Parañaque-Las Piñas

This is a lowland along the Manila Bay in which the South Parañaque, Las Piñas and Zopote rivers run from the southwest to the northeast and pour into Manila Bay and two rivers, namely, Parañaque and San Dionisio rivers flow in parallel with the coastline and join the rivers mentioned above. Due to the inland water as well as the flooding of the river, this area received serious flooding in 1986.

The Parañaque River is a lower reach of the Estero de Tripa de Gallina and receives floodwater from the Tripa de Gallina drainage district of South Manila and Suburbs equipped with a pump station. This water is designed to be discharged into the Manila Bay through three outfalls as shown in Fig. 5-2-13. The features of the outfalls are tabulated in Table 5-2-7. The laterals are installed on a density of 350 m/km$^2$ and 300 m/km$^2$ in Parañaque and Las Piñas, respectively.

Valenzuela

This is a low area located along the Meycauayan River covering 1,842 ha (refer to Fig. 5-2-6). At present, an area of more than 60% is fish ponds or open space, however, 35% of those areas are planned to be developed. The ring dikes has been constructed along the Meycauyan River and the creek running to the west of this area as shown in Fig. 5-2-74, but the height is insufficient. Reflecting on the present land use, no drainage system is found except for small rivers.

## 2.3 Evaluation of Existing Drainage System

There exist two drainage systems in Metro Manila which were established based on their own master plan. Those are systems located in Manila and Suburbs and Dagat-Dagatan in Malabon-Navotas. Those systems are evaluated as the basic study necessary for the formulation of the drainage plan.

## Calculation Conditions of Flow Capacity of Existing Drainage Channels

(1) Cross Section

The flow capacity of esteros was estimated from the cross-sectional survey drawings prepared by the Philippine Government in 1988, while the others were based on the design drawings.

At present, most of the drainage mains/outfalls in Manila and Suburbs are clogged with sand and garbage. Therefore, a substantial decrease in the original design flow capacity is observed. Since the drainage mains/outfalls should be planned on the basis of the maximum flow capacity without deposition, the design drawings are used.

(2) Equation for Flow Capacity Estimate

The flow capacity is computed by the non-uniform flow for esteros of irregular channels and by uniform flow for regular channels (concrete flume). For the drainage mains/outfalls, the following two methods were applied, because either of the two types of flow, namely open channel flow or pressure flow, occur in response to the water level at their outlets.

- Uniform flow calculation when the water level at the outlet is lower than or equal to 90% of the depth of drainage main/outfall.
- Pressure flow calculation when the water level at the outlet is higher than 90% of the depth of drainage main/outfall.

(3) Roughness Coefficient

Most of the existing esteros have sheet piles on both sides with earth bottom. For these channels, Manning's roughness coefficient of 0.030 is applied, while 0.025 is used for the concrete flume.

With regard to the box culverts such as drainage mains/outfalls, the coefficient between 0.013 and 0.016 is generally applied for the one with bend and debris. Within this range, 0.015 is selected for the drainage mains/outfalls in consideration of debris.

(4) Hydraulic Boundary Condition

The drainage channels are classified into two types from the viewpoint of drainage method; namely, the channel without pumping station which drains flood water by gravity flow and the channel with pumping station at its downstream end.

For the channel without pumping station, the higher water level between the Design High Tide (EL 11.80 m) and the Design Water Level at the outlet is used for the channels with outlets at rivers, while the Design High Tide is applied for the channels with outlets at Manila Bay. As for the channels with pumping station, two boundary conditions, namely Pump Starting Water Level (PSWL) and Mean Higher High Water Level (MHHW; EL 11.30 m) are basically used.

Capacity of Existing Drainage Facilities

The capacity of existing drainage facilities, namely pumping stations and principal drainage channels, are discussed hereinafter, comparing with the required pump capacity and peak discharge for 10-year and 5-year return periods.

The required pump capacity was obtained first for the subdrainage area which is a unit of pump drainage calculation (refer to Section 3.3). Then, if there exist more than one pumping station in the subdrainage area, the capacity of each pumping station was set by distributing the obtained capacity in the subdrainage area to each pumping station in accordance with the ratio of peak discharge in the channel connected to the pumping station. The peak discharge of drainage channels is calculated by the rational formula.

(1) Manila and Suburbs

The results of non-uniform flow calculations are shown in Fig. 5-2-14, and the estimated flow capacity of principal esteros and drainage mains/outfalls are indicated in Fig. 5-2-15. The capacity of existing facilities is summarized in Table 5-2-8. For convenience, the tentative names for drainage districts given before are also used. The following are explanations on the capacity of existing drainage facilities.

(a) Sunog Apog

The principal drainage channels are Estero de Vitas, Sunog Apog, Maypajo and Blumentritt Interceptor. The left bank of Estero de Vitas is lower than the Design High Tide around the junction with Estero de Sunog Apog. The survey was not conducted for Sunog Apog and Maypajo but their capacity is estimated at 56 $m^3/s$ and 35 $m^3/s$, respectively, according to the data described in the Appendices of Preliminary Alternative Master Plan Strategy Report for the Metro Manila Integrated Urban Drainage and Flood Control Master Plan (hereinafter referred to as the E/S Report) and so on. These two esteros have the capacity of less than a 5-year return period.

The outlet of Blumentritt Interceptor is low and thus the pressure flow condition is estimated to occur when the sea level is at EL 11.80 m. Blumentritt Interceptor can convey 20.0 $m^3/s$ under the pressure condition, which is lower than a 5-year return period flood discharge.

(b) Vitas

The principal drainage channels consist of Estero de Vitas and Estero de la Reina. The flow capacity of Estero de Vitas is 50 $m^3/s$ and that of Estero de la Reina is 20 $m^3/s$. The flow capacity is smaller than a 5-year return period flood in all reaches.

(c) Balut

In this area, the laterals are the existing drainage facilities.

(d) Northeast Pasig

The laterals are the existing drainage facilities.

(e) Valencia P.S.

The principal drainage channels are Estero de Valencia and Visayas Main. The flow capacity of Estero de Valencia was estimated at 30 $m^3/s$ based on the E/S Report, etc., and this is smaller than a 5-year return period flood. Visayas Main can convey a runoff discharge of 18 $m^3/s$, corresponding to a 10-year return period under pressure flow condition. The capacity of the Valencia Pumping Station is less than a 5-year return period flood.

(f) Aviles-Sampaloc P.S.

Estero de Sampaloc and San Miguel are principal open drainage channels. Lepanto-Gov. Forbes Main connects with Estero de Sampaloc and two drainage mains; namely, Lepanto-Josephina Main and Economia Main. The Aviles-Sampaloc Pumping Station has a capacity of almost a 5-year return period.

Estero de San Miguel has a small cross section; thus, the flow capacity is 5 $m^3/s$ and less than 5-year return period flood. For Estero de Sampaloc, the cross sectional data in 1988 is not available but the flow capacity is estimated at 40 $m^3/s$ based on the E/S Report, etc., and this is a little bit smaller than a 5-year return period flood.

Judging from the elevation of outlets of drainage mains, Lepanto-Gov. Forbes and Lepanto-Josephine Mains can drain water in the open channel condition, while Economia Main is in the pressure condition. Out of the three drainage mains, only Lepanto-Gov. Forbes Main can convey a 10-year return period flood. The other drainage mains have the capacity of less than a 5-year return period.

(g) Quiapo P.S.

In this drainage district, the principal channels are Estero de Quiapo and San Miguel, while the drainage main is Severino Reyes. The flow capacity of Estero de Quiapo and San Miguel are 40 $m^3/s$ and 20 $m^3/s$, respectively. The design flow capacity of Severino Reyes is 7 $m^3/s$ under pressure condition. Among these channels, Esteros Quiapo and San Miguel have the capacity almost equal to a 10-year return period flood, while the drainage main has less than a 5-year return period. The capacity of Quiapo Pumping Station is between 5-year and 10-year return period flood.

(h) Binondo P.S.

The principal drainage channels are Estero de Binondo and Estero de la Reina. During pump operation, water of Reina flows in reverse. The flow capacity of Estero de Binondo is a little bit smaller than a 5-year return period. However, Estero de la Reina has the small flow capacity of less than 5-year return period, especially in reverse condition which is less than the pump capacity but in normal flow condition, the flow capacity is 30 $m^3/s$. The pump capacity of Binondo Pumping Station is also less than a 5-year return period.

(i) Northwest Pasig

In this area, the laterals are the existing drainage facilities.

(j) North Manila Bay

The principal drainage channels are two drainage mains; namely, Pacheco and Lakandula. The outlets of both mains are submerged when the sea level rises at 11.8 m. Under the pressure condition, Lakandula Main can convey a 10-year return period flood, while Pacheco Main has a capacity of less than a 5-year return period.

(k) Makati Slope

Zobel Orbit Outfall is the principal drainage channel which drains flood water into the Pasig River by gravity flow. For this channel, the design high water level of the Pasig River at its outlet (EL 14.0 m) is used as the hydraulic boundary condition. Under this water level, pressure flow condition occurs and flow capacity is about equal to a 10-year return period discharge.

(l) Makati P.S.

The principal drainage channels are Makati Headrace No. 1 and No. 2, which have enough capacity to convey a 10-year return period discharge. The pump capacity is also of the same degree of safety.

(m) Sta. Clara P.S.

Estero de Sta. Clara which is the only principal channel in this drainage district has a capacity to convey a discharge equivalent to the pump capacity of 5.3 $m^3/s$. The capacity of the Sta. Clara Pumping Station is less than a 5-year return period flood.

(n) San Andres

The principal drainage channels are Estero de Pandacan, Tripa de Gallina, Tributary of Tripa de Gallina and Vito Cruz Outfall. The flow capacity is too small in Estero de Pandacan (3 $m^3/s$) and Tripa de Gallina (5 $m^3/s$) compared with a 5-year return period flood. As for the tributary of Tripa de Gallina, no cross-sectional data is available. Vito Cruz Outfall can convey 4 $m^3/s$ under pressure flow condition when water level is EL 11.80 m.

(o) Pandacan P.S.

Estero de Pandacan is the principal drainage channel with a flow capacity of 15 $m^3/s$. This capacity is bigger than the pump capacity but smaller than the peak discharge of a 5-year return period. The pump capacity is less than a 5-year return period.

(p) Paco P.S.

The principal channels are Estero de Paco and Concordia. The flow capacity of the down reaches of Paco is enough to drain a 10-year return period flood, while the middle and upper reaches have the capacity lesser than a 5-year return period flood. The pump capacity of the Paco Pumping Station is less than a 5-year return period.

(q) Balete

The existing drainage facilities are laterals.

(r) Southwest Pasig

The laterals are the existing drainage facilities.

(s) South Manila Bay

Two drainage mains have been installed; namely, Padre Faura and Remedios. The outlets of both mains are high and so open channel flow occurs for the Design High Tide. Both drainage mains can drain a 10-year return period flood.

(t) Libertad P.S.

The principal drainage channels are Estero Tripa de Gallina, Zobel-Roxas Main and three (3) outfalls, namely Buendia-Roxas, Libertad and EDSA. The flow capacity of Estero Tripa de Gallina between Zobel-Roxas Drainage Main and Buendia-Roxas Outfall is even compared with the discharge corresponding to the pump capacity. On the other hand, one drainage main and three outfalls have the flow capacity equal to a 10-year return period. The flow condition of Zobel-Roxas is pressure flow, but outfalls are considered to be in open channel flow condition since the water level at pumping stations is kept to be low due to the large retarding pond and low pump starting water level. The pump capacity of the Libertad Pumping Station exceeds a 5-year return period flood.

(u) Tripa de Gallina P.S.

Estero Tripa de Gallina and the Delain Creek are the principal drainage channels. Tripa de Gallina between the EDSA Outfall and the Delain Creek has the capacity of more than a 10-year return period flood, while the other stretches have less than a 5-year return period flood. As for the Delain Creek, no data is available. The Tripa de Gallina Pumping Station has the capacity of more than a 5-year return period flood.

(2) Dagat-Dagatan

In Dagat-Dagatan, drainage can be done by gravity flow due to the rather high elevation of land. The following are the comparison of drainage channels with peak discharges of 10-year and 5-year return period.

(a) Spine

The flow capacity of the main drainage channel of Spine is 25.8 $m^3/s$, which is a little bit smaller than a 10-year return period flood (26.3 $m^3/s$) but bigger than a 5-year return period flood (23.6 $m^3/s$).

(b) Saluysoy

The Saluysoy channel has the flow capacity of 17.4 $m^3/s$, which is also a little bit smaller than a 10-year return period flood (17.7 $m^3/s$) but bigger than a 5-year return period flood (15.9 $m^3/s$).

(c) Maypajo

There are two main channels called Northern Drain and Southern Drain which are connected to Estero North Sunog Apog. The capacity of these channels are 10.9 $m^3/s$ and 3.0 $m^3/s$, respectively, which are less than a 5-year return period. However, in both the drainage areas, floodwaters of some 50% of the areas are designed to be drained into Estero North Sunog Apog through laterals, therefore, the two main channels can convey a 5-year return period flood from the remaining areas.

(d) Kapitbahayan

In this area, laterals are the existing drainage facilities.

Evaluation of Drainage Facilities

(1) Manila and Suburbs

Two main drainage facilities in Manila and Suburbs, namely main drainage channels and pump stations are evaluated hereunder.

According to the flow capacity of drainage channels mentioned before, drainage districts can be classified into four categories by the comparison with the capacity required for 10-year and 5-year return period as shown in Table 5-2-9. The main drainage channels in 6 of the 16 drainage districts have the capacity that is almost equivalent to a 10-year return period flood at their lower reaches, while those in the other 10 drainage districts have the capacity lower than a 5-year return period flood.

Main drainage channels in 3 of the 10 drainage districts, namely Vitas, San Andres and Sunog Apog will be improved into a safety degree of 10-year return period, together with the construction of the 3 pumping stations mentioned below under the Metro Manila Flood Control Project. Main drainage channels in 5 of the drainage districts will be dredged and declogged under the Project for Retrieval of Flood Prone Areas in Metro Manila. It is expected that the dredging and declogging work will contibute to the restoration of their original flow capacity which may be a 10-year return period judging from the design safety degree of pump stations and drainage main outfalls.

Drainage districts with pumping stations are classified into three categories which are the same as those for the drainage channels. Table 5-2-10 gives the results, together with the 4 drainage districts requiring construction of new pumping stations. Of the 10 drainage districts with pumping stations, 5 drainage districts have pumps with the capacity exceeding a 5-year return period and 5 have the capacity lower than a 5-year return period.

There are 5 drainage districts presently under the gravity drainage method that need the construction of pumping stations. In 3 of these 5 drainage districts, namely Vitas, Balut and San Andress, pumping stations will be constructed with the safety degree of a 10-year return period, together with the improvement of related drainage channels, under the Metro Manila Flood Control Project. The following table shows the total pumping capacity in Manila and Suburbs, together with the pumping capacity required for 10-year and 5-year return period floods.

(Unit: $m^3/s$)

| Item | North Manila & Suburbs | South Manila & Suburbs | Manila & Suburbs (Total) |
|---|---|---|---|
| Present Pump Capacity | 45.5 | 128.3 | 173.8 |
| Capacity of Planned Pumping Stations | 33.8 (Vitas 31.8) (Balut 2.0) | 17.4 (San Andres) | 51.2 |
| Total | 79.3 | 145.7 | 225.0 |
| Pump Capacity for 10-year Return Period | 103.9 | 169.1 | 273.0 |
| Pump Capacity for 5-year Return Period | 82.7 | 135.6 | 218.3 |

After completion of the Metro Manila Flood Control Project, the total pumping capacity in Manila and Suburbs will reach 225 $m^3/s$, which will exceed the pumping capacity required for a 5-year return period flood. In addition to the increment in pumping capacity, the flow capacity of the drainage channels in Manila and Suburbs will be improved under the two projects mentioned before, so that Manila and Suburbs will have the highest level of safety against inland water flooding among the other 8 drainage areas.

(2) Dagat-Dagatan

In this area, all main drainage channels (drains) have the capacity of more than a 5-year return period. To raise the safety degree of these area to a 10-year return period, the construction of small channels (laterals) are enough even in the two drainage districts of Spine and Saluysoy where the runoff discharge is large, because the capacity of main drainage channels in these two drainage districts is almost equal to a 10-year return period.

## 3. FRAMEWORK PLAN

### 3.1 Premises and Conditions for the Study

In accordance with the study results on the existing condition of the drainage areas and the evaluation of the existing drainage system as mentioned before, the Framework Plan is studied on the basis of the premises and conditions described below.

Target Completion Year

The target completion year for the Framework Plan is not specified, but it concerns the far future, because this plan presents the outline of the future comprehensive flood plain management for Metro Manila and some of its neighboring areas after full urbanization has been attained.

Study Area

The Framework Plan is prepared for all the nine (9) drainage areas identified in Section 2 (refer to Fig. 5-2-1.)

Land Use Condition

The land use conditions at the year 2020 is employed. In the present study, the land use conditions at the year 2020 is the farthest that can be set.

Runoff Discharge

The design discharge for this study was calculated on the basis of the land use conditions at the year 2020.

Safety Degree and Design Discharge

In the previous Master Plan Study on the Manila and Suburbs area prepared in 1952 by the Bureau of Public Works (now DPWH), the safety degree of the drainage system was set as the 10-year return period. Taking into consideration this safety degree and the importance of the metropolitan area with a high development potential, the same 10-year return period is adopted for the design return period of the Framework Plan for the drainage system.

Definition of Existing Facilities

Existing facilities are defined as the structures and projects in the following stages.

- After completion
- Under construction
- With financial source for implementation

Design Tide and Water Level

The following tide level and water level were used as the design level for the Framework Plan of the drainage system.

(1) Manila Bay Tide

The recorded highest tide level, 11.80 m was adopted as the design tide level.

(2) Lake Stage of Laguna Lake

The design lake state was set at 12.50 m, which will be obtained when the observed maximum lake stage of EL 14.03 m is lowered by the Parañaque Spillway, which is a component of the Framework Plan, as well as by the Mangahan Floodway and the Napindan River. The design lake stage corresponds to the 40-year return period.

(3) Water Stage of Rivers

Adopted are the higher stage between the above Manila Bay tide level and the river water stage computed from non-uniform calculation with mean spring high tide at EL 11.30 m of Manila Bay.

## 3.2 Planning Criteria for Major Structures

As far as it is allowed by the topographic and hydraulic conditions, the flood control and drainage system plan shall be prepared to attain the requisites of minimum construction cost, easy operation and maintenance, and limited house evacuation and land acquisition. Based on the above concept, the planning criteria were set as discussed hereinafter.

Open Drainage Channel

The existing open drainage channels such as the esteros and creeks shall be improved to drain the inland water. As the main drainage channel, an open channel is preferred in consideration of its easier operation and maintenance.

(1) Alignment

To drain inland water, the existing channels shall be utilized so as to avoid house evacuation and land acquisition as much as possible. In case that new channels are required, the alignment is to be selected also to avoid house evacuation and land acquisition.

(2) Longitudinal Profile

The design high water level shall be equal or lower than the ground height along the channel to ensure the drainage of the surrounding areas. The design channel slope will follow the existing slope or the slope of the ground along the course.

(3) Cross Section

For the improvement of the existing channel, a rectangular type with sheet piles shall be adopted in the ubanized area, while a trapezoidal type with a side slope of 1:1 with concrete revetment or with a side slope of 1:2 without revetment shall be constructed with concrete revetment in the non-urbanized areas. For the excavation of a new channel, which is planned only in the non-urbanized areas, the trapezoidal type mentioned above shall be applied. Typical cross sections are shown in Fig. 5-3-1.

Closed Drainage Channel

Closed drainage channels were constructed in the urbanized area, usually under the main roads, where no space is available for the construction of open drainage channels.

(1) Alignment

The alignment can be determined by selecting the shortest route along the main roads to the discharge point.

(2) Longitudinal Profile

The gradient is planned to generate the velocity of more than 1.0 m/s but less than 3.0 m/s. In areas with a steeper slope, the closed drainage channel is set to have a milder gradient than the ground slope and thus equipped with fall works so as not to exceed the velocity of 3.0 $m^3/s$.

(3) Cross Section

The box culvert type is adopted for flexibility in the use of the installation space (refer to Fig. 5-3-1). The depth of the closed drainage channel is set at 80% of the width, following the existing closed drainage channels in Metro Manila. For the freeboard, 90% of the depth is the design water depth for closed drainage channels.

Lakeshore Dike

A lakeshore dike around the northern part of the Laguna Lake is considered to be constructed in the low flat land to avoid inundation by high lake water stage. An earth dike with a revetted slope of 1:2 at the lakeside and a slope of 1:2 without revetment at the landside is adopted, providing a freeboard of 1.5 m. The crest of the lakeshore dike shall be at EL 14.0 m and 9.1 m wide.

Ring Dike/Coastal Dike

To protect a low-lying area in Malabon-Navotas against high water stage caused by high tide or flood, a ring dike/coastal dike will be constructed around a residential area. A coastal dike which is an earth dike with revetment is designed along the shoreline with consideration on the recorded high tide. The ring dike has the same dimensions as the river dike.

Pump Station

Pump stations will be constructed in areas where the drainage outlets are submerged due to high tide in Manila Bay, high water stage in Laguna Lake, or backwater effect. The installed pump capacity is to cope with a 10-year return period flood with an allowable inundation depth of less than 20 cm and an inundation period of less than 12 hours.

Gate

Gates are planned at the boundary of the drainage area to prevent the inflow of flood from the river and/or other drainage areas and also to drain the storm water by gravity flow. The drainage capacity of the gate shall be designed to meet the flow capacity of the drainage channel connecting to the gate.

Lateral Facilities

As lateral facilities, there are pipes and lateral channels connecting to the main drainage channels. In this planning, only the density of lateral facilities is considered because of the limited topographic information. For the purpose of cost estimation, the design density of lateral facilities is set at 10,000 $m/km^2$, considering the density of existing laterals/pipes at 6,000 $m/km^2$ in the City of Manila as of 1988.

Land Reclamation

Land reclamation shall be carried out in the area located along the Manila Bay, the Laguna Lake and the rivers to which inland water is drained. Land elevation is set to be the lowest elevation of the surrounding urbanized area.

## 3.3 Subdrainage Area

The nine drainage areas identified in Chapter 2 were further divided into subdrainage areas, considering topography, microland forms, present and future land use as well as existing drainage system.

The subdrainage area is a unit to consider the future drainage system and also a unit of inland water calculation aiming to determine pump capacity, if necessary, as well as to estimate flood damage. The number of subdrainage areas for the respective drainage areas is tabulated below. The subdrainage delineation is presented in Fig. 5-3-2.

| Drainage Area | Number of Subdrainage Areas |
|---|---|
| Manila and Suburbs | |
| - North Manila | 5 |
| - South Manila | 5 |
| Malabon-Navotas | 14 |
| East of Mangahan | 4 |
| West of Mangahan | 5 |
| San Juan | 10 |
| Mandaluyong-Pasig | 3 |
| Marikina | 8 |
| Parañaque-Las Piñas | 4 |
| Valenzuela | 1 |

### 3.4 Study on Alternatives

To set up the Framework Plan for the drainage system, several alternative plans for each drainage area were studied.

Manila and Suburbs

Their drainage area has been provided with drainage facilities such as the pump stations and the drainage mains/outfalls. The necessary works are improvement of the existing system, therefore no alternative case was studied.

Malabon-Navotas

Most of this area has a very low-lying and flat topography. Therefore, inundation is more attributed to high tide than river flood. The applicable measures in this drainage area are, basically, the construction of ring dikes/coastal dikes to protect areas from high tide, pumping stations to drain inland water, and drainage channels to collect inland water.

In the Framework Plan, the location of the ring dike, pump stations and drainage channels followed the location proposed in the Feasibility Study. Therefore, no alternative case was studied.

East of Mangahan

In East of Mangahan, the lakeshore dike, pump stations and drainage channels were proposed in the Feasibility Study to protect this area from inundation due to the high lake stage and inland water. Also proposed are the regulation ponds which are to be located in the suitable open space in EM-3 and EM-4. The volume of the regulation pond and the pump capacity were determined as the combination with the least construction cost.

In the Framework Plan, the same drainage method is adopted but the new combination of the pump and the retarding basin was obtained to cope with a 10-year return period flood instead of fixing the volume of the regulation pond and increasing the pump capacity obtained in the Feasibility Stud y. This is because the Framework Plan is to be implemented in the far future and thus the optimum combination of facilities needs to be established.

The following is the proposed combination which has the lowest construction cost.

| Subdrainage Area | Pump Capacity | | Regulation Capacity of Pond ($m^3$) |
|---|---|---|---|
| | Specific Discharge ($m^3/s/km^2$) | Total Discharge ($m^3/s$) | |
| EM-3 | 1.9 | 5.1 | 21,300 |
| EM-4 | 1.5 | 3.0 | 39,000 |

West of Mangahan

In West of Mangahan, the same drainage method as those in East of Mangahan was adopted in the Feasibility Study. Therefore, the new combination of the pump capacity and the volume of the regulation pond was obtained for the same reason mentioned in the East of Mangahan. The optimum combination of the pump capacity and the regulation capacity of the ponds in subdrainage areas where regulation ponds can be placed are as follows.

| Subdrainage Area | Pump Capacity | | Regulation Capacity of Pond ($m^3$) |
|---|---|---|---|
| | Specific Discharge ($m^3/s/km^2$) | Total Discharge ($m^3/s$) | |
| WM-2 | 2.6 | 13.4 | 156,000 |
| WM-3 | 3.4 | 23.2 | 209,100 |
| WM-4 | 3.5 | 50.0 | 330,900 |
| WM-5 | 2.6 | 7.2 | 79,500 |

San Juan

Along the down reaches of the three (3) tributaries, namely, the Talayan, the Salapan and the Maytunas creeks, low lands exist, while the floodwater in the areas of the middle and the upper reaches can be drained into the San Juan River by gravity flow. In consideration of the topography, the backwater dike with pump drainage and the solely pump drainage methods were compared as the alternative cases.

| Creeks | Construction Cost (in million pesos) | |
|---|---|---|
| | Backwater Dike with Mechanical Drainage | Mechanical Drainage |
| Talayan | 15 | 430 |
| Salapan | 40 | 730 |
| Maytunas | 10 | 280 |

Based on the above table, the backwater dike with pump drainage is adopted, since this method is lower in construction cost and the number of house evacuation is limited.

Regarding the integration of pump stations, no alternatives are planned in consideration of the distance of pump stations and topography.

Mandanluyong-Pasig

This drainage area consists of PM-5-1 and PM-5-2 located along the Lower Marikina river and PM-7 located along the Pasig River. PM-5-1 and PM-5-2 can drain the inland water by gravity flow, then installation/improvement of the drainage channels are only considered and no alternatives are studied. In PM-7 where pump drainage is required, the integration of pumps was studied as the alternative case as shown in Fig. 5-3-3.

The construction cost of the respective Alternative Cases are indicated below.

| Alternative Case | Number of Pump Stations | Construction Cost (in million pesos) |
|---|---|---|
| 1 | 1 | 220 |
| 2 | 2 | 190 |
| 3 | 3 | 180 |

Alternative Case 3 is recommended, since the construction cost is the lowest.

Marikina

Marikina Drainage Area is subdivided into eight subdrainage areas. Out of them, PM-3-5 is equipped with a gate to cope with the high water level of the Marikina River, while other subdrainage areas can be drained by the gravity flow. Because of these drainage methods, no alternative case is planned.

Parañaque-Las Piñas

After construction of the proposed river dikes along the South Paraãque-Parañaque rivers, the Las Piñas River and the Zapote River, the Parañaque - Las Piñas Drainage Area is divided into four (4) subdrainage areas. These subdrainage areas are lowland and therefore pump drainage is basically proposed.

In the subdrainage area the Paraãque River, which receives flood water from the SM-5 (Tripa de Gallina P.S. Drainage District) in Manila and Suburbs Drainage Area runs parallel with the coastline.

There exist three (3) outfalls which connect the Parañaque River and the Manila Bay, aiming to drain flood water including the Tripa de Gallina Pumping Station. However, the lowest ground elevation is the same as the design tide level (EL 11.80 m), the drain through the outfalls cannot be expected.

Under this circumstance, it is very difficult to discharge the flood flow or pump drainage discharge from SM-5 through the outfalls. Therefore, a new cutoff channel from the tripa de Gallina Pump Station to the Manila Bay is proposed to be constructed.

Without inflow from the Tripa de Gallina subdrainage area, the Parañaque River can store the inland water when initial level is lowered to the mean sea level by control gates.

In subdrainage areas PA-2 and PA-4, pump drainage is required due to the land elevation. Since the conceivable site of the pump station is only one for each subdrainage area due to the topography and the land use and the boundary of the subdrainage areas are fixed by the dikes mentioned above, no alternative is considered.

Also, in PA-3 in which the gravity drainage can be attained, no alternative is conceived.

<u>Valenzuela</u>

Valenzuela is a low-lying area in which the pump drainage is necessary. As the site of the pump stations, the lowest points of the existing rivers/creeks are conceivable. Using these sites, three alternatives as shown in Fig. 5-3-4 were compared.

| Alternative Case | Number of Pump Stations | Construction Cost (in million pesos) |
|---|---|---|
| 1 | 1 | 130 |
| 2 | 2 | 120 |
| 3 | 3 | 110 |

Based on the above, Alternative Case 3 is proposed.

## 3.5 Proposed Plan

For the nine (9) drainage areas, a drainage system to cope with the 10-year return period is proposed and described hereinafter. The location of the proposed drainage system is shown in Fig. 5-3-5 and the design discharge for related facilities is tabulated in Table 5-4-1.

### Manila and Suburbs

Manila and Suburbs can be divided into two (2) areas, namely, North Manila and Suburbs and South Manila and Suburbs.

Both areas have been provided with drainage channels and pump stations with a high safety level as explained before. However, to protect this area from a 10-year return period flood, more improvement works such as extension/construction of pump stations, lowering of the bed of esteros, and installation of drainage mains are required.

### (1) North Manila and Suburbs

North Manila and Suburbs can be further divided into five (5) subdrainage areas.

| Proposed Structure | Quantity | |
|---|---|---|
| North Manila (Drainage Area: | 2,858 ha) | |
| New Pump Station | 3 sites | (15.5 cums in total) |
| Extension of Existing Pump Station | 2 sites | ( 9.2 cums in total) |
| Gate | 1 site | |
| Channel Improvement | 6,850 m | |
| Closed Channel Construction | 5,750 m | |

(a) Subdrainage Area NM-1

NM-1 (1,681 ha) consists of Sunog Apog, Vitas and Binondo P.S. drainage districts. In Vitas Drainage District, a pump station is decided to be installed and drainage channel improvements will be implemented to cope with the 10-year return period flood. Under these circumstances, drainage facilities in the Binondo P.S. Drainage District solely needs to be improved. The proposed plan is installation of a new pumping station with the capacity of 5.8 $m^3/s$ at the mouth of Estero de la Reina in order to use this channel in the normal flow conditions. In addition, the esteros of La Reina, and its tributaries, namely, Magdalena and San Lazaro is proposed to be improved.

(b) Subdrainage Area NM-2

NM-2 of 36 ha is Balut Drainag District which is lowland situated along the right bank of Estero de Vitas. A pump station with a design capacity of 2 $m^3/s$ is decided to be installed to solve flooding problems in this area, so that no plan was proposed.

(c) Subdrainage Area NM-3

This area covers 906 ha, extending to the right bank of the Pasig River. This is lowland, in which the pumps drainage is necessary and one of the areas which suffered damage most seriously in the 1986 flood. This NM-3 comprises of four (4) existing drainage districts, namely, Northeast Pasig, Valencia P.S., Aviles Sampaloc P.S. and Quiapo P.S.

Based on the evaluation of the existing drainage facilities on those areas, construction of two (2) pump stations in the Northeast Pasig and the Aviles-Sampaloc P.S. and extension of two (2) existing pump stations, namely, the Valencia P.S. and the Quiapo P.S. are proposed with the total capacity of 18.9 $m^3/s$. The new pump station in the Aviles-Sampaloc is located in the lowest point of the San Miguel River and a flood control gate is installed.

Moreover, the improvement of three (3) esteros and extension of three (3) drainage mains are proposed so as to increase the flow capacity to the 10-year return period flood.

The three (3) esteros proposed to be improved are Estero de Valencia in the Valencia P.S. Drainage District and Estero de Sampaloc and Estero de San Miguel in the Aviles Sampaloc P.S. Drainage District, while the three (3) drainage mains are Lepanto-Josefina main and Economia main in the Aviles-Sampaloc P.S. Drainage District as well as Severino Reyes main in the Quiapo P.S. Drainage District.

The length of improvement reaches a total of 2,700 m and the length of the extension of the drainage mains is 2,300 m.

(d) Subdrainage Area NM-4

NM-4 has a drainage area of 69 ha, which is located at the river mouth of the Pasig River. This area suffers from flooding due to the lack of drainage channels, even though the land elevantion is rather high and thus gravity flow can be attained. To solve the flooding problem in this area, two (2) drainage mains are proposed to be installed under main roads with a total length of 1,150 m.

(e) Subdrainage Area NM-5

This subdrainage area is located along the north harbour with an area of 168 ha. This area is also rather high so that inland wate can be drained to the Manila Bay by the gravity flow. Out of two (2) existing drainage mains, namely, Pacheco and Lakandula mains. Pacheco main lacks the flow capacity to drain the design drainage area. Therefore, extension of Pacheco main is planned. Moreover, two (2) new drainage mains are proposed to be installed in the area of insufficient drainage channels, namely, along the Moriones and R-10 roads. The total length of these drainage mains is 2,300 m.

(2) South Manila and Suburbs

South Manila and Suburbs is divided into five (5) subdrainage areas and the following is proposed for the drainage area.

| Proposed Structure | Quantity | |
|---|---|---|
| South Manila (Drainage Area: 4,314 ha) | | |
| New Pump Station | 1 site | (5.3 cums in total) |
| Extension of Existing | | |
| Pump Station | 5 sites | (18.3 cums in total) |
| Pump Station | 1 site | (5.3 cums in total) |
| Gate | 2 sites | |
| Channel Improvement | 7,750 m | |

(a) Subdrainage Area SM-1

SM-1 is 599 ha and includes three (3) drainage districts, namely, Makati Slope, Makati P.S. and Sta. Clara P.S. Makati Slope is located on the high Guadalupe Formation, while two (2) other districts are situated in a lowland along the Pasig River where the pump drainage is required.

The existing drainage system in Makati Slope and Makati P.S. drainage districts can drain the flood of a 10-year return period flood, while the Sta. Clara P.S. drainage system has the capacity of less than a 10-year return period.

In consideration of the above, an extension of the existing Sta. Clara pump station and improvement of Estero de Sta. Clara are proposed to cope with the 10-year return period flood. The increase of pump capacity is 4.3 $m^3$, making the total capacity to 9.5 $m^3/s$. The length of improvement is 2,300 m.

(b) Subdrainage Area SM-2

SM-2 of 706 ha consists of four (4) drainage districts, namely, San Andres, Pandacan P.S. and Paco P.S. and Balete. The subdrainage area is low and thus pump drainage is required. At present, however, pump stations exist in Pandacan P.S. and Paco P.S. drainage districts to drain flood water into the Pasig River.

In San Andres drainage district which suffered the most serious flooding in the 1986 flood, a pump station is decided to be constructed and related channels will be improved with a safety degree of a 10-year return period and thus no plan is proposed in this study.

In other drainage districts, the following improvement of drainage systems is proposed to cope with the 10-year return period flood.

| | | |
|---|---|---|
| Pandacan P.S. | : | Extension of the existing pump station by 2.7 $m^3/s$ (Total capacity: 7.1 $m^3/s$); and<br>Improvement of Estero de Pandacan for 950 m. |
| Paco P.S. | : | Extension of the existing pump station by 2.3 $m^3/s$ (Total capacity: 9.7 $m^3/s$);<br>Improvement of Esteso de Concordia for 850 m; and<br>Improvement of Estero de Paco for 1,000 m. |
| Balete | : | Construction of a new pump station with the capacity of 5.3 $m^3/s$. |

(c) Subdrainage Area SM-3

SM-3 of 141 ha is located along the lowest reaches of the Pasig River. Since the drainage channels have been installed to some extent in this area, in which the gravity drainage can be done, additional installation of laterals is only proposed.

(d) Subdrainage Area SM-4

This subdrainage area extends along the Manila Bay and the inland water can be drained by the gravity flow. The existing two (2) drainage mains, namely, Padre Faura main and Remedios main have the capacity to cope with a 10-year return period flood from the respective drainage areas. Therefore, no additional installation of drainage main is proposed, except for the installation of the laterals.

(e) Subdrainage Area SM-5

SM-5 covers 2,480 ha facing the Manila Bay and the inland water is drained by two (2) pump stations, namely, Libertad pump station to the Manila Bay and Tripa de Gallina pump station to the Parañaque River which runs in the Parañaque-Las Piñas Drainage Area.

In this subdrainage area, the pump stations and some reaches of Estero Tripa de Gallina have the capacity less than the design flood, while the existing drainage mains/outfalls are able to cope with the design flood.

Based on this, the following improvement is proposed in two drainage districts which are covered by two (2) pump stations.

Libertad P.S.: Extension of the pump capacity by 6.2 $m^3/s$
(Total capacity: 54.2 $m^3/s$); and
Improvement of Estero Tripa de Gallina for 1,000 m.
Installation of two gates.

Tripa de Gallina P.S. : Extension of the pump capacity by 2.8 $m^3/s$
(Total capacity: 58.8 $m^3/s$); and
Improvement of Estero Tripa de Gallina for 1,650 m.

The gates in the Libertad P.S. are located in the Kalatagan Creek and Estero Tripa de Gallina to separate this drainage district from the Makati Slope and the San Andres drainage district, respectively.

(2) Malabon-Navotas

In the Framework Plan, the optimum location of ring dikes/coastal dikes proposed in the Feasibility Study is also applied. Due to the intergration of subdrainage areas by the ring dikes, the number of subdrainage areas is reduced to twelve from the present fourteen.

The summarized features of the proposed drainage facilities of this drainage area are as follows.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 2,492 ha) | |
| Ring Dike/Coastal Dike | 22,000 m |
| Pump Station | 8 sites (76.1 cums in total) |
| Gate | 15 sites |
| Channel Improvement | 5,100 m |
| Open Channel Construction | 5,600 m |
| Closed Channel Construction | 800 m |
| Navotas Navigation Lock | 1 site |

The following is the explanation of the facilities by each subdrainage area.

(a) Subdrainage Area MT-4-1

MT-4-1 with a size of 411 ha is located in the right bank of the Tullahan River. A pump station with the capacity of 15.9 $m^3/s$ is proposed to be constructed at Santulan River to drain the flood water into the Tullahan River. Also proposed are the improvements of the Santulan River (1,600 m), construction of a open channel (2,000 m) to collect the water from the eastern areas, and a flood control gate in the Santulan River which divides this subdrainage area and the Valenzuela Drainage Area.

(b) Subdrainage Area MT-4-2

Due to the rather higher elevation than MT-4-1, which is situated on the opposite bank of the Tullahan River, a flood gate is proposed to control the inland water from the area of 218 ha, together with a new open channel running along the Tullahan River with a length of 1,700 m.

(c) Subdrainage Area MA-1-A

MA-1-A is a newly proposed subdrainage area consisting of the eastern part of the existing MA-1 (113 ha). This area will be protected by the proposed ring dike along the Pinagkabalian Road from the flooding of Obando as well as by the river dike along the Malabon River. To drain the inland water, a pump station is proposed, together with a flood gate at the existing creek, with the capacity of 3.6 $m^3/s$. Also proposed are the improvements of the creek (600 m), which is the principal channel in this area and construction of an open channel (1,000 m), which leads the flood water to the creek.

(d) Subdrainage Area MA-1-B, MA-2-A

In addition to the river dike along the Malabon River, the proposed ring dike protects this subdrainage area, which composes of the western part of MA-1 and the southeastern part of MA-2. The size of this subdrainage area is 164 ha. The proposed drainage facilities are a pump station (4.3 $m^3/s$) at the Pinagkabalian River to pump out to the Malabon River and a gate set at the Pinagkabalian River of the ring dike point.

(e) Subdrainage Area MA-2-B, MA-3, MA-4 and MA-5

A continuous ring dike is proposed integrating the existing subdrainage areas MA-3, MA-4, MA-5 and part of MA-2 into one large subdrainage area of 614 ha. In this plan, a pump station with the capacity of 26.5 $m^3/s$ is located at the northernmost point of the Navotas River and the existing rivers such as Navatas, Batasan and Dampalit rivers are utilized as the main drainage channels to lead the flood water to the pump station. Two (2) gates are installed at the end of the North Dampalit River and the ring dike point of the South Damplit River. Instead of gates, a navigation lock will be constructed at the Navotas River to assure the navigation to the ports and the shipyards.

(f) Subdrainage Area MA-6

MA-6 is a low-lying area of 134 ha which is sandwiched by the Malabon River and the planned Dagat-Dagatan area. The proposed drainage plan consists of the construction of a pump station (7.4 $m^3/s$), improvement of the Catmon River (700 m) and construction of two (2) open channels (400 m and 500 m) to be connected to the Catmon River. The flooding from the Malabon River is prevented by the river dike.

(g) Subdrainage Area MA-7

MA-7 (240 ha) covers the planned Dagat-Dagatan area and also the neighbouring area outside Dagat-Dagatan. In the proposed plan, the existing Longos River is improved for 2,200 m to serve as the main channel and a pump station with the capacity of 12.1 $m^3/s$ is installed.

(h) Subdrainage Area MA-8

The existing Dagat-Dagatan area on the left bank of the Bangkulasi River is included in this subdrainage area (376 ha) together with a small area outside Dagat-Dagatan. The gravity drainage can be done in this area and the existing four (4) main channels, namely, Spine Drain, Saluysoy Drain, Northern Drain and Southern Drain have the capacity to cope with the 10-year return period flood. Therefore, additional installation of the laterals is proposed in this area together with the construction of a river wall along the Bangkulasi River and gates to protect this area from the high tide.

(i) Subdrainage Area MA-9

MA-9 is a small and low-lying drainage area of 30 ha located at the river mouth of the Malbon River. To protect this area from high tides, a river wall and a river/coastal dike are constructed and a pump station is proposed to be installed with the capacity of 2.2 $m^3/s$.

(j) Subdrainage Area MA-10

The Dagat-Dagatan of Kapitbahayan composes of MA-10. This area is rather high so that the inland water can be drained through the existing laterals by the gravity flow. Therefore, the proposed drainage plan is the additional installation of the laterals to upgrade the level of the 10-year return period.

(k) Subdrainage Area MA-11

MA-11 (69 ha) is lowland surrounded by the Bangkulasi River, Estero de North Sunog Apog and Estero de Sunog Apog. To protect this area from high tides and inland water flooding, a ring dike along the Estero de North Sunog Apog, a pump station with the capacity of 4.1 $m^3/s$, a closed drainage channel with the length of 800 m and a flood control gate are proposed.

(l) Subdrainage Area MA-12

This is rather a high drainage area surrounded by the Manila Bay, the Estero de Vitas and the Bangkulasi River. Since this drainage area is small (32 ha) and the gravity drainage can be done, installation of the laterals is only proposed.

East of Mangahan

This area is divided into four (4) subdrainage areas by the lakeshore dike and the dikes of the three (3) rivers, i.e., Buli, Baho and Mahaba. The proposed drainage system is a pump station and a regulation pond, if there is suitable space, and improvements/ construction of drainage channels. The features of the proposed drainage facilities for the four (4) subdrainage areas are as follows.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 876 ha) | |
| Pump Station | 4 sites (31.1 cums in total) |
| Gate | 4 sites |
| Channel Improvement | 1,100 m |
| Open Channel Construction | 7,300 m |
| Regulation Pond | 2 sites (60,300 $m^3$ in storage) |

(a) Subdrainage Area EM-1

This area (167 ha) is located in the right bank of the Buli River and has the highest land elevation among the four (4) subdrainage areas. Due to the backwater effect of the Mangahan Diversion Channel, pump drainage is required in this subdrainage area. The adequate space of a regulation pond does not remain in EM-1. Hence, in EM-1 a pump station (10.0 $m^3/s$) without a regulation pond is proposed together with a flood control gate and two (2) new open channels (1,100 m and 700 m).

(b) Subdrainage Area EM-2

EM-2 is an area situated between the Buli and the Baho rivers, with the size of 242 ha. The proposed facilities are a pump station with a flood control gate located near the junction of the Mangahan Diversion Channel and the Baho River. To drain the inland water, two (2) open channels are proposed to be constructed. The pump capacity is 13.0 $m^3/s$ and the length of the channels are 2,000 m and 800 m. The regulation pond is not adopted in this area because of the same reason mentioned in EM-1.

(c) Subdrainage Area EM-3

EM-3 (272 ha) which is sandwiched between the Baho and the Mahaba rivers. Therefore, construction of a regulation pond is conceived in this area together with a pump station. The proposed plan is a combination of a pump station with the capacity of 5.1 $m^3/s$ and a regulation pond with the volume of 21,300 $m^3$, which is placed near the junction of the Mangahan Diversion Channel and the Mahaba River. The two (2) open channels are proposed to be constructed with the length of 2,000 m and 700 m.

(d) Subdrainage Area EM-4

This subdrainage area is located between the proposed lakeshore dike and the Mahaba River, with the area of 195 ha. Since there is an adequate place, a regulation pond of 39,900 $m^3$ is proposed to be constructed near the existing creek, which functions as the main drainage channel, together with a pump station with the capacity of 3.0 $m^3/s$. The existing channel, which lacks the flow capacity, is to be improved for 1,100 m.

West of Mangahan

The land lower than the Design Lake State 12.5 m exists extensively in the west of Mangahan. To protect this area from the flooding of the lakewater, the lakeshore dike is adopted. The alignment is the same as that proposed in the Feasibility Study and the length is 8,900 m.

Regarding the drainage method, the optimum combination of the pump and the regulation pond is basically adopted.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 3,814 ha) | |
| Pump Station | 5 sites (147.6 cums in total) |
| Gate | 10 sties |
| Channel Improvement | 34,100 m |
| Open Channel Construction | 11,000 m |
| Closed Channel Construction | 1,450 m |
| Regulation Pond | 4 sites (775,500 $m^3$ in storage |

(a) Subdrainage Area WM-1

WM-1 (912 ha) is a triangular area located between the Lower Marikina River and the Mangahan Floodway. In WM-1, a pump station of 53.8 $m^3/s$ is proposed to drain the inland water to the Napindan River through the Antipolo River, since the rise of the water level in the Napindan River is almost none and improvement works of the Antipolo River in WM-2 can be reduced. To control the floodwater, a gate is installed in the Antipolo River of the boundary point between WM-1 and WM-2 in addition to a gate at the Napindan River. The Antipolo River is improved from the uppermost point to the junction with the Napindan River for 5,450 m. Also two (2) existing channels are to be improved for 2,000 m and two (2) new channels are to be constructed with length of 2,250 m. The regulation pond is not proposed in WM-1, since no adequate place exists.

(b) Subdrainage Area WM-2

WM-2 is located on the north of the lakeshore dike and sandwiched by the Napindan River and the Mangahan Floodway. A pump station with a regulation pond is proposed to be located at the lowest point of the Antipolo River, which is the main drainage channel in WM-2 of 514 ha. The required capacity of the pump is 13.4 $m^3/s$ and the volume of the pond is 156,000 $m^3$. The Antipoli River is improved for 2,000 m. Moreover, to lead the water to the Antipolo River, two (2) existing rivers of 1,750 m in total are improved and an open drainage channel of 2,150 m is constructed.

(c) Subdrainage Area WM-3

A pump station (23.2 $m^3/s$) with a regulation pond (209,100 $m^3$) is proposed to drain the inland water of WM-3 (683 ha) located to the west of the Napindan River. The site of those facilities are near the outlet of the Tipas-Labasan Creek to the lake. Regarding channels, the existing channel of 6,350 m is improved and open channels of 3,100 m in total is constructed.

(d) Subdrainage Area WM-4

WM-4 of 1,428 ha, the largest subdrainage area in the west of Mangahan extends along the Taguig River. In the proposed plan, the Taguig River is improved in most of its reaches, 7,500 m, together with other existing channels of 8,150 m. Also, the new channels of 3,600 m, including box culvert of 1,450 m, is proposed to be constructed so as to collect the flood water to the Taguig River. A pump station with the capacity of 50 $m^3/s$ is located at the furtherest point down with a regulation pond (330,900 $m^3$). In addition to a gate at the pump station, two (2) gates are installed at the Taguig River and the Tipas River to prevent inflow outside WM-4.

(e) Subdrainage Area WM-5

In WM-5 of 277 ha, the same drainage facilities as those in other areas are proposed. Those are a pump station (7.2 $m^3/s$), a regulation pond (79,500 $m^3$), improvement of the Bicutan Creek (900 m) and construction of new channels (1,350 m).

San Juan

For the three (3) tributaries with low bank elevations at the confluence with the San Juan River that cannot discharge inland water, backwater levees are proposed to drain floodwaters into the San Juan River. Because of these backwater dikes, the existing seven subdrainage areas increase to ten.

Moreover, the construction of new pumping stations and flood gates are proposed for some of the areas and also, closed drainage channels need to be installed in such areas.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 1,260 ha) | |
| Pump Station | 9 sites (52.7 cums in total) |
| Gate | 13 sites |
| Channel Improvement | 1,300 m |
| Closed Channel Construction | 12,300 m |
| Backwater Dike | 3,400 m |

(a) Subdrainage Areas SJ-5-1 and SJ-5-2

By the construction of the dike, the remaining lowland is separated into two (2) subdrainage areas, namely, SJ-5-1 and SJ-5-2. SJ-5-1 is the area with the size of 283 ha, located in the right bank of the Tayalan River, while SJ-5-2 is the area of 31 ha between the Taylay River and the San Juan River. In both areas, flood gates are proposed, since the inundation depth can be kept within 20 cm, the allowable inundation depth. As to other drainage facilities, box culverts are to be constructed with a length of 2,050 m in SJ-5-1 and 800 m in SJ-5-2.

(b) Subdrainage Areas SJ-7-1

SJ-7-1 (256 ha) is located in the right bank of the middle reaches of the San Juan River. In this area, two (2) pump stations with a total capacity of 15.8 $m^3$ is proposed to be constructed at the lower sites. The drainage channels are box culverts with gates at their outlets and their total length is 1,800 m.

(c) Subdrainage Area SJ-7-2

SJ-7-2 is situated across the San Juan River from SJ-7-1 and the size is 92 ha. This area is also low so that the inland water needs to be pumped out. The proposed facilities are the construction of two (2) pumps stations with the total capacity of 8.0 $m^3$ and installation of two (2) box culverts of 1,300 m in total, equipped with gates, which drain flood water to the pump station/San Juan River.

(d) Subdrainage Areas SJ-8-1 and SJ-8-2

Because of the existence of lowland along the Salapan Creek, the construction of the backwater dike to discharge the flood water of the high land (1,061 ha) by the gravity flow and the pump drainage in the remaining lowland of 146 ha are proposed. By the construction of the required dike of 1,200 m the lowland is divided into two (2) subdrainage areas, namely SJ-8-1, the right bank and SJ-8-2, the left bank of the Salapan Creek.

In SJ-8-1 of 87 ha, proposed drainage facilities are a pump station of 6.8 $m^3/s$ and a box culvert of 1,000 m with a flood gate. In SJ-8-2 of 59 ha, a pump station (4.2 $m^3/s$), a box culvert (1,100 m) with a floodgate are also proposed.

(e) Subdrainage Area SJ-9-1

SJ-9-1 is an area situated along the right bank of the lower reaches of the San Juan River. Due to the land elevation and high water level of the San Juan River, the gate control is proposed, since the maximum inundation depth is lower than 20 cm by this method. Another facility proposed is a box culvert with the length of 1,400 m.

(f) Subdrainage Areas SJ-9-2 and SJ-9-3

The lowland on the left bank of the San Juan Rivers is divided into two (2) subdrainage areas by the proposed backwater dike (600 m) of the Maytunas Creek.

In SJ-9-2 (187 ha) located in the right bank of the Maytunas Creek, the drainage by a pump station with the capacity of 9.5 $m^3/s$ is proposed after collecting inland water through two (2) new box culverts of 2,000 m in total. In SJ-9-3 (62 ha), the same drainage method is proposed. The required pump capacity is 3.5 $m^3/s$ and the length of the box culvert is 850 m.

(g) Subdrainage Area SJ-10

SJ-10 extends along the Buhagin Creek, which joins the furtherest point down of the San Juan River. In consideration of low elevation in most of the area and a small catchment area of 109 ha, the pump drainage is proposed. The pump capacity is 4.9 $m^3/s$. To lead the flood water to the pump station and the San Juan River, the creek is improved for 1,300 m and a gate is installed at the junction with the San Juan River.

Mandaluyong-Pasig

Mandaluyong-Pasig Drainage Area consists of three (3) subdrainage areas located along the Lower Marikina River and the Pasig River near the junction of the San Juan River.

The following is the summary of the proposed facilities.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 1,525 ha) | |
| Pump Station | 3 sites (23.0 cums in total) |
| Gate | 3 sites |
| Channel Improvement | 2,500 m |
| Closed Channel Construction | 8,800 m |

(a) Subdrainage Area PM-5-1

PM-5-1 extends along the right bank of the Lower Marikina River. This area of 929 ha is rather high land in which the gravity drainage is possible but the capacity of the existing drainage channels is deemed insufficient. Therefore, improvement of two (2) existing channels for 1,900 m in total, cosntruction of two (2) box culverts of 3,900 m are proposed.

(b) Subdrainage Area PM-5-2

PM-5-2 (138 ha) located across the Lower Marikina River from PM-5-1. This area is also rather high, making it possible for the inland water to be drained into the river. In PM-5-2 one (1) box culvert of 1,200 m is proposed in the area near the Mangahan Floodway, and in other areas which have narrow shape extending to the river, additonal installation of the laterals is proposed to drain the 10-year return period flood.

(c) Subdrainage Area PM-7

PM-7 is low land along the right bank of the Pasig River, in which the pump drainage is necessary. The proposed facilities are three (3) pump stations with the total capacity of 23.0 $m^3$, which are situated in the lower portion of the area of 458 ha and improvement of an existing channel (600 m), construction of four (4) box culters (3,700 m in total), and installation of three (3) flood gates.

Marikina

Marikina is a drainage area along both sides of the Marikina River from the Nangka River to the Mangahan Floodway. Since the existing lowland along the river is used as the channel in the proposed Marikina River improvement plan, most of the remaining areas can be drained by the gravity flow.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 1,168 ha) | |
| Gate | 1 site |
| Open Channel Construction | 1,000 m |
| Closed Channel Construction | 2,600 m |

Marikina can be divided into eight (8) subdrainage areas and the following drainage channels are proposed to be installed in the subdrainage areas.

- Subdrainage Area PM-3-4 : 193 ha

Construction of one (1) Closed Channel: 1,600 m

- Subdrainage Area PM-3-5 : 76 ha

  Gate : 1 site
  Construction of one (1) Open Channel : 1,000 m

- Subdrainage Area PM-4-1 : 344 ha

  Construction of one (1) Closed Channel: 1,000 m in total

In the other subdrainage areas, namely PM-3-1 (32 ha), PM-3-2 (42 ha), PM-3-3 (149 ha), PM-3-6 (125 ha), and PM-4-2 (207 ha), installation of laterials is only proposed judjing from the shape and the slope of the subdrainage areas.

Parañaque-Las Piñas

After cosntruction of the proposed river dikes along the South Parañaque-Parañaque rivers, the Las Piñas River and the Zapote River, the Parañaque-Las Piñas Drainage Area is divided into four (4) subdrainage areas. Those subdrainage areas are lowland and therefore pump drainage is basically proposed.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 1,543 ha) | |
| Pump Station | 2 sites (19.8 cums in total) |
| Gate | 8 sites |
| Channel Improvement | 4,800 m |
| Open Channel Construction | 150 m |
| Cut-off Channel | 500 m |

(a) Subdrainage Area PA-1

The proposed facilities in PA-1 are the construction of a cutoff channel (500 m) to drain the flood water from the Tripa de gallina Drainage Ditrict of Manila and Suburbs, installation of the gates and improvement of the existing channel (2,000 m).

The gates are installed at the existing three outfalls, namely, Rivera, Librada and Seaside.

After construction of the cutoff channel, Rivera Outfall is used to drain the inland water located in the north of the cutoff channel, while the remaining two outfalls are used to control the water level of the Parañaque River by two gates at their outlet and the gate at the junction with the South Parañaque River.

(b) Subdrainage Area PA-2

PA-2 of 246 ha is located in the west of the San Dionisio River and sandwiched by the river dikes of the South Parañaque and the Las Piñas rivers. Due to the low elevation of this area, a pump station with the capacity of 8.9 $m^3/s$ is proposed to be located near the Las Piñas River, since housing development is planned in the Las-Piñas River's side. Two gates will be installed at the outlets of the San Dionisio River to the South Paranaque and the Las Piñas rivers. To cope with the flood water, the San Dionisio is proposed to be improved for 1,650 m.

(c) Subdrainage Area PA-3

PA-3 is an area of 154 ha facing Manila Bay. In PA-3, only the improvement of laterals is proposed, because of the narrow shape and the rather high topography in which the gravity drainage to the Manila Bay can be attained.

(d) Subdrainage Area PA-4

PA-4 is a low area between the Las-Piñas and the Zapote rivers. To drain the inland water of 265 ha, a pump station (10.9 $m^3/s$) is proposed to be constructed. The site is near the Las Piñas River to use the existing drainage channels. This channel is improved for 1,150 m and a new open channel of 150 m is constructed to connect the existing channel with the outlet to the Las Piñas River.

Valenzuela

Valenzuela (ME-9) is a low-lying area of 1,842 ha and is not divided into subdrainage areas in consideration of the topography. The proposed drainage method is the installation of three (3) pump stations near the existing channels, the improvement of the existing three (3) creeks, construction of new open channel and the construction of ring dike along the creek running west of ME-9 and the Meycauayan River.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 1,842 ha) | |
| Pump Station | 3 sites (10.9 cums in total) |
| Gate | 1 site |
| Ring Dike (Reinforcement of existing dike) | 8,000 m |
| Channel Improvement | 12,900 m |
| Open Channel Construction | 500m |

# 4. MASTER PLAN

## 4.1 Premises and Conditions for the Study

The premises and conditions for the Master Plan Study are the same as those of the Framework Plan Study, except the following.

Target Completion Year

The year 2020 is set as the target completion year, considering the land use conditions which are closely related to runoff and vulnerability to flood loss.

Premises for Structural Application

The Framework Plan was formulated without considering financial restrictions. On the contrary, the Master Plan is to formulate the flood control and drainage project that could be realized by the year 2020 within the financial availability up to that year.

Runoff Discharge

The design discharge for this study was calculated on the basis of land use conditions at the year 2020.

Hydraulic Boundary

The tide level of Manila Bay and the water stage of the Laguna Lake were set as follows in accordance with the results of the hydrological analysis.

- Manila Bay Tide : 11.80 m, highest tide level on record.

- Water Stage of River : Adopted are the higher stage between the above Manila Bay tide level and the river water stage computed from non-uniform calculation with mean spring high tide at 11.30 m of Manila Bay.

- Laguna Lake Stage : 13.80 m, obtained from hydrological analysis, to reduce the recorded maximum lake stage of 14.03 m in 1972, considering the flood diversion through Mangahan Floodway to the lake and the reverse flow capacity of the floodway, together with the flow-down into the Pasig River through the Napindan Channel, to lower the lake water level.

## 4.2 Alternative Study Cases

The study on the Master Plan for the drainage improvement was done under the following alternative cases using the same facilities proposed in the Framework Plan.

The improvement scale of facilities for the drainage of inland water was studied in four alternative cases of 2, 3, 5 and 10-year return periods, setting the target area at all nine drainage areas identified in Section 2. The results of the alternative study such as design discharge of each facility and regulation pond volume are tabulated in Table 5-4-1.

## 4.3 Inundation Analysis

Basic Approach of Analysis

(1) Inundation Condition and Model

Inland water inundation in Metro Manila occurs topographically in the flat lowland area where runoff water is stored and spread widely. Inland water inundation was analyzed by the pond type model which can simulate those flooding condition.

(2) Premises and Conditions of Calculation

The premises and conditions are herein stipulated as follows.

(a) The nine drainage areas were divided into subdrainage areas as explained before, and the flooding conditions were estimated for each of the subdrainage areas.

(b) The inland water inundation analysis was done under the condition that floodwaters of the river are controlled completely.

(c) The runoff hydrographs of the respective subdrainage areas were calculated for the return period of 2, 3, 5, 10, 30, 50 and 100-year.

(d) The relation between two hydrographs, namely inland runoff discharge and water stage of rivers/Manila Bay were considered in the manner that the runoff peak discharge occurs at the same time as the peak stage of the river /water level/tide hydrograph.

(e) Based on the tide level and river water stage mentioned under Hydraulic Boundary in Section 4.1, the tide level of Manila Bay and the river stages of San Juan and Marikina were calculated as presented in Fig. 5-4-1.

(f) Inundated water in an area far from the outlet of the drainage channel to rivers/Manila Bay is hard to be drained even after river water level/tide level is lowered. This is because the far area requires more head difference between the inundation water level and the river water level/tide level than an area near to the outlet to make use of the full capacity of drainage channels. To simulate this phenomena, the head difference (Δh) is introducted in the pond type model. The head difference is assumed to be the product of the representative drainage channels gradient and the distance to the center of flood-prone areas from the outlet.

(g) Pump and gravity drainage in the area with pumping station(s) were considered under the following conditions:

- In case the river water/tide stage is higher than the inland water stage, the gate is closed and inland water is drained out by pump.

- In case the river water/tide stage is lower than the inland water stage by Δh mentioned in (f), inland water is drained into the river/Manila Bay by gravity flow.

(h) In the inundation calculation, pump operation is to start when tide or river stage exceeds the pump starting water level. For the existing pumping stations the actual pump starting water level which is, in most cases, the mean sea level, is used. For the proposed pumping stations along the Manila Bay, the pump starting water level is set at the mean sea level, following the existing pumping stations. In other areas, the lowest ground elevation is used as the pump starting water level.

(i) For all of the inundation areas, the relationship between the ground elevation and the inundation area/inundation volume was estimated from the 1/10,000 scaled topographic map. The measurement results are shown in Fig. 5-4-2.

Applied Model

The nine drainage areas were divided into the subdrainage areas as explained before. The subdrainage delineation of each drainage area is presented in Fig. 5-3-2.

Inland inundation conditions are affected by the capacity of each drainage component such as pumping stations and drainage channels. Even though a pumping station has enough capacity if the connecting drainage channels are clogged, the surrounding areas will be inundated. Survey results or design drawings of the channels which are requisites for capacity estimation are not available, except for the principal channels in Manila and Suburbs. Moreover, as for closed channels, the present flow capacity is substantially reduced from the capacity estimated from design drawings due to clogging and thus, even in Manila and Suburbs, the present flow capacity is hard to estimate. Therefore, the estimation of existing drainage capacity was done by comparing the calculated inundation depth using the model mentioned above with the actual inundation survey results of the September 1986 flood.

Comparison results for the areas of Manila and Suburbs and Malabon-Navotas where the survey results are deemed to be considerably definite, are shown in Fig. 5-4-3. The figure shows that the calculated results and the actual survey results well correspond with each other, and the specific drainage discharge is considered at about 2.0 $m^3/s/km^2$ for the Manila and Suburbs area and at about 0.5 $m^3/s/km^2$ for the Malabon-Navotas area. Manila and Suburbs are equipped with drainage facilities such as pumping stations on a rather high level and thus has a larger specific discharge, while Malabon-Navotas has poor drainage facilities and therefore smaller specific discharge. Based on these results, the drainage capacity of 2.0 $m^3/s/km^2$ was applied to Manila and Suburbs, Dagat-Dagatan and PA-1 of the Parañaque-Las Piñas drainage area in which three outfalls have been installed. Meanwhile, 0.5 $m^3/s/km^2$ was used for other areas where the drainage facilities are poorly installed.

Inundation Calculation

By using the above model, the inland water inundation condition was calculated in consideration of the following scale of structures and facilities.

- Manila and Suburbs : Existing condition and 10-year return period

- Other Areas : Existing condition, and 2, 3, 5 and 10-year return periods

By adopting the above scale of structures and facilities, the following return periods of flood were considered in all drainage areas in Metro Manila: 2, 3, 5, 10, 30, 50 and 100-year return period flood. The estimated inundation water stages are as shown in Fig. 6-4-4 and Table 5-4-2.

### 4.4 Proposed Plan

Drainage facilities are proposed for eight drainage areas out of the nine areas defined before. Excluded is the Manila and Suburbs area which will have facilities with the safety degree of more than a 5-year return period after completion of the on-going project.

The proposed facilities are of the same type as those in the Framework Plan with a different degree of safety in most of the drainage areas, except for Valenzuela where only gate control is proposed. Thus, the layout of proposed drainage facilities for only Valenzuela is indicated in Fig. 5-4-5 (refer to Fig. 5-3-5 for other drainage areas). Regarding the design discharge for each facility, refer to Table 5-4-1 which also shows the corresponding safety degree.

(1) Malabon-Navotas

The safety degree of drainage facilities in Malabon-Navotas is 5-year return period. The Dagat-Dagatan area with an existing drainage system is excluded from the Master Plan since the existing system has the capacity of more than 5-year return period. However, a ring dike will be constructed including the Dagat-Dagatan area so as to protect it up to the design tide level of EL 11.8 m as explained in Section 4.1.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 2,492 ha) | |
| Ring Dike/Coastal Dike | 22,000 m |
| Pump Station | 8 sites(62.1 cums in total) |
| Gate | 15 sites |
| Channel Improvement | 5,100 m |
| Open Channel Construction | 5,600 m |
| Closed Channel Construction | 800 m |
| Navotas Navigation Lock | 1 site |

(2) East of Mangahan

In the Master Plan, the design lakewater level is EL 13.8 m, which is 1.3 m higher than the Framework Plan. The pump drainage is applied in addition to the lakeshore dike, drainage channel and gates. Also, regulation ponds are adopted for the subdrainage with open spaces. The safety degree of the drainage facilities consisting of pumps and channels is 5-year return period.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 875 ha) | |
| Lakeshore Dike | 1,800 m (Top of Dike: EL 15.5 m) |
| Pump Station | 4 sites (27.0 cums in total) |
| Gate | 4 sites |
| Channel Improvement | 1,100 m |

| | |
|---|---|
| Open Channel Construction | 7,300 m |
| Regulating Pond | 2 sites (51,000 $m^3$ in storage) |

(3) West of Mangahan

The safety degree of the facility in this drainage area is 5-year return period. Pump station, regulation pind, drainage channels and gates to be located in the same place as those in the Framework Plan are proposed together with the lakeshore dike.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 3,814 ha) | |
| Lakeshore Dike | 8,900 m (Top of Dike: EL 15.5 m) |
| Pump Station | 5 sites (129.0 cums total) |
| Gate | 10 sites |
| Channel Improvement | 34,100 m |
| Open Channel Construction | 11,000 m |
| Closed Channel Construction | 1,450 m |
| Regulating Pond | 4 sites (642,000 $m^3$ in storage) |

(4) San Juan

The proposed drainage facilities are the same as those adopted in the Framework Plan, but with a safety degree of 3-year return period.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 1,260 ha) | |
| Pump Station | 9 sites (31.0 cums in total) |
| Gate | 13 sites |
| Channel Improvement | 1,300 m |
| Closed Channel Construction | 12,300 m |
| Backwater Dike | 3,400 m |

(5) Mandaluyong-Pasig

The proposed drainage facilities are the same as those adopted in the Framework Plan, but with a safety degree of 3-year return period.

| Proposed Structure | Quantity |
| --- | --- |
| (Drainage Area: 1,525 ha) | |
| Pump Station | 3 sites (14.5 cums in total) |
| Gate | 3 sites |
| Channel Improvement | 2,500 m |
| Closed Channel Construction | 8,800 m |

(6) Marikina

The proposed drainage facilities are the same as those adopted in the Framework Plan, but with a 3-year return period.

| Proposed Structure | Quantity |
| --- | --- |
| (Drainage Area: 1,168 ha) | |
| Gate | 1 site |
| Open Channel Construction | 1,000 m |
| Closed Channel Construction | 2,600 m |

(7) Parañaque-Las Piñas

The same drainage facilities as those in the Framework Plan are proposed. The safety degree of the facilities is 10-year return period for the cutoff channel which drains the floodwater of the Tripa de Gallina P.S. drainage district in the Manila and Suburbs, while other drainage facilities have the safety degree of 3-year return period.

| Proposed Structure | Quantity |
| --- | --- |
| (Drainage Area: 1,543 ha) | |
| Pump Station | 2 sites (12.5 cums in total) |
| Gate | 8 sites |

| | |
|---|---|
| Channel Improvement | 4,800 m |
| Open Channel Construction | 150 m |
| Cut-off Channel | 500 m |

(8) Valenzuela

In Valenzuela, gate control is proposed, together with the improvement of the existing channels and the ring dike. Due to the storage capacity of rivers and fishponds, as well as the flat topography, the inundation depth is lower than the allowable depth everywhere for the flood of a 3-year return period.

| Proposed Structure | Quantity |
|---|---|
| (Drainage Area: 1,842 ha) | |
| Gate | 1 site |
| Ring Dike (Reinforcement of existing Dike) | 8,000 m |
| Channel Improvement | 12,900 m |
| Open Channel Construction | 500 m |

# 5. FEASIBILITY STUDY

## 5.1 Drainage Improvement in East and West of Mangahan

### 5.1.1 Study on Alignment of Lakeshore Dike and Target Drainage Area

The east and west areas of Mangahan Floodway suffer from flood damage in almost every rainy season due to the inundation caused by the high water of the Laguna Lake and heavy local rainfall. To protect the areas from lakewater inundation, construction of a lakeshore dike is indispensable.

The alignment of the lakeshore dike is a factor to determine the target area for the improvement of drainage facilities. In this context, a study on the alignment of the Lakeshore Dike and the target area was made as described hereinafter.

Alignment of Lakeshore Dike

(1) Alternative Case

The primary purpose of the flood control works is to protect the existing properties such as residential houses, public utilities and so on. In the East and West of Mangahan, a great number of the properties are scattered in the area higher than EL 11.5 m. Since the properties that can be protected will depend on the alignment of the dike, three alternative alignments were considered. These are Alternative Route 1, Route 2 and Route 3 which protect areas higher than ground elevation of EL 12.5, 11.5 and 10.5 m, respectively, as shown in Fig. 6-5-1.

(2) Findings

Alternative Route 2 is justified to be the optimum alignment of the lakeshore dike for the following economic and social reasons.

(a) Economic Justification

The economic justification has been made under the two land use conditions, i.e., the present and future conditions in which the existing open spaces will be utilized as residential area with some reclamation works.

The economic effects of the three alternative routes are summarized in the following table. As can be seen from the table, Alternative Route 2 shows the highest economic effect in both the present and the future land use conditions.

| Item | Present Condition Route 1 | Present Condition Route 2 | Present Condition Route 3 | Future Condition Route 1 | Future Condition Route 2 | Future Condition Route 3 |
|---|---|---|---|---|---|---|
| Features | | | | | | |
| - Dike Length (m) | 9,500 | 10,700 | 11,300 | 9,500 | 10,700 | 11,300 |
| - Project Area (km²) | 35 | 47 | 54 | 35 | 47 | 54 |
| Project Cost | 84 | 101 | 125 | 118 | 143 | 250 |
| - Annual Construction Cost (for 40 years) | 59 | 72 | 88 | 93 | 113 | 213 |
| - Annual Operation, Maintenance & Replacement Cost | 25 | 30 | 37 | 25 | 30 | 37 |
| Land Value | 281 | 351 | 387 | 499 | 624 | 877 |
| Economic Ratio (Land Value/Project Cost) | 3.33 | 3.48 | 3.08 | 4.24 | 4.36 | 3.50 |

(b) Social Consideration

Fishpens are located mostly along the lakeshore or in the land lower than EL 10.5 m. The lakeshore dike in any alternative case is proposed basically along a contour line higher than EL 10.5 m. In this connection, construction of the dike will never lessen the present productivity of fishpens.

The proposed lakeshore dike will not close the Mangahan Floodway or the Napindan Channel. Therefore, the dike will not hamper navigation in these waterways, although accessibility to the lake from the neighboring landside areas may be affected to a little extent.

Any of the three alternative cases mentioned above will maintain the present conditions and will never bring about serious social problems.

Target Drainage Area

The lakeside boundary of the East and West of Mangahan has been determined by the proposed alignment of the lakeshore dike, so that this drainage area has nine subdrainage areas as presented in Fig. 5-5-2. Since the funds available up to the year 2000 is limited, the improvement work for some subdrainage areas may be implemented after the year 2000. Therefore, each of the subdrainage areas has been investigated on the eligibility as the target area for a priority project.

As the concept for selection of the target area, the following area shall be included in the project.

- The area which has serious flood damage at present.
- The area in which the flood damage is expected to increase due to the drainage improvement works implemented in the other subdrainage area.

As a result of the investigation, as described below, all of the subdrainage areas were identified as priority areas.

- In subdrainage areas WM-1 to WM-5 in West of Mangahan and EM-2 in East of Mangahan, residential areas have serious flood damage.
- Under the present condition, flood damage is not so serious in subdrainage areas EM-1, EM-3 and EM-4 in East of Mangahan. Nevertheless, Buli, Baho and Mahaba river channels will be improved with the backwater dike and the Mangahan Diversion Channel will be constructed to mitigate the flood damage in subdrainage area EM-2. As a result, flooding condition in subdrainage areas EM-1, EM-3 and EM-4 will be more serious than the present condition.

### 5.1.2 Present Condition of Drainage Area

#### Topographic Features

The East and West of Mangahan Floodway consists of the low-lying land bordered by the Sierra Madre Range on the east, the Guadalupe Formation Lowland on the west, Pasig River on the north and Laguna Lake on the south. From the geological point of view, the area comprises the southern half of the Marikina Valley Alluvial Plain.

#### Lake and River Utilization

Urbanization is observed on the higher ground near the Pasig River, while fishpens and open spaces are observed in the lakeshore areas. Fishing and fish culture are briskly conducted in the lake and along the lakeshore. Since the Napindan Channel connects the Pasig River and the lake through the navigation lock at the Napindan Hydraulic Control Structure, brisk navigation can be observed in the channel to transport commodities between the city of Manila and the lake or the areas along the channel.

The Mangahan Floodway is partly utilized for "kangkong" cultivation and also for navigation, though not so brisk because of the weir at the junction of the Pasig River and the floodway.

#### Drainage Related Facilities

Major drainage structures are not observed in this area, except for the privately installed ones. There are a number of creeks and rivers as shown in Fig. 5-5-2, which are functioning as drainage channels to drain storm water into the Napindan Channel and the Mangahan Floodway, or directly into the Laguna Lake.

### 5.1.3 Planning Conditions

Watershed

The target area for drainage improvements as defined in Subsection 5.1.1 is composed of nine subdrainage areas and divided by the Mangahan Floodway. Four of them are located in East of Mangahan and five are in West of Mangahan. (Refer to Fig. 5-5-2.)

Improvement Scale and Design Discharge

The lakeshore dike will be constructed with an elevation of EL 15.8 m based on the design high water level of Laguna Lake corresponding to a 40-year return period. The drainage facilities are designed to cope with the flood of a 5-year return period.

The priority project is implemented in the first phase (target completion year: 2000) of implementation of the Master Plan in which the target completion year is 2020. Therefore, the flood of a 5-year return period estimated under the land use conditions at the year 2020 is, in principle, employed as the design discharge for the respective facilities.

However, the design discharge under the land use conditions at the year 2020 is far bigger than at the year 2000. Therefore, the discharge estimated under the land use conditions at the year 2000 can be used for facilities such as drainage pumps whose capacity can be enlarged easily without any work duplication.

Based on the above consideration, the design discharge for each of the facilities was decided as follows (refer to Fig. 5-5-3):

(a) Facilities planned by the design discharge estimated under the land use condition of the year 2020

- River and drainage channel
- Control gate and sluice
- Regulation pond
- River dikes
- Pump house

(b) Facilities planned by the design discharge estimated under the land use condition at the year 2000

- Pumping equipment

Water Levels of Laguna Lake

The design high water level of Laguna Lake was set at EL 13.8 m, which is equivalent to the 40-year return period water level as mentioned before.

The average water levels obtained from the records of water levels for the past 15 years were identified. In designing the lakeshore dike and other related facilities, reference was made to these average water levels.

| Water Level | Elevation (m) |
|---|---|
| Annual Maximum | 12.5 |
| 95-day | 11.7 |
| 185-day | 11.2 |
| 275-day | 10.7 |
| 355-day | 10.5 |

Premise for Land Reclamation Height

At the present land use conditions, there are open spaces in the area facing Laguna Lake, and they are always inundated by the Laguna lakewater in the rainy season. However, these spaces will be utilized as residential area after completion of the lakeshore dike. This process of urbanization will naturally involve reclamation to avoid flooding.

It is difficult to define the future land reclamation height at this moment. Since the topography of the subdrainage area is strongly related to the estimation of the required facilities, future reclamation height should be determined. On this sense, the height of the future reclaimed area has been assumed at EL 12.0 m, which is almost the lowest elevation of the existing urbanized area, under the consideration that the elevation of the newly reclaimed area will not be higher than that of the existing ones.

Criteria for Structural Design

All the structural design were carried out in accordance with the criteria given in Section 3.2.

5.1.4 Study on Alternatives

From the viewpoint of topographic characteristics, a study has been made to formulate the optimum drainage system on such items as the improvement method of Napindan Channel, the availability of backwater dike, the integration of subdrainage areas, and the determination of pumping capacities.

Improvement Method of Napindan Channel

(1) Alternative Case

According to the results of the Master Plan, the Napindan Channel is recommended to be improved by the backwater dike against the Laguna lakewater. The backwater dike is planned to be constructed in the Napindan stretches of the Laguna lakeside from the junction with the Antipolo River, with the same dimension as the lakeshore dike which has a crest width of 9.1 m and a crest elevation of EL 15.8 m including a freeboard of 2.0 m. The concrete wall is planned to be constructed in the stretches near the Pasig River because the ground elevation in these stretches is almost as high as the design water level of Laguna Lake. The concrete wall will serve as the freeboard.

To construct the backwater dike with a large dimension, a number of house evacuation and huge construction cost may be required. As the alternative plans, the following cases were considered.

Alternative Case 1: Improvement by Backwater Dike with the dimensions mentioned above.

Alternative Case 2: Emergency Control Gate installed in the Laguna lakeside of Napindan Channel, and a dike with crest width of 6.0 m and crest elevation of EL 14.6 m.

(2) Findings

It has been clarified that Alternative Case 1 can be recommended as the optimum method for the reason that construction cost is far smaller than that of Case 2 as shown below, though the number of house evacuation in Case 1 is slighly higher.

| Alternative Case | Construction Cost (in million pesos) | Number of House Evacuation |
|---|---|---|
| 1 | 159 | 250 |
| 2 | 604 | 210 |

Availability of Backwater Dike

(1) Alternative Cases

There exist a number of rivers and creeks which pour into the Laguna Lake, and the drainage areas have different sizes, ground elevations and topographic conditions, depending on which it may be more economically advantageous to drain storm water by the mechanical drainage system without a backwater dike than in combination with a backwater dike, and vice versa.

Based on the above consideration, the river/creeks where the mechanical drainage system is applicable have been identified through the comparative study of the following alternative cases.

Alternative Case 1: Mechanical Drainage System with a Backwater Dike

Alternative Case 2: Mechanical Drainage System only

(2) Findings

The project cost for both alternatives were estimated as shown in the following table. It is economically justified that Buli, Baho, Mahaba and Lower Bicutan should be improved by a combination of mechanical drainage and backwater dike; while, Antipolo, Taguig and Bicutan is by the mechanical drainage method only.

| River or Creek | Construction Cost (in million pesos) | |
|---|---|---|
| | Alternative Case 1 | Alternative Case 2 |
| Buli | 170 | 1,680 |
| Baho | 180 | 1,650 |
| Mahaba | 160 | 960 |
| Lower Bicutan | 10 | 200 |
| Antipolo | 770 | 530 |
| Taguig | 1,060 | 780 |
| Bicutan | 80 | 50 |

Integration of Subdrainage Area

(1) Alternative Cases

East of Mangahan has four subdrainage areas divided by the Buli, Baho and Mahaba rivers as mentioned in the study on availability of backwater dike. Since all of the subdrainage areas are surrounded by the backwater dike for the Buli, Baho and Mahaba rivers and the lakeshore dike, the integration of subdrainage areas in the East of Mangahan is impossible.

West of Mangahan has five subdrainage areas and it is divided into two areas by the Napindan Channel; namely, the area between Mangahan and Napindan which has two subdrainage areas, and the area between Napindan and Lower Bicutan River with three subdrainage areas. The number of subdrainage areas may be reduced by integrating the areas, depending on the total construction cost of drainage facilities, i.e., the construction cost of pumping facilities can be reduced when a large capacity pumping station is integratedly provided, though the construction cost of a drainage channel increases when a bigger discharge is planned to be conveyed to the drainage site.

From the above concept, the alternative cases for the integration of the subdrainage area is selected as follows.

(a) Area between Mangahan and Napindan (Fig. 5-5-4)

Alternative Case 1-1: Subdrainage areas WM-1 and WM-2 will be thought of as forming separate systems and a pump station will be located in each area.

Alternative Case 1-2: Since the ground in the area slopes down towards Laguna Lake, WM-1 and WM-2 will be thought of as forming a single drainage system and one pump station for both will be located at the mouth of Antipolo Drainage Channel.

(b) Area between Napindan and Lower Bicutan River (Fig. 5-5-5)

Alternative Case 2-1: Subdrainage areas WM-3, WM-4 and WM-5 are thought of as forming separate drainage systems along the existing channels and pump stations will be constructed at the mouths of Labasan, Taguig and Bicutan Drainage Channels, respectively.

Alternative Case 2-2: All the discharge water is led to Taguig Drainage Channel, and is drained by one pump station.

Alternative Case 2-3: WM-3 and WM-4 subdrainage areas are integrated, while keeping subdrainage area WM-5 separate. Pumping stations will be constructed at the mouth of Taguig Drainage Channel for WM-3 and WM-4, and at the mouth of Bicutan Drainage Channel for WM-5.

Alternative Case 2-4: Subdrainage areas WM-4 and WM-5 are integrated, while keeping subdrainage area WM-3 separate. Pumping stations will be constructed at the mouth of Taguig Drainage Channel for WM-4 and WM-5, and at the mouth of Labasan Drainage Channel for WM-3.

(2) Findings

It has been clarified that Alternative Case 1-1 in the area between Mangahan and Napindan and Alternative Case 2-1 in the area between Napindan and Lower Bicutan River are recommendable for the reason that construction cost is the lowest as shown in the following table.

| Alternative Case | Construction Cost (in million pesos) |
|---|---|
| 1-1 | 850 |
| 1-2 | 943 |
| 2-1 | 1,193 |
| 2-2 | 1,359 |
| 2-3 | 1,339 |
| 2-4 | 1,297 |

Determination of Pump Capacity

The lake areas below the elevation of EL 12.5 m will be the land area by the construction of the lakeshore dike. At present, these areas are, in the dry season, utilized as paddy field and/or remain as open space. A part of the newly created land area can be used for the construction of flood water regulation pond. Since the regulation capacity of the pond is deeply concerned in the installed capacity of the pump, the following study has been made in the subdrainage area along the lakeshore dike (EM-3 and 4, and WM-2 to 5) which holds the created land area.

The required capacity of the regulation pond has been estimated on the assumptions that the installed pump station has the specific drainage capacity of 1 $m^3/s$, 2 $m^3/s$ and 4 $m^3/s$. The combination of the drainage capacity of the pump and the regulation capacity of the pond which is necessary to control the design discharge will then be decided on the basis of the land use conditions at the year 2020.

Among the combinations mentioned above, the combination of pumping capacity and regulation capacity of the pond which indicates the least construction cost was employed as the optimum. The optimum combination for each subdrainage area is shown in the following table. The optimum dimensions of pumps and regulation ponds are tabulated in Table 5-5-1.

| Subdrainage Area | Pump Capacity | | Regulation Capacity of Pond (m3) |
|---|---|---|---|
| | Specific Discharge ($m^3/s/km^2$) | Total Discharge (m3/s) | |
| EM-1 | 5.4 | 9 | * |
| 2 | 4.5 | 11 | * |
| 3 | 1.8 | 5 | 18,000 |
| 4 | 1.0 | 2 | 33,000 |
| WM-1 | 5.0 | 46 | * |
| 2 | 2.3 | 12 | 138,000 |
| 3 | 2.9 | 20 | 183,000 |
| 4 | 3.2 | 45 | 258,000 |
| 5 | 2.2 | 6 | 63,000 |

* In view of the topographical and land use conditions, regulation ponds were not designed.

### 5.1.5 Pump Capacity for the Year 2000

The design pump capacity for the priority project is that corresponding to the land use condition at the year 2000. Since the land use conditions are not determined officially, the design pump capacity is obtained proportionally with the pump capacity for the years 1986 and 2020.

| Subdrainage Area | Pump Capacity ($m^3/s$) | | |
|---|---|---|---|
| | 1986 | 2020 | 2000 |
| EM-1 | 7 | 9 | 8 |
| EM-2 | 5 | 11 | 8 |
| EM-3 | 5 | 5 | 5 |
| EM-4 | 2 | 2 | 2 |
| WM-1 | 21 | 46 | 32 |
| WM-2 | 3 | 12 | 7 |
| WM-3 | 9 | 20 | 14 |
| WM-4 | 20 | 45 | 31 |
| WM-5 | 2 | 6 | 4 |
| Total | 74 | 156 | 111 |

### 5.1.6 Proposed Plan

The main component of the optimum drainage plan in the East and West of Mangahan are construction works of lakeshore dike and drainage channels, improvement works of the related rivers and existing drainage channels, and installation of pump stations and drainage gates. The principal features of the required structures are presented as follows, and their locations are shown in Fig. 5-5-6.

(1) Lakeshore Dike

The lakeshore dike will be constructed on ground elevation of about EL 11.5 m. The dike will not close the wide channels such as Napindan, Mangahan Floodway, Mangahan Diversion and Lower Bicutan, but bridges will be installed over these channels for the maintenance and transportation. Sluice gates will be installed at small channels that will be closed by the dike, so that effective drainage by pumps can be expected.

| Structure | Quantity |
|---|---|
| Lakeshore Dike (with revetment) | 10,700 m (EL 15.5 m) |
| Sluice Gate (with maintenance bridge) | 5 sites |
| Maintenance Bridge | 4 bridges |

(2) River Improvement

Dredging and diking will be carried out for the Napindan Channel in a bottom width of about 80 m (almost equal to the existing) to assure the flow of lakewater from the Laguna Lake to the Pasig River. The height is from 0.5 to 1.5 m above the ground elevation.

Baho, Buli and Mahaba rivers will be provided with only backwater dikes. It is advisable to execute dredging works for these rivers after the completion of improvement works in their upstream portions.

A diversion channel will be newly excavated along the Mangahan Floodway to drain the storm water in the East of Mangahan into the Laguna Lake.

| Structure | Quantity |
|---|---|
| Napindan River (dredging/diking) | 5,242 m (80 m in bottom width) |
| Mahaba River (diking) | 2,400 m (40 m in width) |
| Baho River (diking) | 1,800 m (45 m in width) |
| Buli River (diking) | 1,600 m (45 m in width) |
| Mangahan Diversion | 3,800 m (80 - 60 m in width) |
| Lower Bicutan River (dredging/diking) | 800 m (15 m in width) |

(3) Drainage System

Dredging works will be carried out for the existing open channesl such as the Taquig, Tipas and Antipolo rivers in a total length of 35,200 m. A number of open and closed channels will be newly installed, as shown in Fig. 5-5-6, in a total length of 18,300 and 1,450 m, respectively.

Nine pumping stations are also proposed and six of them are provided with a regulation pond each (refer to Fig. 5-5-6). In addition to the sluice gates along the lakeshore dike mentioned above, nine flood/sluice gates will be placed at the pump stations and the junction of rivers.

| Structure | Quantity |
|---|---|
| Channel Improvement | 35,200 m |
| Open Channel Construction | 18,300 m |
| Closed Channel Construction | 1,450 m |
| Sluice Gate | 9 sites |
| Regulation Pond | 6 sites (693,000 cum in storage) |
| Pump Station | 9 sites (111.0 cums in total under land use conditions at the year 2000) |

### 5.1.7 Inundation Water Level

To estimate the inundation damage reduction after completion of the proposed project, the inundation water levels in each of the subdrainage areas were estimated under the with- and the without-the-project situations as in the Master Plan. The estimation results are in Table 5-5-2.

## 5.2 Drainage Improvement in Malabon-Navotas

### 5.2.1 Study on Target Area

There are 14 subdrainage areas in Malabon-Navotas and the priority project is urgently required to be implemented for the mitigation of inundation damage (refer to Fig. 5-5-7). From the viewpoint of effective investment of limited funds up to the year 2000, the subdrainage areas which are now suffering from serious inundation damage should be selected as the priority project.

In this sense, the Dagat-Dagatan subdrainage area is excluded from this study because it has drainage facilities with the scale of a 5-year return period which is the same safety level as the proposed Master

Plan. On the remaining 12 subdrainage areas, a study has been made as follows.

Table 5-5-3 shows the size of each subdrainage area and the percentage of the area affected by the 1986 flood that is developed or to be developed. The size of the subdrainage area proprotionately reflects the amount of investment necessary for a new drainage system; hence, the larger the area that is vulnerable to flood damage, the greater is the economic benefit when a drainage system is installed. In this connection, the areal percentage can be used as an index to select the areas for the priority project.

As shown in Table 5-5-3, the subdrainage areas can be classified into two groups based on the present land use conditions. The first group has a high percentage of more than 40%, while the second group has the percentage lower than 20%. Based on the above, feasibility study for the Malabon-Navotas area is recommended to be conducted for seven subdrainage areas, namely MA-2, MA-3, MA-4, MA-5, MA-6, MA-9 and MA-11.

Under the future land use condition, subdrainage area MA-1 shows a rapid increase in percentage, reaching 80% in the year 2020. In consideration of the necessity of the drainage system to keep pace with development, MA-1 is also recommended to be one of the areas for the feasibility study.

### 5.2.2 Condition of Existing Related Facilities in Subdrainage Area

Topographical Features

As shown in Fig. 5-5-8, the objective subdrainage areas are divided by the Malabon-Tullahan River and several creeks. All of the subdrainage areas are located in the low-lying land with a slight variation in ground elevation. The lowest places of each subdrainage area range between EL 10.5 m and EL 11.0 m, which are lower than the mean spring high tide.

With regard to the road condition in the objective area, almost all of the roads have been constructed higher than the ground elevation of the surrounding area to ensure better transportation condition even in the flood season. Especially J.P. Rizal Road, a trunk road running from Caloocan to Obando, the elevation is so high that it serves as part of the ring dike.

River and Creek Utilization

The river and the creeks are utilized for the navigation of cargo boats, fishing boats, etc., and the volume of navigation is considerably brisk. Areas along the river and the creeks are utilized as harbors and shipyards, especially the area along the Navotas River.

Drainage Related Facilities

The existing drainage system is very poor in each subdrainage area, though some facilities such as ring dikes and sluice gates were installed in some subdrainage areas (refer to Fig. 5-2-7).

A ring dike has been constructed on the river bank in almost all of the subdrainage areas, with dimensions of approximately 12 m in height and 1.0 m in crest width. The existing height of the ring dike is not enough, considering the design high tide level and the freeboard.

The gate and sluice are located in the required place, but they have problems in watertightness. In order to use the existing gate and sluice, considerable improvement works are necessary to recover their required functions.

The drainage channel and lateral are under very poor conditions and there is no pumping station in the objective area.

### 5.2.3 Planning Conditions

Watershed

The target area for drainage improvement as defined in Subsection 5.2.1 is composed of eight subdrainage areas. Five of them are located at the north of Malabon, being divided by the Malabon-Tullahan River, and three are at the south of Malabon. (Refer to Fig. 5-5-8.)

Improvement Scale

The consideration on improvement scale of the related facilities is the same as in Subsection 5.1.3.

Design Discharge

The design disharges for each subdrainage area which correspond to a 5-year return period at the year 2020 are presented in Fig. 5-5-9.

Hydraulic Boundary

Tide levels in Manila Bay, according to past records, can be summarized as follows.

| Tide Level | Elevation (m) |
|---|---|
| Design High Tide | 11.8 |
| Mean High Spring Tide | 11.3 |
| Mean Tide | 10.5 |
| Mean Low Spring Tide | 10.0 |

Premise for Land Reclamation Height

According to the present land use conditions, there are some fishponds in the subdrainage areas located in the low-lying area and they are always inundated in the rainy season. However, these fishponds will be transformed to a residential area by 2020 under the existing land development plan. This process of urbanization will naturally involve reclamation to avoid flooding.

It is difficult to define the future land reclamation height at this moment. Since the topography of the subdrainage areas is strongly related to the cost estimate of the required facilities, the future reclamation height should be determined. On this sense, the height of the future raclaimed area has been assumed at EL 11.0 m, which is almost the lowest elevation of the existing urbanized area, under the consideration that the elevation of the newly reclaimed area will not be higher than that of the existing ones.

### 5.2.4 Study on Alternatives

The objective area is topographically divided into two areas, North of Malabon River and South of Malabon River, by the Malabon-Tullahan River. The alternative studies made on the drainage system of each area and the optimum pump capacity are discussed hereinafter.

<u>North of Malabon River</u>

(1) Alternative Case

The North of Malabon River has five subdrainage areas divided by the river and/or creek. Considering the topographical features in this area, twenty (20) alternative cases were selected by combining some of the subdrainage areas, as shown in Fig. 5-5-10, based on the following two concepts.

(a) Difficulty of Land Acquisition for Ring Dike

As a major facility of the drainage system, ring dike shall be constructed against seawater and/or river water. In consideration that the area along the river and creek is highly urbanized, it seems to be very difficult to acquire the right-of-way for the ring dike.

(b) Utilization of Creek as Drainage Channel

To drain stormwater, a main drainage channel has to be provided in each subdrainage area to convey stormwater to the gate and/or pumping station. For the construction of the main drainage channel, it is also very difficult to acquire the right-of-way for an open channel. In case of a closed drainage channel, construction work will be impractical considering the existing highly congested and populated area.

Therefore, in case that some of the subdrainage areas are integrated, the existing creek can be utilized as the main drainage channel.

(2) Findings

From the economical, technical and social points of view as mentioned below, it has been justified that Alternative Case 20 is recommendable as the optimum case. In Case 20, the five (5) subdrainage areas are integrated into one whole drainage area by the ring dike as shown in Fig. 5-5-11.

(a) Economic Justification

The construction cost for Case 20 is the lowest among all the alternative cases as tabulated in Table 5-5-4, while the benefit to be derived from the project is the same for all the alternative cases. Therefore, the economic advantage can be justified by comparing the construction costs of the alternative cases.

(b) Technical Justification

It is recommendable that the river and/or creek be utilized as the main drainage channel on the following two reasons: the number of pumping stations can be reduced to three points by utilizing the river/creeks with the result of easy operation and maintenance of the drainage facilities, and the river/creeks closed by gate may be used as a regulation pond.

(c) Social Justification

Considering the utilization of river channel and river bank, the construction of the control gate is inconvenient for navigation, though the control gate is closed at the time of around mean high spring tide and/or flood time. On the other hand, the construction of the ring dike along the river and creek bank is also inconvenient for access to the river, which is especially true to the shipyard where it is impossible to construct the ring dike facing the river.

From the viewpoint of river utilization, therefore, the advantage of the drainage measure between the control gate and the ring dike cannot be decided. However, the construction length of ring dike can be reduced by installing control gates, resulting in the reduction of acquisition of right-of-way. This can avoid new social problems caused by house evacuation and land acquisition.

<u>South of Malabon River</u>

(1) Alternative Case

Alternative case will be selected based on the concept applied for the study on North of Malabon River.

As defined in 5.2.1, Dagat-Dagatan area is excluded from the target area. However, the ring dike against the river water is deficient in height when the freeboard is considered, and it is not continuous. Therefore, the ring dike in the Dagat-Dagatan area shall be included in this study.

As far as the construction of the ring dike is concerned, the South of Malabon River can be divided into the following three areas: MA-6 subdrainage area plus Dagat-Dagatan (east side) subdrainage area, MA-9 plus Dagat-Dagatan (west side) subdrainage area, and MA-11 subdrainage area. For these three areas the following three alternative cases were prepared (refer to Fig. 5-5-12).

Alternative Case 1: Construction of ring dike for each of the three areas.

Alternative Case 2: Integration of MA-6 plus Dagat-Dagatan (East Side) and MA-11 subdrainage area by the construction of control gate in Estero de Sunog Apog at the junction of Bangkulasi River.

Alternative Case 3: Integration of all three areas by the construction of two control gates: one located in Bangkulasi River at the junction with Malabon River and the other at the estuary of the same river.

(2) Findings

It has been justified that Alternative Case 1 (Fig. 5-5-11) is recommendable as the optimum on the ground that it shows the lowest costs for the economical viewpoint. The technical and social advantages similar to those of the North of Malabon River cannot be obtained.

| Alternative Case | Project Cost including Operation and Maintenance Cost (in million pesos) | Land Acquisition (1,000 $m^2$) |
|---|---|---|
| 1 | 423 | 95 |
| 2 | 497 | 77 |
| 3 | 751 | 66 |

Determination of Pump Capacity

Based on the optimum integration of subdrainage areas mentioned above, the pumping capacities at the year 2020 were determined as follows.

| Subdrainage Area | Pump Capacity | |
|---|---|---|
| | Specific Discharge ($m^3/s/km^2$) | Total Discharge ($m^3/s$) |
| Land Use Conditions at 2020 | | |
| North Bank of Malabon River: | | |
| MA-1-A | 2.7 | 3 |
| MA-1-B, MA-2-A | 2.4 | 4 |
| MA-2-B, MA-3, MA-4, MA-5 | 3.6 | 22 |
| South Bank of Malabon River: | | |
| MA-6 | 4.5 | 6 |
| MA-9 | 6.7 | 2 |
| MA-11 | 6.8 | 4 |
| Total | 26.70 | 41 |

### 5.2.5 Pump Capacity for the Year 2000

As explained in the planning conditions, the discharge at the year 2000 was used for the pumping equipment. This capacity is obtained from those for the Years 1986 and 2020 as follows.

| Subdrainage Area | Pump Capacity ($m^3/s$) | | |
|---|---|---|---|
| | 1986 | 2020 | 2000 |
| North Bank of Malabon River: | | | |
| MA-1-A | 1 | 3 | 2 |
| MA-2-A | 2 | 4 | 3 |
| MA-2-B, MA-3, MA-4, MA-5 | 18 | 22 | 20 |
| South Bank of Malabon River: | | | |
| MA-6 | 3 | 6 | 4 |
| MA-9 | 2 | 2 | 2 |
| MA-11 | 4 | 4 | 4 |
| Total | 30 | 41 | 35 |

### 5.2.6 Features of the Optimum Plan

The main components of the optimum plan are the construction of ring dike and drainage channels, improvement of existing drainage channels, and installation of pump stations and drainage gate. (Three pumping stations will be installed in the North of Malabon River, though all the subdrainage areas are integrated into one.) Their principal features are summarized as follows, and the locations of the structures are shown in Fig. 5-5-13.

| Structure | Quantity |
|---|---|
| (1) North of Malabon River | |
| Coastal Dike (with revetment) | 5,700 m (EL 13.5 m, 2.5 m in height) |
| River Dike (with revetment) | 3,500 m (Raising of existing dike by 1 m) |
| River Dike (without revetment) | 6,700 m ( -ditto- ) |

| | |
|---|---|
| Channel Improvement | 600 m |
| Open Channel Construction | 1,000 m |
| Pump Station | 3 sites (25 cums in total*) |
| Gate | 7 sites |
| Navigation Lock (Navotas River) | 1 site |

(2) South of Malabon River

| | |
|---|---|
| Coastal Dike (with revetment) | 1,100 m (EL 13.5 m, 2.5 m in height) |
| River Dike (with revetment) | 3,600 m (Raising of existing dike by 1 m) |
| Parapet Wall | 8,500 m (Raising of existing parapet wall by 1 m) |
| Channel Improvement | 700 m |
| Open Channel Construction | 900 m |
| Closed Channel Construction | 800 m |
| Pump Station | 3 sites (10 cums in total*) |
| Gate | 5 sites |

* Estimated under the land use condition of the year 2000.

### 5.2.7 Inundation Water Level

To estimate the inundation damage reduction after completion of the proposed project, the inundation water levels in each of the subdrainage areas were estimated under the with- and the without-the-project situations as in the Master Plan. The estimation results are in Table 5-5-5.