangrove forest, built-up area of the Baybay City at the downstream of the Baybay Bridge, and annual crop area at the upstream of the Baybay Bridge. The total inundation area is estimated at around 173 ha with 20-year return period flood, as shown in the table below. The flood inundation map is shown in Figure G.3.5.

Table G.3.4 Area of Flood Inundation of the Dungcaan River Basin

(Unit: ha)

Land Use	Flood Scale (Return Period)
	20-year
Built-up Area	13.0
Fishpond	0.0
Cultivated, Annual Crop	89.1
Other	70.4
Total	172.6

3.4 Basic Layout of Main Structural Measures

3.4.1 Applicable Structural Measures

The flood type of the Dungcaan River Basin is O+B (Group 2). Comparing with the flood type of this basin, the following structural measures are considered as the applicable ones:

Table G.3.5 Basic Applicable Structural Measures for Flood Type in the Dungcaan River Basin

Flood Type	Applicable Measures				
	River Channel Improvement	Dam and Reservoir and/or Sabo dam	Retarding Basin	Diversion Channel	Drainage Facilities
Over Flow (O)	O	O	O	O	O
Bank Erosion (B)	O				

Judging from the river basin conditions, retarding basin, diversion channel and drainage facilities are not applicable considering the topographic and land use conditions. Hence, applicable measures are river channel improvement and dam and reservoir as described below.

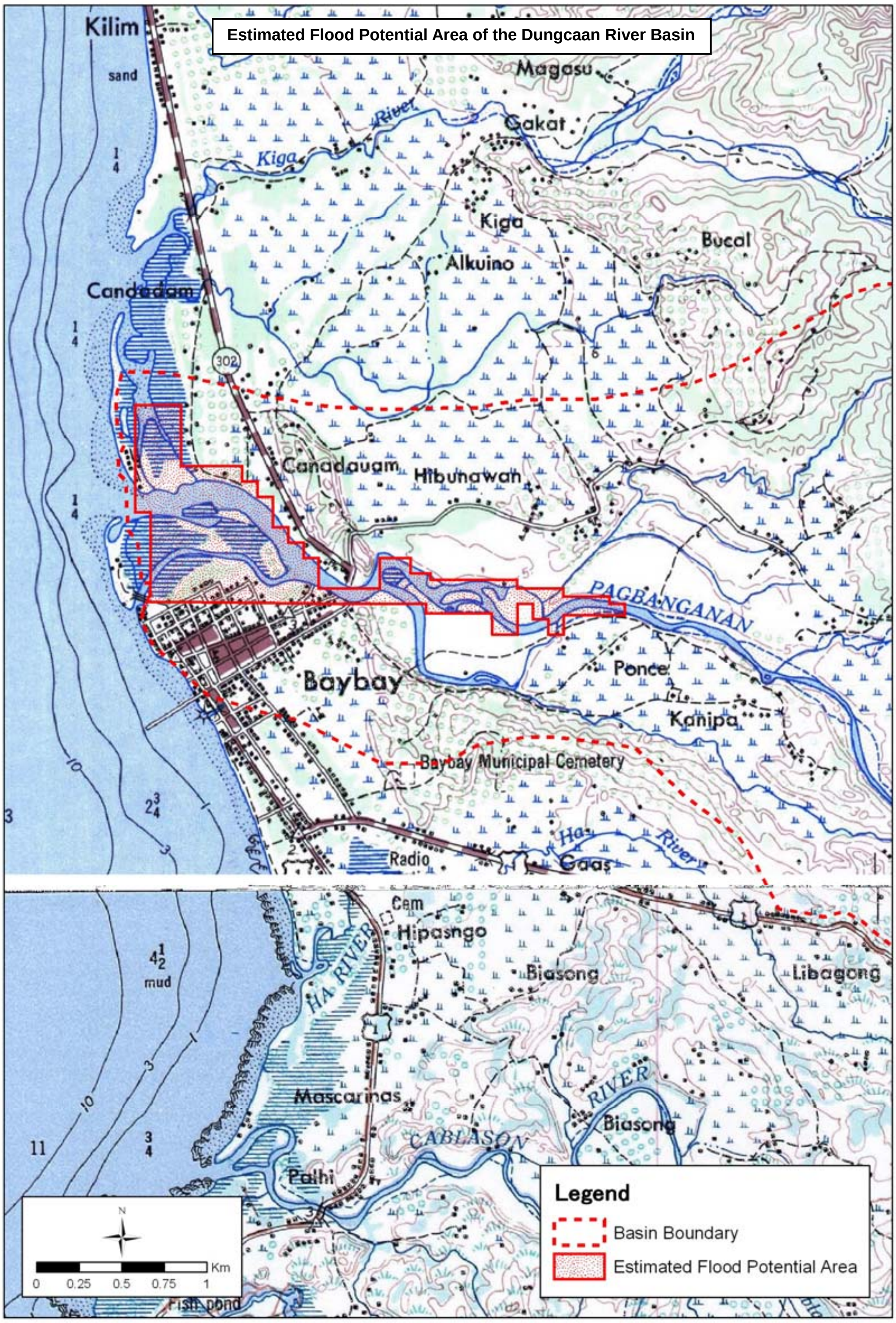


Figure G.3.5 Flood Inundation Area of the Dungcaan River Basin

(1) River Channel Improvement

River channel improvement is applicable for this river. However, for the downstream of the Baybay Bridge, its alignment should be studied considering the socio-environmental conditions, especially mangrove and resettlement.

(2) Dam and Reservoir

Observing the geological conditions, several dam sites are surveyed around the following places:

- Along Dungcaan River, between the confluences with the tributaries, the Tabayagon and Pawonyan Rivers
- Along Pawonyan Rivers, around 1.8 km upstream of the confluence
- Along the Tabayagon Rivers, around 7.0 km upstream of the confluence

As a result, the Pawonyan River site is preliminarily selected for the dam, considering its geological condition, location and storage capacity, etc. This dam is planned as a multi-purpose dam for flood control and irrigation.

As a result, the applicable structural measures are recommended as summarized below.

Table G.3.6 Applicable Structural Measures in the Dungcaan River Basin

Flood Type	Applicable Measures				
	River Channel Improvement	Dam and Reservoir	Retarding Basin	Diversion Channel	Drainage Facilities
O+B	O	O			

3.4.2 Target Area of Flood Mitigation

Target area of flood mitigation is the downstream reach of Dungcaan River, in which built-up area of Baybay exists in the right side of the river.

3.4.3 Basic Idea of Layout

The basic layout of the river channel improvement is studied for the downstream and upstream portions of the Baybay Bridge as described below.

(1) Upstream of the Baybay Bridge

The river channel improvement is planned until around 300 m upstream from the Baybay Bridge against the overflow and bank erosion. There is a bend portion at around 300 m upstream of the Baybay Bridge. For this portion, a series of spur dikes (right bank) and dredging (left bank) is planned to stabilize the channel and make the channel straighter.

(2) Downstream of the Baybay Bridge

The river channel improvement is planned for the downstream of the Baybay Bridge against the overflow and bank erosion. For the planned alignment of the dike, there are two alternatives regarding the socio-environment consideration, as follows:

Channel alignment along the northern main stream for the right bank and the southern sub-stream for the left bank

In this case, the mangrove area is positioned inside the river area. Hence, following impacts are expected:

- Negligible impacts on the mangrove
- Possibility of resettlement for about 20 families, who are dwelling near the seashore. However, the impacts of this resettlement can be mitigated when near resettlement site is found.

Channel alignment along the northern main stream

In this case, the major portion of the mangrove area is positioned outside the river area. Hence, following impacts are expected:

- Probability of negative impacts on the mangrove because of the change of water flows. In this case, reforestation of the mangrove forest is required.
- No necessity of resettlement for about 20 families

3.4.4 Possible Alternative Cases

Corresponding to the above idea, five alternative cases are conceivable, as follows:

(1) River channel improvement only (alignment along the northern main stream and the southern sub-stream)
(2) River channel improvement only (alignment along the northern main stream)
(3) Dam and reservoir only
(4) Combination of river channel improvement (above (1)) and dam and reservoir
(5) Combination of river channel improvement (above (2)) and dam and reservoir

In the case of (3) dam and reservoir only, flood damage still occurs even the dam regulates all the flood discharge from the upstream. Thus, this case is eliminated.

In this regard, the dam size is preliminary designed as shown below, and its construction cost is roughly estimated at 443 million pesos. Based on the storage capacity for flood control and irrigation, the allocated cost for flood control is estimated at 221.5 million pesos. On the other hand, the cost for the river channel improvement only is roughly estimated at below this allocated cost. Hence, the cases (4) and (5) are eliminated, because the river channel improvement cost is added to this allocated dam cost. In addition to this, its land acquisition for the dam construction is expected to be problematic during its implementation.

Table G.3.7 Preliminary Design of Dam

Item	Dimension, etc.
Dam Type	Rockfill
Peak Discharge Cut at Dam Site (m^3/s)	280 (All cut at the dam site)
Total Storage Capacity (MCM) - Flood Control - Irrigation (400-450 ha) - Dead Water	12.0 4.4 4.4 3.2
Dam Height (m)	41.0
Dam Lengthy (m)	160

Consequently, the possible alternative cases are formulated as shown in Table G.3.8 and Figure G.3.6.

Table G.3.8 Alternative Cases in the Dungcaan River Basin

Alternative Cases	Basic Layout of Main Structural Measures
Case-1	• For the downstream of the Baybay Bridge, river channel improvement with its alignment along the northern main stream and the southern sub-stream • For the upstream of the Baybay Bridge, river channel improvement of about 300 m, and spur dikes, dredging and bank protection works
Case-2	• For the downstream of the Baybay Bridge, river channel improvement with its alignment along the northern main stream • For the upstream of the Baybay Bridge, the same layout to the above

3.4.5 Recommended Structural Measures

(1) Optimum Case

The optimum case for the Dungcaan River Basin is studied from the socio-environmental and economic aspects, as follows:

<u>Socio-environmental Aspect</u>

These plans were discussed and explained in the workshop and interview survey, and the following opinions were observed:

- There were opinions about the conservation of the mangrove forest.
- There observed no strong objection on the resettlement. The resettlement would not be problematic if compensation and resettlement are assured on favorable conditions.

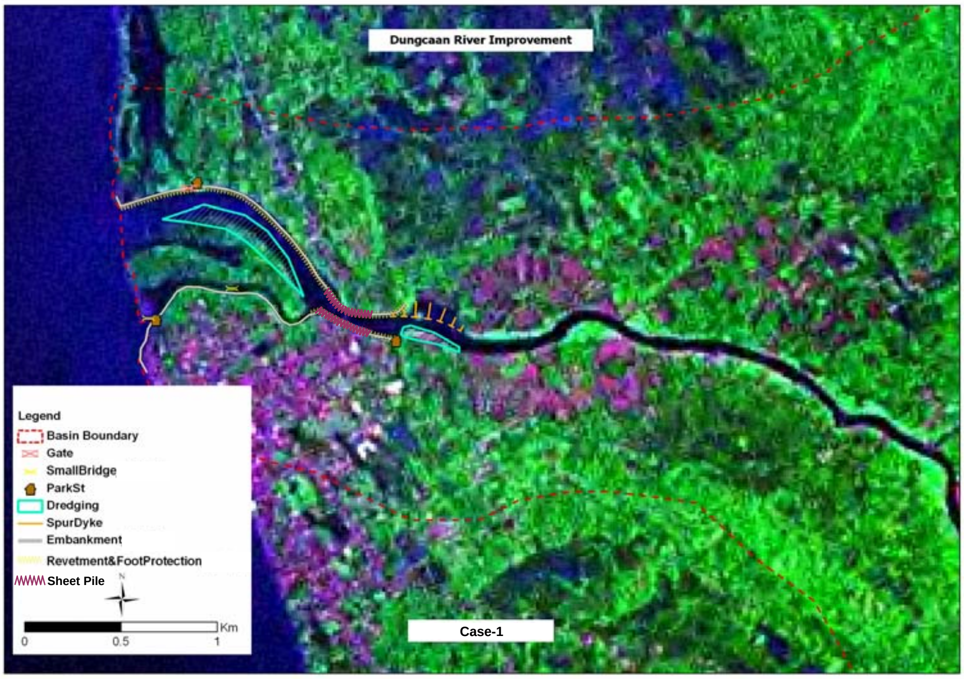
<u>Economic Aspect</u>

The results of the cost comparison are shown in Table G.3.9. Case-1 shows lower cost. However, there is no big difference between both alternatives.

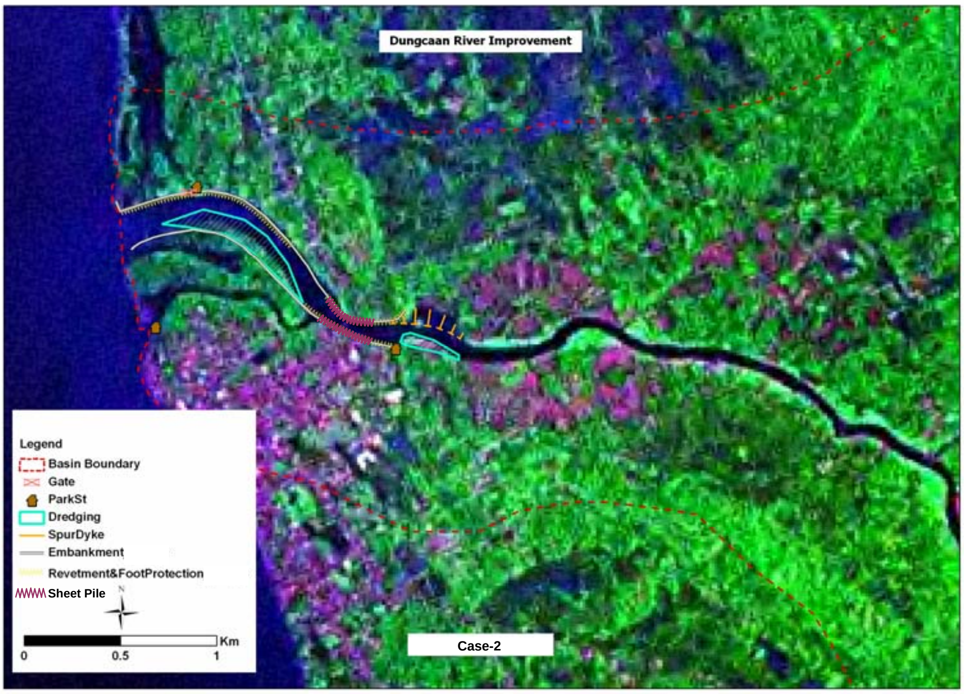
Table G.3.9 Result of Cost Comparison of Alternative Cases in the Dungcaan River Basin

Alternative Cases	Cost (mil. Pesos)
Case-1	211.1
Case-2	264.0

Based on the above, Case-1 is preliminarily selected for the time being as the structural measures, which are the river channel improvement with the alignment along the northern main stream and the southern sub-stream. However, further study is necessary for this selection of the optimum case.



Case-1



Case-2

Figure G.3.6 Comparison of Alternative Cases in the Dungcaan River Basin

With the recommended structural measures, the design discharge of 20-year return period will be distributed as shown in Figure G.3.7.

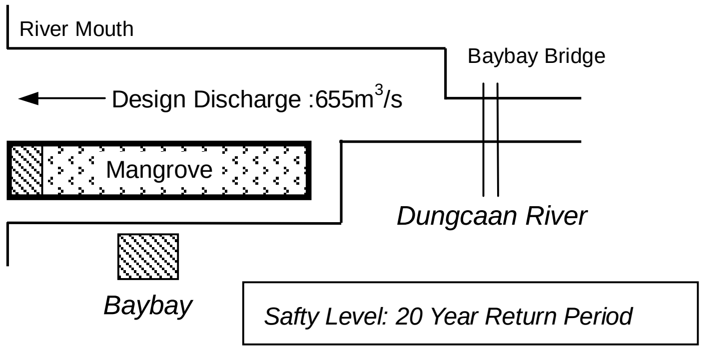


Figure G.3.7 Design Discharge Distribution with Optimum Structural Measures in the Dungcaan River Basin

4. MEYCAUAYAN RIVER BASIN

4.1 Basin Conditions

4.1.1 Natural Conditions

(1) Topography

The Meycauayan River Basin, which has total catchment area of about 201km^2, is characterized as relatively low-land catchment. Table G.4.1 shows share of elevation zones in the Meycauayan River Basin. The average elevation is just 45 m. About 90% of the catchment area is lower than 100 m above MSL. More than 40% is lower than 20 m above MSL, which is flat terrain. The topographic map of the basin is shown in Figure G.4.1.

The most downstream reach of the river basin is very flat and low-lying coastal plains. For Municipality of Obando and parts of Valenzuela City, the ground elevation ranges from Mean Sea Level (MSL) to 1.5 m above MSL. A little high land above EL. 1.5m is locally distributed at south-south-east part in this area. It was formerly a wide estuary, but it filled up partially from the peripheral parts of each sand bar and sand spit, and formed up into current figure, that mainly consisted of commercial district, industrial district, residential area and fishponds. On the lower parts between the sand bars and sand spits, the rivers act as drainage channel.

The elevation gradually increases toward upstream. From around the confluence of the Meycauayan River and the Marilao River to around North Luzon Highway, the elevation ranges around 5m to 10m above MSL.

Table G.4.1 Elevation Zone of the Meycauayan River Basin

Elevation (m)	0-20	20-100	100-200	200-400	400-600	600-800	800-1000	Total
Area (km^2)	89.89	90.60	12.08	8.48	0.00	0.00	0.00	201.05
Percentage (%)	44.71	45.06	6.01	4.22	0.00	0.00	0.00	100.00

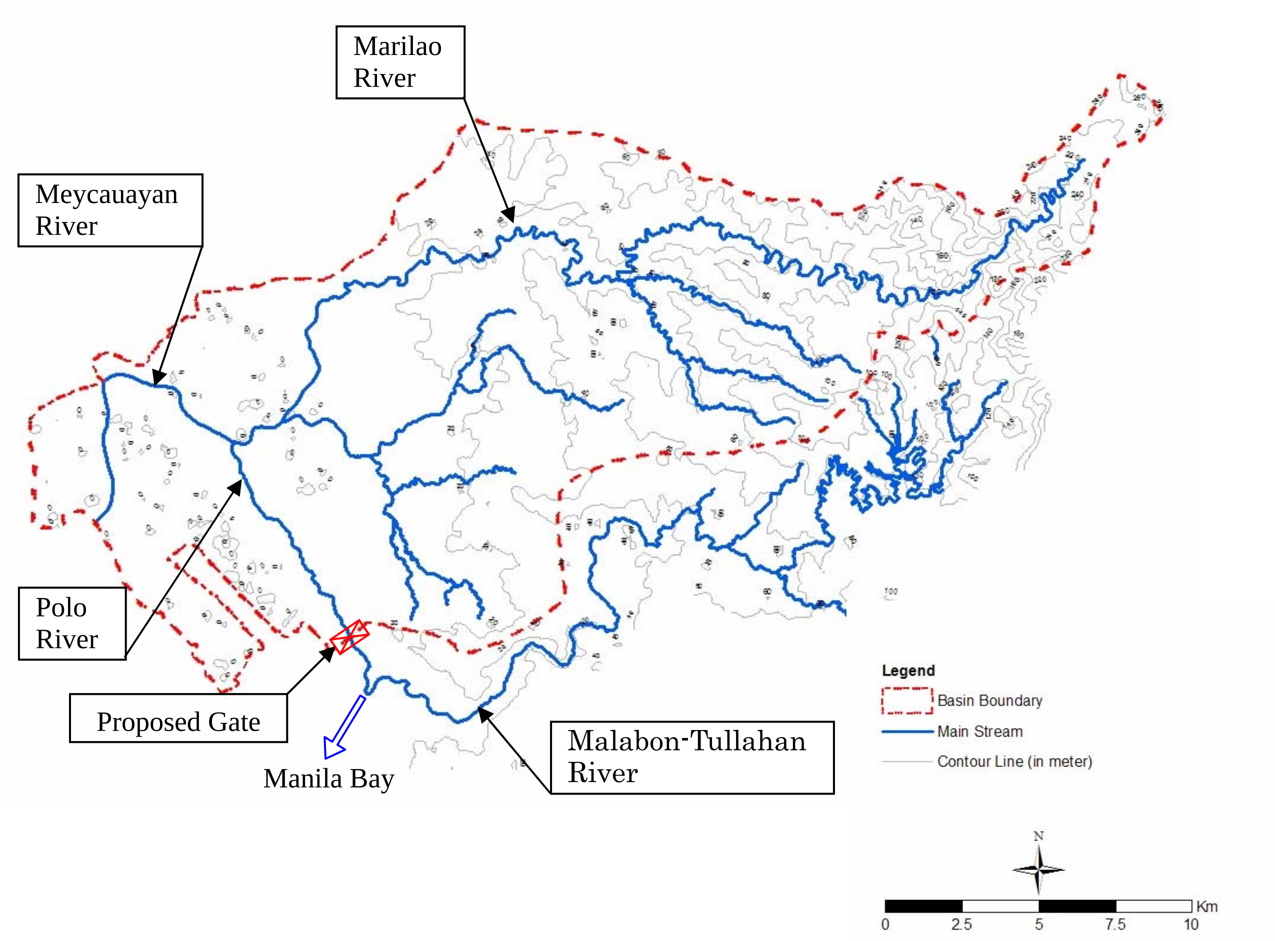


Figure G.4.1 Topographic Map of the Meycauayan River Basin

(2) Existing River System and Structures

The Meycauayan River Basin has total catchment area of about 201km^2, excluding the catchment area of the Bulacan River. The Meycauayan River consists of the main stream and several tributaries. The biggest tributary is Marilao River, which merges to Meycauayan River at around 9km from the river mouth. The Bulacan River also merges to Meycauayan River at around the river mouth. In the present Study, it is decided not to include the Bulacan River Basin, which has much wider watershed area than the Meycauayan River Basin.

Malabon River originates from Quezon City, and is connected to Meycauayan River through Polo area. However, in the on-going flood control project in KAMANAVA area, flood flow from Malabon River is planned to be drained through KAMANAVA area. Therefore, the discharge from the catchment area of Malabon River is not considered in the present Study.

The gradient of the main stream and Marilao River is shown in Table G.4.2.

Table G.4.2 River Gradient of Meycauayan River

Reach	Slope
0 - 9km	1/2,500
9 - 16 km	1/1,000
16 - 32 km	1/450
32 - 45 km	1/250
45 - 49 km	1/30
49 - 52 km	1/150

Up to around 10km, tidal effect is governing the river condition. In this reach, once flood occurs, flood flow diffuses the surrounding low land area, which makes the area widely inundated. In addition to the overflow from the river, inland flood caused by high tide and heavy rainfall can often happen in this area. The VOM (Valenzuela - Obando - Meycauayan) project by DPWH has been conducted at F/S level to reduce the damage by the inland flood.

On the other hand, the middle and upper reach of the river has relatively steep gradient of the riverbed. The river shape is basically trench type, which is referred as an incised channel and has less flood plain area.

The existing structures relating to flood control are, as follows:

- Dike along the Meycauayan River and Marilao River
- Coastal dike in Municipality of Obando
- Pumps and flood gates

However, it is said that height of the dikes are often low compared to flood water level and many pumps and gates have been deteriorated.

There is an irrigation weir at the middle reach of Marilao River. However, it is said that it is not functioning.

(3) Meteorology and Hydrology

The Meycauayan River Basin falls under Type I of the modified Corona’s climate classification. In this climatic region, there are two pronounced seasons, one is dry season from November to April, and another is wet season during the rest in which about 80% of the annual rainfall occurs. In this region, there are regular occurrences of tropical cyclones.

Time of concentration of flood wave at the confluence of the Meycauayan and Marilao River is estimated at about 6 hours. This hydrological characteristic could allow some preparation time for flood. Hence, flood forecasting and warning may reduce damage in the lower reach of the basin. On the other hand, in the middle and upper reach, time of concentration of flood wave is much shorter, which can cause flash flood.

Because many areas of the Meycauayan River Basin have already been highly urbanized and it is expected that the urbanization proceeds more in future, the time of concentration of flood wave may become shorter, which results in the increase of the risk for flash flood more.

(4) Regional Geology

The geological configurations of this area consist of reclaimed landfill, Holocene deposits and Pleistocene deposits in order from the ground surface. The half part of this area is reclaimed land or fishponds and the other half is natural sand bar or sandpit area so that there are thin fill materials. At riverbed, organic clay with very high natural water content is distributed. Holocene deposits consist of loose sand and very weak clay with natural water content higher than the liquid limit. At the sandbar and sand spit area the upper part consist of loose fine sand. At the other area the very weak clay is distributed from the surface of the ground except fill materials.

Total thickness of the very weak clay is confirmed to be 7 to 22m by the investigation, while there is quite a possibility that the thicker part exists because valleys formed at the end of Pleistocene Epoch.

Pleistocene deposits consist of hard tuffaceous clay/silt, the underlying granular deposit and welded tuff. These deposits were sometimes sampled as soft rock core.

The geologic profile in the areas that include the towns of Meycauayan and Marilao consist of alluvium, raised coral reefs, atolls, beach deposits, lacastrine and beach rocks.

4.1.2 Social and Economic Conditions

(1) Population and its Growth

The total population and its density of cities and municipalities located in the lower reach of the Meycauayan River Basin, which is flood prone area, is shown in Table G.4.3. Based on the F/S for the VOM area, it is said that population in the VOM area is expected to be double by 2020.

Table G.4.3 Population in the Meycauayan River Basin

City / Municipality	Population	Land Area (ha)	Population Density (Head/ha)	Source
Meycauayan City	199,040	3,210	62	Municipality Profile 2005
Municipality of Marilao	114,794	2,625	44	Municipality Profile 2004
Municipality of Obando	60,333	1,592	38	Municipality Profile 2005
Valenzuela City	562,000	4,460	126	Year 2000, VOM F/S Report

There are some informal settlers along the Meycauayan and Marilao Rivers with shelter/living structures affixed underneath a bridge similar to those found in the Metropolitan Manila.

(2) Land Use

Figure G.4.2 shows the land use map of the basin (2002/03). Share of each land use is calculated based on the above map and is shown in Table G.4.4. In the Meycauayan River Basin, almost half of the total catchment area is covered by built-up area. The fish ponds shares about 20%, which is located at the most downstream reach, especially for the right bank of Meycauayan River.

In the right bank of the middle reach of Marilao River, there are many newly developing sub-divisions to be used for residential area. On the other hand, in the left bank of the middle reach of Marilao River, there is resettlement project area by National Housing Authority in Caloocan City. Based on the Provincial Environment and Natural Resources Office, DENR Bulacan (PENRO), almost all of the river basin is already alienable and disposable lands.

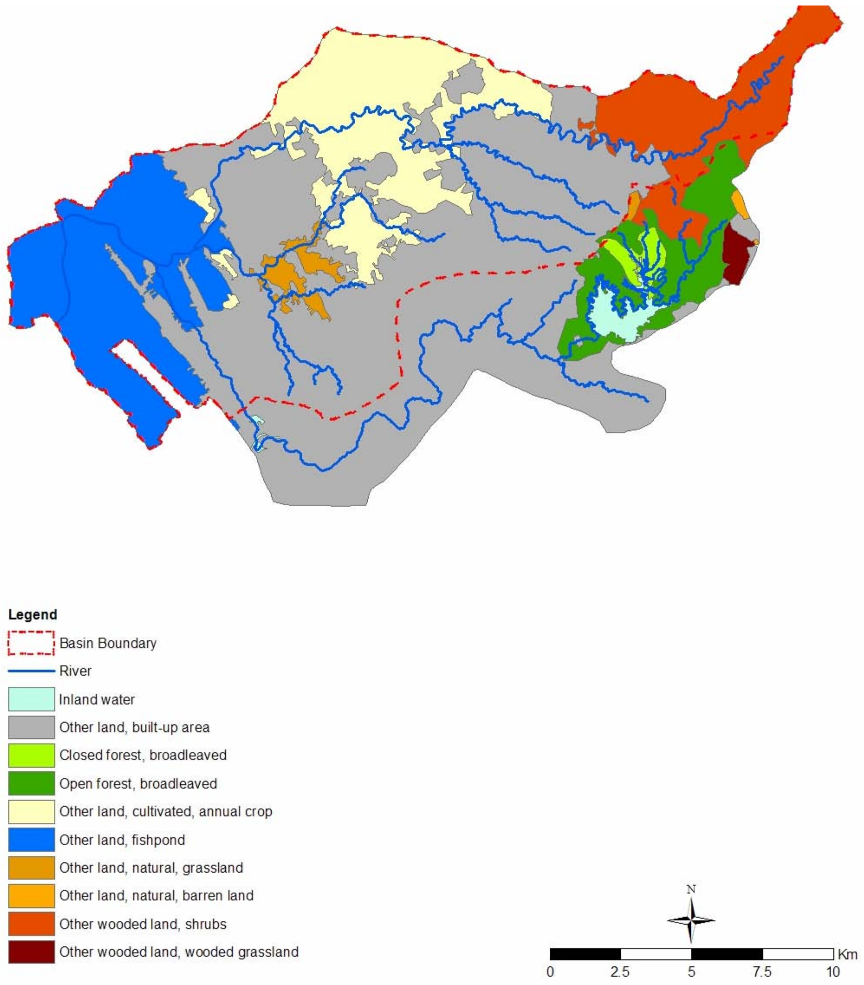


Figure G.4.2 Existing Land Use in the Meycauayan River Basin

Table G.4.4 Share of Land Use in the Meycauayan River Basin

Class	Area (km^2)	Percentage
Closed forest, broadleaved	0.02	0.0
Forest plantation, broadleaved	0.00	0.0
Inland water	0.00	0.0
Mangrove forest	0.00	0.0
Open forest, broadleaved	0.31	0.2
Other land, built-up area	96.39	47.9
Other land, cultivated, annual crop	38.32	19.1
Other land, cultivated, perennial crop	0.00	0.0
Other land, fishpond	41.48	20.6
Other land, natural, barren land	0.00	0.0
Other land, natural, grassland	3.75	1.9
Other wooded land, shrubs	20.77	10.3
Other wooded land, wooded grassland	0.00	0.0
Total	201.05	100.0

(3) Local Economy

In this river basin, there is a preponderance of fishponds, which is a major source of business and personal income, as well as employment, although recently on a dwindling trend. Meanwhile, agriculture is dramatically decreasing in terms of both agricultural produce and income. Further, in the fishpond and agricultural areas, commercial establishments are increasing, which are mostly service-oriented companies. Moreover, the City of Meycauayan is noted for its jewelry industries and leather-crafts, etc.

4.1.3 Floods and Flood Damage

(1) Floods and Flood Damage

The lowest reach of the Meycauayan River Basin is subjected to inland flooding caused by high tide and heavy rainfall. It can occur almost every year. Almost all territory of Municipality of Obando is flood prone area, especially for the inland flooding. A part of Valenzuela City, which is in the VOM area, is also flood prone area. In Meycauayan City and Municipality of Marilao, downstream portion from North Luzon Highway, especially for downstream portion from McArther Highway is generally considered as flood prone area. Damage in the basin is rather concentrated to asset damage. Based on the data by Provincial Disaster Coordinating Council, number of causality is relatively small.

(2) Major Causes of Floods

There are two major causes of flood in the Meycauayan River Basin.
One is high tide and heavy rainfall in the low-lying area located at the most downstream reach of the Meycauayan River Basin. This can be seen in the VOM area, the area along right bank of the

reach downstream from the confluence of Meycauayan River and Marilao River, and the area from Manila bay to the existing coastal dike in Municipality of Obando.

Another one is overflow from Meycauayan River and Marilao River. The area along the reach downstream from North Luzon Highway is potentially risk area against the overflow. Because the watershed area has been already highly urbanized, runoff-volume has been increased, which resulted in the increase of risk against the overflow.

4.1.4 Previous Related Study

For the VOM area, there is a project for "Feasibility Study on Valenzuela-Obando-Meycauayan (VOM) Area Drainage System Improvement Project" in 2001. The stage of the projects is F/S level. After completion of the KAMANAVA project, it is expected that the VOM project will be implemented. The purpose of the project is to reduce damage by inland flood in the VOM area. Safety level has been set as follows:

- Overflow from Meycauayan River: 1/30
- Inland flood in the VOM area: 1/10

The proposed components are shown in the following table:

Table G.4.5 Major Work Items of the VOM F/S

	Components	Work item
1	Meycauayan River Improvement	Masonry wall, Riprap and Embankment
2	Polder Dike Construction	Earth dike
3	New Open Channel Construction	Naked channel excavation & R.C. box culvert
4	Regulation Pond Construction	Excavation and Embankment
5	Raising of Existing Road	Concrete pavement with retaining wall
6	Installation of Gate Structure	Steel roller gate
7	Installation of Pumping Station	Submergible motor pump

4.2 Hydrologic Analysis

The design discharge is set with reference to the previous related study. Distribution of the design discharge for 30-year return period is shown in Figure G.4.3.

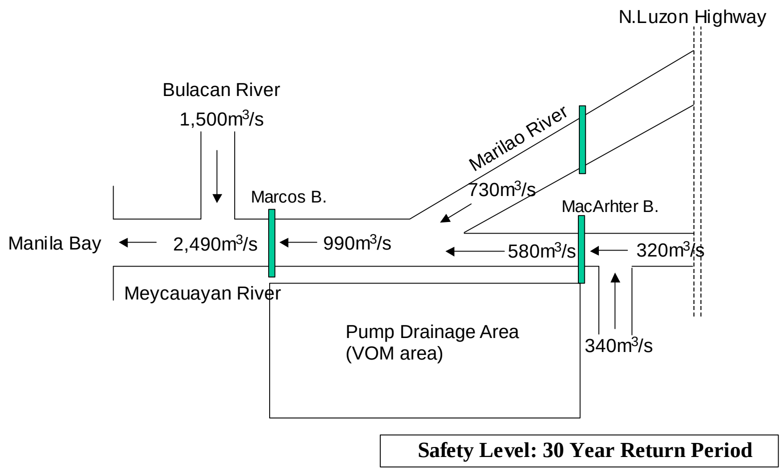


Figure G.4.3 Design Discharge Distribution in the Meycauayan River Basin

4.3 Flood Inundation Analysis

4.3.1 Flow Capacity

The flow capacity of the existing river channel is analyzed with HEC-RAS using the river cross sections newly obtained in the survey. The flow capacities of Meycauayan River are estimated as shown below.

Table G.4.6 Flow Capacity of Existing River Channel in the Meycauayan River Basin

Location of Calculation	Flow Capacity (m^3/sec)
Meycauayan River (Downstream of Confluence)	400
Meycauayan River (Upstream of Confluence)	140
Meycauayan River (Bridge at 31.4 km)	330
Marilao River (Upstream of Confluence)	240

4.3.2 Flood Inundation Area

Flood inundation area is analyzed with HEC-RAS and HEC-GeoRAS using the river cross sections newly obtained. In the analysis, the altitude data of SRTM is adjusted by comparison with the river cross sectional survey data.

Valenzuela, Obando, Meycauayan and Malabon are generally located at very low elevation so that the area is always under the menace of flood inundation. Particularly, the flood inundation area is remarkable in the downstream portion from the North Luzon Highway. The total inundation area is estimated at 5,222 ha with 30-year return period flood, as others are tabulated below. Figure G.4.4 shows the flood inundation area.

Table G.4.7 Area of Flood Inundation of the Meycauayan River Basin

(Unit: ha)

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

4.4 Basic Layout of Main Structural Measures

4.4.1 Applicable Structural Measures

The flood type of the Meycauayan River Basin is F+O/O/F (Group 3). Comparing with the flood type of this basin, the following structural measures are considered as the applicable ones:

Table G.4.8 Basic Applicable Structural Measures for Flood Type in the Meycauayan River Basin

Flood Type	Applicable Measures				
	River Channel Improvement	Dam and Reservoir and/or Sabo dam	Retarding Basin	Diversion Channel	Drainage Facilities
Flash Flood (F)	O	O			
Over Flow (O)	O	O	O	O	O

Note) Flash flood is not a major flood type based on the field survey.

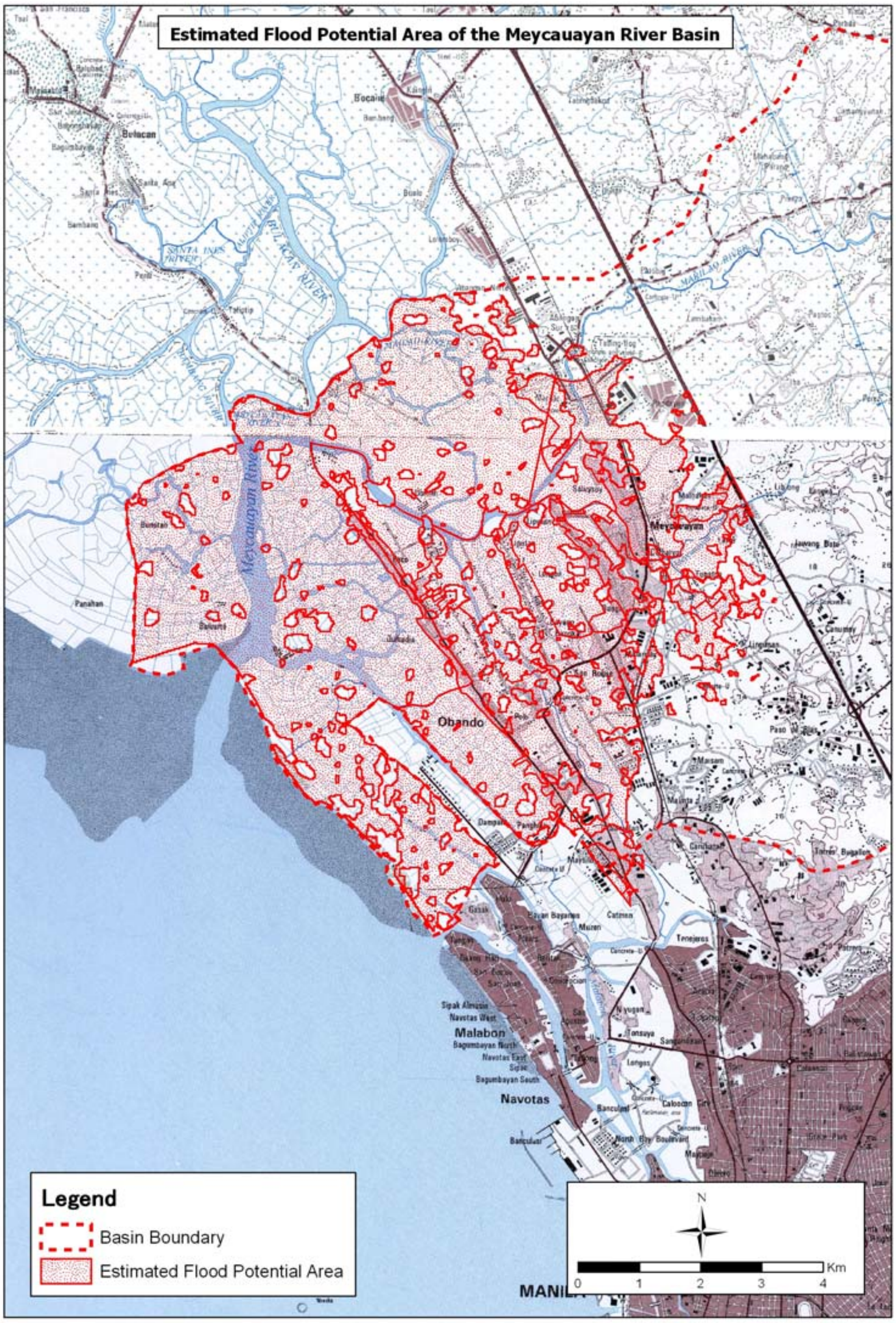


Figure G.4.4 Flood Inundation Area of the Meycauayan River Basin

Judging from the river basin conditions, among these applicable measures, the dam, retarding basin, diversion channel are not applicable to the basin considering the topographic and land use conditions. In addition to this, in the VOM area, drainage facility to reduce inland flooding is necessary. Hence, applicable measures are the river channel improvement and drainage facilities as described below.

Table G.4.9 Applicable Structural Measures for the Meycauayan River Basin

Flood Type	Applicable Measures				
	River Channel Improvement	Dam and Reservoir and/or Sabo Dam	Retarding Basin	Diversion Channel	Drainage Facilities
F+O/O/F O+I (the VOM area)	O				O

4.4.2 Basic Idea of Structural Measures

(1) Target Area of Flood Mitigation

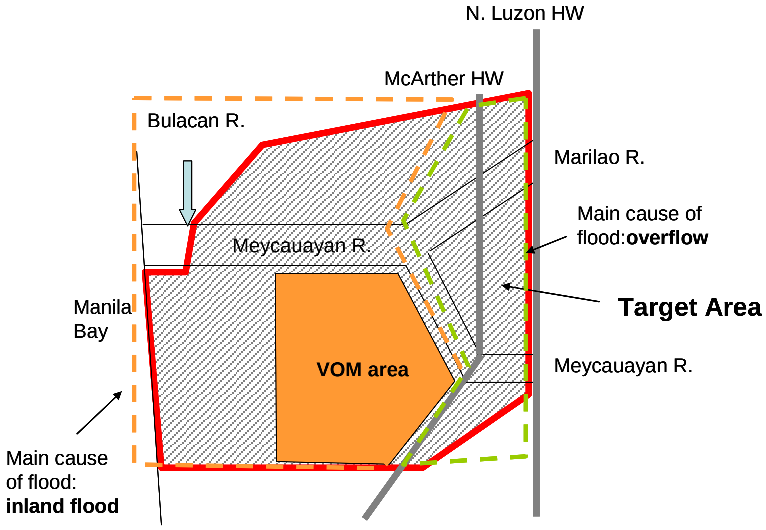
Target area of flood mitigation by structural measures is selected from a potential flood area along the downstream reach of Meycauayan River and Marilao River. Based on the ocular observation during the filed survey and the result of workshop, the potential target reach is set at downstream of North Luzon Highway.

There are following two cases for setting target area in the potential target area as shown in Figure G.4.5.

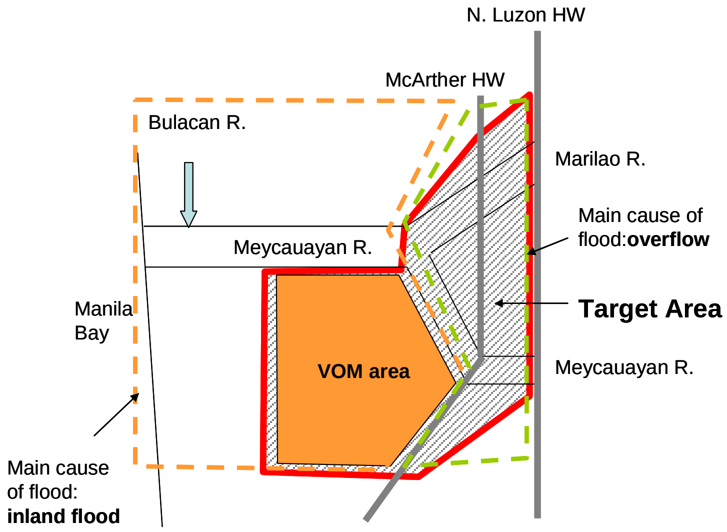
- Case-1: All area downstream from North Luzon Highway
- Case-2: The VOM area and the area upstream from the confluence of Meycauayan River and Marilao River

In the present Study, Case-2 is recommended.

In Case-1, to reduce the damage by flood, both overflow and inland flood should be mitigated. To do so, full scale of river improvement, which consists of excavation and construction dike, construction of coastal dike and installation of drainage facilities, is required for the entire target area. Very rough cost estimation only for river improvement along Meycauayan River (0 to 9km) shows that it may cost at order of 5,000 million pesos. If the cost for the construction of coastal dike and installation of drainage facilities are considered, it would double or triple or more. It is too costly considering the damage by flood in the area without highly urbanized.



Case-1



Case-2

Figure G.4.5 Alternatives for Target Area to be Protected

In the territory of Municipality of Obando, except the VOM area, it is not expected that significant urbanization will proceed, based on the future land use plan by Municipality of Obando. Future land use plan for Municipality of Marilao is currently under preparation. However, in the territory of Municipality of Marilao along the right bank of Meycauayan River at downstream from the confluence of Meycauayan River and Marilao River, there is no clear indication for future significant urbanization. Therefore, Case-1 is not recommendable in the present Study, considering the current situation. Case-1 should be considered in future if significant development plan for the area is proposed, although there might be still several difficulties such as economical feasibility.

(2) Safety Level

Considering the F/S for the VOM area safety level is set, as follows:

- Overflow from Meycauayan River: 1/30
- Inland flood in the VOM area: 1/10

(3) Relationship between the Present Study and the F/S for the VOM Area

The F/S level study has been completed for the drainage improvement of VOM area. In the present Study, it is reviewed briefly and basically same work items are proposed, unless they are not suitable for the additional works for the outside of the VOM area proposed in the present Study:

(4) River Channel Improvement

To reduce risk for flood caused by overflow from Meycauayan River and Marilao River in the target area, it is necessary to keep enough flow capacity of both rivers along the target area. To keep enough flow capacity, excavation and construction of dike for the following reach is proposed:

- Meycauayan River:
  - ➢ From confluence with Marilao River to North Luzon Highway
- Marilao River:
  - ➢ From confluence with Meycauayan River to North Luzon Highway

For conservative estimation, the water level at the confluence is set at the same level as the design high water level set in the previous F/S, which is slightly higher than the past maximum high tide level.

(5) Drainage Improvement in the VOM Area

To reduce the risk for inland flooding in the VOM area, basically same work items proposed in the pervious F/S are proposed. The proposed works comprise, as follows:

- Polder Dike Construction
- New Open Channel Construction
- Regulation Pond Construction
- Raising of Existing Road
- Installation of Gate Structure
- Installation of Pumping Station

4.4.3 Recommended Structural Measures

(1) Recommended Structural Measures

Based on the basic idea above mentioned, the recommended structural measures are the above river channel improvement and drainage improvement for the target area. The major work items proposed by this Study and the previous F/S are shown in Table G.4.10 and Table G.4.11. The location of these structural measures is shown in Figure G.4.6.

Table G.4.10 Major Work Items Recommended in the Study

	Components	Work Item	Description	Quantity
1	Meycauayan River Improvement	Concrete Revetment Excavation	Height: 0.5～3.5m	9,500 m
2	Marilao River Improvement	Concrete Revetment Excavation	Height: 0.5～3.5m	4,500 m
3	Polder Dike Construction	Earth dike	Embankment: 3m high	5,200 m
4	New Open Channel Construction	Naked channel excavation and R.C. box culvert	Channel: 5-10m wide, and 1.5-2.0m deep	2,540 m
5	Regulation Pond Construction	Excavation and Embankment	Excavation: 0.5m Embankment: 1.0m	27ha at 2 sites
6	Raising of Existing Road	Concrete pavement with retaining wall	Width: 12 m Height: 1 m	3,900 m
7	Installation of Gate Structure	Steel roller gate	Leaf area: 416 m^2 in total	11 sites
8	Installation of Pumping Station	Submergible motor pump	Pump capacity: 22.1 m^3/s in total	4 stations
9	Re-Construction of Bridge	Concrete bridge	Length: 40m Width: 12m	5 sites

Table G.4.11 Major Work Items Proposed in the VOM F/S

	Components	Work Item	Description	Quantity
1	Meycauayan River Improvement	Masonry wall, Riprap & Embankment	Raising of existing dike: 1m high	7,240 m
2	Polder Dike Construction	Earth dike	Embankment: 3m high	5,200 m
3	New Open Channel Construction	Naked channel excavation & R.C. box culvert	Channel: 5-10m wide, 1.5-2.0m deep	2,540 m
4	Regulation Pond Construction	Excavation and Embankment	Excavation: 0.5m Embankment: 1.0m	27ha at 2 sites
5	Raising of Existing Road	Concrete pavement with retaining wall	Width: 12 m Height: 1 m	3,900 m
6	Installation of Gate Structure	Steel roller gate	Leaf area: 416 m^2 (333 ton) in total	8 sites
7	Installation of Pumping Station	Submergible motor pump	Pump capacity: 22.1 m^3/s in total	4 stations

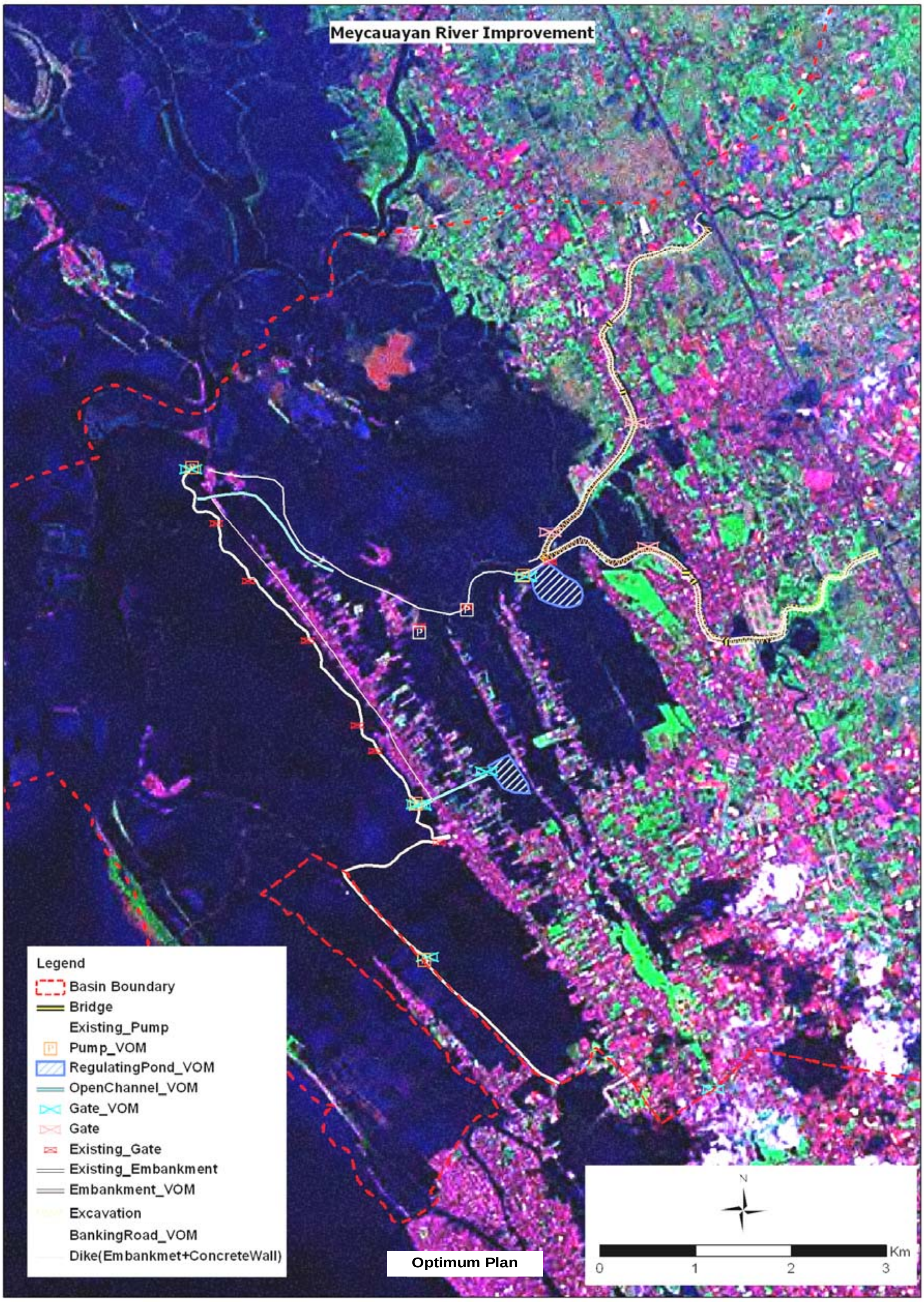


Figure G.4.6 Recommended Structural Measures in the Meycauayan River Basin

With the recommended structural measures, the design discharge of 30-year return period will be distributed as shown below.

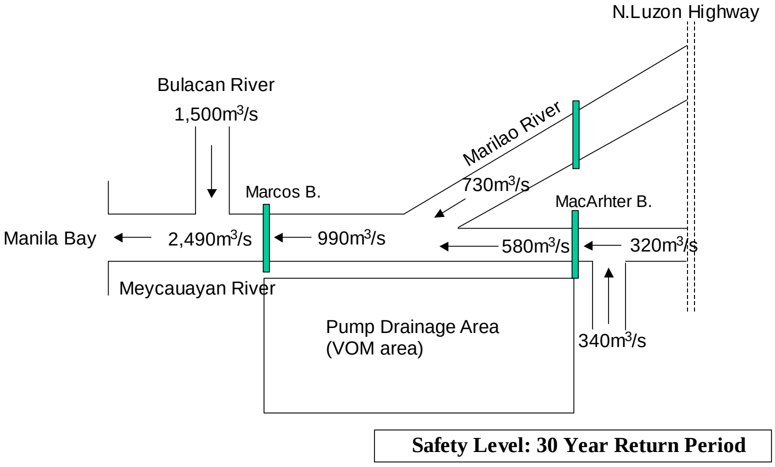


Figure G.4.7 Design Discharge Distribution with Proposed Structural Measures in the Meycauayan River Basin