2.4 FLOOD AND INUNDATION

2.4.1 INTRODUCTION

The core area is inundated locally almost every year. However, the quantitative information on recent inundations such as depth, duration and areas is quite limited, so is information on damages caused by those. The available information that has been obtained is as follows.

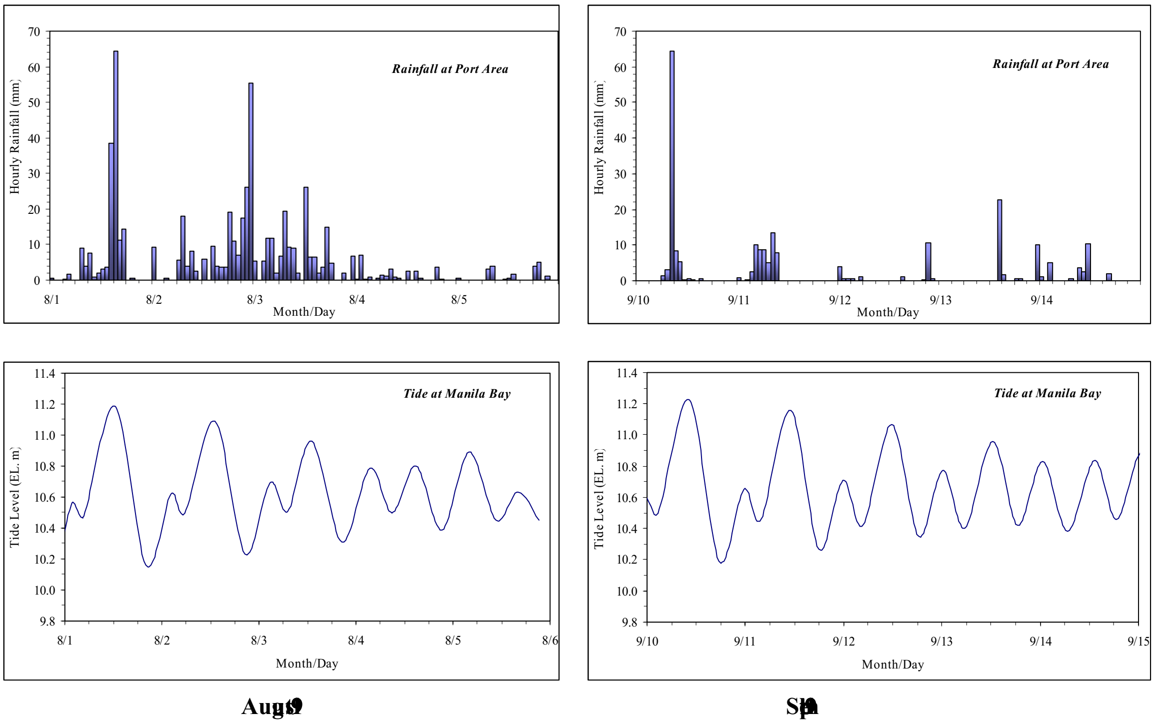
- Interview survey for inundation in 1999 flood by SEDLMM (2000)[1]
- Flood-prone roads in Metro Manila provided by MMDA[2]
- Interview survey for inundation in August 2004

In this chapter, the inundation conditions in 1999 and 2004 are summarized. The more detailed information is compiled in *Supporting Report C*.

2.4.2 INUNDATION CONDITION AND MAJOR PROBLEM AREA IN 1999 FLOOD

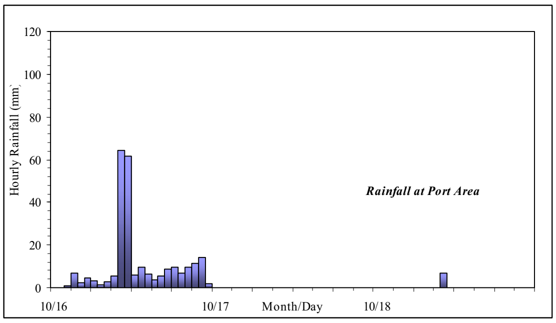
(1) Rainfall and Water Level in Manila Bay and the Pasig River

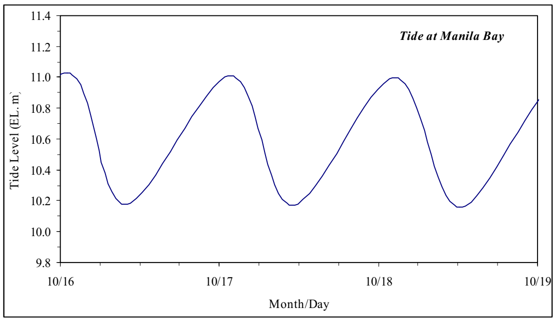
There were three large rainfall events in 1999: August 2-3, September 10-11 and October 16-17. All of those were typhoon-associated rainfall. The meteo-hydrological condition of 1999 inundation has been investigated and is presented in *Figure 2.4.1*. The rainfall is analyzed using the chart data provided by PAGASA. Among the three rainfall events, the largest rainfall event is the one in August 1999. The results of evaluation on return period of the three rainfall events are presented in *Table 2.4.1*.



Source: Hourly rainfall data at Port Area is from chart obtained from Flood Forecasting and Warning Center of PAGASA and tide data at Manila South Harbor is from NAMRIA

Figure 2.4.1 Meteo-Hydrological Condition During 1999 Inundation (1/2)





Ot9

Source: Hourly rainfall data at Port Area is from chart obtained from Flood Forecasting and Warning Center of PAGASA and tide data at Manila South Harbor is from NAMRIA

Figure 2.4.1 Meteo-Hydrological Condition During 1999 Inundation (2/2)

Table 2.4.1 Evaluation of Return Period of 1999 Inundation

Augt9

Station	*Rainfall*	*Duration*				
		1-hr	*6-hr*	*12-hr*	*24-hr*	*48-hr*
Port	*Amount (mm)*	*64*	*136*	*174*	*278*	*455*
Area	*Return Period (Year)*	*4*	*4*	*4*	*12*	*19*

Sp9

Station	*Rainfall*	*Duration*				
		1-hr	*6-hr*	*12-hr*	*24-hr*	*48-hr*
Port	*Amount (mm)*	*65*	*83*	*84*	*116*	*148*
Area	*Return Period (Year)*	*4*	*2*	*< 2*	*< 2*	*< 2*

Ot9

Station	*Rainfall*	*Duration*				
		1-hr	*6-hr*	*12-hr*	*24-hr*	*48-hr*
Port	*Amount (mm)*	*64*	*153*	*203*	*247*	*247*
Area	*Return Period (Year)*	*4*	*5*	*7*	*8*	*3*

Tide level at Manila South Harbor is high for these periods. The observed maximum water levels at pumping stations along the Pasig River during August 2-3, September 10-11 and

October 16-17 are shown in *Table 2.4.2.* Among these, most severe condition, which has the highest water level, appeared in August.

Table 2.4.2 Observed Maximum Water Level along the Pasig River During 1999 Inundation

Pumping Station	*Binondo*	*Escolta*	*Quiapo*	*Balete*	*Paco*	*Aviles*	*Pandacan*
Chanage (km)	*1+550*	*2+150*	*2+600*	*3+300*	*3+650*	*4+800*	*5+200*
DHWL (m)	*12.10*	*12.10*	*12.19*	*12.34*	*12.41*	*12.65*	*12.73*
OMWL (m) August 1999	*N/A*	*11.85*	*N/A*	*12.2*	*12.2*	*12.4*	*12.5*
OMWL (m) September 1999	*N/A*	*11.7*	*N/A*	*11.9*	*11.8*	*11.9*	*12.1*
OMWL (m) October 1999	*N/A*	*11.8*	*N/A*	*12.05*	*12.0*	*12.1*	*12.25*

Pumping Station	*Valencia*	*San Andres*	*Sta. Clara*	*Makati*
Chanage (km)	*5+300*	*8+350*	*10+850*	*12+350*
DHWL (m)	*12.75*	*13.52*	*13.67*	*13.76*
OMWL (m) August 1999	*12.65*	*N/A*	*13.5*	*13.55*
OMWL (m) September 1999	*12.0*	*12.7*	*12.7*	*12.7*
OMWL (m) October 1999	*12.2*	*N/A*	*12.5*	*12.8*

Note:
DHWL = Design High Water Level in the Pasig River
OMWL= Observed Maximum Water Level in the Pasig River

Elevation is above DPWH Datum.

Source DHWH: DPWH, Project for Pasig-Marikina River Flood Control, 2002.[3]
OMWL: Pump operation records provided by MMDA

(2) Inundation Condition

Based on the inundation survey by SEDLMM, inundation maps are arranged. Estimated total area that has more than 20 cm maximum inundation depth is about 29.5 km^2 (about 40% of the study area). *Figures 2.4.2* and *2.4.3* show the contour maps of maximum inundation depth and duration, respectively. The maximum inundation depth is around 1.3 m, which occurs along España Street in North Manila and along PNR Canal in South Manila. The area in which depth of inundation is deeper than 0.5 m extends widely in the central part of North Manila. Duration of inundation in this area exceeds 24 hours. In South Manila, deep inundation occurs along the eastside of PNR Canal and along Estero de Tripa de Gallina. Duration of inundation is less than 12 hours in those areas, however.

The original report in SEDLMM explained that the results of the interview survey reflected September 1999 flood. However, considering the amount of rainfall and uncertainty in people’s memory for the timing of floods, it may be more reasonable that the results of the interview survey reflected all of three inundation conditions.

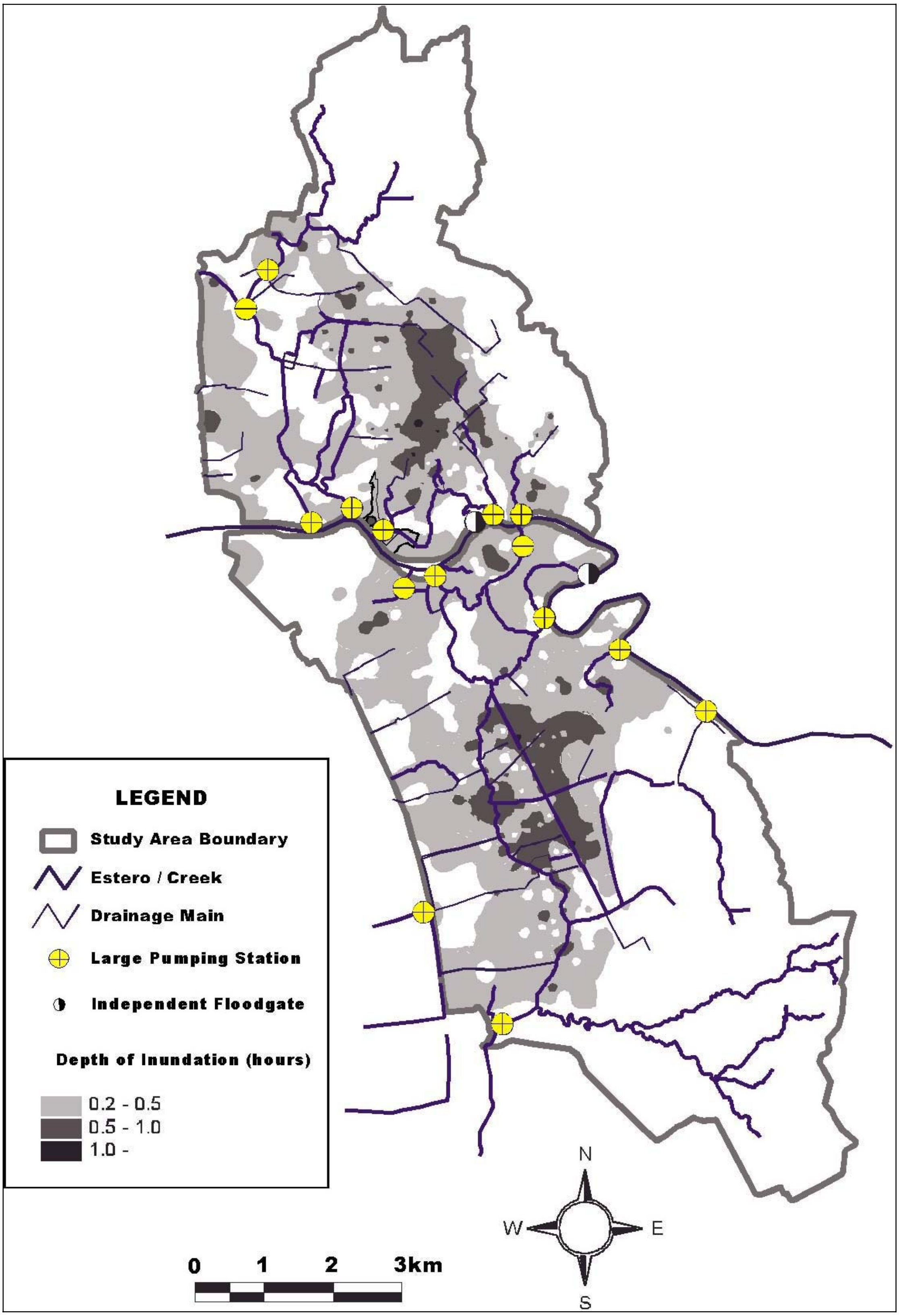


Figure 2.4.2 Maximum Depth in 1999 Inundation

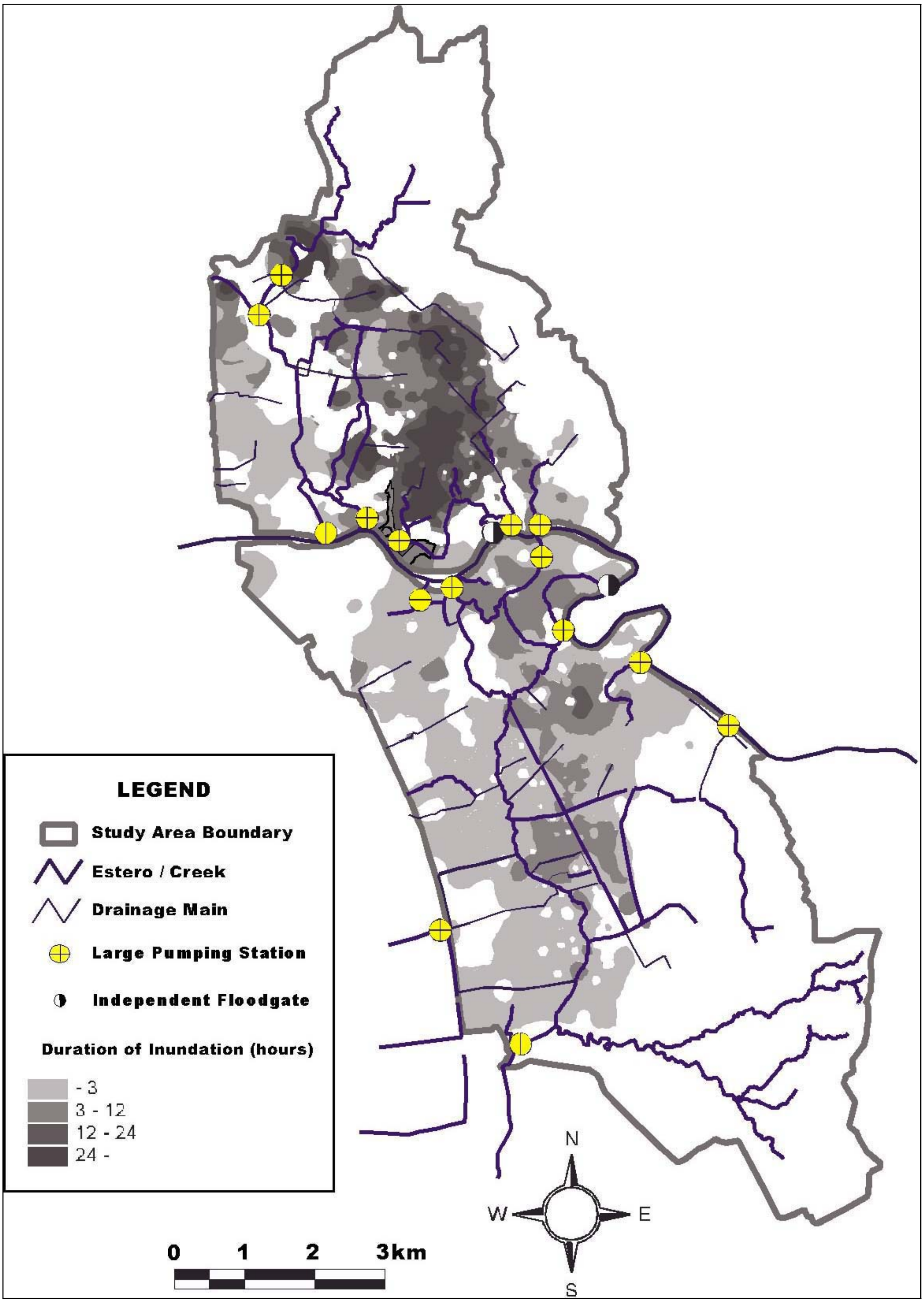


Figure 2.4.3 Duration in 1999 Inundation

(3) Estimated Damages

There is no available quantitative information on damages caused by inundation in 1999, unfortunately. The only available method to estimate the damages is to utilize currently developed GIS database in Metro Manila[4] with the inundation map based upon the interview survey. Using overlay technique of GIS, the following are estimated.

- Number of affected people:
  1,240,660 (55% of total population in the study area)
- Number of affected houses/buildings:
  97,980 (50% of total number of buildings in the study area)
- Total length of inundated road:
  610.4 km (44% of total length of roads in the study area)

(4) MAJOR PROBLEM AREAS

Because of implementation of flood control and drainage improvement made so far, flood and inundation situation has been so much improved in Metropolitan Manila. However, it still remains at several areas and particular local spots. Problem areas can be categorized into two aspects of regional and local inundation areas, based on available information in 1999 inundation. Regional inundation area is the widely spreading portion whose depth of inundation is more than 0.5 m, whereas local inundation area is the area where inundation is limited locally.

1) Regional and Local Inundation Areas in North Manila

The regional inundation area in North Manila is Aviles, Sampaloc area in the upper catchments of Quiapo-Aviles, Vitas-Binondo-Escolta and Maypajo-Blumentritt-Balut drainage blocks. The regional inundation is caused not only by local storm water in Quiapo-Aviles and Vitas-Binondo-Escolta drainage blocks but also by excess storm water in the hilly area of Maypajo-Blumentritt-Balut drainage block. Trunk road España Street running through the regional inundation area is suffering from severe traffic interruptions almost every year. Other drainage blocks do not have so serious and regional problems. However, local inundation areas remain at several spots.

2) Regional and Local Inundation Areas in South Manila

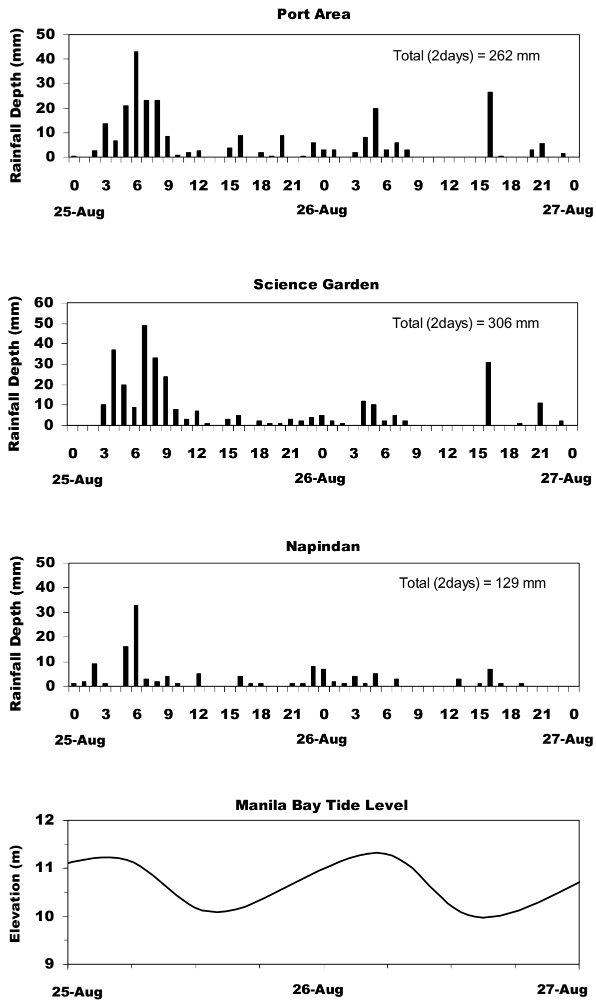
The regional inundation area in South Manila is San Isidro, San Antonio and Pio del Pilar area covered by drainage channels of Zobel-Roxas, PNR Canal and Calatagan Creek I in Libertad-Tripa de Gallina drainage block. Due to various structural and social problems, this area is frequently inundated, even in the dry season from November to April. A trunk road, South Super Highway, running along PNR is suffering from frequent inundations, resulting in severe traffic interruption. In other drainage blocks, serious regional inundation cannot be observed. Local inundation areas are observed at several spots along Estero de Tripa de Gallina, in Balete drainage block, near Pandacan pumping station, etc., however.

2.4.3 Inundation Condition in August 2004

(1) Rainfall and Water Level in Manila Bay and the Pasig River

In early morning of August 25, 2004, heavy rainfall events occurred in the study area. Typhoon AERE caused this rainfall event.

The rainfall amount and pattern during the heavy rainfall event has been investigated by analyzing the chart data provided by PAGASA for Port Area Stations. Aside from this, the rainfall records in Science Garden and Napindan were provided by EFCOS and the tide level at Manila Bay was obtained by Tide Table 2004 issued by NAMRIA. *Figure 2.4.4* shows the rainfall patterns in those three stations and the tide level at Manila Bay. It can be seen that the single peak appeared early morning on August 25. At that time, the tide was also almost at peak level. Rainfall amount at Napindan is much smaller than those at the other stations. This fact shows that the south of the study area received much smaller rainfall compared to the north.



Source:
Port Area: Chart data by PAGASA, Science Garaden and Napindan: EFCOS
Tide level: NAMRIA

Figure 2.4.4 Meteo-Hydrological Condition During August 2004 Inundation

Table 2.4.3 shows continuous rainfall amount for several durations at Port Area and Scienece Garden stations. At Port Area, maximum 24-hour rainfall depth was 183 mm, which corresponds to 3-year return periods. Maximum 6-hour to 12-hour rainfall depth is also equivalent to almost 3-year return period. However, return period of maximum rainfall depth with shorter duration is less than 2 years.

At Science Garden, total 2-day rainfall amount (306 mm) is higher than that at Port Area (262 mm). Maximum 24-hour rainfall depth was 230 mm, which corresponds to 5-year return periods. Maximum 6-hour to 12-hour rainfall depths are equivalent to 5-year return period or more. Return period of maximum rainfall depth with shorter duration is less than 2 years.

Table 2.4.3 Evaluation of Return Period of August 2004 Inundation

PtAa

	60 min	2 hours	3 hours	6 hours	12 hours	24 hours	48 hours
Maximum	44.0	81.5	97.0	136.7	147.4	183.1	262.0
Return Period	<2	2 - 3	-	3 - 5	2 - 3	3	3

SitG

	60 min	2 hours	3 hours	6 hours	12 hours	24 hours	48 hours
Maximum	49.0	82.0	106.0	172.0	201.0	230.0	306.0
Return Period	<2	2 - 3	-	5- 10	5-10	5	3 - 5

The observed maximum water levels at pumping stations along the Pasig River are shown in *Table 2.4.4*. The maximum water levels along the Pasig River are lower than those during August 1999 inundation.

Table 2.4.4 Observed Maximum Water Level Along the Pasig River During August 2004 Inundation

Pumping Station	Binondo	Escolta	Quiapo	Balete	Paco	Aviles	Pandacan
Chanage (km)	1+550	2+150	2+600	3+300	3+650	4+800	5+200
DHWL (m)	12.10	12.10	12.19	12.34	12.41	12.65	12.73
OMWL (m) August 1999	N/A	11.85	N/A	12.2	12.2	12.4	12.5
OMWL (m) August2004	11.75	11.8	11.75	11.95	12.0	12.05	12.0

Pumping Station	Valencia	San Andres	Sta. Clara	Makati
Chanage (km)	5+300	8+350	10+850	12+350
DHWL (m)	12.75	13.52	13.67	13.76
OMWL (m) August 1999	12.65	N/A	13.5	13.55
OMWL (m) August 2004	12.05	12.4	12.5	12.7

N
DHWL = Design High Water Level in the Pasig River
OMWL= Observed Maximum Water Level in the Pasig River

Elevation is above DPWH Datum.

Source DHWH: DPWH, Project for Pasig-Marikina River Flood Control, 2002.[5]
OMWL: Pump operation records provided by MMDA

(2) Inundation Condition

Interview survey was conducted during October 2004 in order to grasp the inundation condition on August 25, 2004. Based on the results, contour maps for inundation depth and duration have been arranged using GIS. Estimated total area that has more than 20 cm maximum inundation depth is about 14.3 km^2 (about 20% of the study area). This is smaller than the inundation in 1999.

Figures 2.4.5 and *2.4.6* show the contour maps of maximum inundation depth and duration, respectively. The maximum inundation depth is around 1.0 m, which occurs mainly along España Street. The area in which depth of inundation is deeper than 0.5 m extends widely in the central part of North Manila. Duration of inundation in this area is almost 12 hours. In South Manila, regional inundation area in which maximum depth exceeds 0.5 m is not observed. Local deep inundation area exists, however.

(3) Pump Operation

Table 2.4.5 shows summary of pump operation during August 2004 inundation. In the table, total volume of drained water at pumping station was estimated by assuming that pump efficiency is 100%. Estimated total volume of drained water per drainage area at pumping stations in North Manila is much larger than that in South Manila. This is presumably because of the difference of rainfall amount between North Manila and South Manila.

In North Manila, pumping stations in Quiapo-Aviles drainage block drained much more water per area than that in Vitas-Binondo-Escolta drainage. The difference (about 150 mm) is larger than the difference between rainfall amount at Port Area and Science Garden (about 50 mm). As shown in *Chapter 2.5*, existing Blumentritt interceptor has almost zero drainage capacity, which may result in almost all excess storm water in the upper drainage basin of the existing Blumentritt interceptor entering into Quiapo-Aviles drainage block. The records of pump operation during August 2004 support this assumption.

According to the pump operation records, no floodgates at pumping stations were opened during August 2004 inundation.

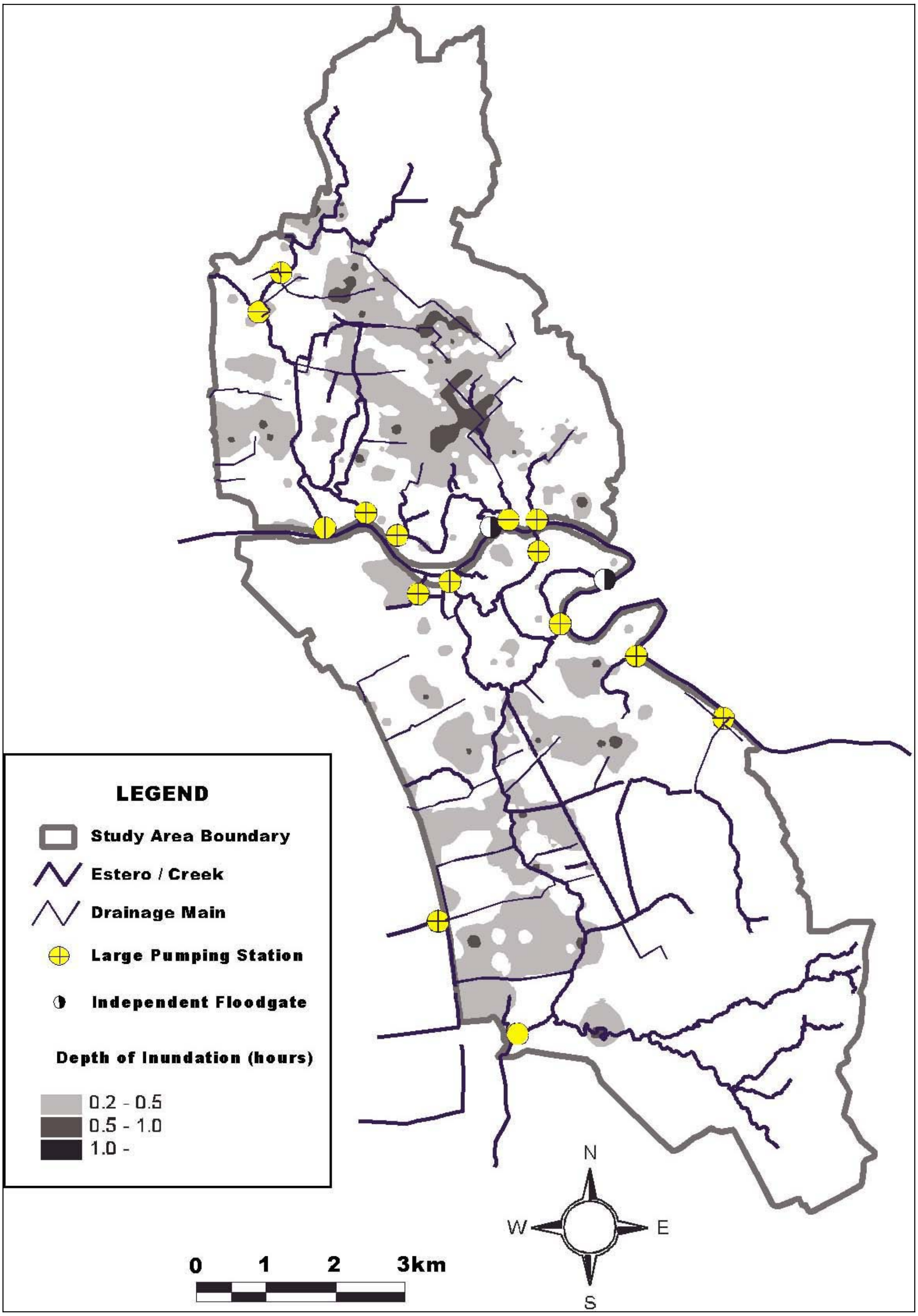


Figure 2.4.5 Maximum Depth in August 2004 Inundation

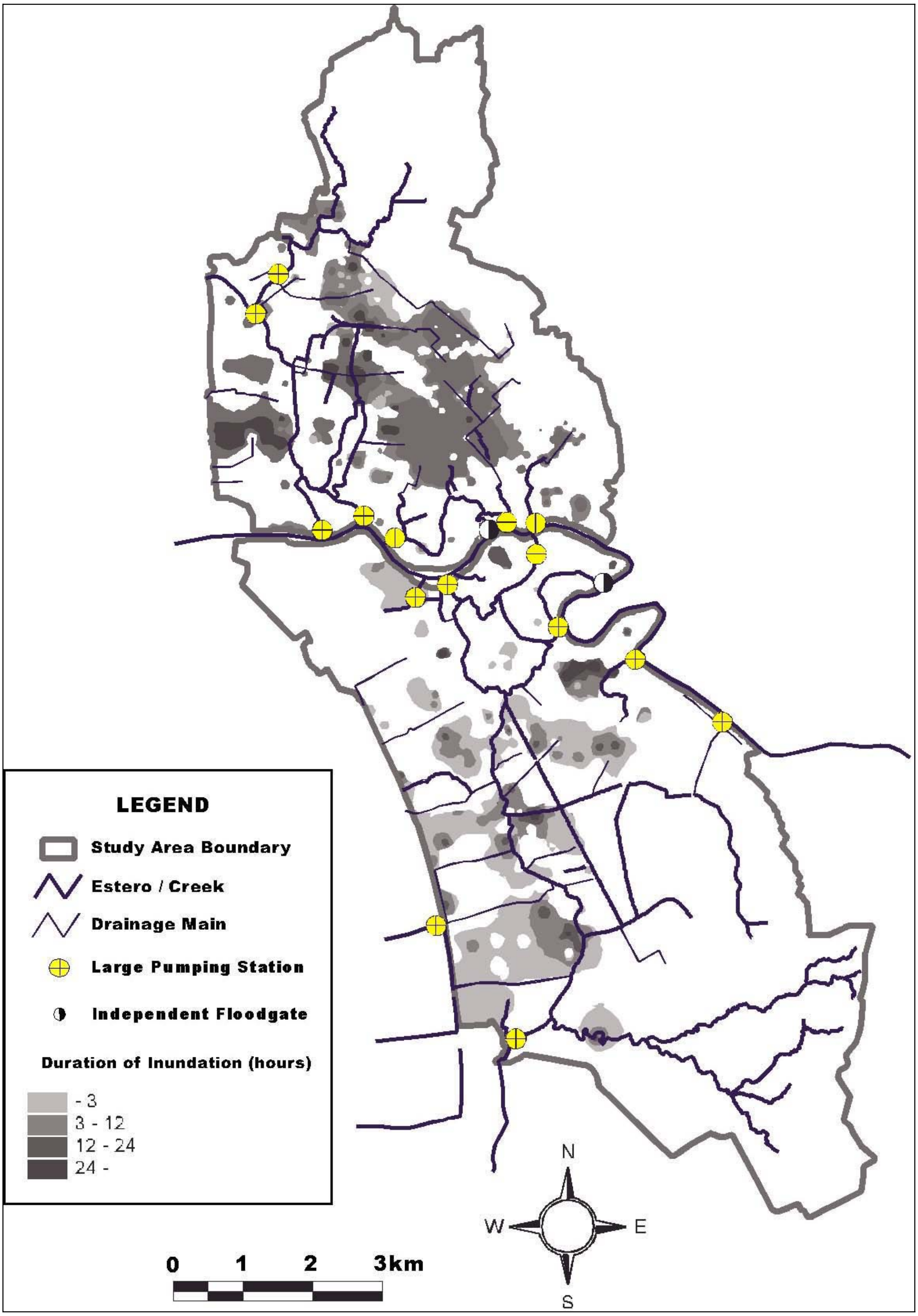


Figure 2.4.6 Duration in August 2004 Inundation

Table 2.4.5 Summary of Pump Operation during August 2004 Inundation

Drainage Block	Pumping Station	Area (km^2)	Total Capacity (m^3/s)	Pump Unit (m^3/s)	Total Operation Hour (hr)*1		Total Volume (m^3)	Total Volume/Area (mm)	PumpStart Level (m)	Max. WaterLevel In Estero (m)*1	WaterLevel Rise in Estero (m)
					25-Aug	26-Aug					
N01	Vitas	5.69	32.0	6.400	48.25	25.75	1704960	294	10.1	10.40	0.30
	Binondo	2.56	11.6	2.900	18.18	56.47	779346		10.0	10.90	0.90
	Escolta	0.30	1.5	0.500	17.00	0	30600		10.0	10.90	0.90
N02	Quiapo	2.29	10.8	2.370	70.23	39.28	934339	443	10.5	10.85	0.35
	Aviles	3.28	15.6	3.530	73.31	47.28	1532458		10.5	11.45	0.95
N03	Valencia	2.37	11.8	2.625	56.64	45.3	963333	406	10.5	11.50	1.00
N04	Balut	0.49	2.0	1.000	29.50	20.75	180900	369	9.1	11.42	2.32
S01	Tripa de Gallina	17.06	57.0	7.000	47.36	39.92	2199456	165	9.9	10.60	0.70
	Libertad	7.52	42.0	7.000	39.75	33.87	1855224		9.9	10.20	0.30
S02	Balete	0.94	3.0	0.400	43.87	27.33	102528	109	10.6	11.45	0.85
S03	Paco	1.74	7.6	2.530	24.71	19.11	399113	166	10.5	10.75	0.25
	Pandacan	1.15	4.4	2.200	8.57	8.33	133848		10.5	10.85	0.35
	San Andres	3.12	19.0	4.750	15.47	11.72	464949		10.5	10.45	-
S04	Sta.Clara	1.63	5.3	2.650	14.19	9.89	229723	141	11.2	11.70	0.50
S05	Makati	1.65	7.0	3.500	8.23	5.96	178794	108	11.3	11.25	-

Source *1: MMDA
Note: Total volume is estimated by assuming that pump efficiency is 100%.

[1] JICA, DPWH, MMDA, Final Report on Study on the Existing Drainage Laterals in Metro Manila in the Republic of the Philippines (SEDLMM), 2000.

[2] MMDA, Statistical Data on Flood-Prone Major Roads in Metro Manila, 2004.

[3] DPWH, Main Report on Detailed Engineering Design of Pasig-Marikina River Channel Improvement Project, 2002.

[4] JICA, MMDA, PHIVOLCS, Draft Final Report on Earthquake Impact Reduction Study for Metropolitan Manila, Republic of the Philippines (MMEIRS), 2004.

[5] DPWH, Main Report on Detailed Engineering Design of Pasig-Marikina River Channel Improvement Project, 2002.

2.5 DRAINAGE SYSTEM

2.5.1 INTRODUCTION

The drainage system in the core area consists of a number of drainage channels and facilities, namely esteros/creeks, outfalls, drainage mains, laterals, road gutters, drainage pumping stations, floodgates, flood wall, etc. In the Study, a total of 74 km in length for esteros/creeks and 35 km in length for drainage mains have been identified based upon the results of previous studies, especially SEDLMM (2000), and the drainage inventory and maps provided by MMDA. The fieldworks, including confirmation of connection of drainages and topographic survey, have been conducted during the Study with the help of MMDA. Inventory of pumping stations and other structures are also conducted. Drainage blocks, basins and sub-basins have also been delineated based on available latest information on drainage connection and topography. In this chapter, these existing conditions of drainage system are summarized. For the detail such as method and procedure of analysis, please refer to *Supporting Report E*.

2.5.2 EXISTING DRAINAGE SYSTEM

(1) Definition of Drainage Channels and Facilities

The terminology of the drainage channels and facilities has been defined in the Study as shown in *Table 2.5.1*.

Table 2.5.1 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 storm water mechanically*
Floodgates	*Gate to control discharging storm water 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 storm water for drainage pumping stations*
Interceptors	*Man-made channel that intercepts and drains storm water into esteros, the Pasig River and Manila Bay*

(2) Drainage System

The total catchment area of the drainage system in the core area is about 73 km^2. Within the catchment, there are esteros / creeks and drainage mains with total length of about 74 km and 35 km, respectively. Density of drainage in the core area is thereby 1.0 km^{-1} for esteros / creeks, and 1.5 km^{-1} for both estreos / creeks and drainage mains. The drainage system in the core area is geographically divided by the Pasig River into two areas: North Manila (north or right bank of the Pasig River) and South Manila (south or left bank of the Pasig River).

The drainage area in North Manila is divided into five drainage blocks with a total catchment area estimated at 28.78 km^2 as shown in *Figure 2.5.1*. Major dimensions of each drainage block are summarized in *Table 2.5.2*.

Table 2.5.2 Major Dimensions of Each Drainage Block in North Manila

ID	*Name of Drainage Block*	*Area (km^2)*	*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*

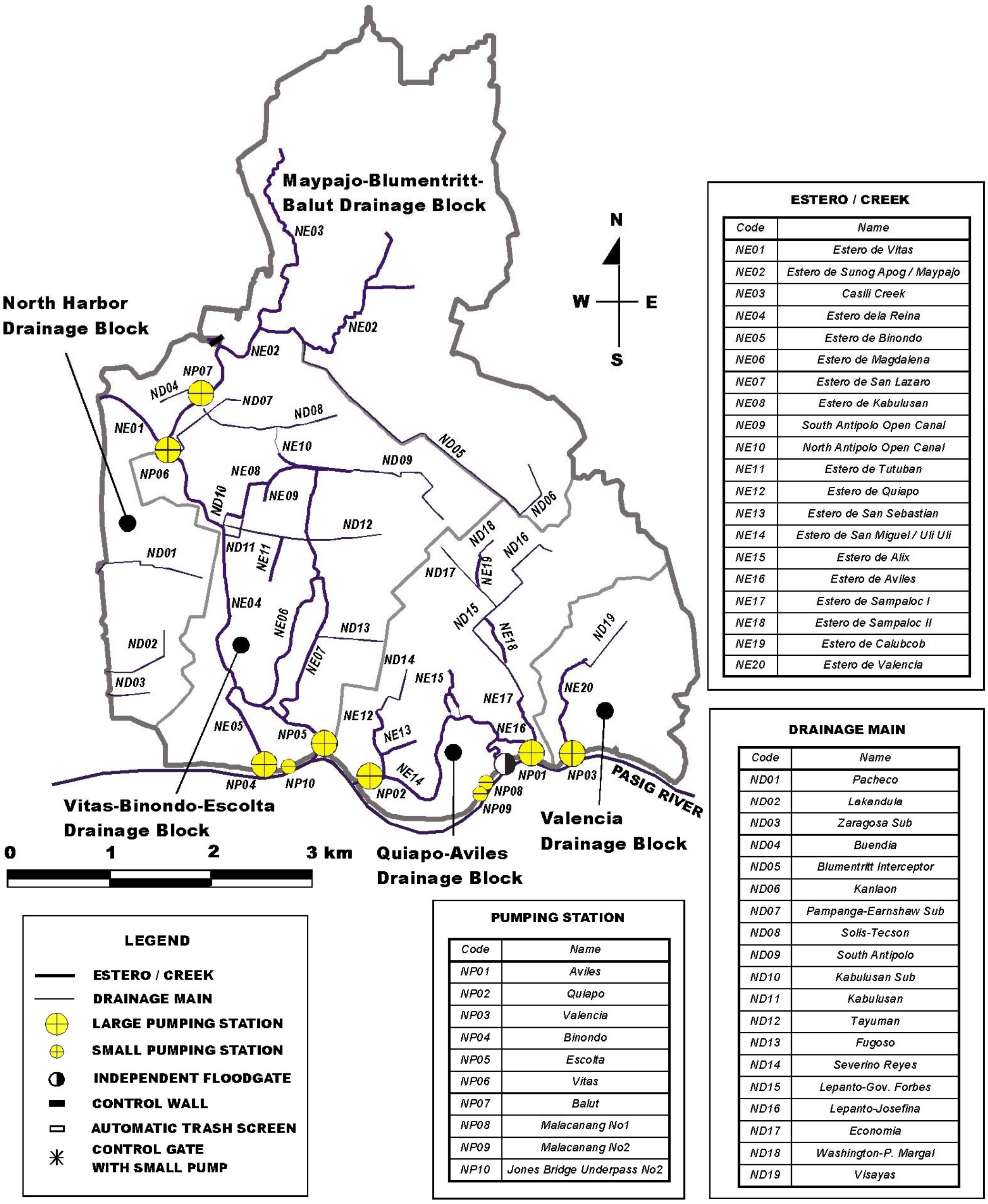
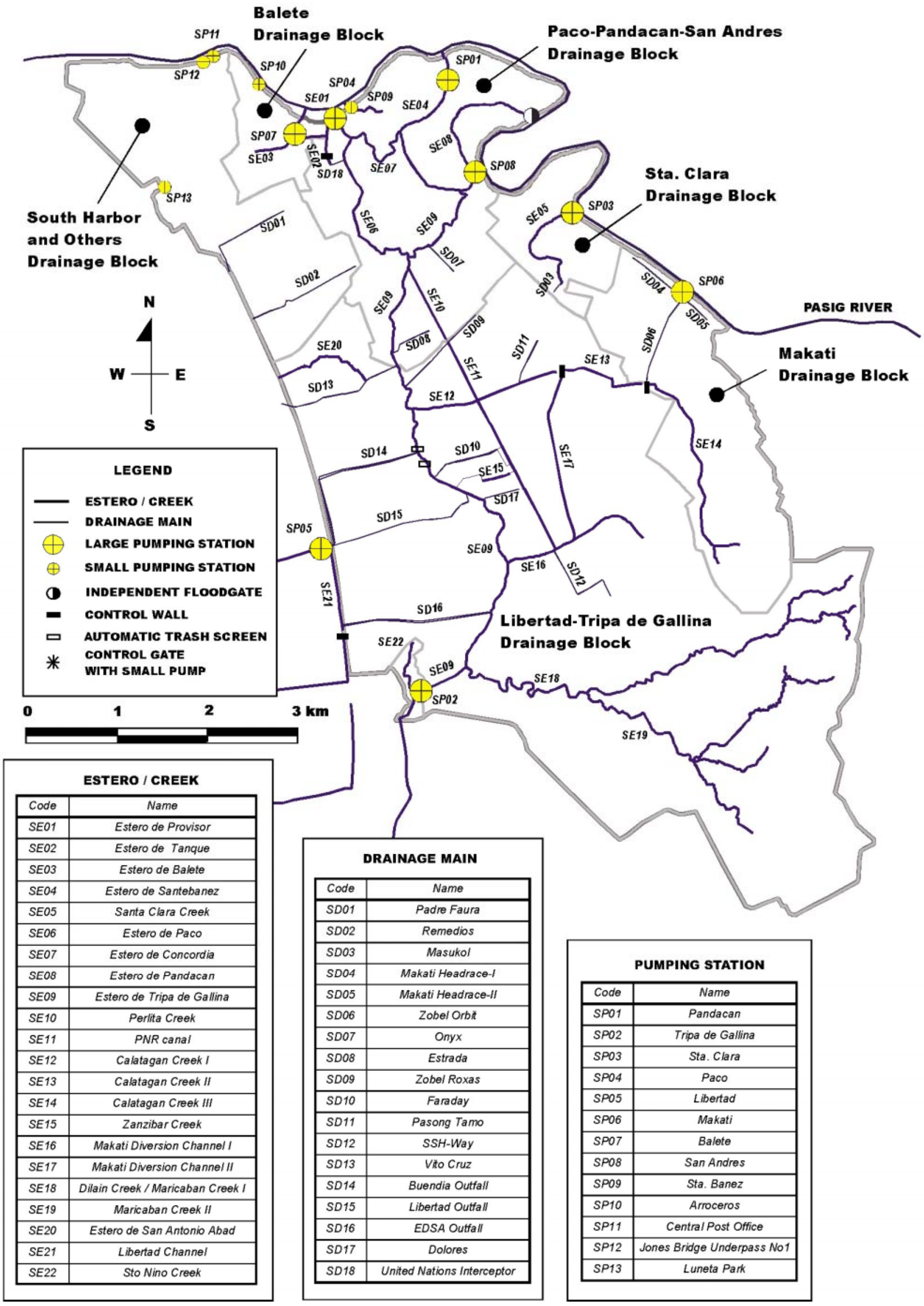


Figure 2.5.1 Drainage System in North Manila

The drainage area in the South Manila area is divided into six drainage blocks as shown in *Figure 2.5.2*, with a total catchment area estimated at 43.80 km^2. Major dimensions of each drainage block are summarized in *Table 2.5.3*.

Table 2.5.3 Major Dimensions of Each Drainage Block in South Manila

ID	*Name of Drainage Block*	*Area (km²)*	*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*



ESTERO / CREEK

Code	Name
SE01	Estero de Provisor
SE02	Estero de Tanque
SE03	Estero de Balete
SE04	Estero de Santebanez
SE05	Santa Clara Creek
SE06	Estero de Paco
SE07	Estero de Concordia
SE08	Estero de Pandacan
SE09	Estero de Tripa de Gallina
SE10	Perlita Creek
SE11	PNR canal
SE12	Calatagan Creek I
SE13	Calatagan Creek II
SE14	Calatagan Creek III
SE15	Zanzibar Creek
SE16	Makati Diversion Channel I
SE17	Makati Diversion Channel II
SE18	Dilain Creek / Maricaban Creek I
SE19	Maricaban Creek II
SE20	Estero de San Antonio Abad
SE21	Libertad Channel
SE22	Sto Nino Creek

DRAINAGE MAIN

Code	Name
SD01	Padre Faura
SD02	Remedios
SD03	Masukol
SD04	Makati Headrace-I
SD05	Makati Headrace-II
SD06	Zobel Orbit
SD07	Onyx
SD08	Estrada
SD09	Zobel Roxas
SD10	Faraday
SD11	Pasong Tamo
SD12	SSH-Way
SD13	Vito Cruz
SD14	Buendia Outfall
SD15	Libertad Outfall
SD16	EDSA Outfall
SD17	Dolores
SD18	United Nations Interceptor

PUMPING STATION

Code	Name
SP01	Pandacan
SP02	Tripa de Gallina
SP03	Sta. Clara
SP04	Paco
SP05	Libertad
SP06	Makati
SP07	Balete
SP08	San Andres
SP09	Sta. Banez
SP10	Arroceros
SP11	Central Post Office
SP12	Jones Bridge Underpass No1
SP13	Luneta Park

Figure 2.5.2 Drainage System in South Manila

2.5.3 DRAINAGE PUMPING STATIONS AND OTHER STRUCTURES

(1) GENERAL

The drainage method in the core area of Metropolitan Manila can be basically categorized into two types of gravity drainage and forced drainage by pumping station. Since a major portion of the core area of Metropolitan Manila is low-lying land, the tidal effect gives rise to one of the primary and most difficult flooding problems. Accordingly, storm water is drained mostly by means of pumping stations covering about 52 km^2 (71%) of the total area of 73 km^2. *Figure 2.5.3* shows the drainage area that is drained by pumping stations.

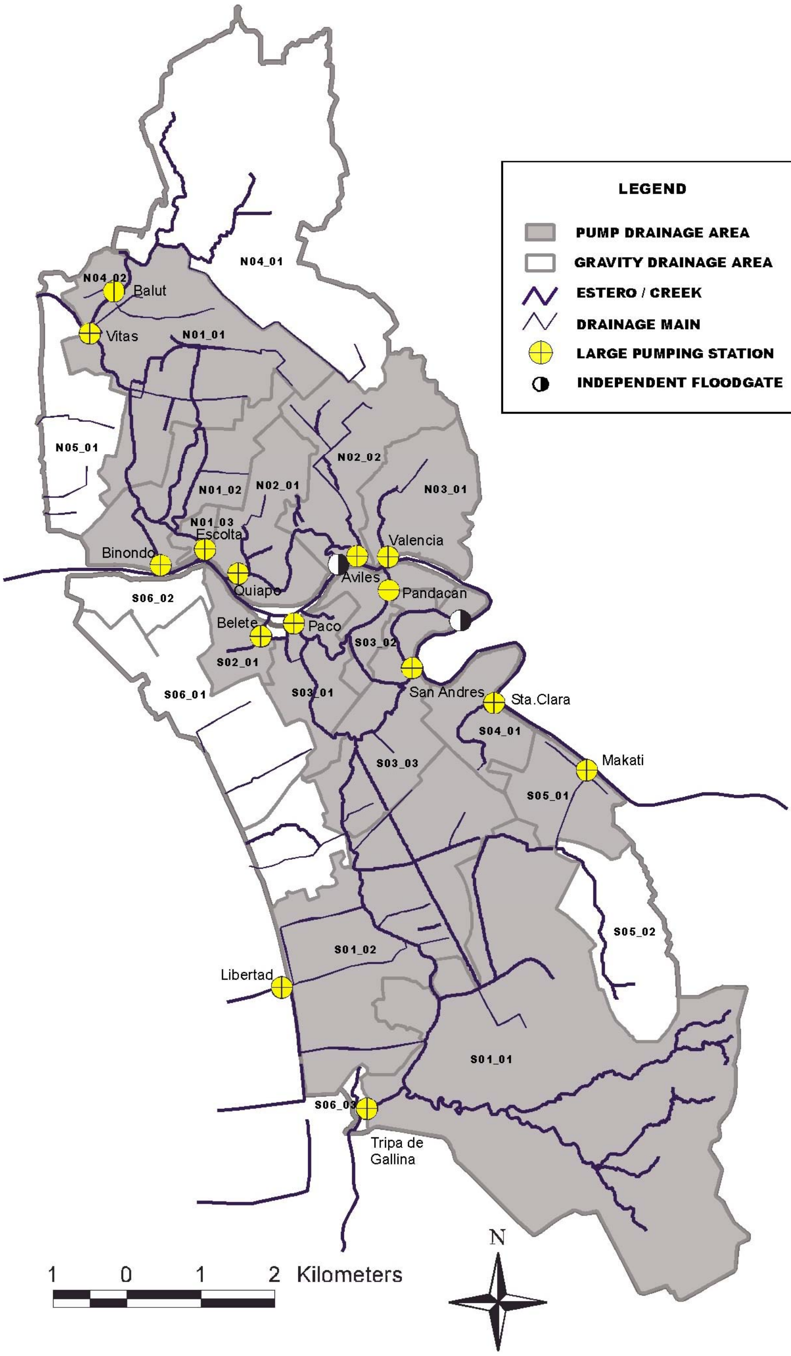


Figure 2.5.3 Drainage Area Drained by Pumping Stations

(2) Large Drainage Pumping Stations

There exist 15 large drainage pumping stations in the core area of Metropolitan Manila. To specify the boundary of drainage basin of each pumping station is quite difficult, because the boundary can vary actually depending on flow condition, rainfall pattern and so on. Therefore, overall basin boundary was firstly specified based on the original plan, and then, small modification was made based on available information for topography and existing drainage laterals. The areas of each drainage basin are shown in *Table 2.5.4* together with capacity of pumping stations.

Table 2.5.4 Total Drainage Capacity and Area of Drainage Basin for Large 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 combined efforts of the two pumping stations.

Major design conditions of the above drainage pumping stations are as follows.

Design flood scale:	10-year stormwater
Operating system:	Electric power by MERALCO with diesel engines
Solid Waste treatment:	Automatic trash removal equipment
Drainage gate:	Gate for gravity drainage
Total drainage capacity:	230.6 m^3/s
Total service area:	51.80 km^2
Average unit drainage capacity per km^2:	4.45 $m^3/s/km^2$

Of the 15 large drainage pumping stations, seven stations were constructed in the 1970s, four stations in the 1980s and four stations in the 1990s. These drainage pumping stations have been working effectively in improving drainage situation in the core area of Metropolitan

Manila. However, almost 20 to 30 years have been past since their constructions, especially for 10 pumping stations. Accordingly, pump equipment and its appurtenant facilities have become old in some pumping stations. To cope with such situations, the drainage pump equipment was rehabilitated in 1988.

Subsequently in 1999, overhauling of pump equipment was made at five stations of Aviles, Tripa de Gallina, Valencia, Libertad and Quiapo. It was found that remarkable problems are deterioration of casing liner, erosion and corrosion of guide casing, crack of various major parts and units of engine, etc., due to aging, extremely low water quality, clogged and overloaded solid waste, decreasing of cooling effect, etc.

(2) Small Drainage Pumping Stations

There exist eight small drainage pumping stations having total drainage capacities of 4 m^3/s. Their locations and capacities are shown in *Figure 2.5.4* and *Table 2.5.5*, respectively.

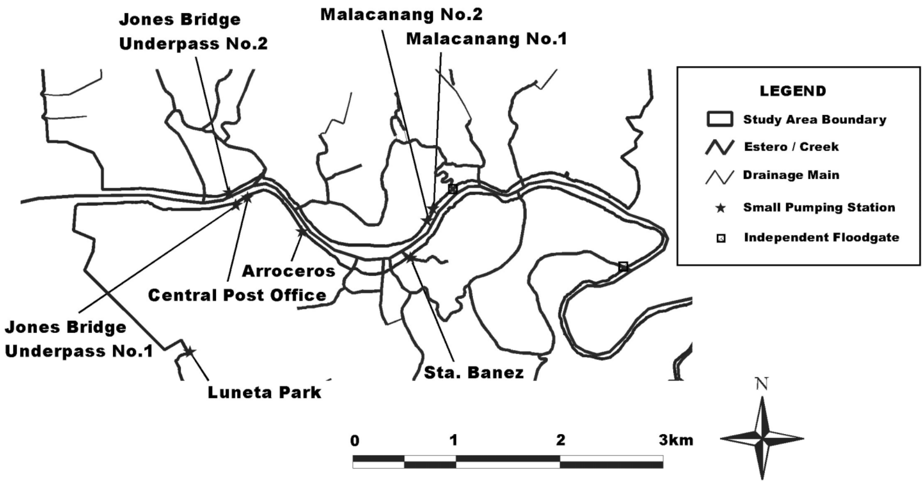


Figure 2.5.4 Locations of Small Pumping Stations

Table 2.5.5 Capacities of Small Pumping Stations

Name of Pumping Station	*Capacity (m^3/s)*
Malacanang No.1	*0.66*
Malacanang No.2	*0.76*
Arroceros	*0.66*
Luneta Park	*0.42*
Central Post Office	*0.56*
Jones Bridge Underpass No.1 (South)	*0.26*
Jones Bridge Underpass No.2 (North)	*0.36*
Sta. Banez	*0.318*

(3) Floodgates and Other Structures

Floodgates and control walls have been constructed at outlets of the esteros or in the esteros, as shown in *Figures 2.5.1 and 2.5.2*. Objectives of the floodgate are to check return flow from the Pasig River in the high water level and to discharge storm water in the esteros to the Pasig River when the water level at Pasig River is lower than those in the esteros, whereas control wall is to control flow direction by installing wall made by concrete, steel or earth dikes.

There are originally 5 floodgates in total at the respective esteros of Escolta, Uli-Uli, Balete, Sta. Banez, and Pandacan. The two floodgates of Uli-Uli and Pandacan are presently independent gates constructed at outlet of each estero, and others are installed jointly with the respective drainage pumping stations of Escolta, Balete and Sta. Banez.

On the other hand, there exist 5 control walls in the respective esteros of Tanque, Calatagan Creek II and III and Libertad channel in South Manila, and Maypajo in North Manila, as presented in *Figures 2.5.1* and *2.5.2*.

There is a control gate jointly equipped with small drainage pump in the south Antipolo creeks. Trash screens, automatic trash screens, are installed at inlet of outfalls along the Estero de Tripa de Gallina.

2.5.4 DRAINAGE BASIN

(1) Sub-Basin

The total study area has been divided into five drainage blocks for North Manila and six drainage blocks for South Manila. Each drainage block has again been divided into small drainage basins (pump and gravity drainage basins) and smaller sub-basins based on topography, laterals network, road network, channel connectivity, drainage facility etc. Drainage basin boundary of previous studies and sub-basin boundary of SEDLMM (2000) have been utilized in preparing drainage basin and sub-basin map of this study. In total, there are seven and eight pump drainage basins, and four and six gravity drainage basins in North and South Manila drainage areas, respectively. Total number of sub-basins in North and South drainage areas is 72 and 120, respectively. In addition, reach basins have been defined as catchment associated with a reach or branch of esteros or drainage mains, which are employed in runoff calculation.

Divisions of drainage blocks, drainage basins, reach basins and sub-basins for North and South Manila drainage areas are shown in *Figure 2.5.5* and *Figure 2.5.6,* respectively.

(2) Existing Land Use and Runoff Coefficient

Reclassified existing land use map prepared by MMEIR (2004) shown in *Figure 2.5.7*. is used to calculate runoff coefficient on each sub-basin. Summary on land use and runoff coefficient for the total study area is as follows.

Land use:

- Of the total study area, urban area comprises 33% in the north and 47% in the south drainage areas with a total of 80%.
- Of the total study area, non-urban area comprises 6% in the north and 14% in the south drainage areas with a total of 20%.
- Within urban area, residential area comprises 25% in the north and 35% in the south drainage areas with a total of 60%.
- Within urban area, informal settlers comprise 0.7% in the north and 0.5% in the south drainage areas with a total of 1%.
- Within urban area, commercial-industrial-institutional area comprises 16% in the north and 23% in the south drainage areas with a total of 39%.

Runoff coefficient:

- For the total study area, runoff coefficient is calculated at 0.68. SEDLMM (2000) applied a little bit higher runoff coefficient (0.70) for the entire study area without making any calculation using land use map.
- Runoff coefficients for the north and south drainage areas are 0.72 and 0.66, respectively.
- Runoff coefficient of the north drainage blocks varies from 0.68 (N03) to 0.80 (N05) and that of the south drainage blocks varies from 0.63 (S04, S05 and S06) to 0.70 (S03).

A comparison has been made between areas and runoff coefficients of pump drainage basins calculated by this study and that of previous studies, as shown in *Table 2.5.6*. In the North Manila drainage area, maximum and minimum increases in runoff coefficient from original (1970s) runoff coefficient are at Balete (23%) and Pandacan (4%) pump drainage basins and those in the South Manila drainage area are at Binondo-Escolta (20%) and Valencia (16%) pump drainage basins.

Table 2.5.6 Increase in Runoff Coefficients of Pump Drainage Basins

Drainage Area	Pump Drainage Basin	1970s Runoff Coefficient		1980s-1990s Runoff Coefficient		This Study Runoff Coefficient	% Increase from Original Runoff Coefficient
North	Vitas		→	0.75	→	0.74	
	Binondo-Escolta	0.64	→	0.64	→	0.77	20
	Quiapo	0.63	→	0.63	→	0.73	16
	Aviles	0.60	→	0.60	→	0.70	17
	Valencia	0.59	→	0.59	→	0.68	15
	Balut		→	0.65	→	0.79	
South	Tripa de Gallina	0.56	→	0.60	→	0.62	11
	Libertad	0.64	→	0.64	→	0.75	17
	Balete	0.52	→		→	0.64	23
	Paco	0.64	→	0.64	→	0.71	10
	Pandacan	0.68	→	0.68	→	0.63	
	San Andres		→	0.72	→	0.72	0
	Sta. Clara	0.56	→	0.56	→	0.63	13
	Makati	0.62	→	0.62	→	0.68	10

(3) Future (or Planned) Land Use and Runoff Coefficient

Unfortunately, future (or planned) land use map for Manila City has not been authorized as yet, so it is not allowed to use for the Study. Since, the map is not complete and also due to difference in legends of land use by LGUs and also due to partial inconsistency of the future land use map with the existing land use map, therefore, estimated future runoff coefficient by reach basin has not been directly used in the runoff analysis. Instead, correlations have been developed between increase in runoff coefficient with increase in urbanization (against existing runoff coefficient and urbanization). The estimated averaged runoff coefficient in the entire study area will increase up to 0.70 from the current value of 0.68.

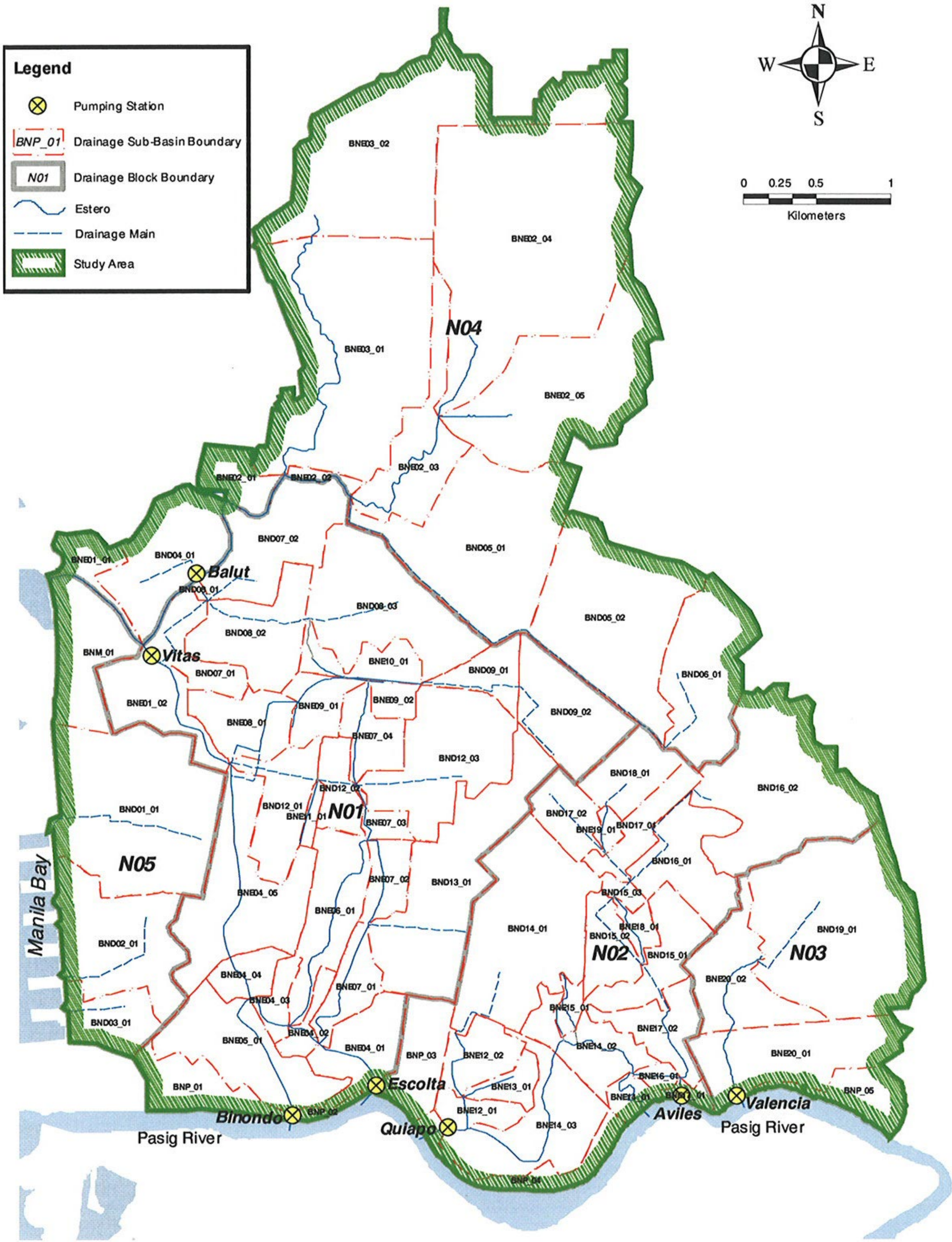


Figure 2.5.5 Sub-Basins of North Drainage Area

Figure 2.5.6 Sub-Basins of South Drainage Area

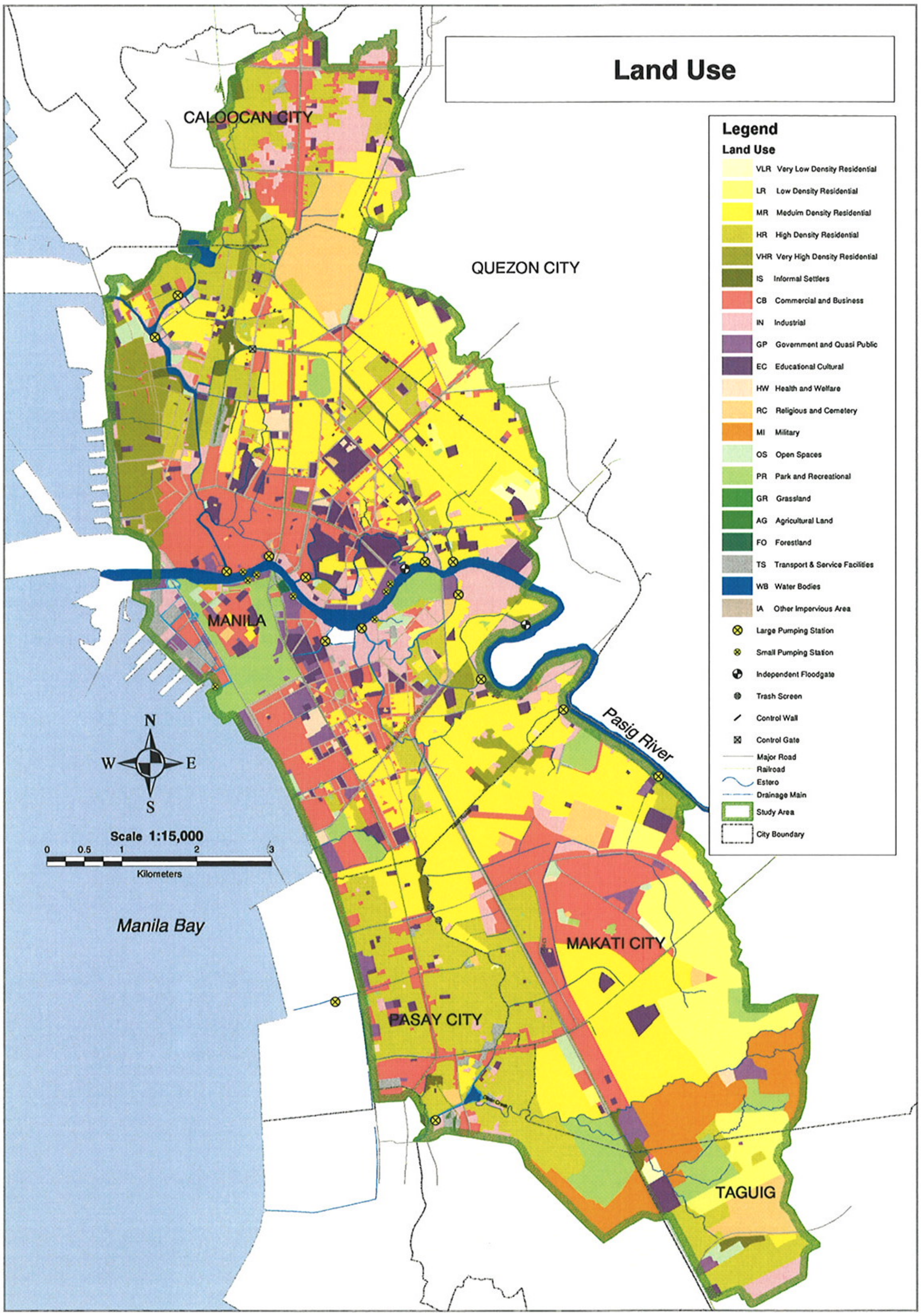


Figure 2.5.7 Existing Land use Map (2003)