# M. GUIDELINE FOR DRAINAGE IMPROVEMENT

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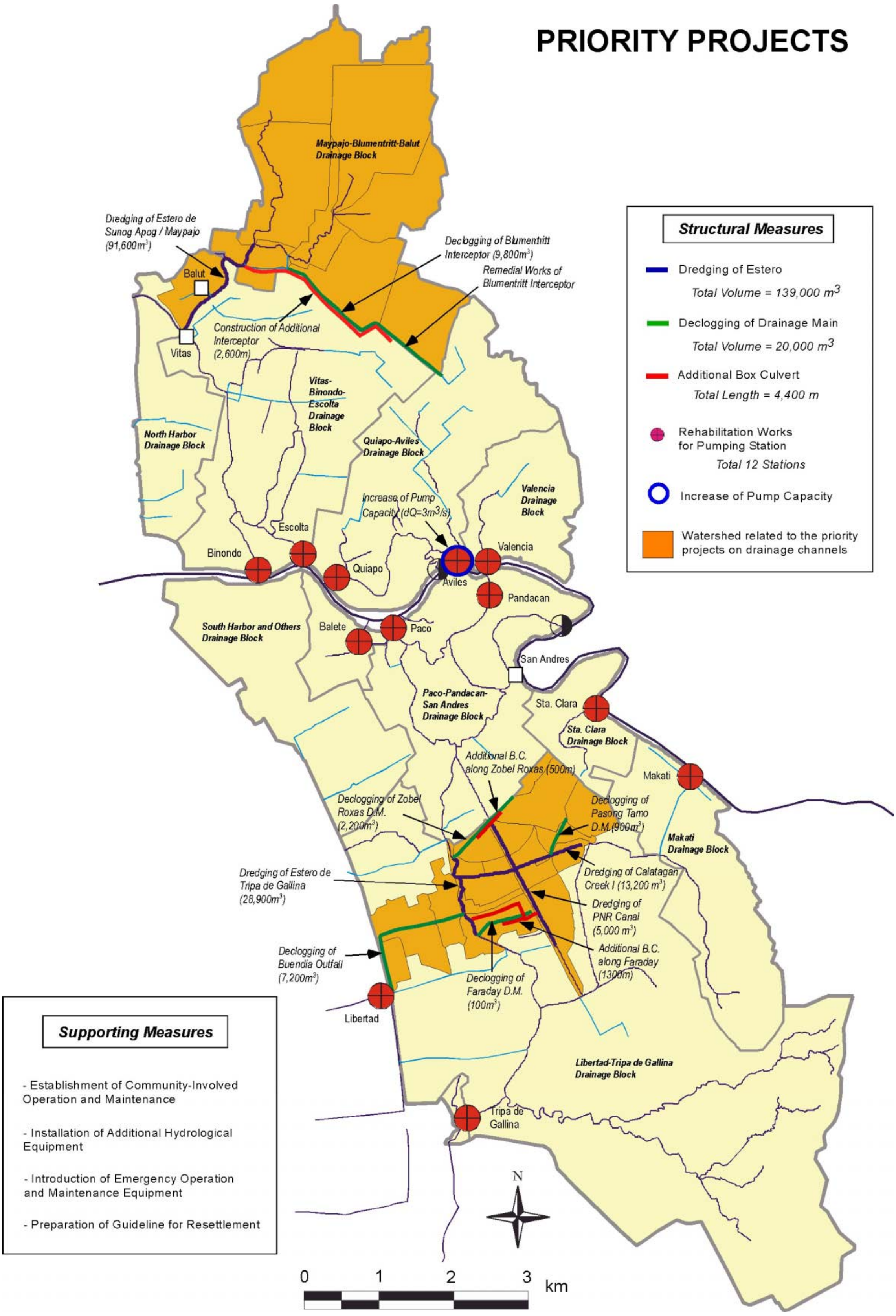
Vitas
Binondo
Escolta
Quiapo
Aviles
Valencia
Pandacan
Balete
Paco
San Andres
Sta. Clara
Makati
Libertad
Tripa de Gallina
Pump Gates
N
0
1
2
3
km

# PRIORITY PROJECTS



# M.1 INTRODUCTION

## M.1.1 BACKGROUND

The basic scheme of drainage improvement in the core area of Metropolitan Manila is based on the "Plan for the Drainage of Manila and Suburbs", prepared by the then Bureau of Public Works in 1952, which is composed of flood control and stormwater drainage for the capital area and reviewed by international agencies in the 1960s. The major flood control and drainage improvement works were really commenced by the ODA of the Government of Japan after the severe flood in 1972.

In line with the above scheme, the construction of Mangahan floodway and 10 major drainage pumping stations were completed by 1984 and 5 more major drainage pumping stations were completed in 1997. Accordingly, the floods from the Pasig River and inundation problems in the core area have been reduced significantly. However, it was observed during the 1999 floods that there remained severe inundation areas regionally and locally. Such floods and inundations caused heavy traffic congestion and disturbed commercial activities and urban living in the core area. The further drainage improvement is one of the major tasks in the core area of Metropolitan Manila.

For coping with such problems, the Study on Drainage Improvement in the Core Area of Metropolitan Manila was conducted in the period of February 2004 to March 2005, which was agreed upon among the Metropolitan Manila Development Authority (MMDA), the Department of Public Works and Highways (DPWH) and the Japan International Cooperation Agency (JICA). The Study formulated a Master Plan of Comprehensive Drainage Improvement for the Core Area of Metropolitan Manila and conducted a Feasibility Study for Priority Projects identified in the Master Plan.

## M.1.2 PROPOSED MASTER PLAN AND PRIORITY PROJECTS

The proposed drainage improvement plan is composed of structural, non-structural and supporting measures. The structural measures consist of rehabilitation and additional works.

The rehabilitation works are to recover original flow area of drainage channels by dredging/declogging and to revive smooth operation of drainage pumping stations by replacement/repair of pump equipment and appurtenant facilities. The additional works are to improve the present poor systems in severe inundation areas by construction of new channels.

The non-structural and supporting measures are proposed to support and sustain the recovered functions of drainage channels and pumping stations. As the non-structural measures, countermeasures for rapid urbanization and application of existing floodplain management are recommended. On the other hand, improvement of operation and maintenance organization and activities of drainage system, installation of equipment and facilities for effective O & M, community-involved solid waste management and O & M, preparation of guideline for resettlement are proposed as supporting countermeasures.

### M.1.3 IMPLEMENTATION OF THE PROJECTS

Projects proposed in the master plan are to be conducted for 15 years aiming at the year of 2020. Meantime, the priority projects for urgent implementation are scheduled in the period of 2005 to 2010.

It is planned that the projects identified in the master plan including resettlement of informal settlers residing in the open channels are to be implemented by a Coordination Committee System consisting of related member agencies. DPWH and MMDA are major responsible agencies for structural, non-structural and supporting measures as implementing body.

### M.1.4 OBJECTIVE AND COMPOSITION OF THE GUIDELINE

For consideration of technical aspect of drainage improvement, the respective "Design Guidelines, Criteria and Standards" prepared by DPWH and the "Technical Standards and Guidelines for Planning and Design, Volume II: Urban Drainage" prepared by the Project ENCA, etc., are available in the Philippines.

This Guideline was prepared as a basic reference aiming at smooth and effective implementation of the proposed projects, and gives more emphasis to the necessary considerations and procedures for further drainage improvement including operation and maintenance activities of the constructed channels and facilities in the core area of Metropolitan Manila.

The composition of the guideline is as follows.

M.1: Introduction
M.2: Investigation, Planning and Designing of Drainage Improvement
M.3: Construction Management
M.4: Operation and Maintenance

## M.2 INVESTIGATION, PLANNING AND DESIGNING OF DRAINAGE IMPROVEMENT

In the 1940s, the then Bureau of Public Works (BPW, the present DPWH) initiated flood control and drainage improvement in Metropolitan Manila. Since then, various flood control and drainage improvement works have been made so far. Owing to implementation of such improvement works, flood control and drainage situations in Metropolitan Manila have been so much improved. However, frequent inundations still remain in the core area. To cope with such situations, further drainage improvement is one of the major tasks in the core area of Metropolitan Manila.

For further consideration and procedure for drainage improvement in the core area of Metropolitan Manila, major items obtained through the present study are described in this chapter. The contents of this chapter are 1) Overall work flow for drainage improvement, 2) Investigation and study, 3) Basic planning concept for drainage improvement, 4) Proposed structural measures for drainage facilities of esteros/creeks and box culverts, 5) Proposed structural measures for drainage pumping stations, 6) Proposed non-structural and supporting measures, and 7) Designing of drainage facilities of box culvert in priority projects.

### M.2.1 OVERALL WORK FLOW FOR DRAINAGE IMPROVEMENT

In planning and designing of drainage improvement works, it is important to grasp and understand the present conditions of drainage system and related natural and social aspects in the core areas of Metropolitan Manila by investigation and study. Study items will be various characteristics of socio-economy, topography, hydrology and hydraulics, finance, implementing and operation and maintenance organizations, laws and regulations, etc. Throughout the investigation and study, drainage problem structures of the core area will be clarified. Subsequently, drainage improvement plan and works are to be formulated so as to cope with clarified problems and constraints. In this section, technical aspects of drainage improvement are mainly explained. Overall study flow including those of further implementation stages of detailed design, construction and operation & maintenance are outlined below.

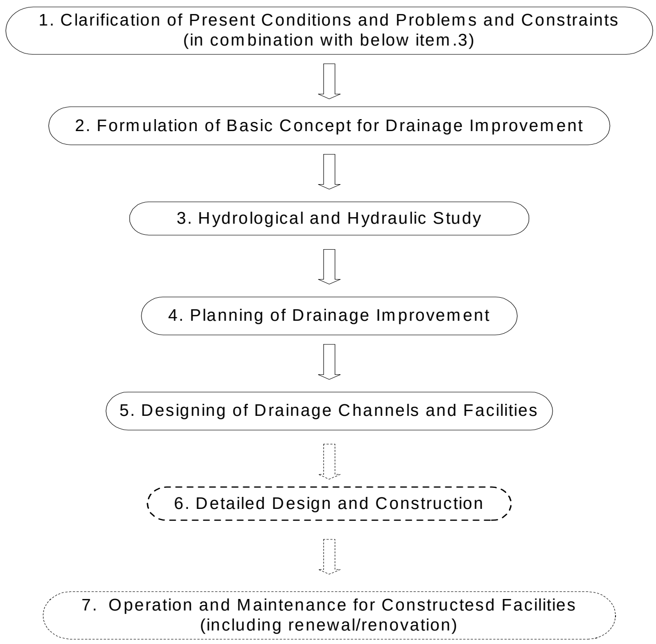


*Figure M.2.1* shows general study flow of drainage improvement in the core area of Metropolitan Manila.

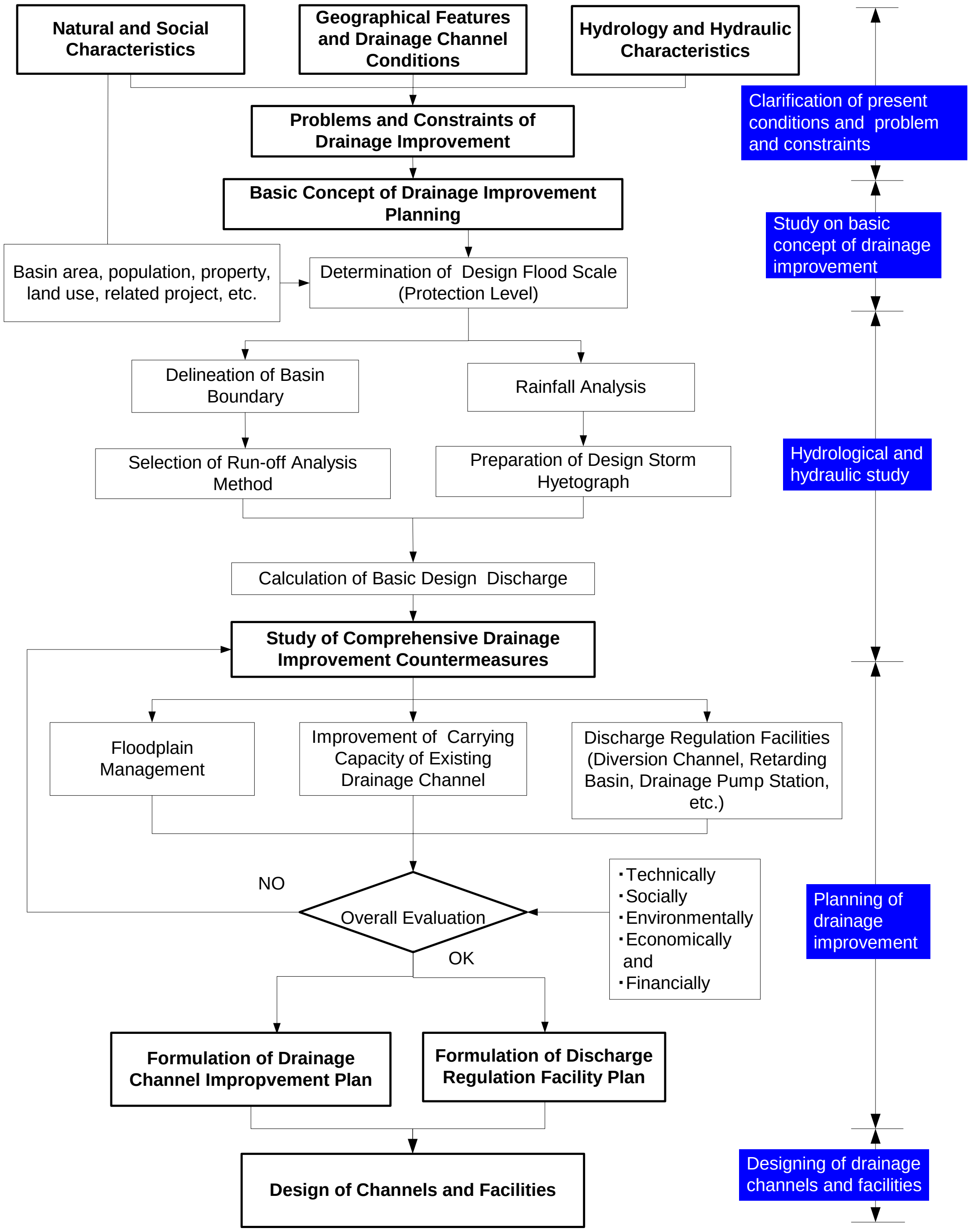



**Figure M.2.1 General Study Flowchart**

## M.2.2 INVESTIGATION AND STUDY

### (1) Characteristics of Present Drainage System

Characteristics of present drainage system and conditions within the core area of Metropolitan Manila have been investigated and clarified. Those data are stored in the developed GIS DATABASE, which includes drainage basins, drainage facilities, inundation condition, topography, socio-economy, and other related data. The GIS database consists of 4 major hierarchies: 1) data on drainage management system, 2) data on ArcView, 3) reference data and 4) collected data. The developed database is an effective and useful tool in consideration and procedure for further drainage improvement and management of drainage system in the core area and it is expected that updates are performed on them for future use. Major items are described below.

### (2) Drainage system

The terminology of the drainage channels and facilities has been defined in the guideline as shown in *Table M.2.1*.

**Table M.2.1 Definition of Drainage Channels and Facilities**

| | |
|---|---|
| ***Esteros / Creeks*** | *Open channels* |
| ***Drainage mains*** | *Closed channels consisting of one or two box culverts mostly connected to esteros* |
| ***Outfalls*** | *Drainage mains directly connected to Manila Bay or the Pasig River* |
| ***Laterals*** | *Small drainage channels other than above* |
| ***Drainage pumping stations*** | *Drainage facilities that drain stormwater mechanically* |
| ***Floodgates*** | *Gate to control discharging stormwater from esteros to the Pasig River when the water level at the Pasig River is lower than those in esteros* |
| ***Control gates*** | *Gate that controls the flow direction in esteros as boundary of drainage block* |
| ***Control walls*** | *Earth or concrete dike that controls flow direction in esteros as boundary of drainage block* |
| ***Detention ponds*** | *Pond that retards stormwater for drainage pumping stations* |
| ***Interceptors*** | *Man-made channel that intercepts and drains stormwater into esteros, the Pasig River and Manila Bay* |

The total catchment area of the drainage system in the core area is about 73 km$^2$. The drainage system in the core area is geographically divided by the Pasig River into two areas: South Manila (south or left bank of Pasig River) and North Manila (north or right bank of Pasig River).

The existing drainage area in North Manila is divided into 5 drainage blocks with a total catchment area estimated at 28.78 km$^2$ as shown in *Figure M.2.2*. Major dimensions of each drainage block are summarized in *Table M.2.2.*

The existing drainage area in the South Manila area is divided into 6 drainage blocks as shown in *Figure M.2.3*, with a total catchment area estimated at 43.80 km$^2$. Major dimensions of each drainage block are summarized in *Table M.2.3*.

**Table M.2.2 Major Dimensions of Each Drainage Block in North Manila**

| *ID* | *Name of Drainage Block* | *Area (km²)* | *Total Length of Esteros /Creeks (km)* | *Total Length of Drainage Mains (km)* |
|---|---|---|---|---|
| *N01* | *Vitas-Binondo-Escolta* | *8.55* | *13.14* | *6.62* |
| *N02* | *Quiapo-Aviles* | *5.58* | *6.77* | *3.90* |
| *N03* | *Valencia* | *2.37* | *1.22* | *0.67* |
| *N04* | *Maypajo-Blumentritt-Balut* | *9.91* | *6.65* | *4.13* |
| *N05* | *North Harbor* | *2.37* | *0.00* | *2.46* |
|  | *Total* | *28.78* | *27.78* | *17.78* |

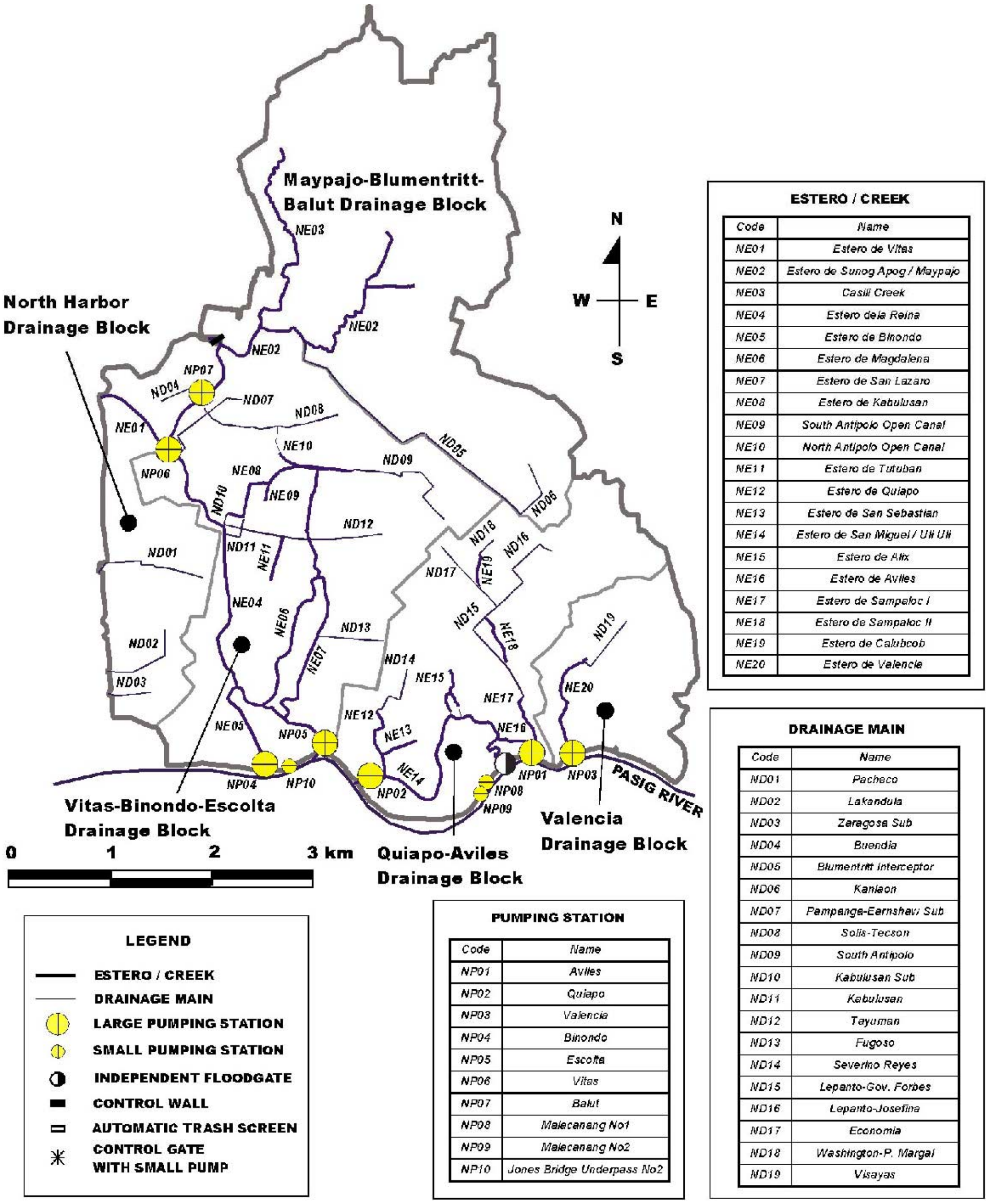



**Figure M.2.2 Existing Drainage System in North Manila**

**Table M.2.3 Major Dimensions of Each Drainage Block in South Manila**

| *ID* | *Name of Drainage Block* | *Area ($km^2$)* | *Total Length of Esteros /Creeks (km)* | *Total Length of Drainage Mains (km)* |
|---|---|---|---|---|
| *S01* | *Libertad-Tripa de Gallina* | *25.96* | *29.80* | *11.02* |
| *S02* | *Balete* | *0.94* | *0.55* | *0.00* |
| *S03* | *Paco-Pandacan-San Andres* | *6.12* | *10.59* | *1.10* |
| *S04* | *Sta. Clara* | *1.57* | *1.49* | *0.13* |
| *S05* | *Makati* | *4.31* | *2.56* | *2.24* |
| *S06* | *South Harbor and Others* | *4.90* | *0.73* | *2.51* |
| | *Total* | *43.80* | *45.72* | *17.00* |

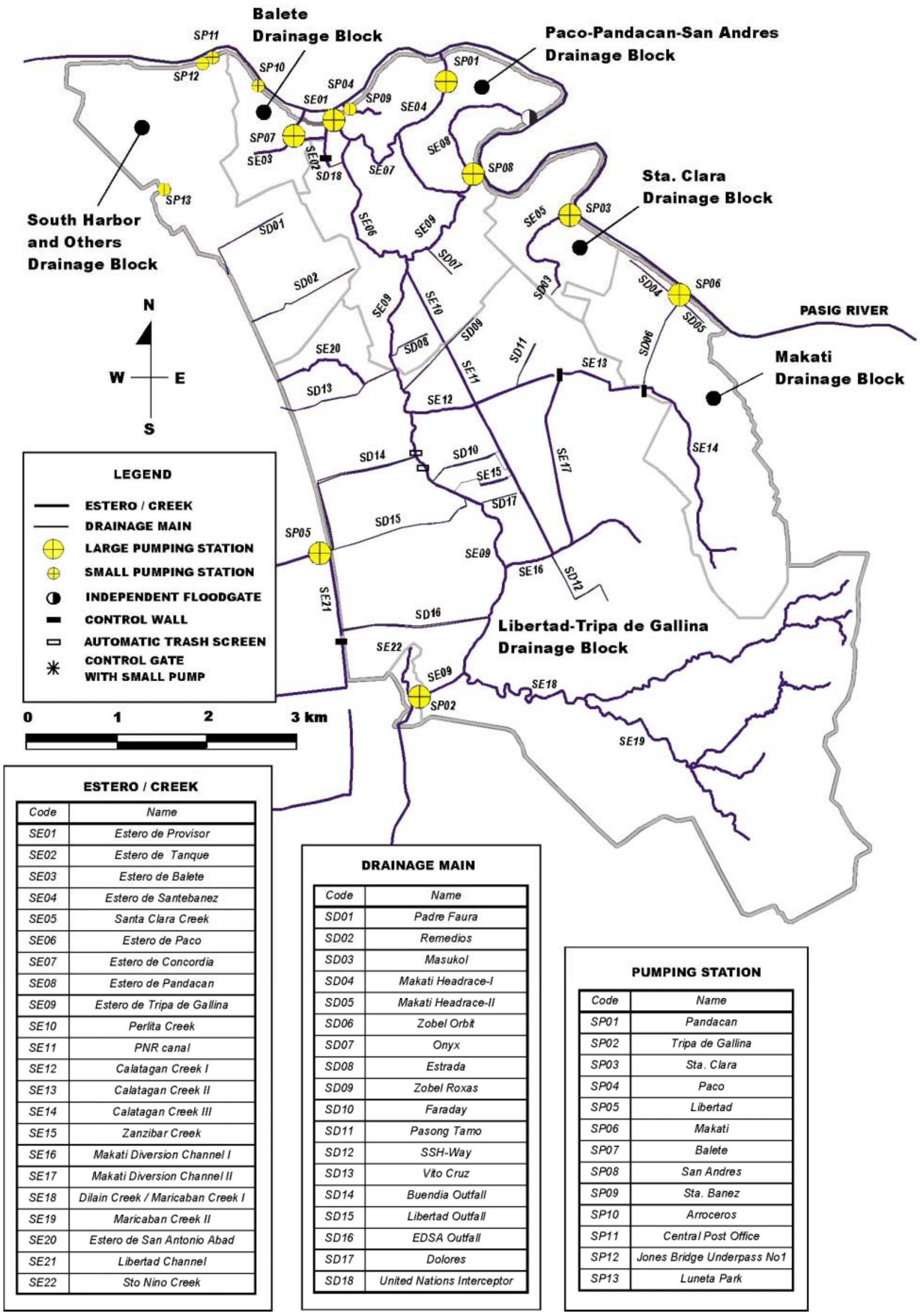



**Figure M.2.3 Existing Drainage System in South Manila**

### (3) DIMENSIONS OF CHANNELS AND DRAINAGE PUMPING STATIONS

In the core area of Metropolitan Manila, stormwater is drained mostly by means of pumping stations covering about 52 km$^2$ (71%) of the total area of 73 km$^2$. *Figure M.2.4* shows the drainage area that is drained by pumping stations.

There exist 15 large drainage pumping stations in the core area of Metropolitan Manila. The area of each drainage basin is shown in *Table M.2.4* together with capacity of pumping stations.

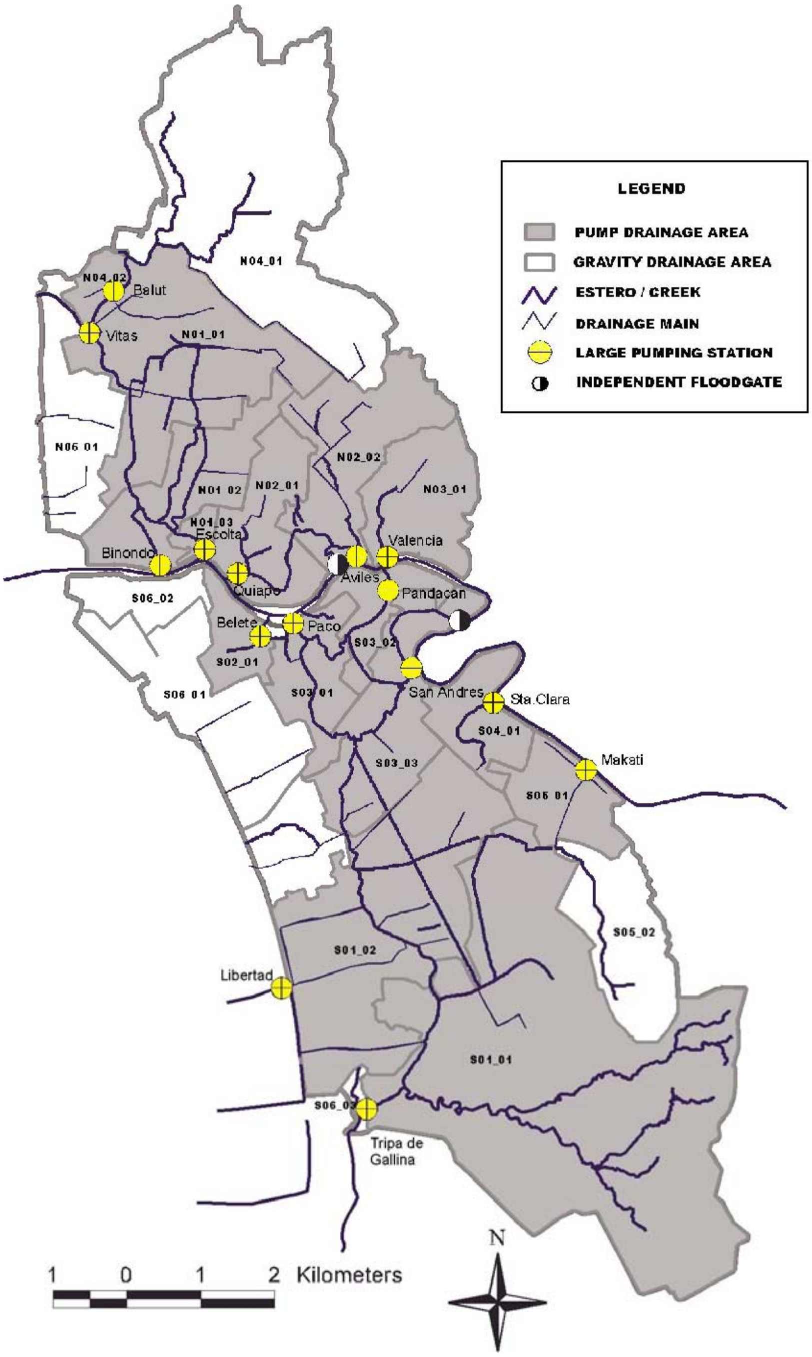



**Figure M.2.4 Drainage Area Drained by Pumping Stations**

**Table M.2.4 Capacity and Area of Drainage Basin of Pumping Stations**

| *Basin_ID* | *Name of Pumping Station* | *Drainage Area[*1] ($km^2$)* | *Capacity ($m^3/s$)* | *Specific Discharge ($m^3/s/km^2$)* |
|---|---|---|---|---|
| *N01_01* | *Vitas* | *5.56* | *32.0* | *5.76* |
| *N01_02* | *Binondo* | *2.69* | *11.6* | *4.31* |
| *N01_03* | *Escolta* | *0.30* | *1.5* | *5.07* |
| *N02_01* | *Quiapo* | *2.29* | *10.8* | *4.71* |
| *N02_02* | *Aviles* | *3.28* | *15.6* | *4.75* |
| *N03_01* | *Valencia* | *2.37* | *11.8* | *4.98* |
| *N04_02* | *Balut* | *0.49* | *2.0* | *4.05* |
| *S01_01* | *Tripa de Gallina[*2]* | *17.05* | *57.0* | *3.34* |
| *S01_02* | *Libertad[*2]* | *7.48* | *42.0* | *5.61* |
| *S02_01* | *Balete* | *0.94* | *3.0* | *3.19* |
| *S03_01* | *Paco* | *1.74* | *7.6* | *4.37* |
| *S03_02* | *Pandacan* | *1.15* | *4.4* | *3.84* |
| *S03_03* | *San Andres* | *3.23* | *19.0* | *5.88* |
| *S04_01* | *Sta. Clara* | *1.57* | *5.3* | *3.38* |
| *S05_01* | *Makati* | *1.65* | *7.0* | *4.24* |

Note: [*1] Based upon the review by JICA Study Team
[*2] Drainage boundary of Tripa de Gallina and Libertad is quite unclear. Stormwater in these drainage areas is actually drained by the two pumping stations working together.

The identified existing esteros/creeks and drainage mains are shown in *Figures M.2.3* and *M.2.4*. There are 20 esteros/creeks in North Manila and 22 esteros/creeks in South Manila. *Table M.2.5* summarizes main dimensions of esteros/creeks. There exist 18 and 19 drainage mains in North Manila and in South Manila, respectively. The dimensions of the drainage mains are summarized in *Table M.2.6*.

### Table M.2.5 Main Dimensions of Esteros/Creeks

| Block_ID | Code | Name | Length (m) | Width (m) | Source |
|---|---|---|---|---|---|
| N01 | NE01 | Estero de Vitas (*1) | 1990 | 15 - 72 | a |
| | NE04 | Estero dela Reina | 3020 | 8-21 | a |
| | NE05 | Estero de Binondo | 1040 | 15 -32 | a |
| | NE06 | Estero de Magdalena | 1510 | 5 - 36 | b |
| | NE07 | Estero de San Lazaro | 2830 | 3 - 16 | b |
| | NE08 | Estero de Kabulusan | 690 | 9 | b |
| | NE09 | South Antipolo Open Canal | 830 | 2.5 - 7 | b |
| | NE10 | North Antipolo Open Canal | 780 | 3 - 4.5 | b |
| | NE11 | Estero de Tutuban | 450 | 2 - 2.5 | a |
| N02 | NE12 | Estero de Quiapo | 1120 | 12 - 26 | b |
| | NE13 | Estero de San Sebastian | 380 | 6 - 12 | b |
| | NE14 | Estero de San Miguel / Uli-Uli | 2670 | 7.5 - 21 | b |
| | NE15 | Estero de Alix | 650 | 2.5 - 3 | a |
| | NE16 | Estero de Aviles | 380 | 4.5 - 11 | b |
| | NE17 | Estero de Sampaloc I | 720 | 8 -16 | b |
| | NE18 | Estero de Sampaloc II | 510 | 2 -10 | a |
| | NE19 | Estero de Calubcob | 340 | 9 - 10 | b |
| N03 | NE20 | Estero de Valencia | 1220 | 5 - 27 | a |
| N04 | NE02 | Estero de Sunog Apog / Maypajo | 4270 | 5 -72 | b |
| | NE03 | Casili Creek | 2380 | 2.5 - 7.5 | b |
| S01 | SE09 | Estero de Tripa de Gallina (*2) | 7640 | 4 - 30 | a |
| | SE11 | PNR canal | 2660 | 1.5 - 3 | b |
| | SE12 | Calatagan Creek I | 1710 | 4.5 - 8 | b |
| | SE13 | Calatagan Creek II | 1000 | 6 - 8.5 | b |
| | SE15 | Zanzibar Creek | 330 | 5 - 7.5 | b |
| | SE16 | Makati Diversion Channel I | 1790 | 4 - 10 | b |
| | SE17 | Makati Diversion Channel II | 1990 | 6.5 - 10 | b |
| | SE18 | Dilain Creek / Maricaban Creek I | 6320 | 5 -15 | b |
| | SE19 | Maricaban Creek II | 4240 | 6 - 25 | b |
| | SE20 | Estero de San Antonio Abad | 1220 | 3 - 6 | a |
| | SE21 | Libertad Channel | 900 | 15 - 20 | a |
| S02 | SE03 | Estero de Balete | 550 | 6 - 12 | a |
| S03 | SE01 | Estero de Provisor | 1020 | 15 - 26 | a |
| | SE02 | Estero de Tanque | 340 | 5 - 25 | a |
| | SE04 | Estero de Santa Banez | 520 | 4 - 10 | a |
| | SE06 | Estero de Paco | 2400 | 6 - 23 | b |
| | SE07 | Estero de Concordia | 1070 | 3 - 18 | a |
| | SE08 | Estero de Pandacan | 4320 | 3 - 16 | a |
| | SE10 | Perlita Creek | 920 | 3 - 4 | b |
| S04 | SE05 | Santa Clara Creek | 1490 | 3 - 8 | a |
| S05 | SE14 | Calatagan Creek III | 2560 | 5.5 - 7 | b |
| S06 | SE22 | Sto. Nino Creek | 730 | N/A | N/A |

*Source* a: JICA Study Team, b: SEDLMM database (2000)

*Note* *1: This is included also in N04. *2: This is included also in S02.

# Table M.2.6 Dimensions of Drainage Mains (1/2)

| Basin_ID | Code | Name | Length (m) | Location of manhole (m) | Type | Number of Cell | Width (m) | Depth (m) or Diameter (m) |
|---|---|---|---|---|---|---|---|---|
| N01_01 | ND07 | Pampanga-Earnshaw Sub | 1040 | 44 - 501 | Box Culvert | 2 | 2.60 - 2.80 | 2.40 - 3.36 |
| | | | | 652 - 1037 | Box Culvert | 1 | 2.20 - 3.20 | 2.20 - 2.40 |
| | ND08 | Solis-Tecson | 1430 | 0 - 60 | Box Culvert | 1 | 2.00 | 1.30 - 1.52 |
| | | | | 166 - 1004 | Box Culvert | 2 | 1.50 - 2.00 | 1.09 - 1.53 |
| | | | | 1041 - 1359 | Box Culvert | 1 | 2.00 | 1.15 - 1.48 |
| | | | | 1428 | Pipe | 1 | | 1.02 |
| | ND09 | South Antipolo | 1380 | 0 - 1218 | Box Culvert | 1 | 3.00 - 4.50 | 1.85 - 2.67 |
| | | | | 1375 | Box Culvert | 1 | 2.00 | 2.14 |
| | ND10 | Kabulusan Sub | 130 | 14 - 142 | Box Culvert | 1 | 2.81 | 2.40 |
| | ND11 | Kabulusan | 360 | 8 - 367 | Box Culvert | 1 | 3.35 - 5.80 | 2.00 - 2.70 |
| | ND12 | Tayuman | 1600 | 0 -692 | Box Culvert | 1 | 2.12 - 3.10 | 1.36 - 2.40 |
| | | | | 875-1303 | Box Culvert | 1 | 1.85-1.91 | 1.48 - 1.89 |
| N01_02 | ND13 | Fugoso | 670 | 0 - 365 | Box Culvert | 2 | 2.00 - 2.20 | 1.63 - 2.87 |
| | | | | 470 - 546 | Box Culvert | 1 | 2.80 - 3.00 | 1.50 |
| N02_01 | ND14 | Severino Reyes | 640 | 70 - 220 | Box Culvert | 1 | 3.10 - 3.20 | 1.60 |
| | | | | 332 - 648 | Box Culvert | 1 | 2.65 - 3.20 | 1.60 - 1.77 |
| N02_02 | ND15 | Lepanto-Gov. Forbes | 1160 | 0 - 1160 | Box Culvert | 3 | 3.40 - 4.00 | 1.75 - 3.15 |
| | ND16 | Lepanto-Josefina | 1060 | 0 | Box Culvert | 3 | 3.40 | 2.24 |
| | | | | 133 - 223 | Box Culvert | 2 | 2.00 - 2.12 | 2.00 - 2.24 |
| | | | | 916 - 1021 | Box Culvert | 1 | 4.10 - 4.30 | 3.00 - 3.24 |
| | ND17 | Economia | 820 | 0 - 232 | Box Culvert | 3 | 2.30 - 3.40 | 2.25 - 2.70 |
| | | | | 555 - 695 | Box Culvert | 1 | 1.40 - 1.53 | 2.20 - 2.70 |
| | ND18 | Washington-P. Margal | 200 | 12 - 167 | Box Culvert | 1 | 2.80 | 2.37 - 2.48 |
| N03_01 | ND19 | Visayas | 670 | 2 - 324 | Box Culvert | 2 | 2.00 | 2.00 |
| | | | | 403 - 573 | Box Culvert | 2 | 1.70 | 1.70 |
| | | | | 673 | Box Culvert | 1 | 2.90 | 1.60 |
| N04_01 | ND05 | Blumentritt Interceptor | 2980 | 10 - 1463 | Box Culvert | 2 | 1.20 - 2.62 | 2.00 - 2.63 |
| | | | | 2276 - 2840 | Box Culvert | 2 | 1.40 - 2.15 | 1.57 - 2.25 |
| | | | | 2978 | Box Culvert | 1 | 2.10 | 1.44 |
| | ND06 | Kanlaon | 630 | 0 | Box Culvert | 1 | 2.19 | 1.44 |
| | | | | 328 - 459 | Pipe | 1 | | 0.61 |
| | | | | 483 | Box Culvert | 1 | 0.762 | 0.762 |
| N04_02 | ND04 | Buendia | 390 | 125 - 293 | Box Culvert | 1 | 2.50 - 3.00 | 1.93 - 2.40 |
| | | | | 437 - 511 | Box Culvert | 1 | 2.50 - 3.00 | 1.66 - 1.67 |
| N05_01 | ND01 | Pacheco | 1160 | 0 - 866 | Box Culvert | 1 | 4.00 - 4.40 | 1.60 - 2.72 |
| | | | | 913 - 1041 | Box Culvert | 1 | 3.00 | 0.74 - 1.75 |
| | ND02 | Lakandula | 870 | 0 -212 | Box Culvert | 1 | 3.84 - 4.20 | 2.01 - 2.62 |
| | | | | 740 - 873 | Pipe | 1 | | 1.07 |
| | ND03 | Zaragosa Sub | 430 | 0 - 429 | Pipe | 1 | | 0.91 |

**Note** 1) Dimensions are basically based uopn SEDLMM database (2000).

# Table M.2.6 Dimensions of Drainage Mains (2/2)

| Basin_ID | Code | Name | Length (m) | Location of manhole (m) | Type | Number of Cell | Width (m) | Depth (m) or Diameter (m) |
|---|---|---|---|---|---|---|---|---|
| S01_01 | SD12 | SSH-Way | 1100 | 5 - 568 | Box Culvert | 1 | 3.00 - 5.30 | 2.50 - 3.70 |
| | | | | 741 | Box Culvert | 1 | 2.00 | 0.95 |
| | | | | 900 - 1108 | Pipe | 1 | | 1.07 - 1.52 |
| S01_02 | SD09 | Zobel Roxas | 1150 | 0 - 725 | Box Culvert | 1 | 2.80 - 4.40 | 1.22 - 2.52 |
| | | | | 764 - 1157 | Pipe | 1 | | 1.22 |
| | SD10 | Faraday | 790 | 30 - 453 | Box Culvert | 2 | 1.50 - 1.96 | 0.91 - 1.29 |
| | | | | 567 - 821 | Pipe | 2 | | 0.85 - 1.07 |
| | SD11 | Pasong Tamo | 540 | 0 - 303 | Box Culvert | 1 | 3.50 - 4.05 | 1.55 - 1.90 |
| | SD14 | Buendia Outfall | 1970 | 15 - 1977 | Box Culvert | 2 | 3.50 - 3.80 | 2.50 - 3.25 |
| | SD15 | Libertad Outfall | 1780 | 14 - 1697 | Box Culvert | 1 | 3.00 - 4.80 | 2.35 - 3.13 |
| | SD16 | EDSA Outfall | 1700 | 25 - 911 | Box Culvert | 2 | 4.20 - 4.95 | 2.43 - 3.09 |
| | SD17 | Dolores | 430 | 0 - 430 | Box Culvert | 1 | 1.80 (*1) | 2.50 (*1) |
| S01_03 | SD13 | Vito Cruz | 1450 | 200 - 941 | Box Culvert | 1 | 1.52 - 2.00 | 1.30 - 1.63 |
| S03_01 | SD18 | United Nations Interceptor | 150 | 0 - 150 | Box Culvert | 1 | - | - |
| S03_03 | SD07 | Onyx | 410 | 6 - 413 | Box Culvert | 1 | 2.50 - 2.60 | 1.30 - 2.15 |
| | SD08 | Estrada | 510 | 4 - 306 | Box Culvert | 1 | 2.50 - 2.83 | 1.20 - 1.67 |
| | | | | 388 | Pipe | 1 | | 1.25 |
| S04_01 | SD03 | Masukol | 130 | 0 - 130 | Box Culvert | 1 | 3.00 (*1) | 2.00 (*1) |
| S05_01 | SD04 | Makati Headrace-I | 630 | 0 - 626 | Box Culvert | 1 | 4.06 - 5.20 | 2.30 - 2.50 |
| | SD05 | Makati Headrace-II | 400 | 0 - 265 | Box Culvert | 1 | 2.97 - 3.54 | 1.95 - 2.63 |
| S05_02 | SD06 | Zobel Orbit | 1170 | 0 - 541 | Box Culvert | 1 | 4.90 - 5.18 | 2.97 - 3.10 |
| S06_01 | SD01 | Padre Faura | 1160 | 0 - 374 | Box Culvert | 1 | 3.30 - 3.47 | 2.30 - 2.70 |
| | | | | 577 - 650 | Box Culvert | 1 | 2.20 - 2.70 | 2.03 - 2.37 |
| | | | | 982 - 1070 | Box Culvert | 1 | 2.20 | 1.33 - 1.88 |
| | SD02 | Remedios | 1350 | 0 - 418 | Box Culvert | 1 | 4.40 | 2.26 - 3.20 |
| | | | | 1082 | Box Culvert | 1 | 2.60 | 1.28 |
| | | | | 1348 | Pipe | 1 | | 1.22 |

***Note*** *1) Dimensions are basically based uopn SEDLMM database (2000).*

*2) *1: based upon inventory maps provided by MMDA*

## (4) Meteorological and Hydrological Analysis

### 1) Probable Rainfall

The results of probability of annual maximum short duration rainfalls at Port Area are summarized in *Table M.2.7*.

**Table M.2.7 Results of Probability Analyses on Annual Maximum Rainfalls**

***Port Area***

| Return Period (Years) | Probable Rainfall Depth (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Minutes | | | Hours | | | | | |
| | 10 | 30 | 60 | 2 | 6 | 12 | 24 | 48 | 72 |
| 2 | 20 | 39 | 54 | 76 | 110 | 136 | 153 | 219 | 256 |
| 3 | 23 | 45 | 62 | 88 | 131 | 162 | 184 | 268 | 318 |
| 5 | 26 | 51 | 70 | 101 | 154 | 192 | 218 | 324 | 387 |
| *10* | *30* | *59* | *81* | *118* | *183* | *229* | *260* | *394* | *474* |
| 20 | 34 | 67 | 92 | 134 | 211 | 264 | 301 | 461 | 558 |
| 30 | 36 | 72 | 98 | 143 | 226 | 285 | 324 | 499 | 606 |
| 50 | 39 | 77 | 106 | 155 | 246 | 310 | 354 | 548 | 665 |
| 100 | 43 | 85 | 116 | 171 | 273 | 345 | 393 | 613 | 746 |
| Sample (n) | 83 | 83 | 80 | 66 | 52 | 52 | 88 | 81 | 75 |

Period: 1903-2003

### 2) Rainfall Intensity-Duration-Frequency (RIDF) Curves at Port Area

Using the calculated probable rainfall depths, RIDF curves and equations for different return periods have been constructed as shown in *Table M.2.8*.

**Table M.2.8 Rainfall Intensity – Duration – Frequency Curves at Port Area Station**

| *RIDF Parameter* | *Values of RIDF Parameters for Different Return Periods* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *2-year* | *3-year* | *5-year* | *10-year* | *20-year* | *30-year* | *50-year* | *100-year* |
| *a* | *1054* | *1006* | *1105* | *1216* | *1281* | *1307* | *1419* | *1518* |
| *b* | *14* | *12* | *11* | *11* | *10* | *9* | *10* | *9* |
| *n* | *0.69* | *0.65* | *0.64* | *0.63* | *0.61* | *0.60* | *0.60* | *0.60* |

(Data: 1903 – 2003)

Equation of Rainfall Intensity-Duration-Frequency Curve: $R = a/(t+b)^n$

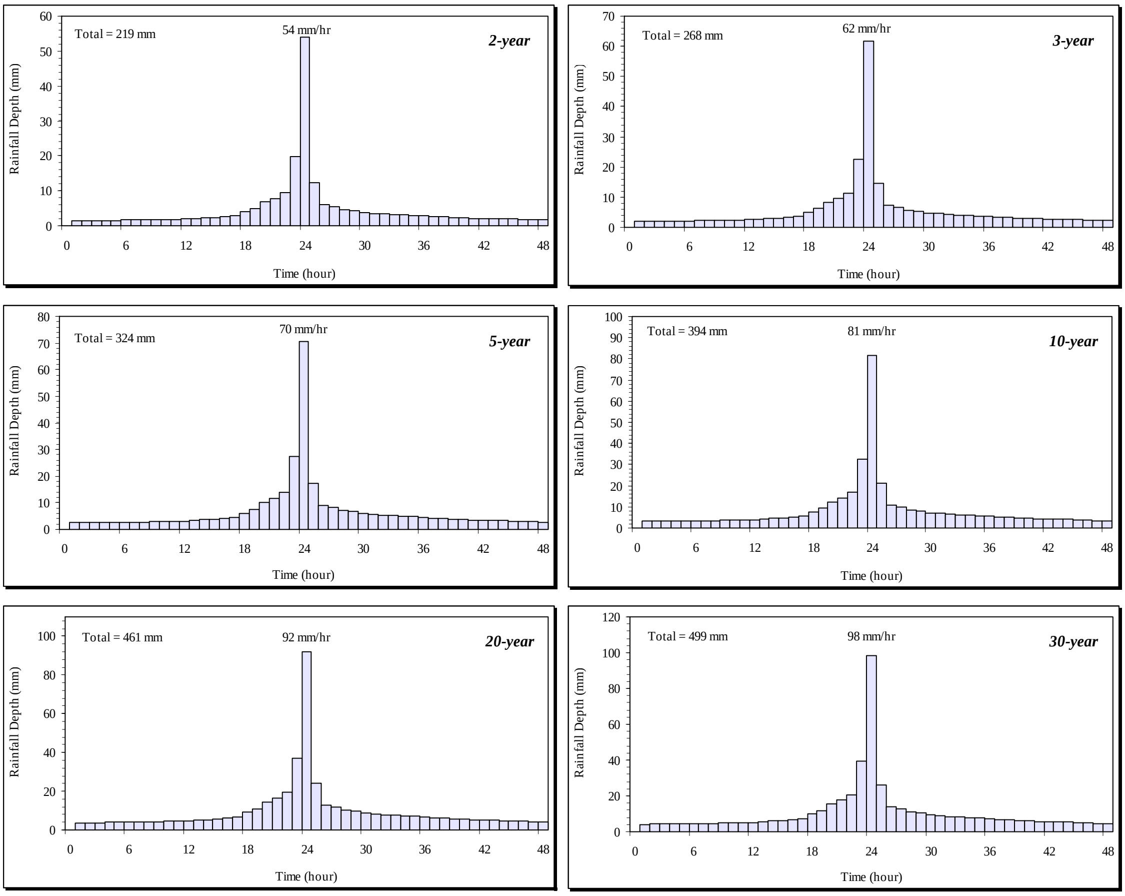
Where: R = Rainfall Intensity (mm/hr), t = Time (minutes), a, b, n = Parameters.

### 3) Design Rainfall Hyetograph

Design rainfall hyetographs with 1-hour time interval have been prepared for different return periods, considering averaged mass curve of annual maximum rainfall events for period 1982 to 2003 and RIDF curve, as shown in *Figure M.2.5*.

### 4) Areal Reduction Factor for Runoff Analysis

In order to take account of the spatial distribution of rainfall, areal reduction factor (ARF) has been applied to point rainfall data at Port Area. No areal reduction factor curve could be available for Metro Manila. However, World Meteorological Organization (WMO, 1983) has published typical depth-area-duration (DAD) curves, which have been updated by the Study for the core area using calculated values. The factor in the study area ranges from 0.95 to 1.0.




Source: Constructed by the Study based on probable rainfall depths calculated using data from 1903 ~ 2003.

**Figure M.2.5 Design Rainfall Hyetographs at Port Area Station**

### 5) Tide Level on Manila Bay

Daily variation in tide level at Manila South Harbor for year 1999 is shown in *Figure M.2.6*. It can be seen that highest tides occur in the months of July-September.

The mean tide values of 1970-1988 series are shown in *Table M.2.9.*

Historical maximum (EL. 11.91 m) and minimum (EL. 9.33m) tide levels were observed in July 12, 1972 and February 3, 1913, respectively.

### 6) Design Tide and Water Levels

Since July ~ August are the most critical months in terms of inundation when both tide level and rainfall are high, the annual maximum tide pattern averaged over the last five years has been selected as the design tide pattern. As for the maximum and minimum design tide levels, mean high spring tide (MHST) level of EL. 11.34 m and mean lower low water (MLLW) level of EL. 10.00 m have been applied. The design tide level is shown in *Table M.2.10*.

As for design water levels at the pump stations along the Pasig River and the Paranaque River, same design tide pattern as at Manila Bay with maximum water levels corresponding to 30-year return period (derived from previous studies since 30-year is the design scale of rivers surrounding the study area) and minimum water levels as calculated from the difference between MHST and MLLW at Manila Bay have been applied. The maximum water levels at the pump stations along the Pasig River and the Paranaque River are shown in *Table M.2.11*.

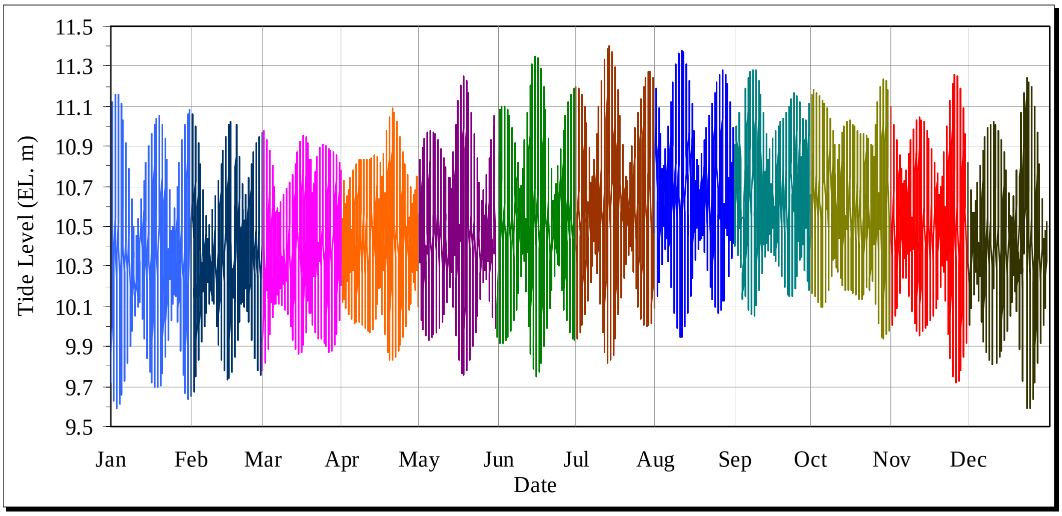



**Figure M.2.6 Daily Variation in Tide Level at Manila South Harbor for Year 1999**

**Table M.2.9 Tide Levels at Manila South Harbor, 1970 - 1988 Tide Series**

| *Series* | *Tide Levels (EL. m) (DPWH Datum)* |
|---|---|
| *MLLW* | *10.00* |
| *MLW* | *10.10* |
| *MHLW* | *10.20* |
| *MSL* | *10.47* |
| *MTL (MHW+MLW)/2* | *10.48* |
| *MLHW* | *10.71* |
| *MHW* | *10.86* |
| *MHHW* | *11.00* |
| *MHST* | *11.34* |
| *MR (MHW - MLW)* | *0.76* |

*Source:*

1) DPWH, The Study on Flood Control and Drainage System Improvement for Kalookan-Malabon-Navotas-Valenzuela (KAMANAVA) Areas, 1998
2) MPWH, Metro Manila Drainage System Rehabilitation Project (PH-66), Drainage Improvement Plans for Estero de Vitas and Other Catchment Areas, Supplementary Study Report, 1987
3) MPWH, Metro Manila Drainage System Rehabilitation Project, Study Report, 1988

*Definitions of Terms:*

MLLW = Mean Lower Low Water: Average of 1st low (lowest) water levels of a tidal day
MLW = Mean Low Water: Average of the maximum height reached by each rising tide
MHLW = Mean Higher Low Water: Average of 2nd low water levels of a tidal day
MSL = Mean Sea Level: The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings
MTL = Mean Tide Level: A plane midway between Mean High Water and Mean Low Water
MLHW = Mean Lower High Water: Average of 2nd low water levels of a tidal day
MHW = Mean High Water: Average of the minimum height reached by each falling tide
MHST = Mean High Spring Tide: Average of monthly 1st and 2nd high water levels (spring tides occurring at full and new moon SYZYGY)
MHHW = Mean Higher High Water: Average of 1st high (highest) water levels of a tidal day
MR = Mean Range: Difference in height between daily Mean High and Low Water

**Table M.2.10 Design Tide on Manila Bay**

| *Difference (hh:mm)* | *Time dd hh:mm* | *Tide Level (EL. M)* |
|---|---|---|
| *0:00* | *Day1 17:00* | *10.03* |
| *16:05* | *Day2 9:05* | *11.32* |
| *8:40* | *Day2 17:45* | *10.00* |
| *16:15* | *Day3 10:00* | *11.34* |
| *8:25* | *Day3 18:25* | *10.02* |
| *16:30* | *Day4 10:55* | *11.32* |
| *8:10* | *Day4 19:05* | *10.08* |
| *Maximum* | | *11.34* |
| *Minimum* | | *10.00* |

**Table M.2.11 Design Maximum Water Levels at Pump Stations**

| *Pumping Station* | *Binondo* | *Escolta* | *Quiapo* | *Balete* | *Paco* | *Aviles* |
|---|---|---|---|---|---|---|
| *Maximum Water Level* | *12.10* | *12.10* | *12.19* | *12.34* | *12.41* | *12.65* |
| *Pumping Station* | *Pandacan* | *Valencia* | *San Andres* | *Sta. Clara* | *Makati* | *Tripa de Gallina* |
| *Maximum Water Level* | *12.73* | *12.75* | *13.52* | *13.67* | *13.76* | *12.61* |

### (5) Categorization of Drainage Channels

The existing drainage channels: esteros/creeks, drainage mains, outfalls and laterals, are categorized due to their drainage functions or roles. The 15 large drainage pumping stations drain stormwater from about 70% of the core area. The esteros, which are directly connected to the pumping stations, are essential for the pump drainage system. These channels act not only as channels for discharging stormwater to pumping stations but also as regulating ponds of pumping stations. Therefore, they should be categorized as the trunk channels. The open and closed channels connecting to trunk channels are also important and categorized as the secondary channels. The rest of drainage channels except laterals are categorized as the tertiary channels. The existing channels are categorized as follows and the categorized ones are shown in *Figure M.2.7*.

- Trunk channel:
  Esteros which are directly connected with the major drainage pumping stations
- Secondary channel:
  Esteros, creeks, and drainage mains/outfalls/interceptor which discharge to trunk channel
- Tertiary channel:
  Other channels except for trunk and secondary channels and laterals
- Lateral:
  Drainage pipes and gutters

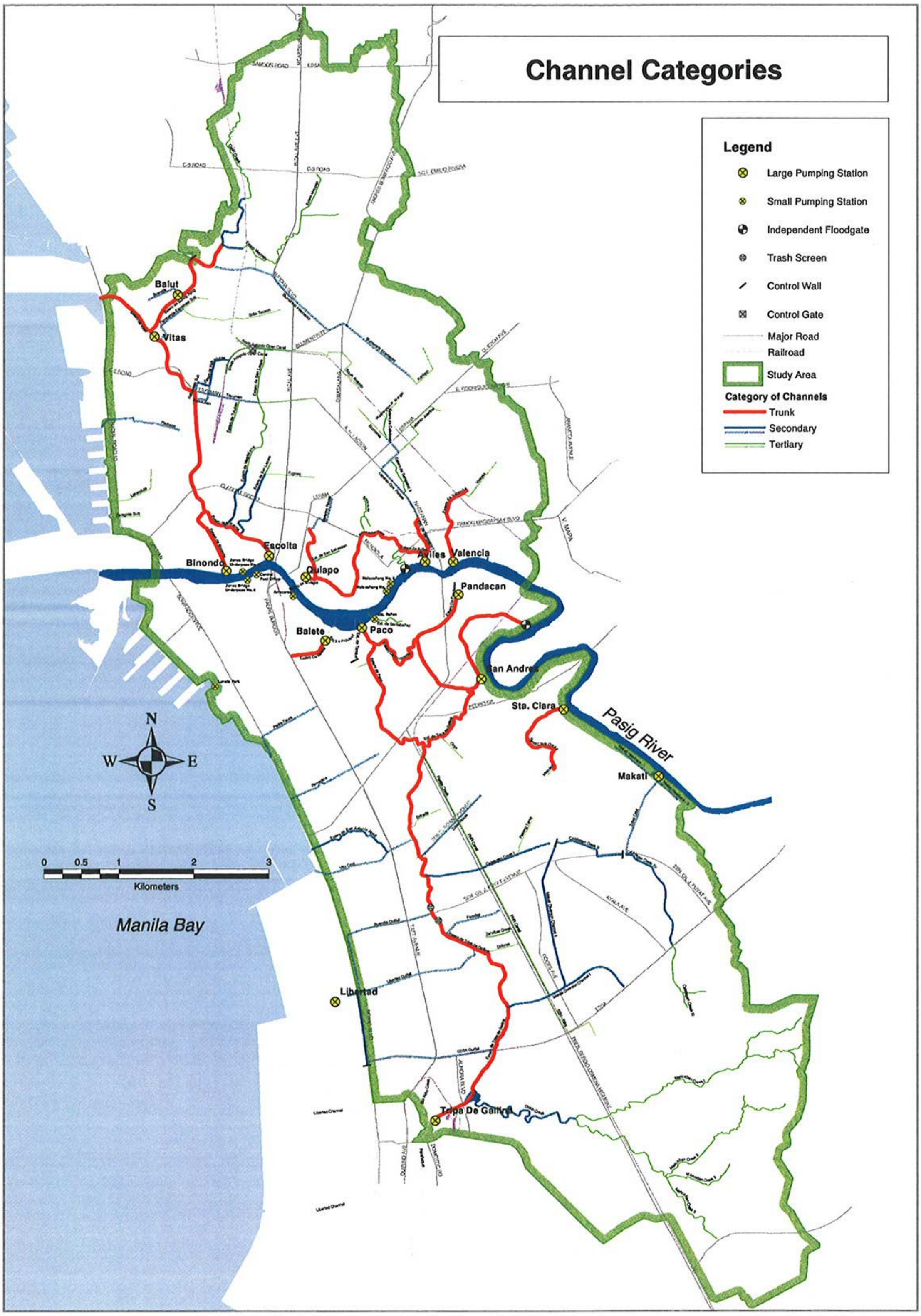



**Figure M.2.7 Categorized Drainage Channels**

### (6) Problems and Constraints

The core area of Metropolitan Manila has been mostly developed within the low-lying area formed by interaction of the behaviors of Pasig-Marikina River and the tidal action of Manila Bay. In view of geomorphologic and metrological characteristics in the core area of Metropolitan Manila, it can be said that the core area is subject to frequent flooding and inundations. Such vulnerability against flooding and inundations is encouraged by other social characteristics of densely populated areas extended over the core area, delay of implementation of countermeasures, improper and lack of operation and maintenance activities, etc. In addition, various illegal social activities are observed in the present system. They are dumping of solid waste and industrial waste, encroachment of houses and structures, etc. Thus, there are complicated circumstances behind the present drainage situations: <u>"Mega city Metropolitan Manila" facing "Mega Problems".</u> As a basic reference, the root of drainage problems in the core area of Metropolitan Manila is categorized as shown in *Figure M.2.8*.

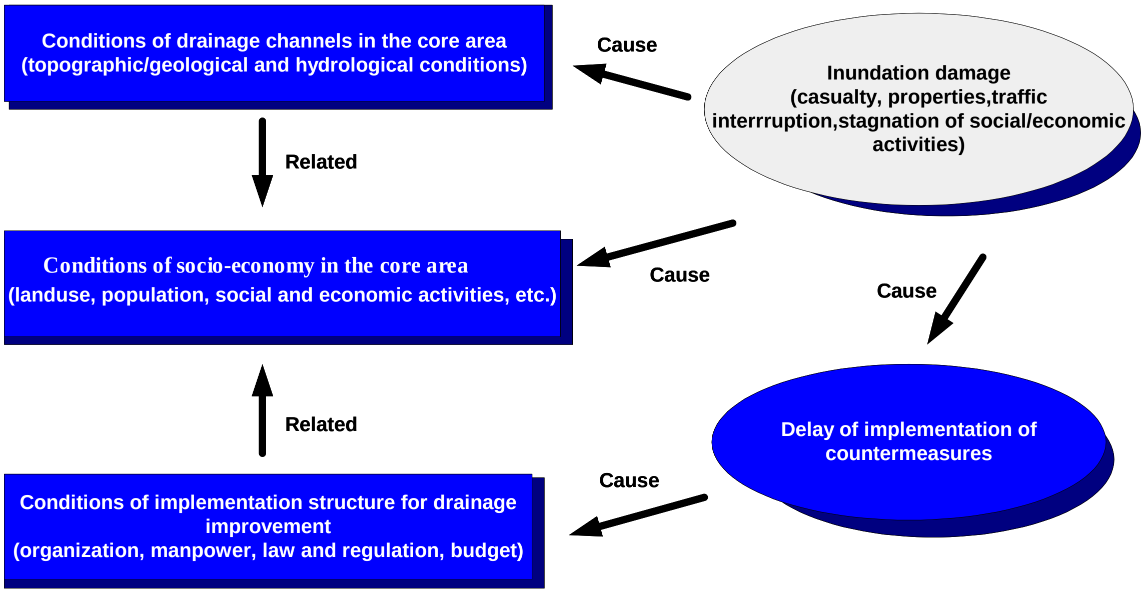



**Figure M.2.8 Drainage Problem Structure**

*Figure M.2.9* shows further detailed interrelationship of drainage problems and causes of inundations in the core area of Metropolitan Manila. Various matters concern all of the present drainage conditions in the core area. It can be said that the drainage improvement would not be achieved only by strong structural measures. In combination with structural measures, it is needed to employ various related measures to support and sustain existing and improved structural measures. In this sense, it is important and indispensable to scrutinize and identify problems and constraints involved in the present drainage conditions of the core area. Such esults are highly helpful for the study on drainage improvement.


**Figure M.2.9 Interrelationship of Drainage Problems and Causes**

In the core area of Metropolitan Manila, it is reported that construction of major drainage channels (culverts) and facilities were commenced in the 1940s. Additional channels and facilities including drainage pumping stations were constructed according to the progress of urbanization in the core area. Many years have been passed since their original constructions. Accordingly, functional deterioration of the drainage system has been advanced so far. It is recognized that the present drainage channels and facilities are losing their original flow capacities and no longer working properly due to clogging, encroachment of informal settlers, lack of integrated operation and maintenance system, etc. Major problems and constraints identified in the present study are summarized by sector as follows.

Inundation

- Flood frequency is still high and serious inundation area remaining locally.
- Floods and inundation are causing various adverse impacts to the core area and severe inundation causes serious problems to the urban transportation and socio-economic activities.

Drainage Basin and Drainage Facilities

- Most of the pump drainage basins are not independent and connected to other basins by estero or creek.
- Drainage facilities are losing their discharge capacities because of encroachment of informal settlers and illegal dumping of solid waste.
- The existing 15 large drainage pumping stations are fundamental drainage facilities in the core area, but 10 of them require urgent rehabilitation.

O & M of Drainage Pumping Station

- Increase of annual operation hours at some specific pumping stations.
- Insufficient budget allocation is causing shortage of spare parts and affecting the O & M activities.
- Number of O & M experts is decreasing due to low wage level.
- A large volume of solid waste must be collected daily at the pumping stations.

O & M of Drainage Channel

- Insufficient budget allocation for the O & M activities of drainage channels.
- No integrated management of O & M activities for PSFO, DWO and LGUs.
- Need to improve the method of solid waste collection at barangays along drainage channels and waterways to reduce illegal dumping of solid waste.
- Need to monitor and relocate informal settlers from critical parts.
- Need to promote the information, education and communication (IEC) by MMDA and LGUs for enhancement of public awareness.

Environmental and Social Aspect

- Throwing waste into drainage channels.
- Informal settlements along and on drainage channels.

### M.2.3 BASIC PLANNING CONCEPT OF DRAINAGE IMPROVEMENT

Based on the investigation results and clarified problems including constraints, basic concept for formulating drainage improvement plan has been studied. The basic concept to be formulated is objective area, design scales, countermeasures to be applied, topography and elevation datum to be used, etc. Major concept applied in this study is explained below.

#### (1) Delineation of Drainage Basin in the Core Area

The drainage system in the core area consists mostly of artificial ones with constructed channels and drainage pumping stations. Delineation of drainage basins is also modified by the proposed plans and works. The planned drainage block and sub-basin applied in the master plan study are presented in *Figures M.2.10* and *M.2.11*, respectively. The planned drainage block dimensions are summarized in *Table M.2.12*. For further consideration of drainage improvement in the core area, it is strongly requested to follow the planned drainage basins.

**Table M.2.12 Proposed Drainage Blocks**

| *ID* | *Name of Drainage Block* | *Existing Area ($km^2$)* | *Proposed Area ($km^2$)* | *Remarks* |
|---|---|---|---|---|
| *N01* | *Vitas-Binondo-Escolta* | *8.55* | *8.26* | *-0.29 $km^2$* |
| *N02* | *Quiapo-Aviles* | *5.58* | *6.19* | *+0.61 $km^2$* |
| *N03* | *Valencia* | *2.37* | *2.37* | *No change* |
| *N04* | *Maypajo-Blumentritt-Balut* | *9.91* | *9.59* | *-0.32 $km^2$* |
| *N05* | *North Harbor* | *2.37* | *2.37* | *No change* |
| *S01* | *Libertad-Tripa de Gallina* | *25.96* | *25.96* | *No change* |
| *S02* | *Balete* | *0.94* | *0.94* | *No change* |
| *S03* | *Paco-Pandacan-San Andres* | *6.12* | *6.12* | *No change* |
| *S04* | *Sta. Clara* | *1.57* | *1.57* | *No change* |
| *S05* | *Makati* | *4.31* | *4.31* | *No change* |
| *S06* | *South Harbor and Others* | *4.90* | *4.90* | *No change* |

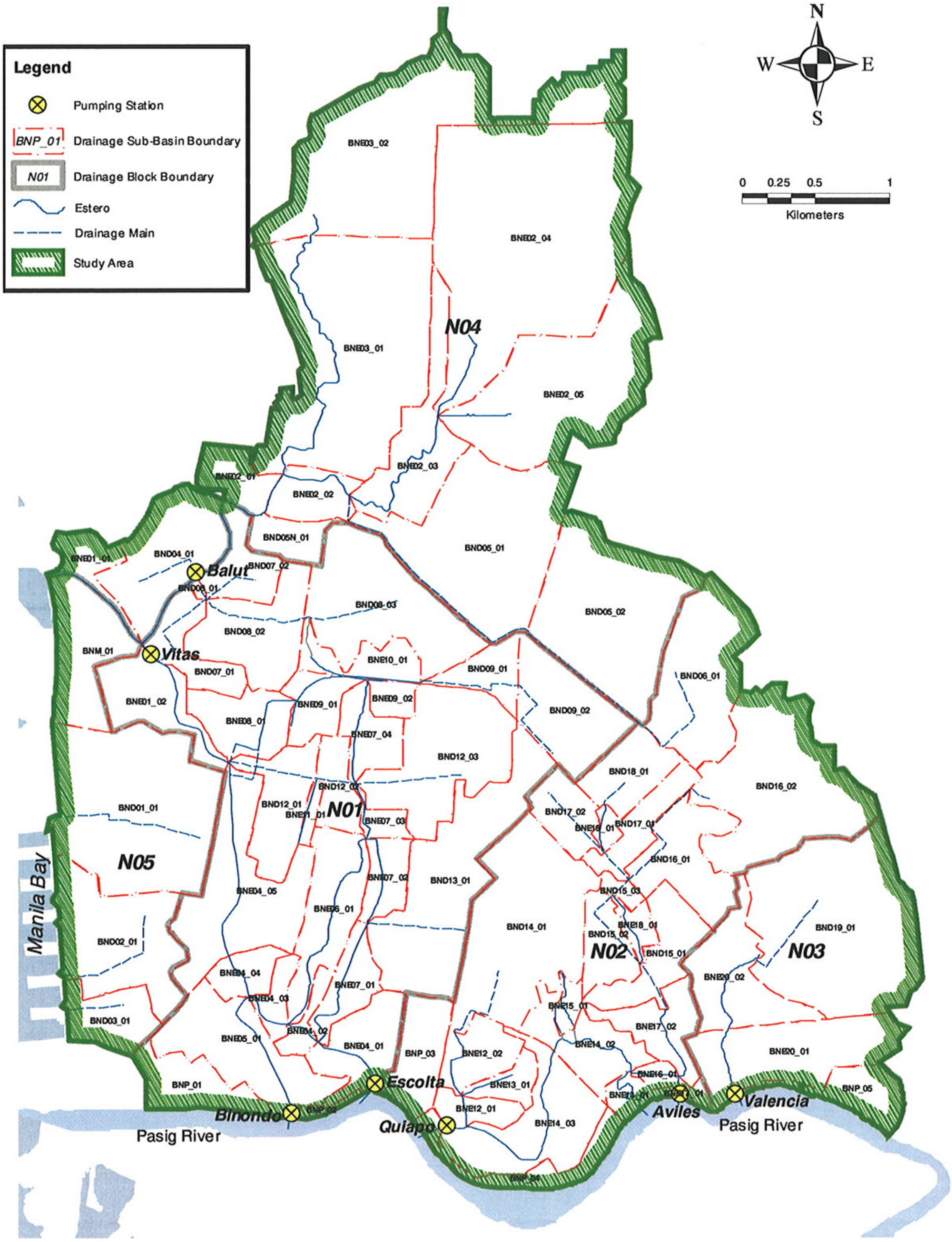



**Figure M.2.10 Planned Drainage Block and Sub-Basin in North Manila**

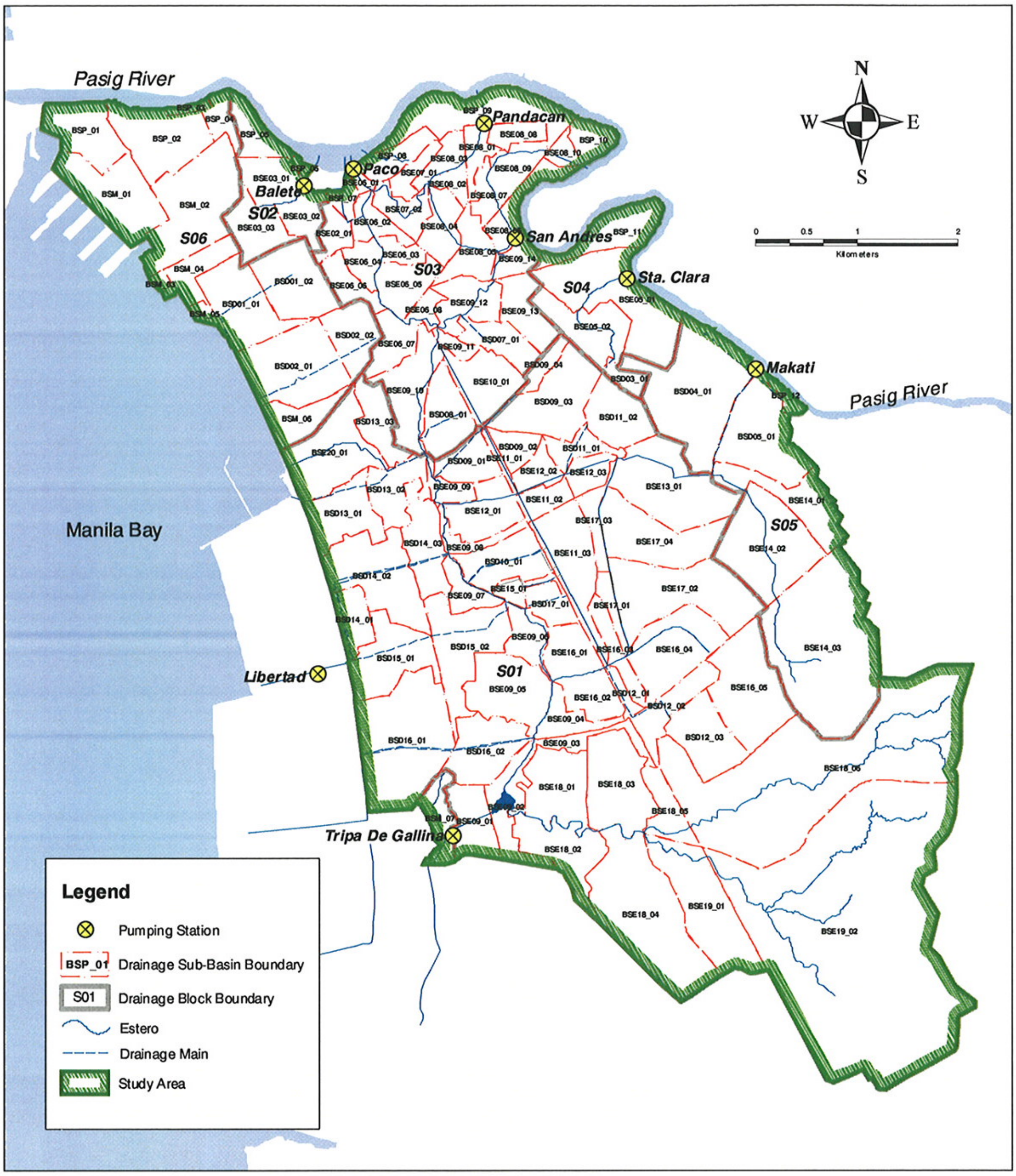



**Figure M.2.11 Planned Drainage Block and Sub-Basin in South Manila**

## (2) Design Scale

Objective of flood/drainage improvement plan is to mitigate flooding and inundation damage to be caused by disasters of typhoons, torrential rainstorms, etc. The flood control and drainage improvement plan is formulated so as to convey design discharge for certain design scales. The design scale is a safety level of the structural measures of river and drainage channels to be proposed/constructed against assumed flood or inundation in the target area and expressed as occurrence probability (return period: for example 1/10) of rainfall amount within the certain duration to be considered in the plan. A return period of 1/10 means a safety level of structural countermeasures against flood/inundation caused by a magnitude which occurs once in 10 years. Also, it is important to take balance of adopted design scales between main channel and tributary or secondary channel in the target river basin or drainage basin, i.e. main channel by 1/10 and secondary channel by 1/3.

The design scale is determined as a whole based on various evaluation factors such as size of objective area, extent of cost of damageable properties, expected function of social and economic activities, extent of damages in the past, financial aspect, and stabilization of public welfare and people’s livelihood, with political judgment. In determining the design scale, it is not enough to consider individual river basins/drainage basins; it is also necessary to take a comprehensive view of the affected areas. However, it is considerably difficult to evaluate the above various factors for determination of design scale. In such case, one option is to adopt the maximum flood/inundation event in the past as a design scale.

## (3) Target of Rehabilitation Works and Design Scale for Additional Works

According to the “Plan for the Drainage of Manila and Suburbs”, prepared in 1952, the major channels were designed for a 10-year return period, whereas local channels had no prepared action. A subsequent study, the 1984 Metro Manila Integrated Urban Drainage and Flood Control Plan, proposed a 10-year return period for design discharge for major channels and drainage pumping stations, and a 2-year return period for those for local channels. Accordingly, the present channels and facilities have been basically constructed and improved according to these plans. From the above background, the design scale for additional works applied in this project is summarized in *Table M.2.13*.

**Table M.2.13 Design Scale for Additional Works**

| | |
|---|---|
| *Drainage Pumping Station<br>(15 Large Pumping Staions)* | *10-year return period<br>(269 mm/24 hours)* |
| *Trunk Channel* | *10-year return period<br>(80 mm/hour)* |
| *Secondary Channel<br>Interceptor to be proposed* | *3-year return period<br>(60 mm/hour)* |
| *Tertiary Channel<br>Lateral<br>Small Pumping Station* | *To recover original capacity,<br>not specified* |

Main purpose of the rehabilitation works is to revive original cross-sectional area of drainage channels and box culverts, and original functions of drainage pumping stations so as to operate properly. Accordingly, the rehabilitation target is to remove the accumulated bottom deposits in the channels and culverts by means of dredging or declogging including related works of construction of stop log gates and raising of covered maintenance hole due to road pavement, and to repair and replace damaged pump equipment and appurtenant facilities of the pumping stations.

Aside from the above, there are additional works to construct new box culverts for further improvement of the present poor drainage situation. For Blumentritt interceptor, construction of inlets for road surface flow and widening of narrow sections will be added as remedial works. The design scale for additional works is a safety level against a certain rainfall amount evaluated by occurrence probability to design and construct new drainage channels, generally called as "design scale".

### (4) Estimation of Probable Peak Discharge and Specific Discharge

Probable discharges of the major channels were estimated at several observation points of the existing esteros/creeks and drainage mains. The estimation was made in the following conditions.

- Drainage basin: Reach-basins associated with planned drainage sub-basins are units of calculation of runoff.
- Runoff coefficients: Future expected land use condition is assumed.
- Time of concentration: Summation of time of flow and time of inlet is used to calculate time of concentration. Time of flow is estimated assuming uniform flow against improved/estimated original condition of objective channels. Time of inlet is based upon assumed flow pass within a reach basin.
- Rainfall Intensity: Probable rainfall intensity for Port Area station evaluated in the present study is employed.

The estimated results are summarized in *Figures M.2.12* and *M.2.13*, and *Tables M.2.14* and *M.2.15*. These probable discharges can be applied for evaluation of extent of flow capacity of the existing channels. In the case of reconstruction of existing channels and construction of additional drainage, those probable discharges are applied as a design discharge for design of channel dimensions.

Based on these estimated probable discharges, "specific discharge" by different probability is calculated and shown in *Figure M.2.14*. A specific discharge is defined as a value of (Discharge ($Q$) divided by Catchment Area ($A$)) with the unit of $m^3/s/km^2$. The specific discharge will be a convenient tool for estimation of design discharge. It is noted that the estimated specific discharge should be applied within the same basin condition without remarkable changing of land use and meteorological conditions.

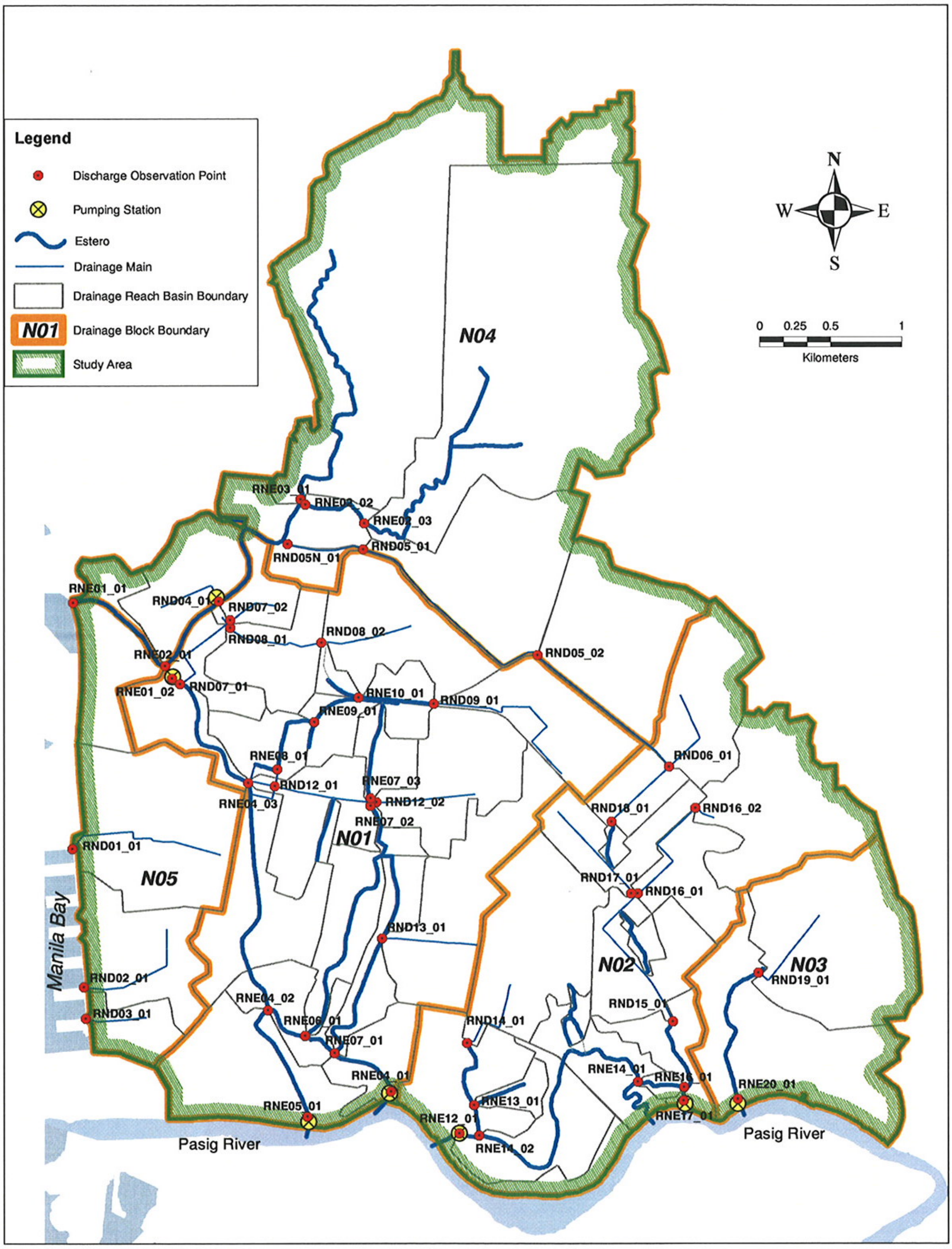



**Figure M.2.12 Discharge Observation Points in North Manila**

# Table M.2.14 Probable Peak Discharge in North Manila

| Block_ID | Basin_ID | WaterWay ID | Observation Point (Reach_ID) | Drainage Area A (km2) | Runoff Coef. C | Time of Concentration $T_c$ (hour) | Areal Reduction Factor | Q10 ($m^3/s$) | Q5 ($m^3/s$) | Q3 ($m^3/s$) | Q2 ($m^3/s$) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N01 | N01_01 | NE01 | RNE01_02 | 5.403 | 0.744 | 1.46 | 0.98 | 73.6 | 63.9 | 55.2 | 47.4 | Vitas P.S. |
| N01 | N01_01 | ND07 | RND07_01 | 1.559 | 0.746 | 0.81 | 0.99 | 29.6 | 25.8 | 22.3 | 19.4 | |
| N01 | N01_01 | ND07 | RND07_02 | 0.203 | 0.785 | 0.34 | 1.00 | 6.1 | 5.4 | 4.6 | 4.0 | |
| N01 | N01_01 | ND08 | RND08_01 | 1.141 | 0.737 | 0.70 | 0.99 | 23.0 | 20.1 | 17.4 | 15.2 | |
| N01 | N01_01 | ND08 | RND08_02 | 0.705 | 0.744 | 0.55 | 0.99 | 16.1 | 14.1 | 12.2 | 10.6 | |
| N01 | N01_01 | NE08 | RNE08_01 | 1.282 | 0.746 | 1.22 | 1.00 | 19.7 | 17.2 | 14.8 | 12.8 | |
| N01 | N01_01 | NE09 | RNE09_01 | 1.014 | 0.748 | 1.10 | 1.00 | 16.6 | 14.4 | 12.5 | 10.8 | |
| N01 | N01_01 | NE10 | RNE10_01 | 0.768 | 0.747 | 0.99 | 1.00 | 13.3 | 11.6 | 10.0 | 8.7 | |
| N01 | N01_01 | ND09 | RND09_01 | 0.592 | 0.739 | 0.85 | 1.00 | 11.0 | 9.6 | 8.3 | 7.2 | |
| N01 | N01_01 | ND12 | RND12_01 | 1.410 | 0.695 | 0.55 | 1.00 | 30.6 | 26.8 | 23.2 | 20.2 | |
| N01 | N01_01 | ND12 | RND12_02 | 0.647 | 0.641 | 0.40 | 1.00 | 14.9 | 13.1 | 11.3 | 9.8 | |
| N01 | N01_01 | NE07 | RNE07_03 | 0.189 | 0.742 | 0.32 | 1.00 | 5.5 | 4.9 | 4.2 | 3.7 | |
| N01 | N01_01 | NE07 | RNE07_02 | 0.069 | 0.705 | 0.26 | 1.00 | 2.1 | 1.8 | 1.6 | 1.4 | |
| N01 | N01_01 | NE04 | RNE04_03 | 3.522 | 0.736 | 1.23 | 1.00 | 53.4 | 46.4 | 40.1 | 34.6 | |
| N01 | N01_02 | NE05 | RNE05_01 | 2.562 | 0.774 | 1.65 | 0.99 | 34.3 | 29.7 | 25.7 | 22.0 | Binondo P.S. |
| N01 | N01_02 | NE04 | RNE04_02 | 1.766 | 0.762 | 1.44 | 0.99 | 25.1 | 21.8 | 18.9 | 16.2 | |
| N01 | N01_02 | NE06 | RNE06_01 | 0.392 | 0.745 | 0.41 | 1.00 | 10.4 | 9.1 | 7.9 | 6.9 | |
| N01 | N01_02 | NE07 | RNE07_01 | 1.197 | 0.765 | 1.34 | 1.00 | 18.0 | 15.6 | 13.5 | 11.6 | |
| N01 | N01_02 | ND13 | RND13_01 | 0.863 | 0.768 | 0.93 | 1.00 | 15.8 | 13.8 | 11.9 | 10.3 | |
| N01 | N01_03 | NE04 | RNE04_01 | 0.296 | 0.795 | 0.41 | 1.00 | 8.4 | 7.4 | 6.3 | 5.5 | Escolta P.S. |
| N02 | N02_01 | NE12 | RNE12_01 | 2.293 | 0.737 | 1.00 | 0.99 | 38.6 | 33.6 | 29.1 | 25.2 | Quiapo P.S. |
| N02 | N02_01 | NE14 | RNE14_02 | 0.505 | 0.716 | 0.38 | 1.00 | 13.3 | 11.6 | 10.0 | 8.8 | |
| N02 | N02_01 | NE13 | RNE13_01 | 0.100 | 0.709 | 0.26 | 1.00 | 3.0 | 2.7 | 2.3 | 2.0 | |
| N02 | N02_01 | ND14 | RND14_01 | 0.926 | 0.741 | 0.81 | 1.00 | 17.6 | 15.4 | 13.3 | 11.6 | |
| N02 | N02_02 | NE17 | RNE17_01 | 3.901 | 0.707 | 1.34 | 0.99 | 53.6 | 46.6 | 40.2 | 34.6 | Aviles P.S. |
| N02 | N02_02 | NE16 | RNE16_01 | 0.451 | 0.743 | 0.58 | 1.00 | 10.2 | 8.9 | 7.7 | 6.7 | |
| N02 | N02_02 | NE14 | RNE14_01 | 0.410 | 0.741 | 0.48 | 1.00 | 10.1 | 8.9 | 7.6 | 6.7 | |
| N02 | N02_02 | ND15 | RND15_01 | 3.167 | 0.700 | 1.21 | 0.99 | 45.5 | 39.6 | 34.2 | 29.5 | |
| N02 | N02_02 | ND16 | RND16_01 | 1.312 | 0.688 | 0.91 | 1.00 | 21.9 | 19.1 | 16.5 | 14.3 | |
| N02 | N02_02 | ND16 | RND16_02 | 0.943 | 0.688 | 0.70 | 1.00 | 17.9 | 15.7 | 13.5 | 11.8 | |
| N02 | N02_02 | ND17 | RND17_01 | 1.272 | 0.702 | 0.87 | 1.00 | 22.2 | 19.3 | 16.7 | 14.5 | |
| N02 | N02_02 | ND18 | RND18_01 | 0.855 | 0.686 | 0.66 | 1.00 | 16.8 | 14.7 | 12.7 | 11.0 | |
| N03 | N03_01 | NE20 | RNE20_01 | 2.370 | 0.678 | 0.66 | 0.99 | 45.3 | 39.5 | 34.2 | 29.8 | Valencia |
| N03 | N03_01 | ND19 | RND19_01 | 1.208 | 0.646 | 0.50 | 1.00 | 25.4 | 22.2 | 19.2 | 16.8 | |
| N04 | N04_01 | NE01 | RNE01_01 | 14.848 | 0.711 | 2.40 | 0.95 | 141.4 | 122.2 | 105.3 | 89.4 | Est Vitas |
| N04 | N04_01 | NE02 | RNE02_01 | 9.309 | 0.694 | 1.82 | 0.96 | 102.6 | 88.9 | 76.7 | 65.6 | |
| N04 | N04_01 | NE03 | RNE03_01 | 3.019 | 0.751 | 1.44 | 0.99 | 42.3 | 36.7 | 31.7 | 27.2 | |
| N04 | N04_01 | NE02 | RNE02_02 | 3.634 | 0.688 | 1.39 | 0.97 | 46.6 | 40.5 | 35.0 | 30.1 | |
| N04 | N04_01 | NE02 | RNE02_03 | 3.444 | 0.681 | 1.35 | 0.99 | 45.5 | 39.6 | 34.2 | 29.4 | |
| N04 | N04_01 | ND05 | RND05_01 | 1.997 | 0.583 | 1.09 | 0.99 | 25.4 | 22.1 | 19.1 | 16.5 | |
| N04 | N04_01 | ND05 | RND05_02 | 0.946 | 0.704 | 0.70 | 0.99 | 18.2 | 15.9 | 13.8 | 12.0 | |
| N02 | N02_02 | ND06 | RND06_01 | 0.617 | 0.664 | 0.50 | 1.00 | 13.3 | 11.7 | 10.1 | 8.8 | |
| N04 | N04_02 | ND04 | RND04_01 | 0.494 | 0.789 | 0.31 | 1.00 | 15.6 | 13.7 | 11.8 | 10.3 | Balut P.S. |
| N05 | N05_01 | ND01 | RND01_01 | 1.127 | 0.831 | 0.60 | 1.00 | 28.0 | 24.5 | 21.2 | 18.5 | |
| N05 | N05_01 | ND02 | RND02_01 | 0.618 | 0.850 | 0.31 | 1.00 | 20.9 | 18.4 | 15.8 | 13.8 | |
| N05 | N05_01 | ND03 | RND03_01 | 0.229 | 0.850 | 0.30 | 1.00 | 7.9 | 6.9 | 6.0 | 5.2 | |
| N04 | N04_01 | ND05N | RND05N_01 | 2.143 | 0.597 | 1.25 | 1.00 | 26.1 | 22.7 | 19.6 | 16.9 | New oulet of Blumentritt Interceptor |

*Note: Observation points are basically located at downstream end of each reach basin.*


**Figure M.2.13 Discharge Observation Points in South Manila**

## Table M.2.15 Probable Peak Discharge in South Manila

| Block_ID | Basin_ID | WaterWay ID | Observation Point (Reach_ID) | Drainage Area A (km2) | Runoff Coef. C | Time of Concentration $T_c$ (hour) | Areal Reduction Factor | Q10 ($m^3/s$) | Q5 ($m^3/s$) | Q3 ($m^3/s$) | Q2 ($m^3/s$) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S01 | S01_01 | SE09 | RSE09_01 (*1) | 11.561 | 0.619 | 1.24 | 0.95 | 99.1 | 80.9 | 64.5 | 50.2 | Tripa P.S. |
| S01 | S01_01 | SE18 | RSE18_01 (*1) | 10.839 | 0.614 | 1.13 | 0.96 | 98.0 | 80.1 | 63.8 | 49.7 | |
| S01 | S01_01 | SE18 | RSE18_02 | 2.935 | 0.646 | 0.85 | 0.98 | 46.8 | 40.8 | 35.3 | 30.6 | |
| S01 | S01_01 | SE19 | RSE19_01 (*1) | 5.401 | 0.565 | 0.82 | 0.97 | 35.5 | 25.8 | 16.9 | 9.5 | |
| S01 | S01_01 | SE09 | RSE09_02 | 0.439 | 0.716 | 0.57 | 1.00 | 9.6 | 8.4 | 7.3 | 6.4 | |
| S01 | S01_01 | SE09 | RSE09_03 (*2) | 5.489 | 0.740 | 1.81 | 0.98 | 65.9 | 57.1 | 49.3 | 42.1 | |
| S01 | S01_01 | SE16 | RSE16_01 (*2) | 4.829 | 0.735 | 1.61 | 0.98 | 61.6 | 53.5 | 46.2 | 39.6 | |
| S01 | S01_01 | SD12 | RSD12_01 (*2) | 0.715 | 0.726 | 0.59 | 1.00 | 15.6 | 13.7 | 11.8 | 10.3 | |
| S01 | S01_01 | SE16 | RSE16_02 (*2) | 1.207 | 0.694 | 1.21 | 0.99 | 17.2 | 15.0 | 12.9 | 11.2 | |
| S01 | S01_01 | SE17 | RSE17_01 (*2) | 2.266 | 0.746 | 1.54 | 0.99 | 30.4 | 26.4 | 22.8 | 19.6 | |
| S01 | S01_01 | SE13 | RSE13_01 (*2) | 0.724 | 0.727 | 0.35 | 1.00 | 20.1 | 17.6 | 15.2 | 13.3 | |
| S01 | S01_02 | SD14 | RSD14_01 | 4.740 | 0.740 | 1.78 | 0.98 | 57.5 | 49.8 | 43.0 | 36.8 | Buendia |
| S01 | S01_02 | SE09 | RSE09_06 | 2.506 | 0.718 | 1.41 | 0.99 | 34.0 | 29.5 | 25.5 | 22.0 | |
| S01 | S01_02 | SE09 | RSE09_07 | 1.120 | 0.720 | 1.21 | 1.00 | 16.8 | 14.6 | 12.6 | 10.9 | |
| S01 | S01_02 | SD09 | RSD09_01 | 1.007 | 0.722 | 0.92 | 1.00 | 17.5 | 15.2 | 13.2 | 11.4 | |
| S01 | S01_02 | SD09 | RSD09_02 | 0.786 | 0.726 | 0.77 | 1.00 | 15.0 | 13.1 | 11.3 | 9.9 | |
| S01 | S01_02 | SE12 | RSE12_01 | 1.272 | 0.719 | 1.21 | 1.00 | 19.0 | 16.5 | 14.3 | 12.3 | |
| S01 | S01_02 | SE11 | RSE11_01 | 0.042 | 0.850 | 0.40 | 1.00 | 1.3 | 1.1 | 1.0 | 0.8 | |
| S01 | S01_02 | SE11 | RSE11_02 | 0.136 | 0.799 | 0.32 | 1.00 | 4.3 | 3.7 | 3.2 | 2.8 | |
| S01 | S01_02 | SE12 | RSE12_02 | 0.772 | 0.704 | 1.07 | 1.00 | 12.1 | 10.5 | 9.1 | 7.8 | |
| S01 | S01_02 | SD11 | RSD11_01 | 0.488 | 0.683 | 0.73 | 1.00 | 9.1 | 7.9 | 6.8 | 6.0 | |
| S01 | S01_02 | SE09 | RSE09_05 | 1.094 | 0.767 | 0.87 | 1.00 | 20.8 | 18.2 | 15.7 | 13.6 | |
| S01 | S01_02 | SD10 | RSD10_01 | 0.849 | 0.766 | 0.74 | 1.00 | 17.6 | 15.3 | 13.2 | 11.5 | |
| S01 | S01_02 | SE11 | RSE11_03 | 0.499 | 0.797 | 0.54 | 1.00 | 12.5 | 10.9 | 9.4 | 8.3 | |
| S01 | S01_02 | SD15 | RSD15_01 | 1.357 | 0.777 | 0.77 | 0.99 | 27.6 | 24.1 | 20.8 | 18.1 | Libertad |
| S01 | S01_02 | SE09 | RSE09_04 | 0.351 | 0.785 | 0.41 | 1.00 | 9.8 | 8.6 | 7.4 | 6.5 | |
| S01 | S01_02 | SD16 | RSD16_01 (*2) | 6.869 | 0.743 | 2.35 | 0.97 | 70.7 | 61.1 | 52.7 | 44.7 | EDSA |
| S01 | S01_03 | SD13 | RSD13_01 | 0.885 | 0.724 | 0.99 | 1.00 | 14.8 | 12.9 | 11.2 | 9.7 | |
| S01 | S01_03 | SD13 | RSD13_02 | 0.528 | 0.706 | 0.76 | 1.00 | 9.9 | 8.6 | 7.5 | 6.5 | |
| S01 | S01_03 | SE20 | RSE20_01 | 0.549 | 0.639 | 0.58 | 1.00 | 10.7 | 9.4 | 8.1 | 7.1 | |
| S02 | S02_01 | SE03 | RSE03_01 | 0.939 | 0.668 | 1.03 | 1.00 | 14.2 | 12.4 | 10.7 | 9.3 | Balete P.S. |
| S03 | S03_01 | SE06 | RSE06_01 | 1.740 | 0.738 | 0.72 | 0.98 | 34.5 | 30.1 | 26.0 | 22.7 | Paco P.S. |
| S03 | S03_01 | SE07 | RSE07_01 | 0.299 | 0.725 | 0.35 | 1.00 | 8.2 | 7.2 | 6.2 | 5.4 | |
| S03 | S03_01 | SE06 | RSE06_02 | 1.218 | 0.766 | 0.68 | 0.99 | 25.9 | 22.6 | 19.5 | 17.0 | |
| S03 | S03_02 | SE08 | RSE08_01 | 1.147 | 0.628 | 0.42 | 0.99 | 25.2 | 22.1 | 19.0 | 16.6 | Pandacan P.S. |
| S03 | S03_02 | SE08 | RSE08_02 | 0.233 | 0.736 | 0.29 | 1.00 | 7.0 | 6.2 | 5.3 | 4.7 | |
| S03 | S03_03 | SE08 | RSE08_04 | 3.232 | 0.720 | 1.61 | 0.99 | 40.8 | 35.4 | 30.6 | 26.2 | SanAndres P.S. |
| S03 | S03_03 | SE08 | RSE08_03 | 0.239 | 0.747 | 0.49 | 1.00 | 5.9 | 5.1 | 4.4 | 3.9 | |
| S03 | S03_03 | SE09 | RSE09_09 | 2.124 | 0.725 | 1.51 | 1.00 | 28.3 | 24.5 | 21.2 | 18.2 | |
| S03 | S03_03 | SD07 | RSD07_01 | 0.226 | 0.732 | 0.54 | 1.00 | 5.2 | 4.5 | 3.9 | 3.4 | |
| S03 | S03_03 | SE06 | RSE06_03 | 0.084 | 0.830 | 0.26 | 1.00 | 3.0 | 2.6 | 2.3 | 2.0 | |
| S03 | S03_03 | SE09 | RSE09_08 | 1.146 | 0.725 | 1.18 | 0.99 | 17.3 | 15.0 | 13.0 | 11.2 | |
| S03 | S03_03 | SE10 | RSE10_01 | 0.352 | 0.702 | 0.71 | 1.00 | 6.8 | 5.9 | 5.1 | 4.5 | |
| S03 | S03_03 | SD08 | RSD08_01 | 0.323 | 0.715 | 0.57 | 1.00 | 7.1 | 6.2 | 5.3 | 4.7 | |
| S04 | S04_01 | SE05 | RSE05_01 | 1.569 | 0.632 | 0.54 | 1.00 | 31.2 | 27.3 | 23.6 | 20.6 | Sta. Clara P.S. |
| S05 | S05_01 | SD04 | RSD04_01 | 1.002 | 0.657 | 0.70 | 1.00 | 18.3 | 15.9 | 13.8 | 12.0 | Makati P.S. |
| S05 | S05_01 | SD05 | RSD05_01 | 0.649 | 0.715 | 0.54 | 1.00 | 14.6 | 12.8 | 11.0 | 9.6 | Makati P.S. |
| S05 | S05_02 | SD06 | RSD06_01 | 2.657 | 0.604 | 0.93 | 0.99 | 38.1 | 33.2 | 28.7 | 24.9 | |
| S05 | S05_02 | SE14 | RSE14_01 | 2.657 | 0.604 | 0.80 | 0.99 | 41.2 | 35.9 | 31.0 | 27.0 | |
| S06 | S06_01 | SD01 | RSD01_01 | 0.932 | 0.806 | 0.47 | 0.99 | 24.9 | 21.8 | 18.8 | 16.4 | |
| S06 | S06_01 | SD02 | RSD02_01 | 0.924 | 0.792 | 0.52 | 0.99 | 23.2 | 20.4 | 17.6 | 15.4 | |

*Note: Observation points are basically located at downstream end of each reach basin.*

*Note: *1 Diversion by Maricaban Interceptor is considered.*

*Note: *2 Stormwater from these reaches is assumed to be drained through EDSA outfall, considering the existing condition.*

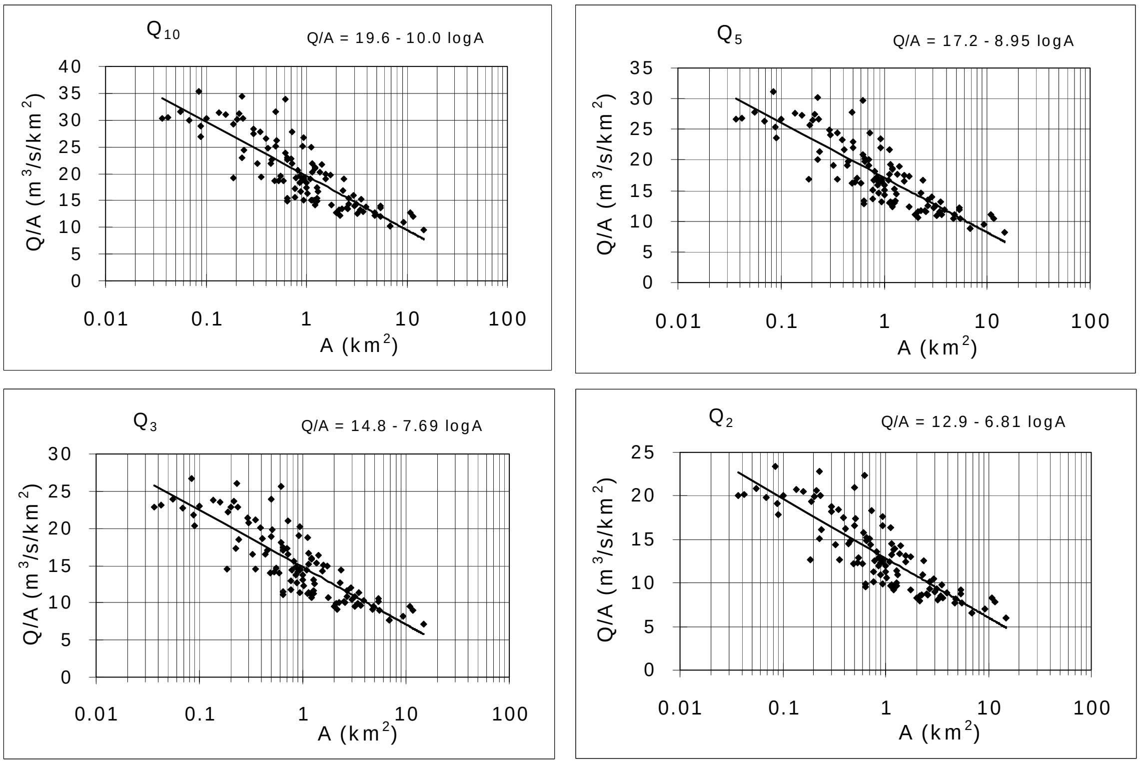



**Figure M.2.14 Specific Discharge in the Core Area**

### (5) Applied Countermeasures for Drainage Improvement

#### 1) Major Problems to Be Solved

Major problems that must be solved and countermeasures in the core area of Metropolitan Manila are summarized below.

**Table M.2.16 Necessary Countermeasures Against Problems to be Solved**

| Problems to be solved | Countermeasures |
|---|---|
| Major drainage pumping stations mostly become old and need urgent rehabilitation. | - Early rehabilitation of drainage pumping equipment<br>- Preparation of a rehabilitation program for each pumping station<br>- Arrangement and strengthening of O & M organizations<br>- Increment of the budget for O & M |
| Due to the rapid urban development, some of the drainage facilities (drainage channels and drainage pumping stations) are finding it difficult to meet the increased stormwater runoff. | - Remedial works and additional works for drainage improvement |
| Most of the drainage channels have decreased drainage capacities due to the heavily accumulated bottom deposits. | - Resettlement of informal settlers in drainage channels<br>- Execution of dredging and declogging<br>- Public participation to O & M activities<br>- Improvement of solid waste collection system at barangay level<br>- Promotion of public involvement in solid waste collection system<br>- Reduction of informal dumping by innovating inspection system and enhancing public awareness |
| Increase of informal settlers in drainage channels causing decrease of the drainage capacity and becoming obstacles for O & M activities. | - Inspection against informal activities<br>- Relocation of informal settlers |
| Insufficient O & M activities. | - Increase of O & M budget of MMDA<br>- Formulation of O & M plan<br>- Providing O & M equipment<br>- Improvement and strengthening of O & M organizations<br>- Innovation of public participation for O & M activities |

#### 2) Applied Countermeasures for Drainage Improvement

In order to achieve the targets for drainage improvement, structural, non-structural and supporting measures are taken up in the drainage improvement in the core area. The countermeasures in above section are, in this study, categorized into the three measures mentioned and broken down as shown in *Figure M.2.15*.

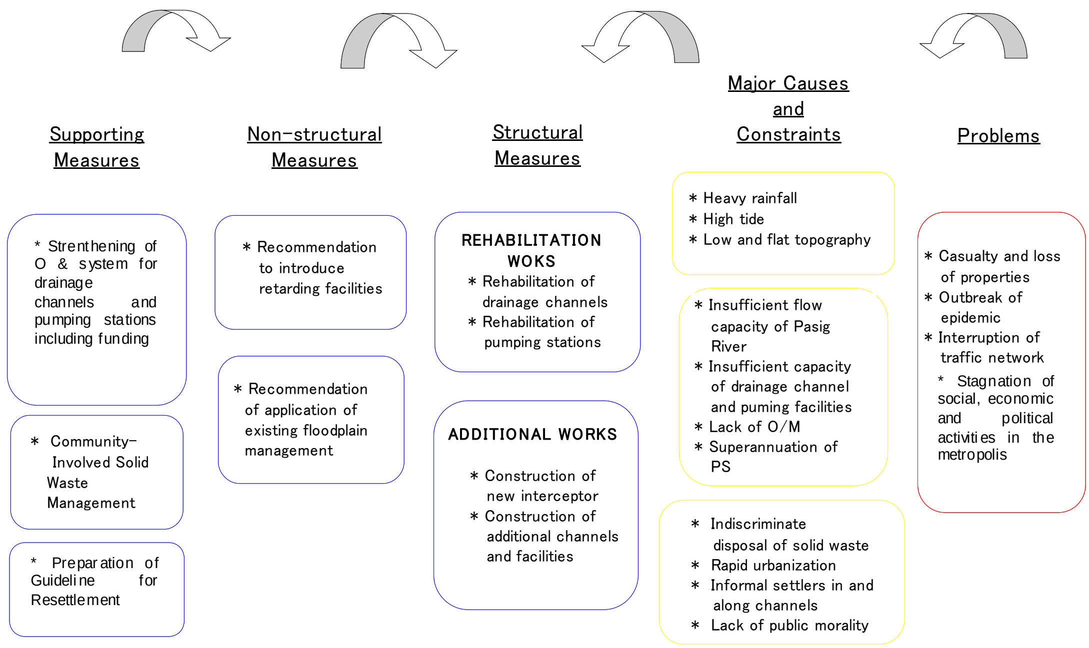



**Figure M.2.15 Proposed Countermeasures for Drainage Improvement**

As a reference, various other measures of drainage improvement are presented in *Figure M.2.16*.

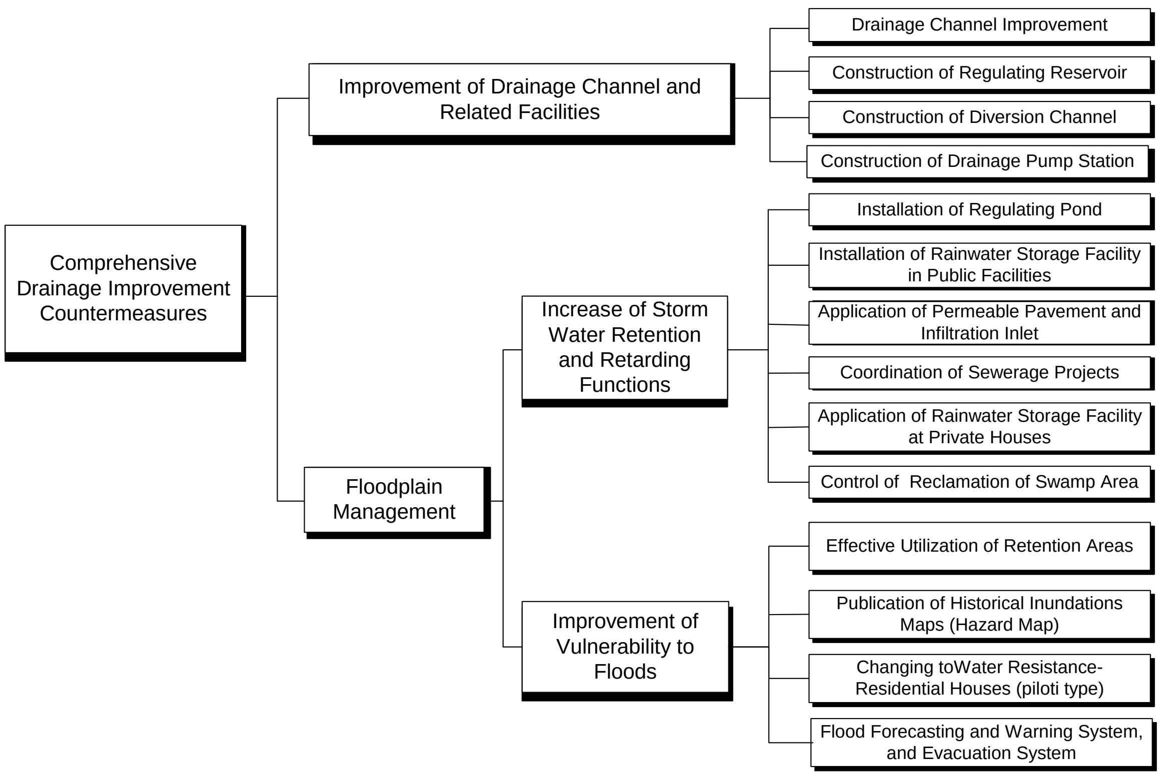



**Figure M.2.16 Various Measures of Drainage Improvement**

### (6) Other Conditions for Drainage Improvement

Other conditions for formulating drainage improvement plan are summarized below. In application for further considerations and procedures of drainage improvement in the core area, special attention should be paid to such conditions applied in the Study.

#### 1) Maps and Data used

Topographic Maps

- The most recent available topographic information based on 1:5,000 topographic map prepared in 2004, with low-lying areas modified using the result of manhole survey in 2000, is utilized for preliminary design.
- Primary benchmark is BM-ML3 located in Quezon City.
- Elevation above DPWH datum of 10.475 m is equivalent to Mean Sea Level (MSL).

Channel Cross-Sections and Profiles

- For rehabilitation works, cross-sections and longitudinal profiles of the channels surveyed in the master plan stage and in SEDLMM (2000) are used as basis to retrieve original channel section.
- For additional works, cross-sections (ground elevation) at major points (100m interval) and longitudinal profiles (ground elevation) surveyed in the feasibility stage of 2004 are used as basis in the design of box culvert channel.

Design High Water Levels at Surroundings

- Mean Spring High Tide Level (El. 11.34 m) is applied for design high tide level on Manila Bay.
- Completion of on-going Pasig-Marikina River Improvement Project is assumed. As for design high water level along the Pasig River, water level for a 30-year return period event is applied.

Referred Guidelines and References

- Design Guidelines, Criteria and Standards for Public Works and Highways, Volume-II (Orange book) DPWH
- Technical Standards and Guidelines for Planning and Design, Volume-II, Urban Drainage, DPWH
- Technical Standard for River and Sabo Works, River Association of Japan, Ministry of Land, Infrastructure and Land (MLIT)

#### 2) Hydraulic Analysis

Discharge capacities after dredging of open channels

- Uniform flow
- Bankfull flow
- Resistance law: Manning formula
- Manning’s coefficient: 0.025 for open channels
- Surface water slope: Average bed slope or planned bed slope

Discharge capacity (estimation of required cross-sectional area) for a box culvert

Discharge capacity for a box culvert is determined as the discharge without overflow at any manholes along the culvert in question. For box culvert, the design discharge estimated in the master plan is basically applied to design. To estimate the discharge capacity, pressure flow is assumed because when large flood comes, the water level becomes almost equal to bank elevation in esteros/creeks. In such situation, pressure flow in the box culvert would occur. The water level at the following downstream ends is assumed as follows.

- Esteros/creeks: Top level of drainage main (culvert)
- Drainage mains: Top level of drainage main (culvert)
- Pumping stations: Pump start level

Other conditions are as follows.

- Resistance law: Manning formula
- Manning's coefficient: 0.015 for box culvert

Hydraulic Simulation

After necessary or recovered dimension of the drainage channels is determined, a more sophisticated unsteady, hydrodynamic simulation by MOUSE is executed to confirm its validity.

### M.2.4 PROPOSED STRUCTURAL MEASURES FOR DRAINAGE CHANNEL FACILITIES OF ESTEROS/CREEKS AND BOX CULVERTS

The structural measures aim to mitigate inundation damage by the two categories; rehabilitation works and additional/remedial works against the present drainage system in the core area of Metropolitan Manila.

The rehabilitation works are to recover original functions of drainage channels and drainage pumping stations. However, even after rehabilitation works be completed, inundations still remain at several spots due to lack of present flow capacities in the related systems, especially in Aviles-Sampaloc area in North Manila and San Isidro-San Antonio-Pio del Pilar area in South Manila. Accordingly, the additional and remedial works are taken up to improve such poor inundation conditions in the core area by constructing new culverts. They are described as follows.

#### (1) Rehabilitation Works of Esteros/Creeks and Box Culverts (Closed Channels)

Original flow area or flow capacity of the drainage channels is to be revived by removing accumulated bottom deposits for open channels and/or by declogging for closed channels as follows. The bed elevation to be dredged is set at original channel bed elevation or assumed original conditions of the channels. In other words, the channel width and shape of cross-section provided by original drainage channels is revived, without cross-sectional modification, only by removing accumulated bottom deposits in the drainage channels. An image of rehabilitation works of open channels is shown in *Figure M.2.17*.

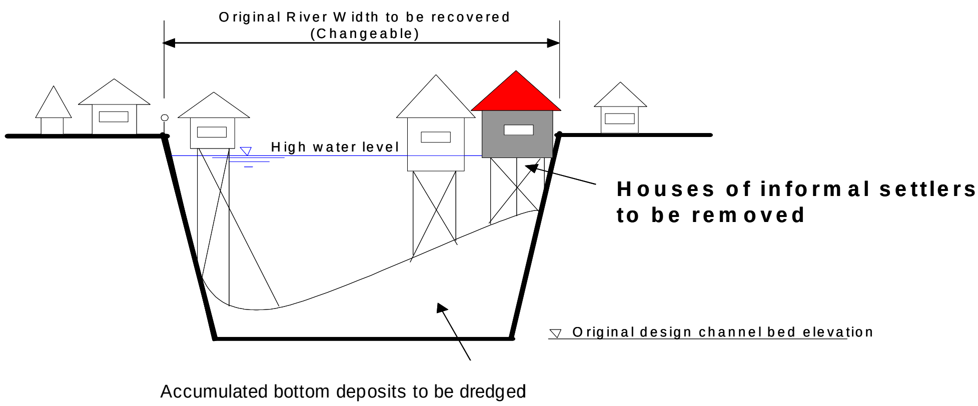



**Figure M.2.17 Image of Rehabilitation Works for Drainage Channel**

### (2) Basic Line of Dredging and Declogging of Esteros/Creeks and Box Culvert

The following are the basic line for dredging and declogging of drainage channels.

- Bottom deposits accumulated in the esteros/creeks are to be removed by dredging/declogging. The channel bed elevation to be dredged is set either at original bed elevation in the previous construction stage or at assumed bed elevation considering existing base elevations of bank protection works, depth of accumulated bottom deposits, etc.
- Informal settlers residing in the object channels are to be resettled.
- Riverbed at the upper part of stretch to be dredged is excavated with a slope of 1:10 to prevent washing away of riverbed materials
- Bottom deposits accumulated in the box culverts are to be cleaned by declogging. In declogging, maintenance holes, which are improper conditions for practical maintenance activities, are repaired.

Under the condition that dredging or declogging be completed, flow capacities of recovered channels and culvert have been evaluated as shown in *Figure M.2.18*, by using estimated probable peak discharges.

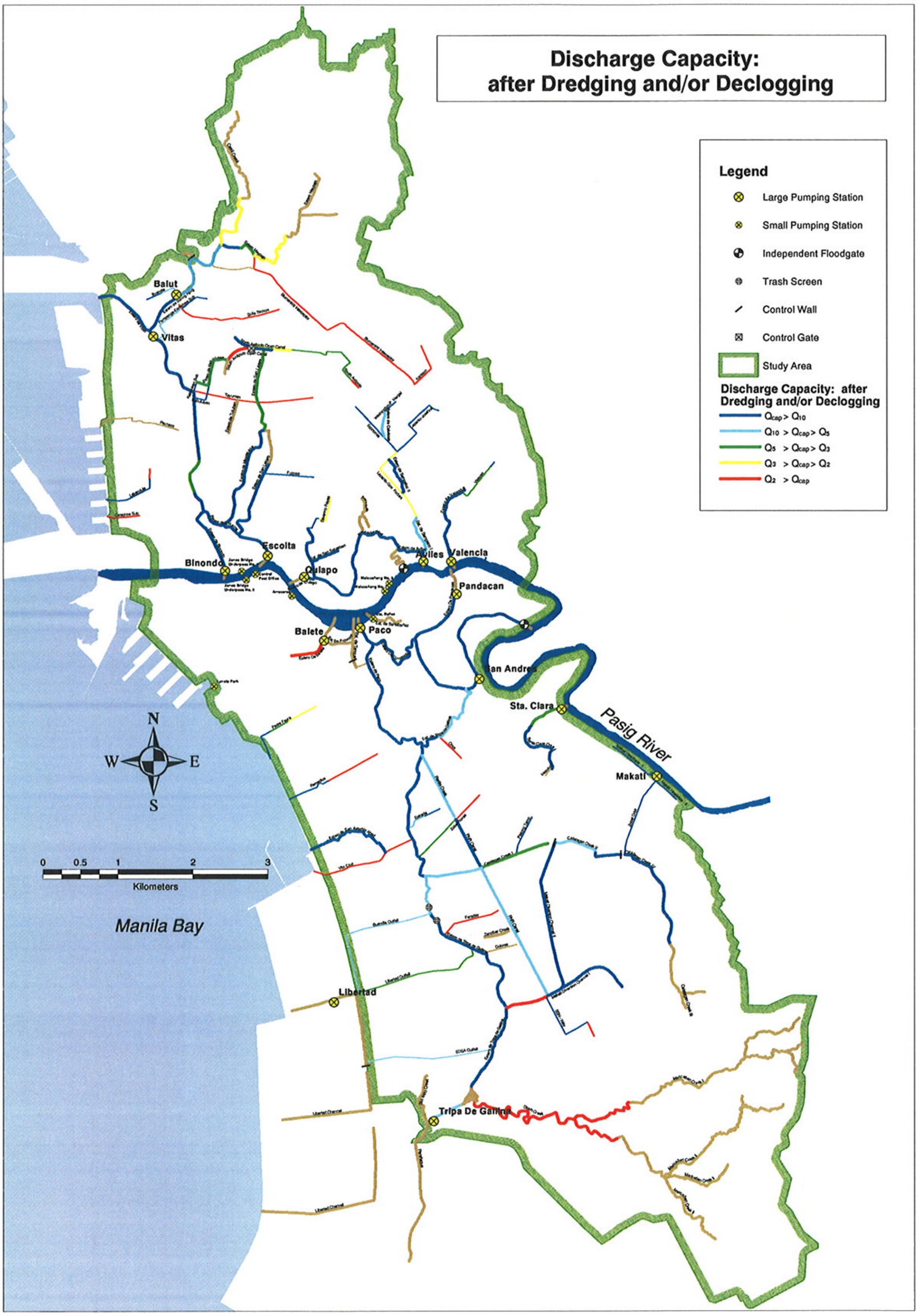



**Figure M.2.18 Estimated Carrying Capacity after Dredging and Declogging of Channels**

### (3) Ideal Typical Section of Esteros/Creeks and Easement

*Figure M.2.19* shows an ideal typical cross-section of drainage channel. In view of smooth operation and maintenance activities in the core area of Metropolitan Manila, it is recommended to eventually revive an open space consisting of drainage channel and its easement in future. Realization of this concept is considerably worthy of beatification and greening of the drainage channels as shown in *Figure M.2.20*.

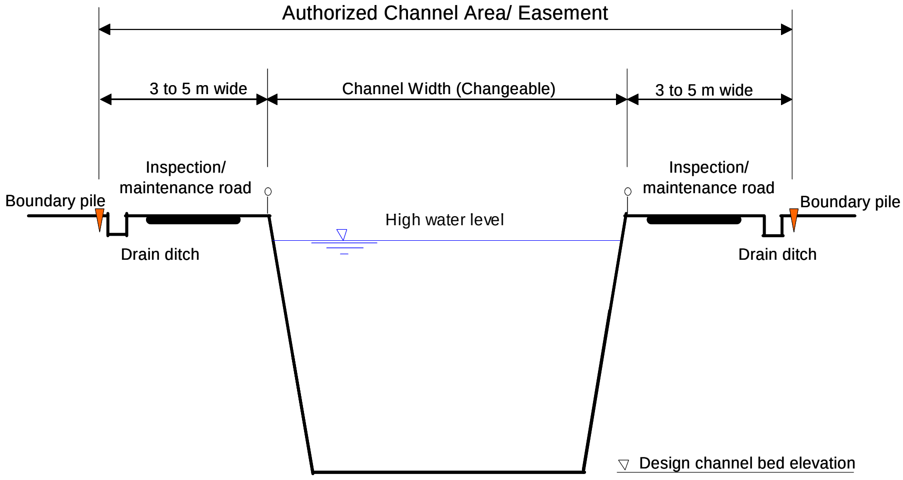



**Figure M.2.19 Ideal Typical Cross-Section of Channel and Easement**

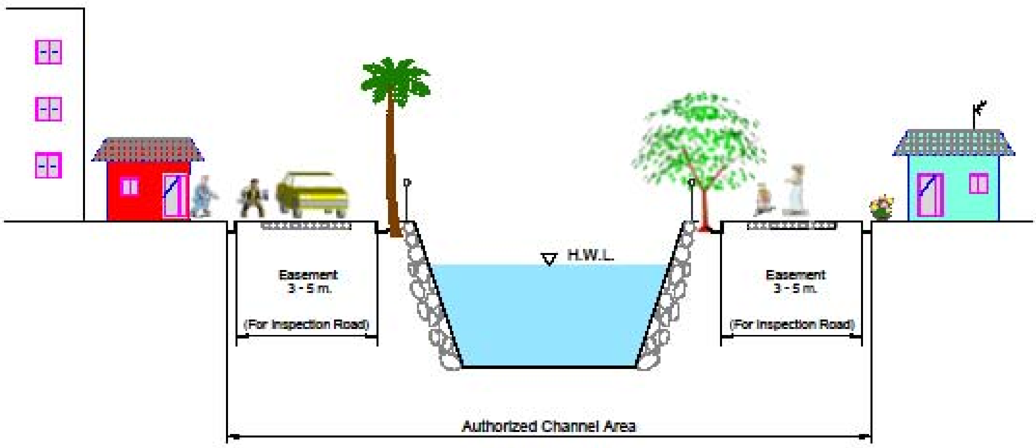



**Figure M.2.20 Image of Environment-Friendly Channel and Easement**

### (4) Related Works to Rehabilitation

There exists several improper structures in the closed channels (culverts) such as uneven channel size, lack of numbers of maintenance holes, and closed maintenance holes due to road pavement. For such improper structures, related works are proposed by modifying the existing structures for effective operation and maintenance. The closed maintenance holes are recovered as shown *Figure M.2.21* so as to maintain the box culvert periodically and effectively.

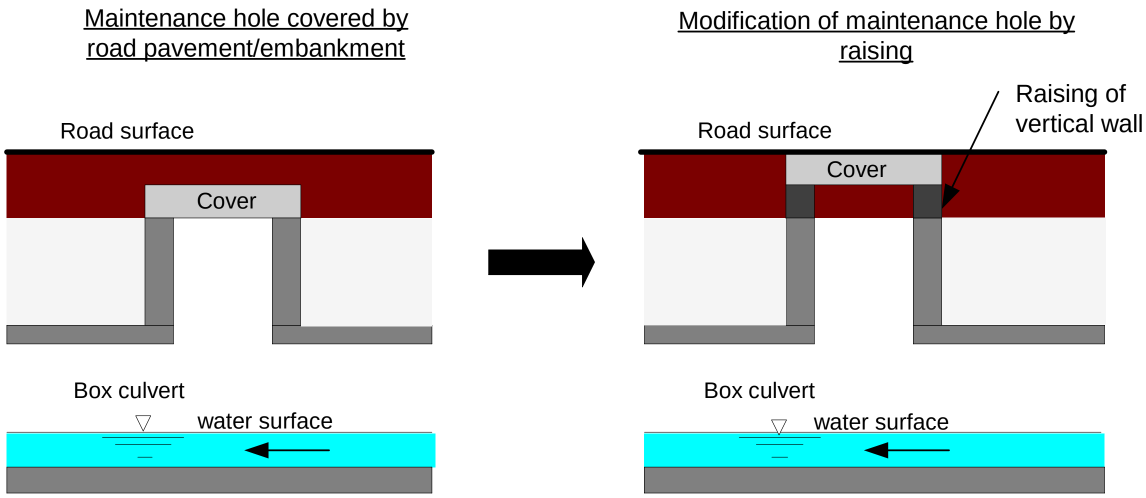



**Figure M.2.21 Modification of Closed Maintenance Hole due to Road Pavement**

Regarding existing major box culverts, especially Blumentritt interceptor and Buendia outfall, they are always submerged due to back water from outlets resulting in difficulty of periodical maintenance activities. For this problem, stop log gates are to be installed at major sections. The stop log gates will be installed as shown in *Figure M.2.22*.

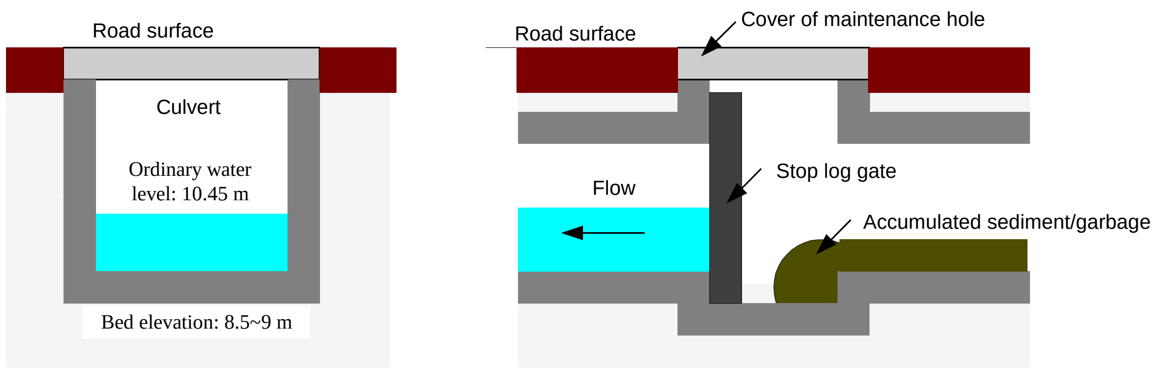



**Figure M.2.22 Image of Stop Log Gates to be Installed**

### (5) Additional and Remedial Works

Even after completion of rehabilitation works, as already explained, regional and local inundations still remain in the core area. Such remained inundations result from lack of flow capacity of existing channels and insufficient flow networks in the regional and local areas. In order to solve such aspects, additional and remedial works were proposed.

In order to drain road surface flow into the box culvert smoothly and effectively, inlets are newly installed at the sections in question. Inlet ditch is installed on the whole carriageway width as shown in *Figure M.2.23* and covered by steel grating as the remedial works.

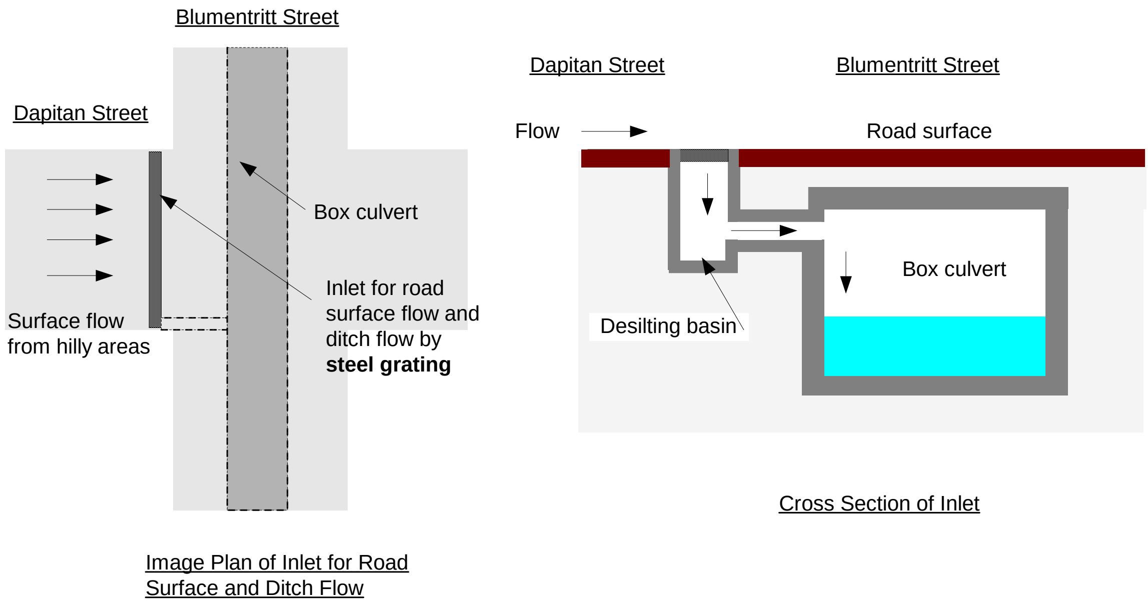



**Figure M.2.23 Inlet for Road Surface Flow into Box Culvert**

On the other hand, the additional works are proposed to increase flow capacity of the channels in question. Increase of flow capacity is made by constructing a new culvert (box culvert and interceptor) in parallel with the channel in question or along another route. The details are given in *Chapter M.2.7*.

## M.2.5 PROPOSED STRUCTURAL MEASURES FOR DRAINAGE PUMPING STATIONS

The 12 drainage pumping stations except Vitas, Balut and San Andres have already been operating for a long time (the oldest since 1976) and have remarkable problems such as deterioration of casing liner, erosion and corrosion of guide casing, and crack of various major parts and units of engine. For such mechanical and electrical aspects, actual working hours/years since their initial operations or constructions are a fundamental factor in order to maintain effective operation. To show required functions of pumping station surely and promptly, it is necessary to maintain pump equipment and appurtenants facilities at a certain level.

The existing drainage pumping station is thus mostly not fully functioning due to not only deterioration of pump equipment and electrical parts but also out-of-stock status of spare parts. Also, operation hours at some pumping stations are remarkably increasing for purpose of not drainage but removal of floating solid waste, which promotes further superannuation of pumping stations. In this viewpoint, the drainage pumping stations are rehabilitated by means of replacement or repair of pump equipment and appurtenant facilities based on the diagnosis result conducted in the investigation stage of the Study.

### (1) Rehabilitation of Drainage Pumping Stations

The capacities of the 12 pumping stations are principally kept by means of repair and/or replacement of pump equipment and appurtenant facilities complying with the extent of mechanical and electrical aging. It is noted that the capacity should be increased at Aviles station. The existing and proposed drainage capacities of the 12 stations with the respective scales of 10-year return period applied in the original design are shown in *Table M.2.17.*

**Table M.2.17 Drainage Capacity of Pumping Stations**

| Pumping station | Construction Year and (Operation Hours as of June 2004) | Existing discharge capacity ($m^3/s$) | Proposed discharge capacity( $m^3/s$) | Remarks |
|---|---|---|---|---|
| Aviles | 1976 (14,650) | 15.6 | 18.6 | + 3 $m^3/s$ |
| Quiapo | 1976 (15,830) | 10.8 | 10.8 | No change |
| Valencia | 1976 (10,790) | 11.8 | 11.8 | No change |
| Pandacan | 1976 (10,890) | 4.4 | 4.4 | No change |
| Paco | 1977 (16,630) | 7.6 | 7.6 | No change |
| Sta. Clara | 1977 (7,420) | 5.3 | 5.3 | No change |
| Tripa de Gallina*1 | 1977 (8,010) | 57.0 | 57.0 | No change |
| Libertad*1 | 1977 (12,880) | 42.0 | 42.0 | No change |
| Makati | 1984 (4,030) | 7.0 | 7.0 | No change |
| Binondo | 1985 (8,220) | 11.6 | 11.6 | No change |
| Balete | 1988 (140) | 3.0 | 3.0 | No change |
| Escolta | 1982 (360) | 1.5 | 1.5 | No change |

Note: *1 indicates installed pump is horizontal one (the others are vertical ones).

### (2) Basic Line of Rehabilitation of Pump Equipment and Appurtenant Facilities

In rehabilitation works of the drainage pumping stations, the basic lines to be considered are as follows:

- In the implementation stage, a further careful and thorough technical investigation and analysis through overhauling at the12 drainage pumping stations is to be conducted for formulation of a detailed rehabilitation program. The rehabilitation works are to be made based on the above detailed rehabilitation program consisting of two categories of repair and replacement works.
- In principle, no action is considered to the pump houses and other civil works.
- Detailed work items by the above categories for the 12 stations are to be clarified.
- Based on the diagnosis results conducted in the master plan stage, the categorization of detailed work items for repair and replacement of pump equipment and appurtenant facilities are to be made.
- Mean spring high tide level (El. 11.34 m) is applied for design high tide level on Manila Bay.
- On-going Pasig-Marikina River Improvement Project is assumed to be complete. The design high water level along the Pasig River determined by the on-going Pasig-Marikina River Improvement Project is applied.
- Change of present (original) start/stop levels of pump operation as shown in *Table M.2.18* including other minor adjustment of total working head will be made in the next stage of detailed investigation. The minor adjustment of drainage capacity due to changing of the total working head or increase of drainage capacity (3 $m^3/s$) at Aviles station can be made by means of changing the angle of impeller without installation of additional pump equipment.

**Table M.2.18 Present Pump Start/Stop Levels for Drainage Pumping Station**

| Pumping station | Pump Start level (EL.m) | Pump Stop Level (EL.m) | Remarks |
|---|---|---|---|
| Aviles | 10.5 | 10.3 | + 3 $m^3/s$ |
| Quiapo | 10.5 | 10.2 | |
| Valencia | 10.5 | 10.3 | |
| Pandacan | 10.5 | 10.2 | |
| Paco | 10.5 | 10.2 | |
| Sta. Clara | 11.2 | 11.0 | |
| Tripa de Gallina | 9.9 | 9.6 | |
| Libertad | 9.9 | 9.6 | |
| Makati | 11.3 | 10.9 | |
| Binondo | 10.0 | 9.8 | |
| Balete | 10.6 | 10.5 | Pump gate |
| Escolta | 10.0 | 9.8 | Pump gate |

- Manual of Rehabilitation of Pump Equipment and Appurtenant Facilities, Ministry of Land, Infrastructure and Transport (MLIT), Japan will be referred to in the rehabilitation works.
- As reference, average working life of pump equipment and electrical parts is summarized from both the aspects of physical and functional in *Table M.2.19*, which is from the above manual by MLIT, Japan.

**Table M.2.19 Working Life of Pump Equipment and Appurtenants Facilities**

| System | Equipment/Facilities | Physical Working Life (year) *1 | Functional Working Life (year)*2 |
|---|---|---|---|
| Main pump equipment | Main pump | 40 | 30 |
| | Main discharge pipe | 40 | 40 |
| | Valve | 40 | 25 |
| Engine | Prime mover for diesel | 40 | 27 |
| | Reduction gear | 40 | 30 |
| Fuel System | Fuel transfer pump | 20 | 20 |
| | Storage tank | 30 | 30 |
| Cooling System | Cooling water pump (vertical/horizontal) | 20 | 18 |
| | Cooling water pump(submergible) | 10 | 10 |
| Air Supply System | Air compressor | 20 | 17 |
| Electrical System | Panel | 20 | 18 |
| | Generator | 40 | 18 |
| Trash Rake | Trash rake/conveyor/ screen | 20 | 20 |
| Crane | Overhead crane | 40 | 40 |
| Flood Gate | Sluice gate | 40 | 40 |

Note; *1: Working life based on life cycle cost (physical life), *2; Working life to be replaced by working reliability (functional life)

### (3) Identification of Detailed Rehabilitation Work Items by Stations

The proposed rehabilitation works intend to partially improve the system by repair/renewal applying new technology, and finally, to recover the capacity of pump facilities to its original condition. The rehabilitation works of drainage pumping stations consist of 1) repair and replacement works of pump equipment and appurtenants facilities, and 2) supply of spare parts and consumables.

In the implementation stage, a further careful and thorough technical investigation and analysis including overhaul at 12 drainage pumping stations is to be conducted for the formulation of a detailed rehabilitation program, and the detailed rehabilitation work items will be finalized accordingly based on the results of the above technical investigation and analysis.

The detailed work items taken up in the rehabilitation are tentatively summarized in *Table M.2.20.*

# Table M.2.20 Tentative Detailed Work Items to be Taken Up in Rehabilitation

| No. | Pump Equipment/Appurtenant Facilities | Aviles | Quiapo | Valencia | Pandacan | Paco | Sta. Clara | Tripa de Gallina | Libertad | Makati | Binondo | Balete | Escolta |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Main Pump | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ● | ● |
| 2 | Reduction Gear | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 3 | Butterfly Valve (inclu. replace of actuator | □/● | □/● | □/● | □/● | □/● | □/● | □/● | □/● | □/● | □/● | N/A | N/A |
| 4 | Flap Valve | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | ● |
| 5 | Diesel Engine for Main Pump | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 6 | Generator Panel | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ○ | ○ |
| 7 | Diesel Engine for Generator | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ |
| 8 | Vacuum Pump (for priming) | N/A | N/A | N/A | N/A | N/A | N/A | ● | ● | N/A | N/A | N/A | N/A |
| 10 | Clear Water Pump | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 11 | Cooling & Sealing Water Pump | N/A | N/A | N/A | N/A | N/A | N/A | ● | ● | N/A | N/A | N/A | N/A |
| 12 | Cooling Water Pump for Gen. | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 13 | Fuel Transfer Pump | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 14 | Cooling Tower | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 15 | Air Compressor | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 16 | Air Reservoir Tank | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | N/A | N/A |
| 17 | Ventilating Fan | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 18 | Fuel Storage Tank | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | N/A | N/A |
| 19 | Fuel Service Tank | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | N/A | N/A |
| 20 | Cooling Water Tank | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | N/A | N/A |
| 21 | W. L. Gauge at Inlet (ultrasonic type) | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| 22 | W. L. Gauge at Outlet (ultrasonic type) | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| 23 | Automatic Trash Rake and Screens | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | N/A | N/A |
| 24 | Horizontal Conveyor | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | N/A | N/A |
| 25 | Inclined Conveyor | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | N/A | N/A |
| 26 | Hopper | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | ▲/○ | N/A | N/A |
| 27 | Conveyor Pit Drain Pump | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 28 | Pump Room Drain Pump | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | N/A | N/A |
| 29 | Overhead Crane | □/○ | □/○ | □/○ | □/○ | □/○ | □/○ | □/○ | □/○ | □/○ | □/○ | N/A | N/A |
| 30 | Flood Gate/Control Panel | -/● | -/● | -/● | -/● | -/● | -/● | -/● | -/● | -/● | -/● | ▲ | ▲ |
| 31 | Electric Panel | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |

Note: Definition of marks is as follows.

□: Inspection

▲: Overhaul

○: Repair

●: Replacement

- : No action

N/A: Not applicable