5.3 Flood Protection Plan

5.3.1 Existing Conditions

(1) Land Elevation

The majority of land in the study area is characterized as undeveloped land such as agricultural, unused land and forests which have an original land level of between 0.4 m and 0.8 m MSL. In developed areas such as residential, commercial, and industrial areas, the ground level has been raised approximately 1.0 m to 1.5 m above the original ground level.

The subsoil in the Bangkok area consists mainly of soft clay layers to a depth of 10 m to15 m. Stiff clay continues to a depth of 15 m to 30 m and is underlain by a sequence of sand and clay layers. Over time, the process of consolidation, which is the natural process of soft clay together with the over-pumping of groundwater, has caused land subsidence across most of the Bangkok area.

(2) Land Subsidence

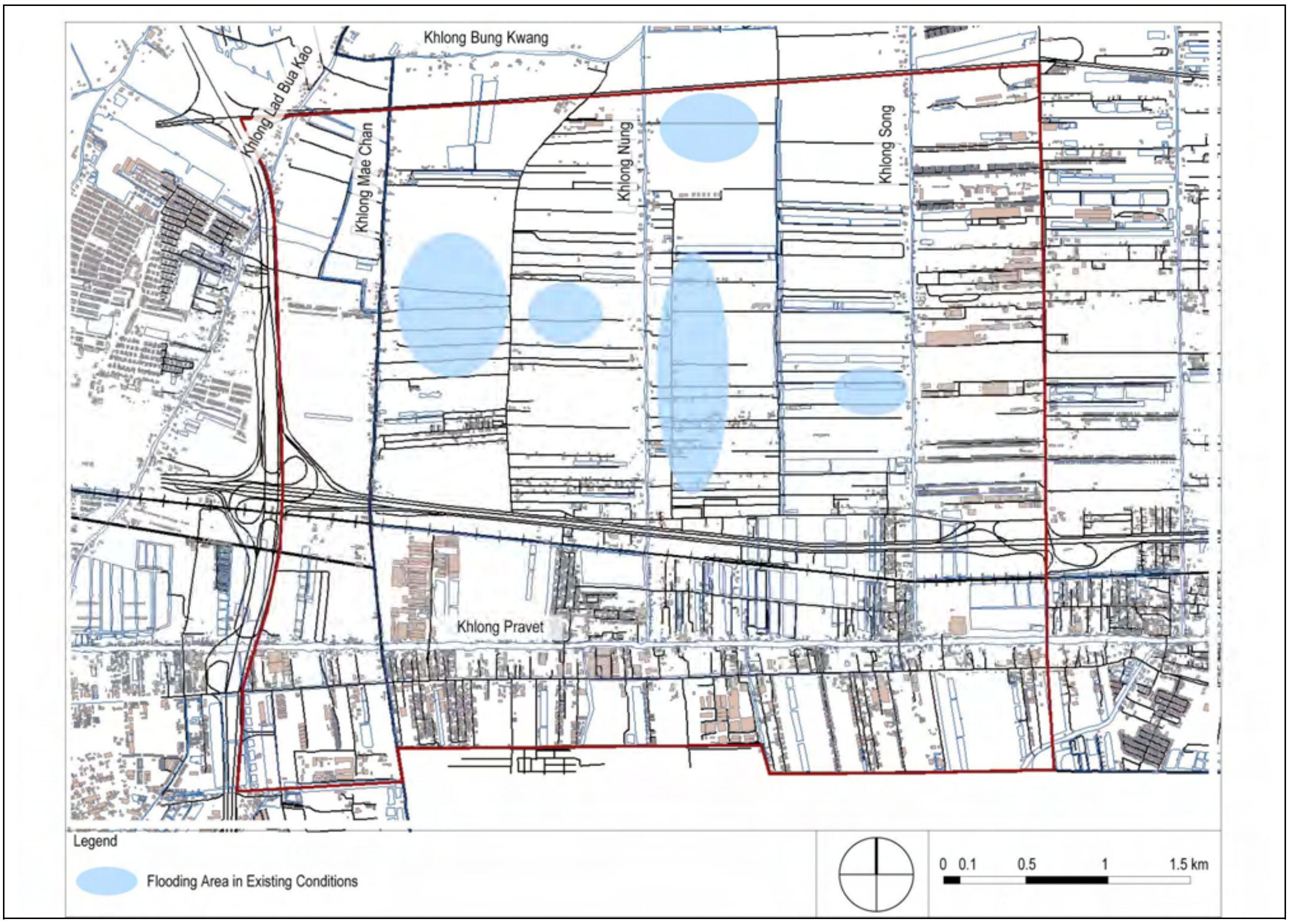
In the Suvarnabhumi Aerotropolis Development Plan land subsidence rates have been reported for the whole Bangkok area for the year 2000. The land subsidence rate is approximately 3 cm per year. The long term average land subsidence rate is recorded as 0.7 cm per year between 1933 and 1987. The rate has increased recently due to the growth in urbanization and the increase in ground water consumption.

In the master plan for infrastructure development and the preliminary design of flood protection and drainage systems for the eastern suburban area in 1996, the annual land subsidence is reported at 2 cm/year for the areas along the King's dike. Therefore an average annual land subsidence rate of 2 cm/year is used in this study. This assumes that the rate will reduce due to the expansion of the piped water supply system in the BMA in the future.

(3) Drainage Conditions and Flood Problems

There are three main *khlongs* which flow in a north to south direction in and around the study area. These are named *khlong* Mae Chan, *khlong* Nung, and *khlong* Song. These *khlongs* merge into *khlong* Pravet which flows in an east to west direction in the south of the study area. *Khlong* Pravet discharges into *khlong* Prakanong. Finally, the water in *khlong* Prakanong is pumped into the Chao Praya River at the Prakanong gate station which is located 13.5 km away from the study area.

Due to the remote location of the gate station, the water level in *khlong* Pravet in the study area normally increases to a high level during heavy rainfall. This high water level in the *khlong*, together with the relatively low and flat topographical conditions, causes regular flooding in the study area in the rainy season. According to the Lat Krabang district office of the BMA, the flooding continues for three to four months in the undeveloped areas and in places where the drainage system is insufficient, such as in Phattana Chonnabot 2.



Source: Lat Krabang District Office, BMA

Figure5.25: Flooding Area in the Study Area under Existing Conditions

5.3.2 Proposed Methodology for Flood Protection

Under existing conditions the study area has been found to be prone to flooding. Although increasing the drainage capacity of *khlong* Prakhanong and *khlong* Pravet to reduce the water level in the *khlongs* is impractical, the flooding problem in the study area is expected to become more serious due to land subsidence and changes in land use in the future. Therefore, a flood protection and drainage improvement project will be required as part of the sub-center development, including the measures listed below.

1) Under good conditions the water level in the *khlong* network will be kept at a low level to enable drainage from the adjacent plots of lands into the *khlong* network. The sub-polder system surrounding the study area will be developed to protect the study area from flooding.

2) The water level in the *khlongs* will be maintained at the control level by use of the main drainage system consisting of pumping stations and gates.

3) Following development, to retain the same level of discharge into *khlong* Pravet as under existing conditions in order to prevent the surrounding area from flooding. Since the study area is just as if the retention ponds for the surrounding areas, it shall be indispensable to regulate the discharge by the retention ponds.

(1) Alternatives for the Sub-polder System

A sub-polder system will be required for flood protection as mentioned above. From an economic point of view, the dikes will follow the existing roads or railways as much as possible.

1) Krung Thep Kritha Road is selected as the northern dike with a length of about 4.9 km. The road elevation is designed at 1.97 m MSL.

2) Rom Khlao Road is selected as the eastern dike and is the existing dike of the main polder system (or the King's Dike). The average road level is designed at 2.47 m MSL which is equivalent to the 100-year flood level.

3) The OBRR is selected as the western dike with the length of about 2.8 km. The road elevation of the OBRR is designed to be higher than that of Krung Thep Kritha road.

4) The southern dikes will be newly developed on the bank of *khlong* Pravet with a total length of about 4.86 km. If Lat Krabang Road is selected for the southern dikes, the gate will be installed in *khlong* Pravate at the intersection with the western dike. During discussions with a BMA officer regarding the construction of the gate at the proposed location in *khlong* Pravet, the officer pointed out that the BMA had planned to construct the gate in the same location, however the residents objected to this location. Therefore, the dike alignment has been shifted to a new location on the right side (or the upper side) of *khlong* Pravet.

To develop the sub-polder system, a gate or regulator will be installed in all *khlongs* in alignment with the dikes in order to control the flow of water between the polder area and the surrounding area. The part of the study area outside the sub-polder system, or to the south of *khlong* Pravet, will be raised up by a land embankment for flood protection.

Based on the conditions for the sub-polder system, the following two alternatives have been prepared.

1) Alternative A: The sub-polder system is developed in the form of unique enclosed dikes. The main drainage canals consist of *khlong* Nung, *khlong* Song and *khlong* Mae Chan. Gates will be installed in those three *khlongs* to enclose the sub-polder system. The discharged rainfall will drain into *khlong* Pravet via pumps located in the three *khlongs*.

2) Alternative B: The sub-polder system is divided into two protected areas. *Khlong* Nung will be outside of the sub-polder system and will function as the main drainage canal for the upper part of the sub-polder system. The main drainage canal will be *Khlong* Mae Chan for the eastern area and *khlong* Song for the western area. Pumps and gates will be installed as discharge control facilities in *khlong* Mae Chan and *khlong* Song.

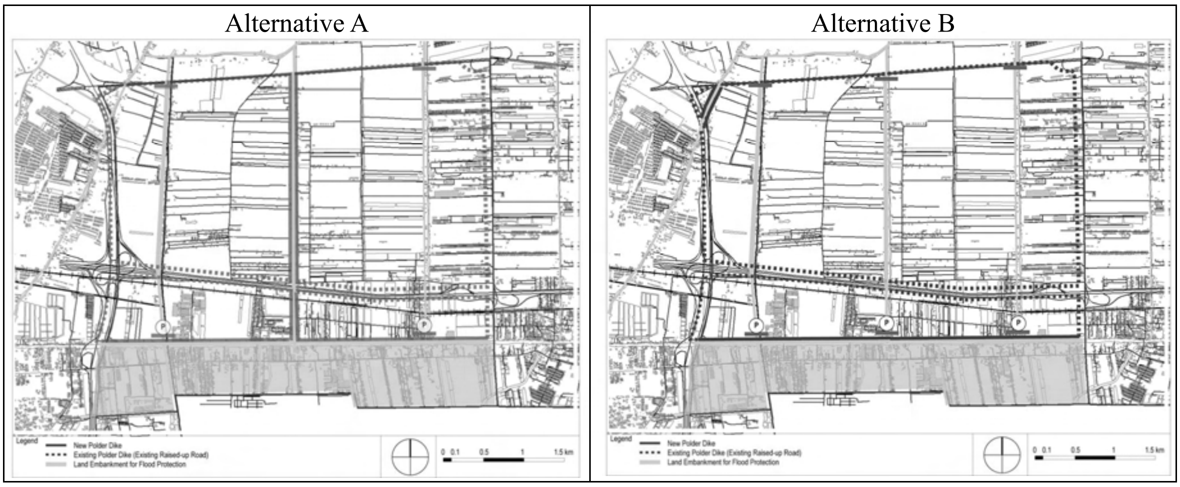


Figure 5.26: Alternatives for the Sub-polder System

A preliminary hydrodynamic model simulation has been carried out to examine the effects of the two alternatives. In Alternative B, the proposed sub-polder system will affect the drainage conditions in the upper part of the *khlongs*. The sub-polder system will raise the water level in *khlong* Bung Kwang and *khlong* Lad Bua Khao to a higher level than under existing conditions. In order to mitigate the negative effects in these *khlongs*, improvement works are required to *khlong* Lad Bua Khao including the construction of retaining walls on both sides of the *khlong* and deepening of the *khlong*. In discussions with an officer in the DDS, it was pointed out that the social impact on the residents outside the study area is anticipated to stimulate the implementation of the improvements to *khlong* Lad Bua Khao. It is noted that dense settlements are located on both banks of the *khlong*.

Under Alternative A, *khlong* Numg has sufficient capacity to carry the discharge from the surrounding area. This alternative will not cause any negative effects on the surrounding area. Therefore, Alternative A is selected for the sub-polder system.

In discussions with the BMA, it was pointed out that improvement works should not be planned for all of the three *khlongs* in the north to south direction. Hence, the improvement works shall be planned for *khlong* Nung and *khlong* Mae Chan. *Khlong* Nung requires capacity improvement in order to contain the water flow from the upper stream, while urbanization along *khlong* Mae Chan is relatively behind that of *khlong* Song.

(2) Planning Criteria

In accordance with the standards issued by the DDS, the planning criteria for flood protection are as mentioned below.

1) Polder Dike: The crest level of the polder dike will be designed to comply with the requirements mentioned below.

   - Crest level > design flood level + freeboard + land subsidence for 20 years where: Freeboard height = 20 cm for dikes along main *khlongs,* Annual land subsidence rate = 2 cm/year.

2) Rainfall Intensity: The design return period is set at 5 years. The rainfall intensity formula is applied for the design of the collection system and the retention capacity in

the dry season. A rainfall volume of 210 mm in seven days of rainfall, which is a higher amount than given by the formula, is applied for the retention capacity in the rainy season.

Table 5.6: Rainfall Intensity

Item	Unit	Collection System	Retention Pond	
			Dry Season	Rainy Season
Rainfall Intensity	mm/hr	Ir=7059.59/ ((t+37)^1.01346)	Ir=7059.59/ ((t+37)^1.01346)	Not applied
	mm	Not applied	Not applied	210
Rainfall Duration	hour	Time of discharge concentration	24	168
Time Unit for Calculation	minute	Same as above	30	60

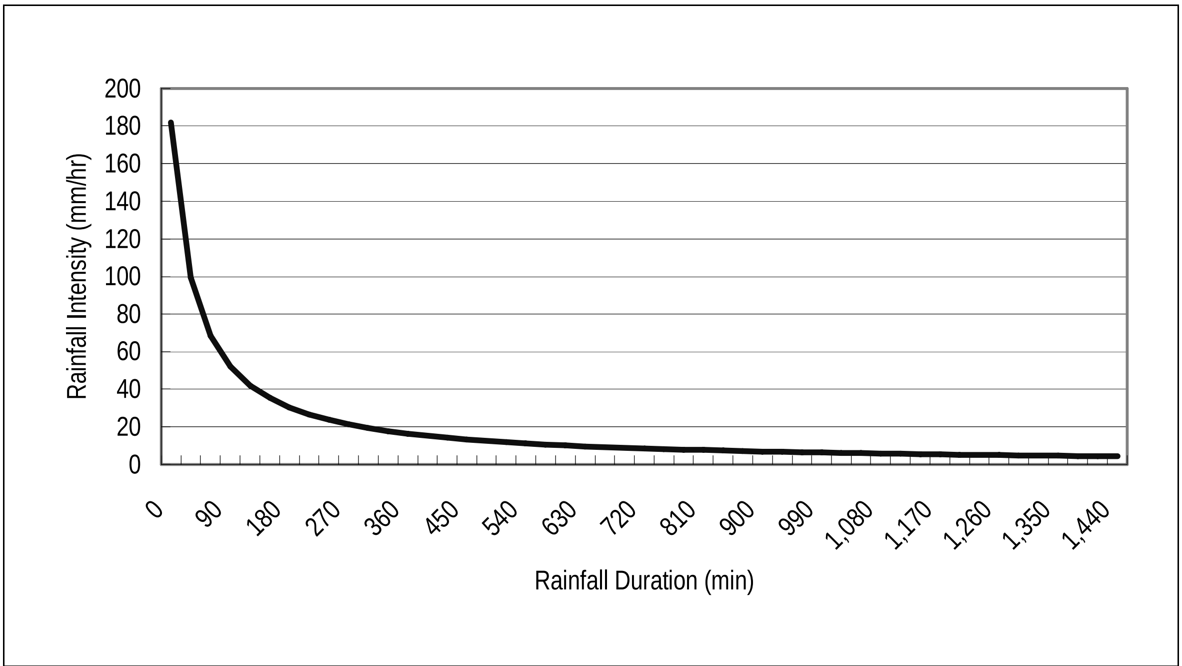


Figure 5.27: Rainfall Intensity estimated by the Rainfall Intensity Formula using a 5-year Return Period

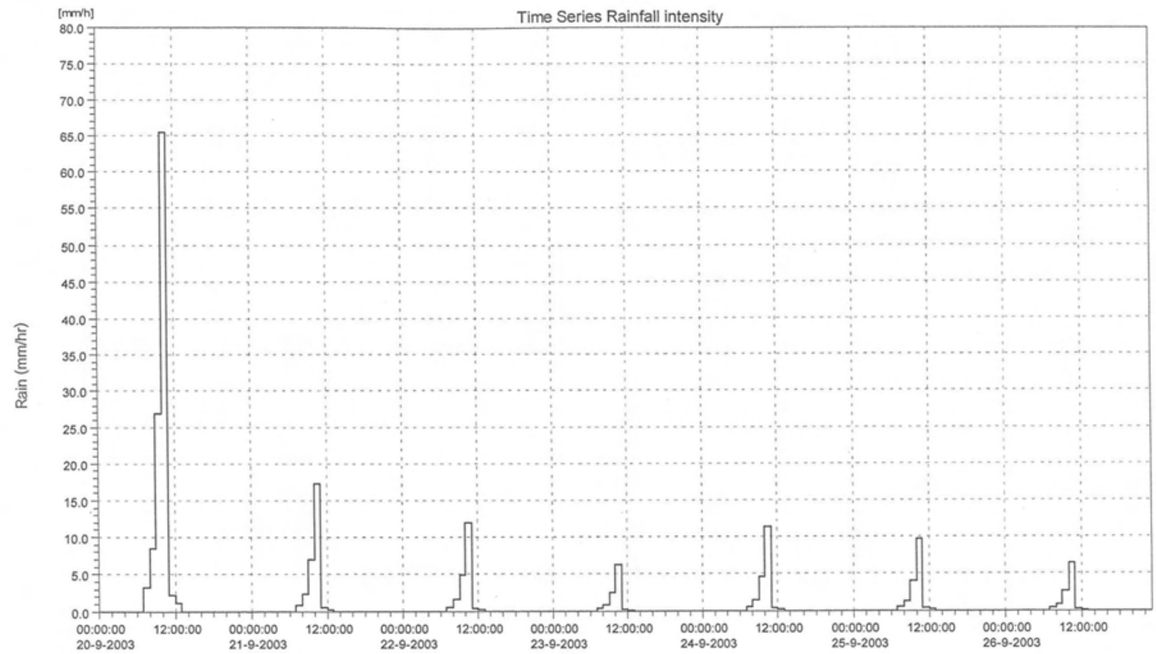


Figure 5.28: Rainfall Intensity of 7 Days Rainfall using a 5-year Return Period

3) Runoff Coefficient: The runoff coefficient for the retention pond is set at 0.9 for roads and river areas. Taking into account the long rainfall duration, the coefficient for other land use areas is set at 0.8 which is higher than the highest coefficient in the standards.

Table 5.7: Runoff Coefficient

Land Use	Collection	Retention Pond
Residential-Low rise building	0.300	0.800
Residential-Middle-high rise building	0.400	0.800
Culture Town	0.450	0.800
Trade & Distribution	0.350	0.800
Hybrid Town Center	0.450	0.800
RDD & Enterprise	0.450	0.800
Public facility	0.350	0.800
Value Creation	0.350	0.800
Green and Park Area	0.250	0.800
Road	0.900	

4) Runoff Discharge: The discharged rainfall volume is estimated by the formulae given below.

$$Q = 0.278 \times C \times I \times A$$

where:
Q = design peak discharge (m^3/s)
C = runoff coefficient
I = rainfall intensity (mm/hr)
A = catchment area (km^2)

$T_c = t_o + t_d$
where:
T_c = time of concentration (min)
t_o = time of overland flow > 15 (min,)
t_d = time of flow in channel or conduit (min)
in general time of overland flow (t_o) = 15 min

5) Drainage Capacity: Hydraulic design of flow in conduits is calculated using Mannings equation:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

where:
Q = discharge capacity (m^3/s)
A = submerged area (m^2)
R = hydraulic radius (m)
S = energy slope
n = Mannings coefficient

The hydraulic design of pipe diameters is based on the full submerged flow. The design of pipe slopes and invert levels are based on free flow conditions. The minimum flow velocity for self-cleaning is set at 0.9 m/s.

The requirements for pipe installations are summarized in the box below.

1) The pipe size for new installations is 0.6 m minimum and 1.2 m maximum. The larger pipe sizes are replaced with box culverts.
2) The minimum coverage depth is 0.6 m.
3) The distance between manholes is set at not more than 16 m.

5.3.3 Hydraulic Analysis of Existing Conditions

(1) Hydrodynamic Model Calibration

The hydrodynamic model was calibrated to enable analysis of the items listed below:

1) Analysis of flooding and drainage under existing conditions
2) Effectiveness of the flood protection measures proposed for the study area
3) Effect of the proposed measures on the surrounding areas

The study area is part of the flood protection area for the eastern suburban project. The drainage in the study area and the surrounding area is interconnected by the *khlong* network. Therefore the model has been set up to cover the whole eastern suburban area within the main polder system. The data necessary for setting up the model is as follow:

1) Cross-section of the *khlongs* together with the configuration of the *khlong* network

2) Physical data and operation rules for gates and pumps

3) Catchment boundary conditions

Before the model can be used to study the effectiveness of the proposed flood protection measures, the model is calibrated based on the hydrological conditions in the rainy season of the year 2003. The maximum water levels in and around the study area during the rainy season are normally in the range of 0.3 – 0.5 m MSL. The simulated water level is confirmed against the water level observed at the Krathum Sua Pla gate of the E.22 *khlong* Pravet station 1.5 km east of the study area. The water level is estimated at 0.3 – 0.4 m MLS in *khlong* Pravet and 0.3 – 0.4 m MSL in other *khlongs* within the study area. The consistency of the two water levels proves that the model can simulate the physical behavior of the drainage system.

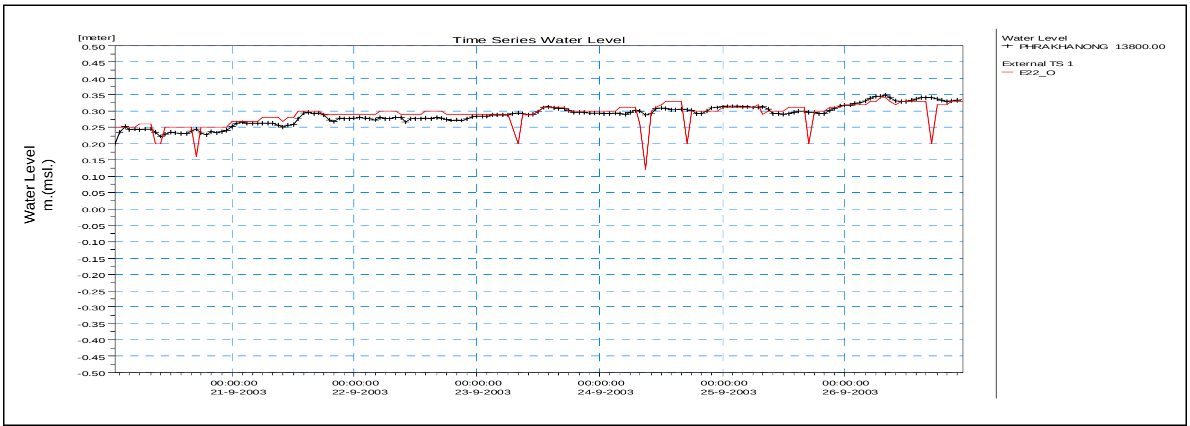


Figure 5.29: Water Level estimated by the Simulation Model and recorded at Station E.22

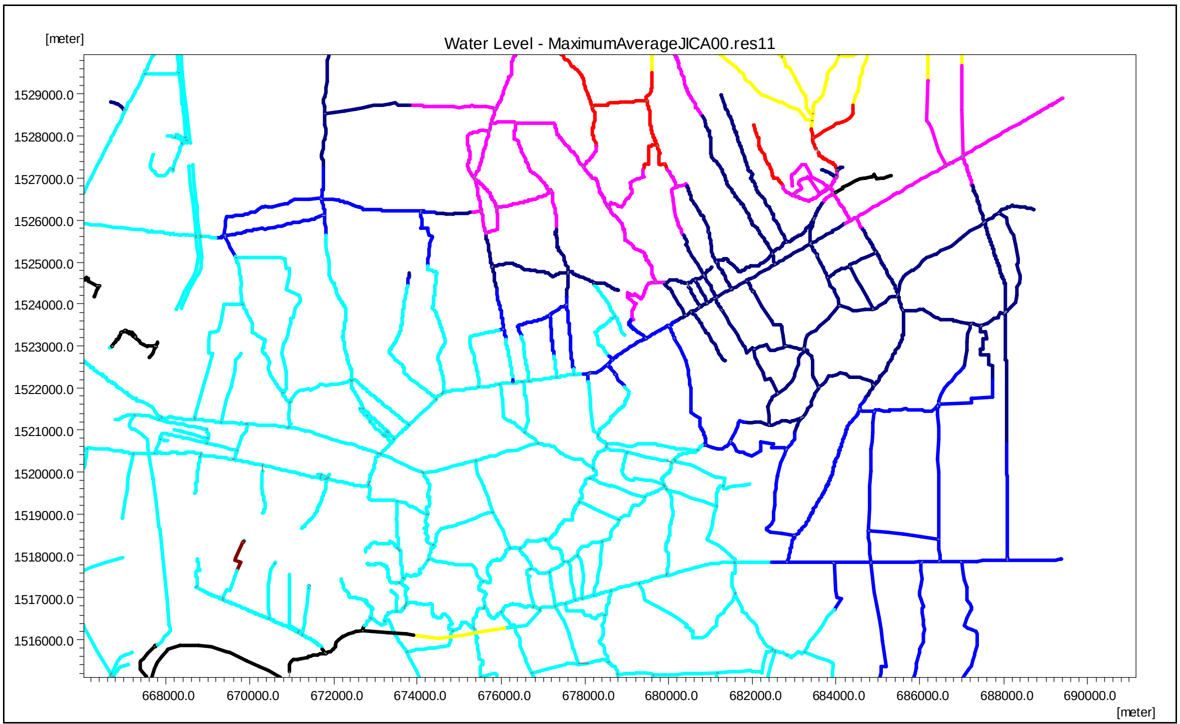


Figure 5.30: Estimated Maximum Water Level in the *Khlong* Network in the Rainy Season in 2003

Table 5.8: Estimated Maximum Water Level in the Khlong Network in the Rainy Season in 2003

Area	*Khlong*	HWL (m MSL)
1. Within Study Area	*Khlong* Nung, *khlong* Song, *Khlong* Mae Chan	0.3 – 0.4
2. Upper Part of Study Area	*Khlong* Bung Kwang, *khlong* Lad Bua Khao	0.4 – 0.5
3. Within & Lower Part of Study Area	*Khlong* Pravet	0.3 – 0.4

(2) Existing Flood Water Levels based on a 5-year Return Period Rainfall

The water levels in and around the study area were simulated using the hydrodynamic model under existing conditions for 7 days rainfall in the 5-year return period. The results showed that the maximum water level increases to the same level as the existing ground level in the undeveloped areas. The high water level is estimated at 0.3 – 0.5 m MSL in *khlong* Pravet and 0.4 – 0.6 m MSL in other *khlongs* within the study area.

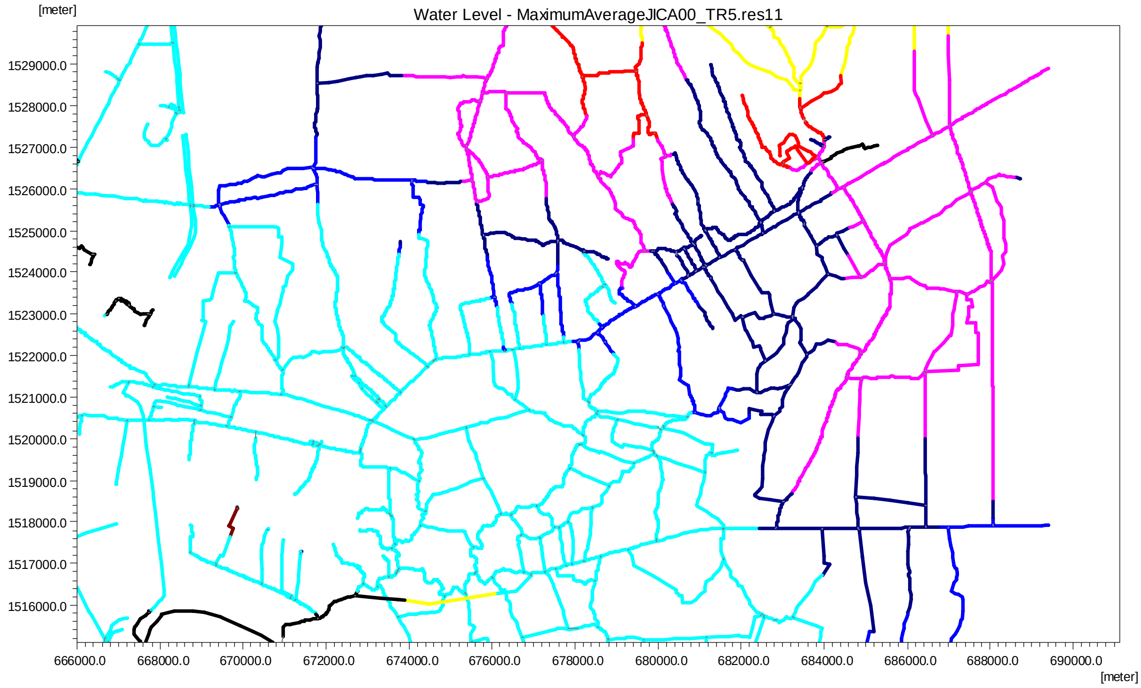


Figure 5.31: Existing High Water Level in the *Khlong* Network based on 5-Year Return Period rainfall

Table 5.9: Existing High Water Level in the *Khlong* Network based on 5-Year Return Period rainfall

Area	*Khlong*	HWL (m MSL)
1. Within the Study Area	Upper part of *khlong* Mae Chan, *khlong* Nung, and *khlong* Song	0.5 – 0.6
	Lower part of *khlong* Nung, and *khlong* Mae Chan	0.4 – 0.5
2. Upper Part of the Study Area	*Khlong* Bung Kwang	0.5 – 0.6
	khlong Lad Bua Khao	0.5 – 0.6
3. Within & Lower Part of the Study Area	*Khlong* Pravet	0.3 – 0.5

(3) High Water Level in the Sub-polder System

The original ground level in the sub-polder system varies from 0.4 – 0.8 m MSL. Therefore, the normal water level is set at 0.0 m MSL while the allowable maximum water level during the 5-year return period rainfall should be 0.4 m MSL.

(4) Allowable Discharge to Downstream Areas

The catchment area of the Prakanong PS is interconnected with that of the Sam Sen PS and the *Khlong* Toey PS. The pumping capacity per square kilometer is estimated at 1.65 $m^3/s/km^2$ from dividing the total pumping capacity of 348 m^3/s by the total catchment area of 150.71 km^2 which is multiplied by the runoff coefficient. The sub-polder system in the study area has a catchment area of 1,503 ha with an average runoff coefficient of 0.38. Therefore, the allowable pumping capacity of the sub-polder system is estimated at 9.40 m^3/s which may be larger than the effective capacity of the Prakanong PS.

Table 5.10: Allowable Pump Capacity for the Study Area

Item		Unit	Quantity
Pump Capacity	Sam Sen	m^3/s	45.0
	Khlong Toey	m^3/s	30.0
	Prakanong	m^3/s	173.0
	Total	m^3/s	248.0
Catchment Area		km^2	347.63
	Multiplied by Runoff Coefficient	km^2	150.71
Pump Capacity per Catchment Area		$m^3/s/km^2$	0.71
	Multiplied by Runoff Coefficient	$m^3/s/km^2$	1.65
Pump Capacity for the Study Area	Catchment Area	ha	1,503
	Runoff Coefficient		0.38
	Allowable Capacity	m3/s	9.40

Source: Master Plan for Basic Infrastructure Systems and Preliminary Design for the Flood Protection and Drainage Systems in Eastern Suburban Bangkok, BMA, 1996

Note:

1) Catchment area for the study area covers the area within the sub-polder system.
2) Runoff coefficient for the study area is set at 0.38 as specified in the master plan for eastern suburban Bangkok.

The effective pumping capacity is examined by simulating the rainfall discharge from the sub-polder system into the *khlongs* based on the 5-year return period rainfall. The average discharge volume to *khlong* Nung, *khlong* Song, and *khlong* Mae Chan is estimated at 4.02 m^3/s over 24 hours. Therefore, the allowable discharge volume from the sub-polder system is set at 4.0 m^3/s.

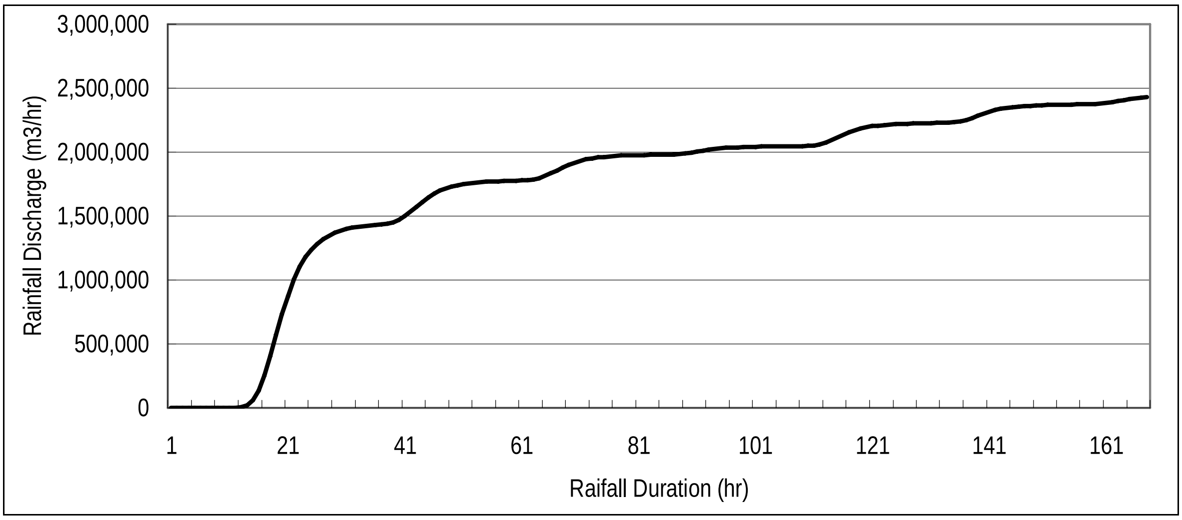


Figure 5.32: Rainfall Discharge from Sub-polder System into *Khlongs* Nung, Song, and Mae Chan based on the 5-year return period Rainfall (210 mm)

5.3.4 Hydraulic Analysis of the Proposed Flood Protection System

(1) Water Level and Retention Capacity in the Dry Season

The retention capacity in the dry season may be smaller than that in the rainy season, because the normal water level (NWL) in the dry season is set at 0.0 m MSL which is higher than that in the rainy season. Under normal conditions, the *khlongs* are connected to *khlong* Pravet without any control measures. The design conditions for the dry season are set as follows.

1) The NWL is set at 0.0 m MSL, while the HWL is allowed to increase to 0.6 m MSL which consists of the existing minimum HWL at 0.4 m MSL and a freeboard of 0.2 m.

2) A surface retention capacity is assumed for roads, parks, and riverside green areas in order to minimize the retention capacity of the sub-polder system. The depth of surface retention is set at 15 cm.

3) The water depth in the retention pond is set at 0.75 m. (HWL of surface retention (planned road elevation at 1.45 m MSL + water depth of 0.15 m) – HWL of drainage system (planned road elevation – covering of 0.6 m))

4) The hydrograph is designed to allocate the peak rainfall intensity at the end of the rainfall duration.

5) The average runoff coefficient is estimated at 0.819 for the western part and 0.818 for the eastern part of the sub-polder system.

Table 5.11: Land Area and Average Runoff Coefficients in the Sub-polder System

Item	Land Area (ha)	
	Western Part	Eastern Part
Residential Low-Rise Buildings	252.5	0.0
Residential Middle to High-Rise Buildings	124.8	103.8
Culture Town	31.7	77.6
Trade & Distribution	0.0	201.8
Hybrid Town Center	23.0	34.0
RD&D & Enterprise	104.6	189.2
Public Facilities	1.9	10.7
Value Creation	36.5	0.0
Park and Green Areas	40.7	84.5
Roads	58.8	61.3
Khlongs	5.5	6.3
Green Areas along Khlongs	4.8	6.2
Total	684.9	775.4
Average Runoff Coefficient	0.819	0.818

In practice the pumps will be operated based on the water level difference between the inside and outside of the sub-polder system. When the water level outside the polder is higher than that within the polder, the rainfall will be discharged by gravity flow, while the rainfall within the polder will be pumped out in the opposite situation. As a detailed record of the water levels is unavailable, the hydraulic calculation is conducted on the assumption that the rainfall within the polder is only discharged by pumping. In this assumption, the pumps are started when the water level is 0.1 m higher than the NWL and the pumps are stopped when the water level is 0.1 m lower than the NWL.

As a result, the land area required for the retention ponds is estimated to be 28 ha for the western part and 30 ha for the eastern part in order to control the high water level (HWL) to 0.6 m MSL in *khlong* Mae Chan and *khlong* Song.

Table 5.12: Planning Criteria and Results for the Dry Season

Item		Unit	West	East	Note
Allowable Discharge Volume		m^3/s	2.000	2.000	Pumping Capacity
Planned Water Level	NWL	m MSL	0.000	0.000	At the mean sea level
	HWL	m MSL	0.600	0.600	HWL in the rainy season + freeboard
Khlong Retention	Water Depth	m	0.600	0.600	*Khlong* Mae Chan and Song
	Capacity	m^3	35,700	37,740	*Khlong* Mae Chan and Song
Road Surface Retention	Planned GL	m MSL	1.450	1.450	15% of the plots of land in the regulatory controlled area
	Water Depth	m	0.150	0.150	Height of sidewalk
	Capacity	m^3	198,697	187,175	
Park Surface Retention	Planned GL	m MSL	1.450	1.450	Same level as the road elevation
	Water Depth	m	0.150	0.150	Height of sidewalk
	Capacity	m^3	83,172	151,455	Incl. pocket, neighborhood, and district parks
Pump	WL for Start	m MSL	0.100	0.100	NWL + 0.1m
	WL for Stop	m MSL	-0.100	-0.100	NWL - 0.1m
	Required Water Depth	m	1.200	1.200	Minimum depth required for the pump operation
	Bottom EL	m MSL	-1.300	-1.300	WL for stop – Required water depth
Retention Pond	Land Area	ha	28	30	
	Water Depth	m	0.750	0.750	HWL of road surface retention – HWL of drainage (Road EL – Covering of 0.6 m)
	Capacity	m^3	210,000	225,000	
Planned Retention Capacity		m^3	491,868	563,631	Total capacity of *khlong*, road, park, and retention pond
Required Retention Capacity		m^3	489,118	558,526	
Estimated HWL		m	0.600	0.600	

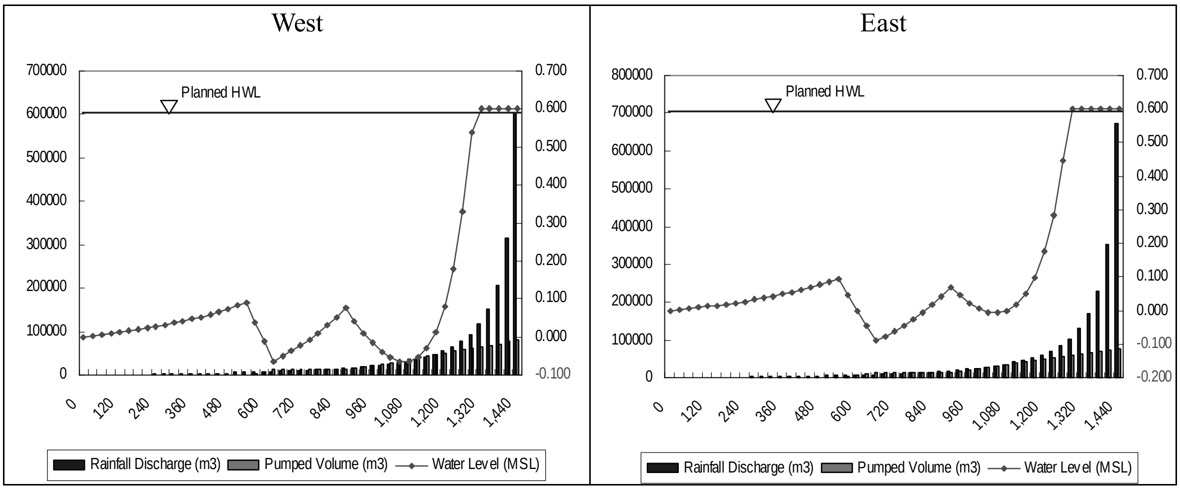


Figure 5.33: Accumulated Runoff and Pumped Volumes and Water Level in the Dry Season

(2) Water Level and Retention Capacity in the Rainy Season

The design criteria for the rainy season are the same as for the dry season except for the NWL and HWL as mentioned below.

1) The NWL in *khlong* Song is set at 0.0 m MSL, because the dredging work has not been implemented for this *khlong*. The NWL in *khlong* Mae Chan is set at – 0.65 m MSL.

2) The HWL in both *khlongs* is set at 0.4 m MSL which is the same level as the existing minimum HWL.

The required retention pond area is estimated as 31 ha for the western part and 39 ha for the eastern part.

Table 5.13: Planning Criteria and Results for the Rainy Season

Item		Unit	West	East	Note
Allowable Discharge Volume		m^3/s	2.000	2.000	Pumping Capacity
Planned Water Level	NWL	mMSL	-0.650	0.000	
	HWL	mMSL	0.400	0.400	Existing minimum HWL
Khlong Retention	Water Depth	m	1.050	0.400	*Khlong* Mae Chan and Song
	Capacity	m^3	56,228	25,160	*Khlong* Mae Chan and Song
Road Surface Retention	Planned GL	mMSL	1.450	1.450	15% of plots of land in the regulatory controlled area
	Water Depth	m	0.150	0.150	Height of sidewalk
	Capacity	m^3	198,697	187,175	
Park Surface Retention	Planned GL	mMSL	1.450	1.450	Same as the road elevation
	Water Depth	m	0.150	0.150	Height of sidewalk
	Capacity	m^3	83,172	151,455	Incl. pocket, neighborhood, and district parks
Pump	WL for Start	mMSL	-0.550	0.100	NWL + 0.1m
	WL of Stop	mMSL	-0.750	-0.100	NWL - 0.1m
	Required Water Depth	m	1.200	1.200	Minimum depth required for the pump operation
	Bottom EL	mMSL	-1.950	-1.300	Required water depth
Retention Pond	Land Area	ha	31	39	
	Water Depth	m	0.750	0.750	HWL of road surface retention – HWL of drainage (Road EL – Covering of 0.6 m)
	Capacity	m^3	232,500	292,500	
Planned Retention Capacity		m^3	514,368	631,131	Total capacity of *khlong*, road, park, and retention pond
Required Retention Capacity		m^3	509,311	630,594	
Estimated HWL		m	0.400	0.400	

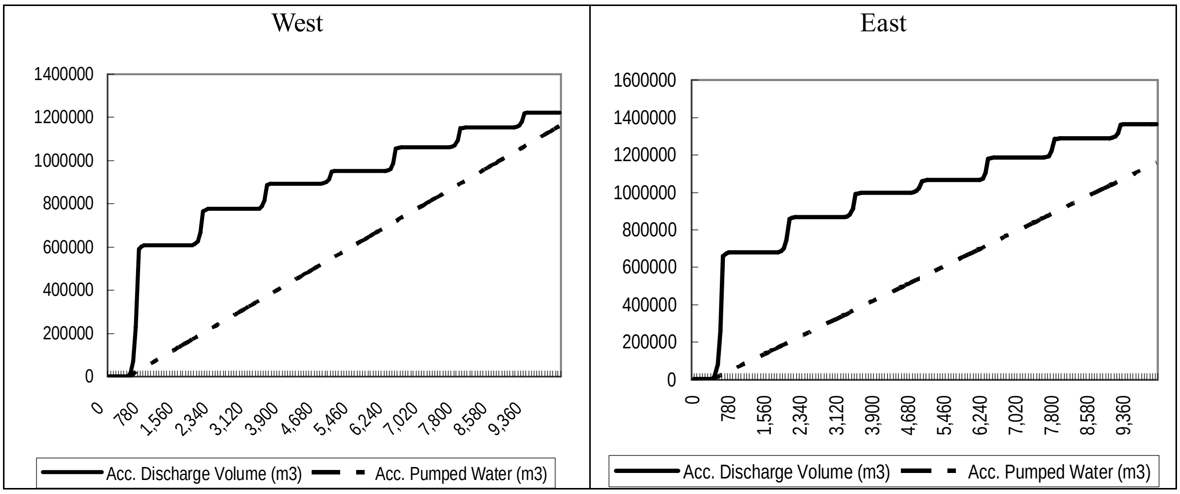


Figure 5.34: Accumulated Runoff and Pumped Volumes in the Rainy Season

(3) Water Level estimated by the Simulation Model

Based on the conditions presented in the previous sections, the water level in the rainy season has been simulated using the hydrodynamic model. The HWL in the *khlongs* within the sub-polder system is estimated at 0.2 – 0.3 m MSL, while the HWL in *khlong* Pravet is estimated at 0.3 – 0.4 m MSL. The HWL in the *khlongs* in the upper part of the study area is projected at 0.4 – 0.6 m MSL. Therefore, the HWL in and around the study area is confirmed to be less than the HWL under existing conditions based on the 5-year return period rainfall.

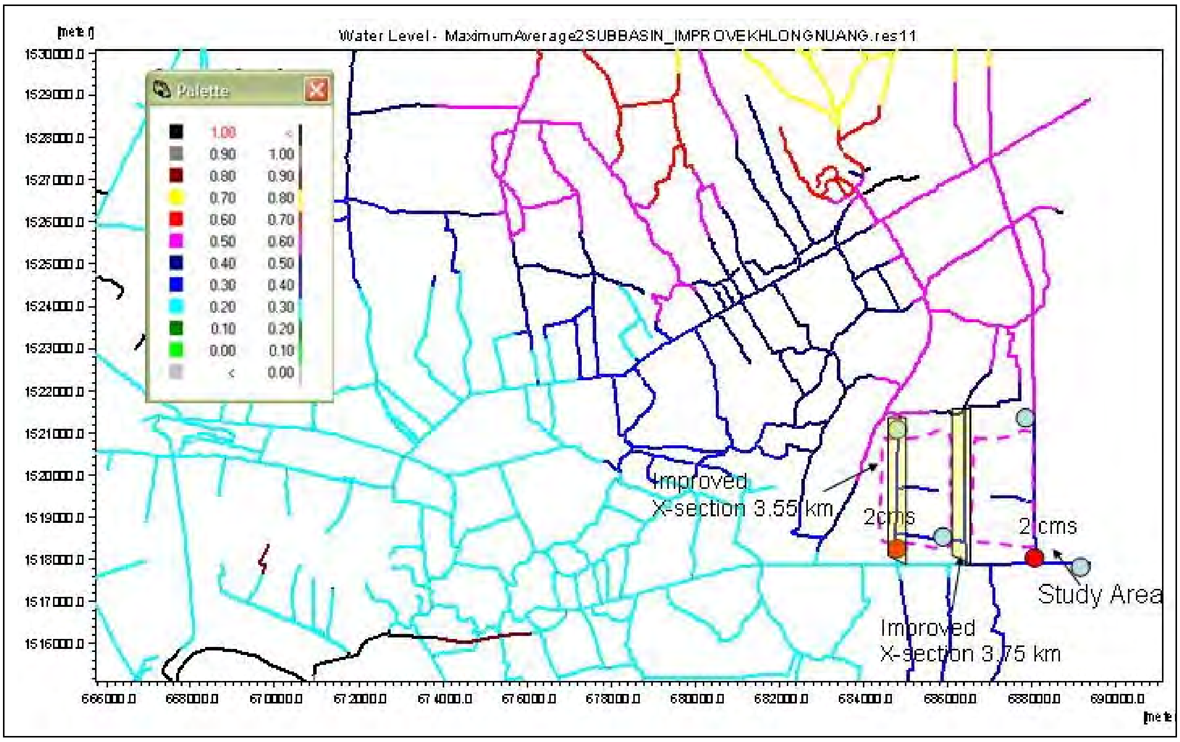


Figure 5.35: Simulated HWL based on the 5-Year Return Period rainfall with 7 Days Rainfall in the Rainy Season

Table 5.14: HWL results in the Rainy Season

Area	*Khlong*	Maximum WL (MSL)
1. Within the Polder System	*Khlong* Mae Chan, *Khlong* Song	0.2 – 0.3
2. Upper Part of the Polder System	*Kholong* Bung Kwang, *Khlong* Lad Bua Khao	0.4 – 0.6
3. Lower Part of the Polder System	*Khlong* Pravet (u/s reach) *Khlong* Pravet (d/s reach)	0.3 – 0.4 0.2 – 0.3

5.3.5 Plan of Flood Protection Facilities

(1) Polder Dikes

The polder dikes are components of the sub-polder system within the main polder system in the eastern suburban area. The crest levels of the dikes are designed as follows:

1) The HWL is set at 0.4 m MSL of the minimum HWL along the *khlongs* within the sub-polder system in the existing condition and at 0.6 m MSL of the minimum HWL along the *khlongs* outside the sub-polder.

2) The minimum crest elevation is set at 1.0 m MSL within the sub-polder system and 1.2 m MSL outside the system based on the addition of the freeboard height of 0.2 m and the land subsidence of 0.4 m.

Taking into account the HWL of the surface retention on the primary and secondary roads, the crest elevation of the dikes is designed at 1.7 m MSL within and outside the sub-polder system.

(2) *Khlong* Improvement Plan

Improvement works for *khlong* Nung, *khlong* Mae Chan, and *khlong* Pravet are required for development of the sub-center.

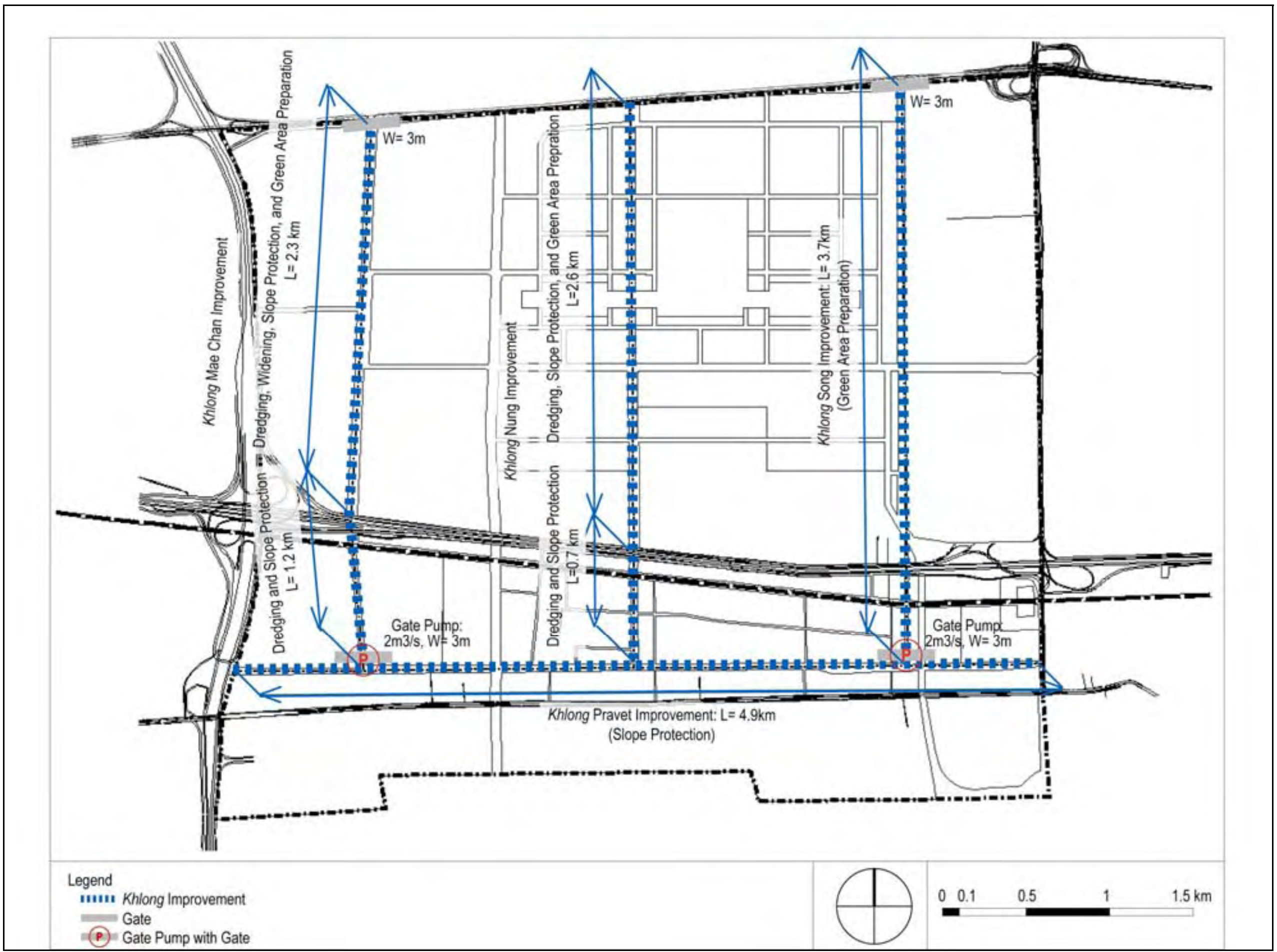
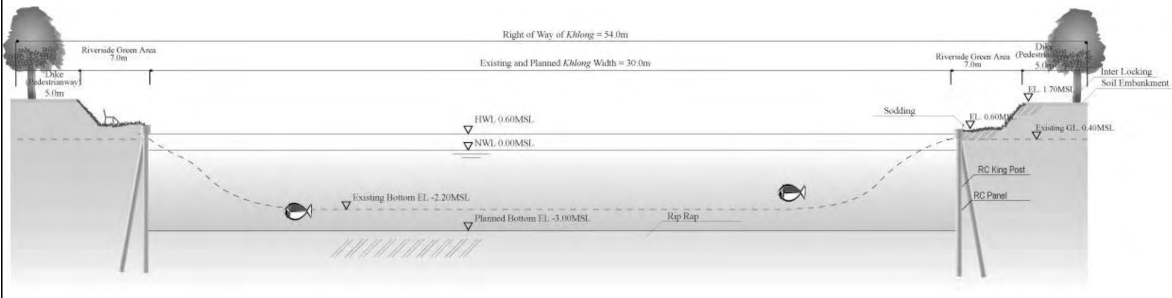


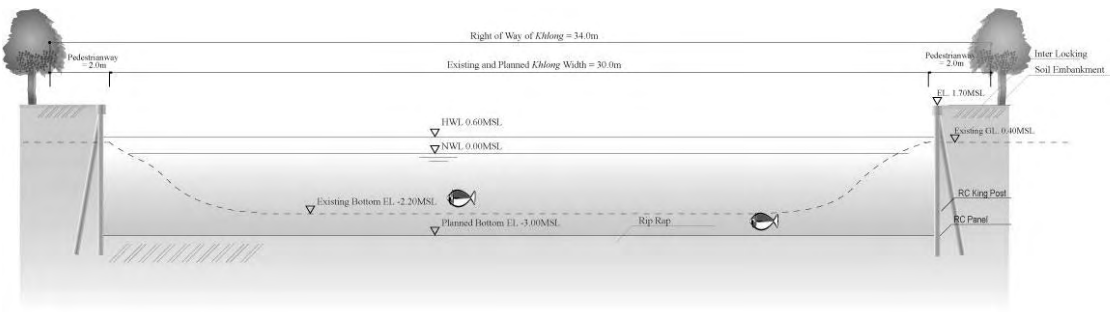
Figure 5.36: *Khlong* Improvement in the Sub-polder System

Improvement of *khlong* Nung is required to ensure sufficient flow capacity, while the improvement of *khlong* Mae Chan aims to increase the retention capacity. The improvement works consist of dredging, slope protection using King's piles, and preparation of the riverside green areas. In the urbanized area to the south of the expressway, the improvement works focus on slope protection and dredging. As an alternative to the King's piles, a gravel mattress is recommended for slope protection in the future. The gravel mattress has the advantage to suit the land deformation and to improve water quality, however the unit price of gravel mattresses is high at present due to the expensive wire mesh.

To the North of the Expressway



To the South of the Expressway



To the North of the Expressway (Alternative: Gravel Mattress)

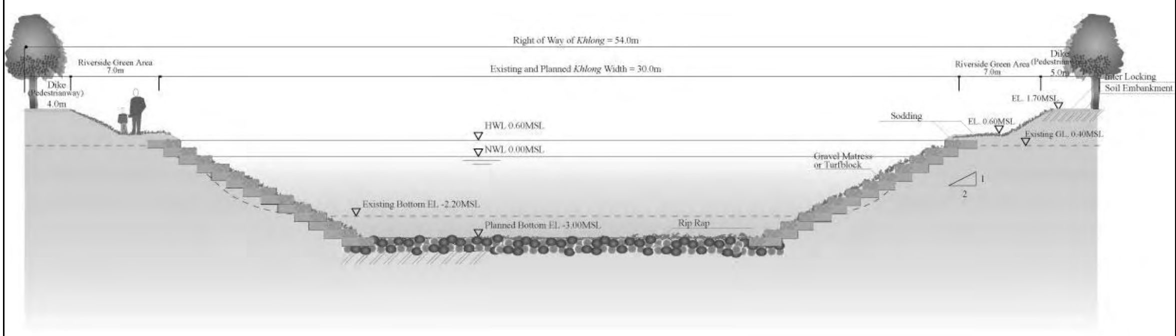
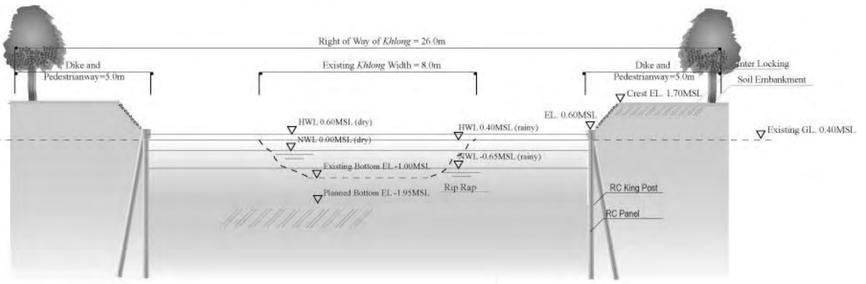
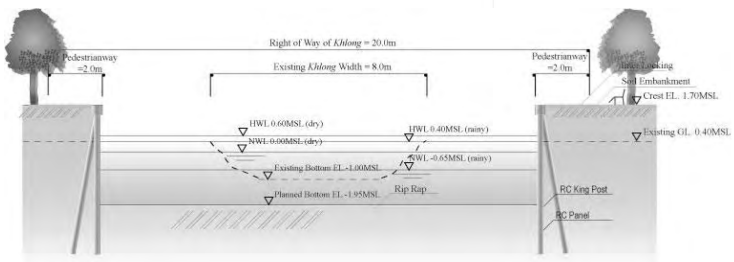


Figure 5.37: Improvement of *Khlong* Nung

To the North of the Expressway



To the South of the Expressway



To the North of the Expressway (Alternative: Gravel Mattress)

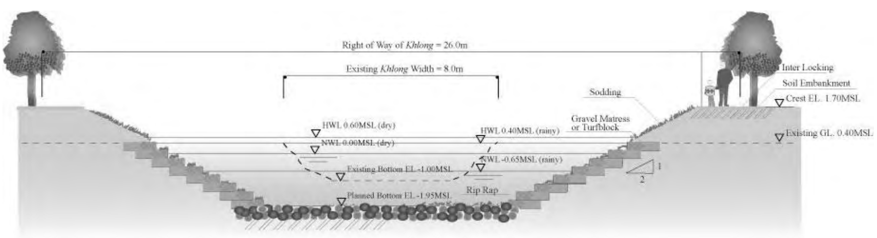


Figure 5.38: Improvement of *Khlong* Mae Chan

Improvement of *khlong* Song is required to prepare the riverside green areas in the new development area. In the pump pit at the intersection of *khlong* Pravet, the bottom elevation needs to be -1.3 m MSL for pump operation.

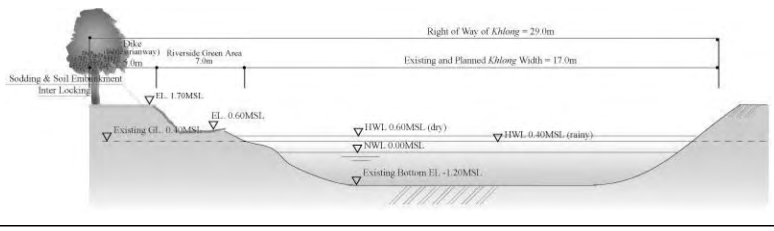


Figure 5.39: Improvement of *Khlong* Song

The improvements to *khlong* Pravet aim to provide accessibility and land uses suitable for the water market in the cultural town. It is proposed that King's piles will be used for slope protection and these will be capped by stairways that will create access to the *khlong* with no obstacles caused by the changes in water level. As the riverside areas are densely developed, the improvements will be implemented in undeveloped areas along the *khlong*.

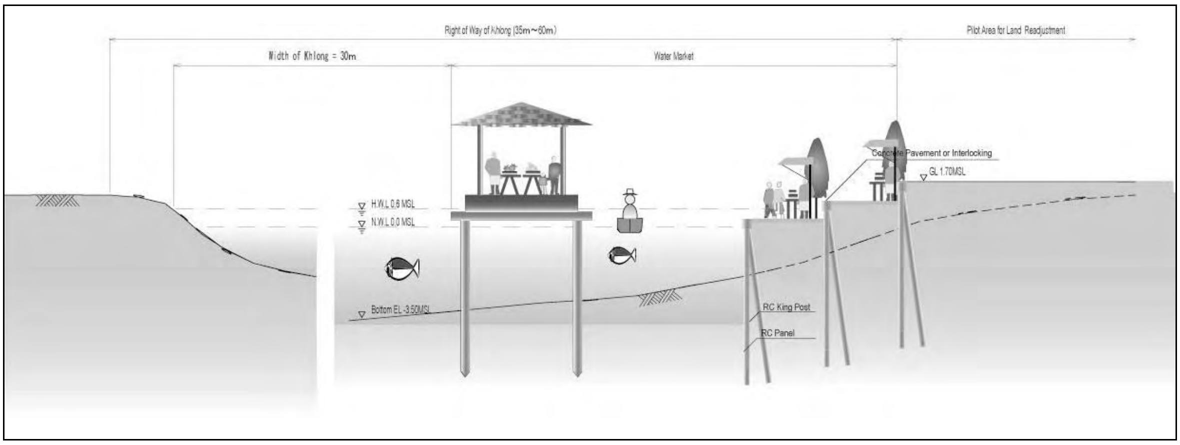


Figure 5.40: Improvement of *Khlong* Pravet

(3) Pumps and Gates

In *khlong* Mae Chan and *khlong* Song, pumps with a capacity of 2 m^3/s will be installed at the junction with *khlong* Pravet. The recommended pump type is the gate pump which has the advantage of allowing gravity flow under stand-by conditions and can be installed in the *khlong* without the need for any additional land area for apparatus next to the pump. Water gates shall be installed in the two *khlongs* in the north of the sub-polder system.

(4) Roadside Drainage System

Rainfall runoff in the regulatory control area within the sub-polder system will discharge into the on-site retention pond and then flow into the drainage system along the primary and secondary roads. The collected rainfall will flow into *khlong* Mae Chan and *khlong* Song. It will finally be pumped out into *khlong* Pravet.

On the other hand, the rainfall runoff in the new development area will flow into the retention pond in the district park and will then be pumped out into *khlong* Mae Chan and *khlong* Song.

Outside the sub-polder system, the rainfall runoff will discharge into the *khlongs* via the roadside drainage system without any retention measures.

The dimensions of the collection systems were calculated based on the design criteria given in the previous sections. As a result, the drainage system requires collection pipes with diameters of 0.6 – 1.2 m and box culverts with minimum dimensions of 1.2 m x 1.2 m and maximum dimensions of 1.8 m x 1.8 m.

Figure 5.41: Plan of Roadside Drainage System in 2035

(5) On-site Retention Ponds in the Sub-polder System

The LWL in the retention ponds is set at 0.85 m MSL which is the HWL in the roadside drainage system. The HWL is set at 1.15 m MSL which is equivalent to the HWL of the road surface retention. As specified in the previous sections, the land area required for the retention ponds is estimated to be 31 ha for the western part and 39 ha for the eastern part in the rainy season. This total land area can be converted to a land area per parcel of 12.0 m^2 in the west and 13.9 m^2 in the east for a land parcel of 200 m^2. This converted land area is similar to the size of the parking lot on the parcel of land.

Table 5.15: Retention Pond Area per Land Parcel in the Sub-Polder System

Item	Unit	West	East	Note
Land development area	ha	515	562	Excl. pocket parks, neighborhood parks, and feeder and on-site roads
Area of Retention Pond per Land Parcel	$m^2/200m^2$	12.0	13.9	Similar size to a parking lot

(6) On-site Retention Pond in the New Development Area

It is proposed that the rainfall runoff in the new development area will flow into the retention pond in the district park. The design conditions for the retention pond in the district park are as listed below.

1) The allowable discharge from the retention pond to the *khlong* is estimated from the proportional land area to the whole sub-polder system.

2) The area of the retention ponds is set at 3.5 ha (35% of the western district park) for the west and 10.7 ha for the east (21% of the eastern district park).

3) HWL in the retention pond is set at 0.4 m MSL to allow for the discharge from the drainage system by gravity flow.

4) Water depth between NWL and HWL is set at 1.0 m.

As a result, the total area of the on-site retention ponds in the land parcels is estimated at 5.5 ha for the western part and 11.0 ha for the eastern part. In other words, the area of the on-site retention ponds is required to be 10.3 m^2 in the west and 10.2 m^2 in the east for a land parcel of 200 m^2.

Table 5.16: Retention Ponds in the District Park and on Land Parcels in the New Development Area

Item		Unit	West	East	Note
Rainfall Volume		mm	210	210	5-year return period
Duration of Rainfall		hr	168	168	7 days
Return time		minute	60	60	
Catchment Area		ha	146	312	
Average Runoff Coefficient			0.818	0.814	
Allowable Discharge to Downstream		m^3/s	0.400	0.800	Proportional volume by the catchment area
Planned Water Level in Retention Pond in District Park	HWL	mMSL	0.400	0.400	
	NWL	mMSL	-0.600	-0.600	
	Water Depth	m	1.000	1.000	Change of water level within 1 m
Road Surface Retention	Planned GL	mMSL	1.450	1.450	
	Water Depth	m	0.150	0.150	
	Capacity	m^3	65,068	65,068	
Pump	WL for Start	mMSL	-0.500	-0.500	NWL +0.1m
	WL for Stop	mMSL	-0.700	-0.700	NWL -0.1 m
	Required Water Depth	m	1.150	1.150	More than 0.8 D + 1.5 D below WL for stop
	Bottom El.	mMSL	-1.850	-1.850	
	Inlet EL	mMSL	-1.450	-1.450	More than 1.5 D below WL for stop
Park Surface Retention	Planned GL	m^2	1.450	1.450	Pocket and neighborhood parks
	Water Depth	m^2	0.150	0.150	
	Capacity	m	2,400	4,320	
Pond Retention in District Park	Water Area	m^2	35,000	107,100	
	Water Depth	mMSL	1.000	1.000	
	Capacity	m^3	35,000	107,100	
Retention Pond in Land Development	Required Capacity	m^3	41,095	80,447	
	Required Land Area	m^2	54,793	107,263	Water depth of 0.75 m
	Land Development Area	ha	106	210	Excl. pocket and neighborhood parks
	Retention Area per Parcel	$m^2/200m^2$	10.3	10.21	Similar size to one parking lot

Two sets of pumps are required at the retention pond in the district park to discharge the rainfall to the *khlongs* through the pressured outlet pipes.

Table 5.17: Pumps and Pump Outlet for the Retention Pond in the District Park

Item	Unit	West	East	Note
Number of Pump	unit	2	2	
Capacity	$m^3/s/unit$	0.20	0.40	
Velocity	m/s	2.00	2.00	Within the range of 1.5 - 3.0 m/s
Diameter (pump outlet)	mm	400	500	
Diameter (conveyance pipe)	mm	500	700	

(7) Main Facilities for Flood Protection

The main facilities required for flood protection in the study area are illustrated in the figure below.

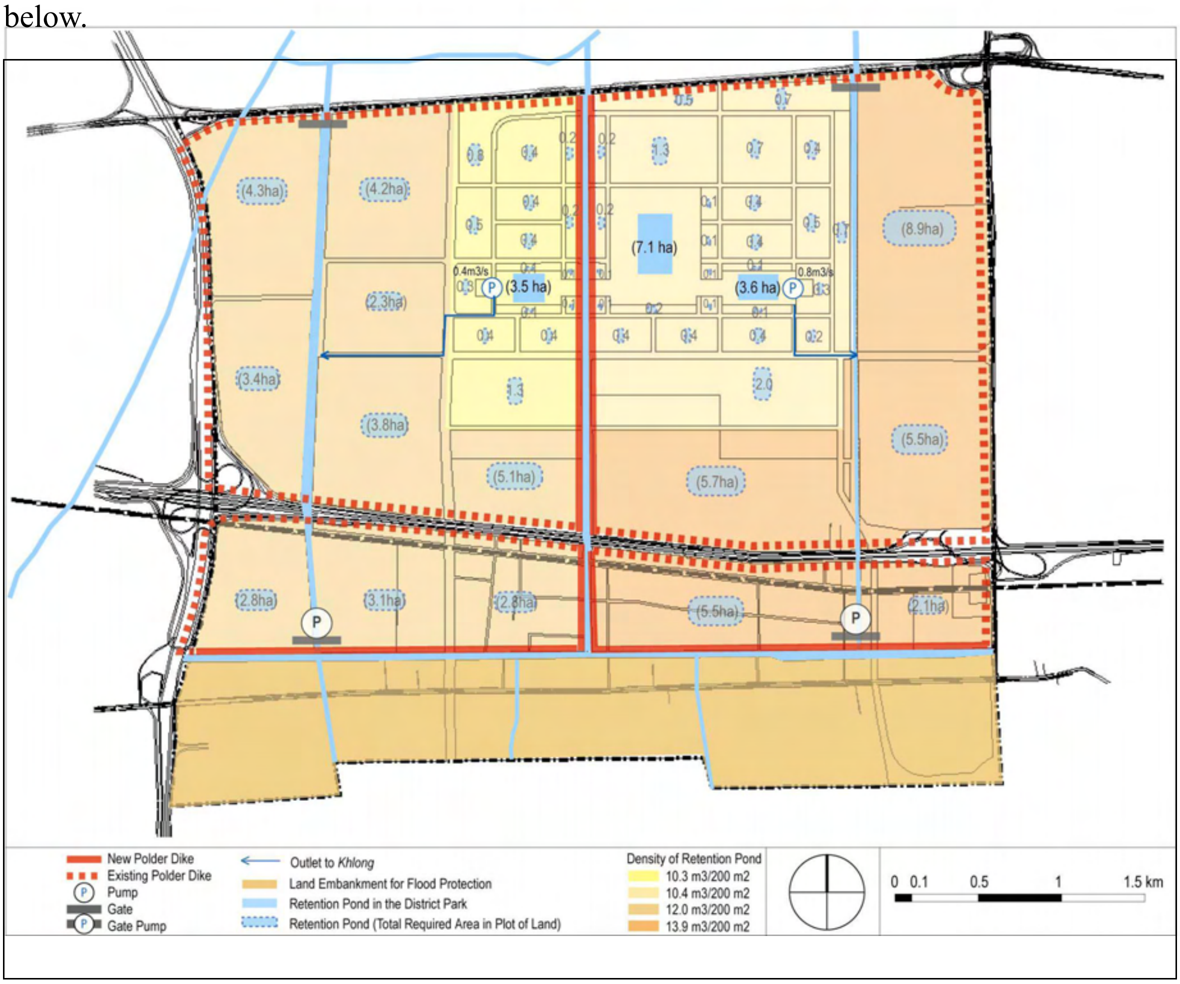


Figure 5.42: Flood Protection Facilities in 2035

5.4 Utilities Planning

5.4.1 Water Supply

(1) Existing Water Supply System

The Minburi MWA office supplies drinking water to the study area via two pumping stations (PS), namely Lat Krabang PS and Minburi PS. According to the MWA, these pumping stations have a total capacity of 1,118,880 m^3/day. The maximum daily water supply was