CHAPTER 4 FIELD SURVEYS AND INVESTIGATIONS

4.1 Influent and Treated Effluent Quality and Quantity at Wastewater Treatment Plants

4.1.1 Objective and Methods of Survey

(1) Objective

Two surveys were undertaken, the first in October and November 1998 and the second in June and July 1999. A survey was also undertaken by the Counterpart Team in January and February 1999.

The purpose of the first survey was:

i) to determine current wastewater characteristics,
ii) to make an assessment of unit flows and loads,
iii) to determine current treated effluent quality for possible subsequent use,
iv) to determine variations in wastewater quality during storms.

The purpose of the second survey and Counterpart Team survey was to enhance the results of the first survey but no further assessment was made of unit flows and loads.

(2) Survey Procedures

1) General Procedures

a) First Survey

The survey included sampling and analysis of :

i) the sewage at the inlets to Si Phraya and Huay Kwuang WWTPs,
ii) the treated effluent for these WWTPs.

Flows were measured at the time of sampling.

Sampling and flow measurement of sewage and treated effluent during the first survey was undertaken every 6 hours over 24 hours during the wet and dry seasons, and every 15 minutes over 2 hours during a storm event.

Analysis was undertaken in accordance with the Standard Methods for the Examination of Water and Wastewater, 19th edition, by the American Waterworks Association (AWWA). All samples were analysed for BOD, suspended solids and COD. Heavy metals were analysed once in each season.

A subcontract was arranged with Environment and Laboratory Co. Ltd. which were monitored by the Study Team. The technical specification for

the subcontracted works is included in Supporting Report J. The Counterpart Team undertook their survey with their own staff.

b) Second Survey

The survey was carried out during the wet season and included sampling and analysis of

i) the sewage at the inlet to Si Phraya WWTP,
ii) the treated effluent from the WWTP.

Samples of sewage and treated effluent were taken every 2 hours over three 24 hour periods and made into composite samples for analysis. Two sets of storm event samples were taken for the inlet at 15 minute intervals over a 3 hour period and analysed separately.

Analyses were undertaken in accordance with the Standard Methods as for the first survey by the same subcontractor supervised by the Study Team. All samples were analysed for TSS, VSS, BOD, and COD.

c) Counterpart Team Sampling and Analysis

The Counterpart Team undertook further sampling and analysis Programme of the wastewaters at the inlets to the two WWTPs during January and February 1999 on behalf of the Study Team and under their guidance. This included 18 samples taken at 4 hour intervals from each WWTP analysed for BOD, COD and suspended solids.

2) Procedures at Si Phraya WWTP

Samples of sewage were taken from the inlet pumping station which includes a mixer which should ensure that the wastewater is homogeneous, Effluents were sampled at the outlet of the chlorination contact tank just before the outlet to the khlong. These sampling locations are the same as those used by BMA for routine monitoring.

The WWTP measurement weir at the outlet to the plant was used for flow measurement during the first survey and the WWTP meters read simultaneously to check the meter. This equipment has both analogue and digital meters. The head over the weir was determined as the difference in the depth to the weir from the depth to the upstream water level.

3) Procedures at Huay Kwuang WWTP

Wastewaters and treated effluents were sampled and analysed in the first survey.

Samples of sewage were taken from the inlet channel close to the measurement flume and the effluent was sampled at the outlet from the final clarifiers before the outlet to the khlong.

The WWTP measurement flume was used for flow measurement and the WWTP meters read simultaneously to check the meter. The depth of flow upstream of the flume was measured as the difference in the depth to the flume invert and upstream water level.

In view of the difficulties in interpreting the survey results from the drain surveys described in Section 4.2, the Study Team decided to undertake an investigation of the population and water consumption in the Huay Kwuang catchment as this was built as an independent separate sewerage system serving a known number of residential apartment blocks.

4.1.2 Si Phraya and Huay Kwuang Wastewater Treatment Plants

(1) Si Phraya Central WWTP

1) Wastewater System

This scheme serves a design population of 120,000 in the city center with wastewater collection through the combined drains and a new interceptor sewer. The scheme is described in Section 3.1.1 and Data Book A

2) Survey Results

The results of the Normal Weather and Storm Event surveys are presented in Table L1 in Data Book L and summarized in Table 4.1.2.1. These indicate an average normal weather wastewater BOD of 41 mg/l with values as low as 8 mg/l up to 82 mg/l and storm event values within this range. Heavy metal analyses are given in Table 4.1.2.2.

3) Comparison with WWTP Records

The metered flow at the WWTP was found to be consistently higher than that measured in the survey. The analogue meter read on average 20 % higher (539 m^3/h compared with 449 m^3/h) during the wet season and the digital meter 17 % higher (527 m^3/h). Subsequent investigation by the Study Team found the meter not to zero correctly.

Average sewage BOD records over 43 months from October 1995 to April 1999 (monthly average of weekly readings) indicate an average of 61 mg/l, a maximum of 89 mg/l and a minimum of 37 mg/l. Full records are included in Data Book M. These indicate that the survey results are untypically low.

One reason for this is that BMA take samples during the working day when the wastewater strength would be expected to be higher, whereas the Study surveys took samples throughout the 24 h. However, the survey results do not indicate a marked hourly strength variation pattern and the reason for some low values is not fully accounted for. Corresponding effluent qualities had an average of 5 mg/l BOD ranging between 3 and 9 mg/l.

4) Interpretation

The Si Phraya WWTP records indicate very weak wastewater, and the surveys indicates that it can be even weaker on occasions. This implies that there is poor separation of the wastewater from khlong water in the drainage system. An inspection of 3 of the 14 interceptors on the interceptor sewer during dry weather in the dry season found one close to the pumping station to have a drowned overflow weir and there may be other such faults in the collection system.

The 1998 population of the service area is estimated as 95,000 from the 1998 Wastewater User Charge Study assuming 20 % of 110,900 in Bang Rak, 55 % of 67,600 in Samphanthawong, and 30 % of 119,100 in Pom Prap Sattru Phai. Subsequently, average unit flows and loads may be calculated from these figures as 121 l/c/d (average flow in both seasons of (11,450 m^3/d ÷ 95,000 population) and only 3 g/c/d BOD (121 l/c/d x average BOD in both seasons of 22 mg/l). However, these unit flows and loads are not considered representative as the flow was found to be limited by the working pump capacity and the survey BOD analyses untypically low.

If the full design pumping capacity was available, the per capita flow might be as much as 316 l/c/d (30,000 m^3/d ÷ 95,000 population) and adopting the average BOD from the WWTP records of 61 mg/l, the unit BOD load could be 19 g/c/d (316 l/c/d x 61 mg/l).

The relatively low TSS:BOD ratio is expected to be due to deposition of solids in the combined drains. TSS concentrations are generally rather higher than BOD concentrations in municipal wastewaters.

The high proportion of volatile solids is unexpected. This is discussed in Section 4.2.2.

The ratio of BOD:COD is approximately 1:2 and is normal for municipal wastewater.

The heavy metal concentrations measured in the wastewater are all within acceptable limits not to impair wastewater treatment.

The storm events indicate that the suspended solids concentration can double during storms and that the BOD concentration can increase by 50 %. Total wastewater loads during storms will be limited by the DWF pumping capacity.

(2) Huay Kwuang Community WWTP

1) Wastewater System

This scheme serves a design population of 16,800 in an area of residential apartment blocks through a separate sewerage system. The WWTP is described in Section 3.1.1 and Data Book C.

2) Survey Results

The result of the wet and dry season 24 hour surveys sampling every 6 hours, and the storm event survey sampling every 15 minutes are presented in Table L3 in Data Book L and summarized in Table 4.1.2.3. Normal weather wastewater BOD was found to average 169 mg/l with values ranging from 102 to 240 mg/l and up to 615 mg/l during the storm event. Heavy metal analyses are given in Table 4.1.2.4.

3) Comparison with WWTP Records

The metered flow at the WWTP was found to be very different from that measured in the survey. The meter read on average 23 % lower (43 m^3/h compared with 59 m^3/h) during the both wet and dry seasons and differences fluctuated considerably during the storm event when the flows were more variable. It is recommended that the meter be re-calibrated.

Records from the WWTP routine monitoring program are included in Data Book M. Sewage BOD records (monthly average of weekly readings) indicate an average of 246 mg/l with a maximum of 400 mg/l and a minimum of 160 mg/l over the 43 month period from October 1995 to April 1999. Corresponding effluent qualities had an average of 19 mg/l BOD. Average flow from the records is 1,268 m^3/d. The results indicate that the survey wastewater analyses were untypically low, and that the dry season effluent quality was unusually poor during the survey. As at Si Phraya, the survey results did not show an hourly variation in wastewater strength and the low results from the Survey are not fully accounted for.

4) Interpretation

a) Unit Flows and Loads

i) Population

The population of the catchment was counted in October 1998 and found to be 11,995 residing in the 38 apartment blocks. Where there was no response from occupants, the number of occupants was assumed to be the average for the block. Empty apartments were also recorded. Details of this survey are given in Table L.5 in Data Book L.

ii) Water Consumption

Records of water supply consumption were collected from the office of the National Housing Authority, which recorded for the 10 months from January to October 1998. Meters are generally read monthly and only occasionally is water consumption estimated. These indicate an average consumption for the catchment of 65,515 m^3/month as indicated in Table L6. Daily consumption per person is derived from this data with an average of 183 l/c/d and this is presented in Table L7. The average number of occupants in each apartment is 3.6.

iii) Wastewater Flows

The survey flow data indicates an average wastewater flow of 111 l/c/d (1,330 m^3/d ÷ 11,995 population), and the WWTP flow records indicate an average of 90 l/c/d (1,076 m^3/d ÷ 11,995 population), only half the metered water consumed. The large loss between water consumption and wastewater measured at the WWTP is difficult to account for. Reasons for this must include:

- wastewater leaking from the sewer system,
- domestic water consumption which is not discharged to the separate foul sewerage system, such as watering plants and washing cars,
- uncertainties concerning wastewater measurement at the WTTP possible direct wastewater discharges to the drainage system or to the khlongs.

It is, therefore, concluded that water consumption provides a better indication of wastewater production than measurements at the WWTP. The domestic unit wastewater flow is determined as 183 l/c/d on this basis.

iv) Domestic Load

On the basis of 183 l/c/d, the unit domestic load may be determined as:

20 g/c/d based on the Study Team dry season survey (183 l/c/d x 110 mg/l)

33 g/c/d based on the Study Team wet season survey (183 l/c/d x 181 mg/l)

45 g/c/d based on the WWTP records (183 l/c/d x 246 mg/l)

Since the survey analyses are not considered representative, the figure of 45 g/c/d of BOD is considered as typical for the catchment.

b) First Flush Flows During Storms

The survey data in Table L3 indicates a large increase in flow and load during the storm event suggesting that the sewerage system is not totally separate. Flows increased up to 6 x average (7,440 m^3/s ÷ 1330 m^3/s), BOD concentration up to 4 x average (615 mg/l ÷ 146 mg/l) and solids concentration up to 10 x average (1,325 mg/l ÷136 mg/l). Pollution loads (the product of flow and concentration) rose 20 times in BOD (6 x 4) and 60 times in solids (6 x 10). Such high load variation is not normally found in separate sewerage systems suggesting that some storm drains may be connected to the foul sewers.

c) Other Evaluation

The heavy metal concentrations measured in the wastewater are all within acceptable limits not to impair wastewater treatment.

The BOD:COD ratio is generally as expected for municipal wastewater. The relatively low TSS, especially in the Counterpart Team Survey analyses, is unexpected.

4.2 Wastewater Quality and Flow Rate in the Drainage System

4.2.1 Objectives and Methods

(1) Objectives

Two surveys were undertaken, the first in October and November 1998 and the second in June and July 1999. A survey was also undertaken by the Counterpart Team in January and February 1999.

The purpose of the first survey was to make an assessment of unit flows and loads which may be adopted for planning purposes and future wastewater scheme design.

The investigation was to determine unit flows and loads by wastewater flow measurement, sampling and analysis in three typical catchments both during Normal Weather and Storm Events.

i) commercial,
ii) mixed commercial and residential,
iii) residential.

The Counterpart Team survey provided additional wastewater analyses from the same sampling locations.

The purpose of the second survey was to obtain more representative wastewater quality data from larger catchments in the six existing and ongoing wastewater scheme areas in both Normal Weather and Storm Events.

(2) Survey Procedures

1) Catchment Selection

a) First Survey

Possible drainage catchments were determined from the various drainage plans available from BMA Department of Drainage and Sewerage (DDS) and those from the contractor for the Yannawa Wastewater Scheme. These indicated that most of the drainage catchments had multiple outlets and measured wastewater quantities could therefore not be attributed to particular areas and populations. A number of closed catchments were nevertheless indicated on the available plans and 30 of these were inspected. However, most were found to be more extensive than indicated on the plans and also likely to also have multiple outlets. Furthermore, several of the remaining possibilities were found to have no significant flow when, with the assistance of BMA DDS, the manholes were opened.

The difficulty in finding suitable catchments for this survey gives an indication of the nature and condition of the drainage system.

i) Most of the drainage system is in a ring form network with multiple outlets.
ii) Much of the system was found to have no significant flow and to contain stagnant sewage.
iii) Much of the system was found to be heavily silted.

This suggests that the drainage system is far from ideal for conveying wastewater and requires extensive maintenance and probably repair work if it is to be fully effective.

This investigation indicated that the survey of the drainage catchments would be of limited value, and for this reason a further investigation of the Huay Kwuang WWTP catchment was undertaken as described in Section

4.1.1. The most suitable catchments for the survey were nevertheless selected and investigations undertaken.

i) Commercial catchment in Soi Song Phra measured at the junction with Thanon Rama IV in the Si Phraya wastewater service area
ii) Mixed residential and commercial catchment in Thanon Charoen Krung Soi 77 measured at the junction with Charoen Krung in the Yannawa wastewater service area
iii) Residential catchment in Soi Wachirathum Sahit 31 measured at the junction with Sukumvit Soi 101/1 in the proposed Khlong Toey East wastewater service area

The locations of these monitoring stations are indicated in Figure 4.2.1.1. The Counterpart Team took and analyzed samples from the same sampling locations.

b) Second Survey

Similar investigations were undertaken for the second survey. Initial desk studies also took account of the new wastewater scheme interceptor sewer layouts, which were confirmed by the contractors and engineers for the schemes. BMA drainage plans are generally only available for the older parts of the city, but the Yannawa scheme contractor's drainage catchment plans were useful in identifying larger catchments. Possible suitable sampling locations were identified from these plans and some 25 were investigated in the field. Generally, this was possible without opening manhole covers as several manholes have open grating covers and flows could be observed through holes or gaps in concrete covers. The manholes in the vicinity and upstream of the selected sampling locations were subsequently investigated with assistance from BMA DDS to open covers.

Similar difficulties were encountered in finding suitable sampling locations to those for the first survey. Furthermore flow patterns in parts of the drainage system appeared inconsistent and highly variable.

i) Flows could often not be traced downstream.
ii) Flows varied considerably sometimes with changes in direction. This is likely to be due to the operation of pumping or outlet controls downstream.

Catchments were selected with various types of development.

i) Mixed commercial, residential and some institutional high density development in the heart of the city in Th Maitri Chit in the Si Phraya Scheme area.

ii) Established medium density residential, small industrial and some commercial development in Th Sathu Pradit near Th Chan in the Yannawa Scheme area.

iii) Well established medium density residential and commercial development near Chulalongkorn University in Th Banthat Thong in the Din Daeng Scheme area.

iv) Medium density residential and some commercial development in the old part of the city in Th Ti Thong in the Ratanakosin Scheme area.

v) A high density commercial market area with mostly poor quality residential properties at the Bang Kae Market in Th Phet Kasem in the Nong Khaem Scheme area.

vi) A developing medium and low density residential, industrial and commercial area at Th Suksawat near Soi 23 in the Ratburana scheme area.

These wastewater sampling locations are indicated in Figure 4.2.1.1 and their position in the wastewater scheme areas in Data Book L.

The catchment areas contributing wastewaters to the sampling locations were very approximately estimated from observations of flow patterns in the manholes upstream and calculations based on flow estimations at the sampling locations.

2) Wastewater Monitoring

a) First Survey

Sampling and flow measurement was to be undertaken every 6 hours over 24 hours during the wet and dry seasons, and every 15 minutes over 2 hours during a storm events in both wet and dry Seasons. One sample at each location was analysed for heavy metals during the dry season. However it was not possible to monitor any storm events during the dry season, as there was no significant rain during the survey period. Nor was it possible to monitor the wet season storm event or dry season flow in the residential catchment in Khlong Toey East area due to the reconstruction of the drain. Samples in the dry season were taken from a manhole in the adjacent road, Soi Wachirathum Sahit 31, where unfortunately there was no significant flow.

Flows were determined using an electronic current meter to measure velocity and measurements of the cross section area of the flow. Where necessary, temporary plywood orifice plates were installed in the manholes to reduce the flow area and increase the velocity to within the operating range of the current meter. Elsewhere, flow depths were measured at several locations

across the width of the manhole above the sediment to determine the area of flow.

Analyses were undertaken in accordance with the Standard Methods for the Examination of Water and Wastewater 19th edition, AWWA.

The Study Team surveys were also undertaken by Environment and Laboratory Co. Ltd. and monitored by the Study Team. The technical specification for the subcontracted works is included in Supporting Report J.

b) Second Survey

Spot samples were taken at 2 hour intervals over 24 hour periods during Normal Weather and equal volumes were made up into composite samples for analysis. Storm Event samples spot samples were taken at 15 minute intervals over 3 hour periods commencing as soon as possible after the start of the storm. Unfortunately there was a delay in the monitoring of two storm events, and further storm event sampling is planned at these locations.

Samples were generally taken using a hand operated vacuum pump through a ridged draw pipe carefully located at mid depth in the wastewater flow and ensuring continuous delivery through the pump before taking the sample.

The second survey was arranged with the same subcontractor as the first and supervised by the Study Team, and the same methods of analysis adopted.

c) Counterpart Team Sampling and Analysis

The Counterpart Team undertook further sampling and analysis under the guidance of the Study Team. Sixteen samples were taken at 4 hour intervals from each of two of the first survey drain locations of the first Study Team survey and 4 from the third. These were analysed for BOD, COD, and suspended solids.

4.2.2 Wastewater Quality and Quantity

(1) First Survey

1) Commercial Catchment in Si Phraya Scheme Area

a) Catchment and Population

Properties in the catchment are predominantly shop houses, terraced houses with commercial premises at ground level and residential apartments above. An estimate of the limits of the catchment were made but there were uncertainties concerning the possibility of wastewater flows entering or leaving the catchment especially from the west.

The properties within the catchment are listed in Table L8 in Data Book L as determined from an inspection by the Study Team. At an assumed average of 4.5 persons per property as adopted by MWA, the catchment serves an estimated population of 1,463.

b) Survey Results

The survey results are presented in Table L9. BOD averaged 83 mg/l during normal weather ranging between 48 and 120 mg/l. During the storm event BOD fell from 120 to 25 mg/l. Heavy metal analyses are given in Table L10.

2) Mixed Residential and Commercial Catchment in Yannawa Scheme Area

a) Catchment and Population

Close to the main road there is an area of mostly older poor quality shop houses but behind this lies an area of new good quality terraced town houses. The catchment is walled off from neighboring areas and there is a security post at the entrance to the residential area. A khlong runs along the southern side of the catchment outside the wall.

The properties within the catchment are listed in Table L11 as determined from an inspection by the Study Team. Properties under construction and those evidently unoccupied are excluded from this table. At an assumed average of 4.5 persons per property as adopted by MWA, the catchment serves an estimated population of 1,022.

b) Survey Results

The results of the survey are presented in Table L12. BOD averaged 100 mg/l during normal weather and ranged between 34 and 150 mg/l. Storm event analyses were within this range. Heavy metal analyses are given in Table L13.

3) Residential Catchment in Proposed Khlong Toey East Scheme Area

a) Catchment and Population

The catchment is a low density suburban area of medium and good quality detached and semi-detached houses. The adjacent road where dry season samples were taken is similar.

The properties within the catchment are listed in Table L14 as determined from an inspection by the Study Team. At an assumed average of 4.5

persons per property as adopted by MWA, the catchment serves an estimated population of 284.

b) Survey Results

The results of the survey are presented in Table L15. These indicate an average of only 42 mg/l BOD. Heavy metal analyses are given in Table L16.

(2) Second Survey

1) City Center Catchment in Th Maitri Chit in Si Phraya Scheme Area

a) Catchment and Population

This is a well established city center area with high density residential, commercial and institutional development. Most of the properties are of the older terraced shop-house type but there are also some newer buildings. The buildings are generally between 4 and 7 stories on the main roads but more commonly 2 or 3 stories in the narrow alleys behind. There are also some newer apartment blocks of up to 9 stories. The area includes some banks, shops and other institutions and there are small collections of market stalls and fast food stalls mostly in some of the wider alleys off the main roads.

The catchment is estimated to be about 6 ha with a population of some 3,000.

b) Survey Results

The survey analyses presented in Table L17. Average normal weather BOD from the three 24 hour composite samples averaged 52 mg/l confirming the typically weak quality of the Si Phraya wastewater, but the high proportion of volatile solids is unexpected.

The storm event analyses indicate that the suspended solids concentration can increase fourfold at this location and that the BOD concentration can double even during small storms.

2) Residential and Small Industry Catchment in Th Sathu Pradit in the Yannawa Scheme Area

a) Catchment and Population

This is an established residential, industrial and commercial medium density area with wide side roads allowing vehicle access. Most properties are of the terraced shop-house type with shops and some institutional buildings along the main roads. In the side roads there are mostly terraced residential properties many of poor quality and these typically lead to small factories,

especially on the east of Th Sathu Pradit and south of Th Chan. The main road properties are mostly 3 to 5 stories and the side street terraced mostly 2 to 3. Further south there are some areas of single 2 story houses of mixed quality in the side streets. There is a small covered market off Th Chan.

The flow through this manhole was observed to be in opposite directions on different occasions but never stationary. This may be due to the operation of the river outlet control structure and tides in the Chao Phra River. Nevertheless the observed flow indicated a varying catchment area of some 60 ha with a population of about 20,000

b) Survey Results

The survey analyses presented in Table L18 indicates very weak wastewater with the same unexpectedly high volatile suspended solids. Average normal weather BOD from the three 24 h composite samples was found to be 51 mg/l.

The first storm event exhibited rather higher strength wastewater initially but rather lower than normal towards the end of the storm conforming to expectations. The variations from normal strength wastewater were small, as the storm was only slight. The second storm event was only recorded late after the storm commenced and there was consequently only a small variation in wastewater strength. The third storm showed much more variation with TSS up to 10 times and BOD up to 3 times average concentration.

3) Residential and Commercial Catchment in Th Banthat Thong in Din Daeng Scheme Area

a) Catchment and Population

This is a well established area of medium density development in the older part of the city. Buildings are predominantly of the 3 storey shop-house type with some 2 storey and occasional higher buildings including some apartment blocks, one of 14 stories, to the east. The area includes Chulalonkorn University at the south and there are a number of sports facilities such including tennis courts. There is a covered market (Suan Luang) and shops along the main road, and many small machine and engine repair shops at the south of the area.

The catchment area is estimated to be about 20 ha with a resident population of about 6,000.

b) Survey Results

The survey analyses presented in Table L19 indicate similarly weak wastewater with similarly high volatile suspended solids. Normal weather BOD from the three 24 h composite samples averaged only 37 mg/l.

The relatively light storms showed only small variations in strength, but more interesting was the fact that the organic concentration during the second storm was about 5 times greater than that of the first. This may be due to greater activity during the busier part of the evening and the higher rainfall and consequent dilution during the first storm.

4) Residential Catchment in Th Ti Thong in Ratanakosin Scheme Area

a) Catchment and Population

This is in the old part of the city with traditional medium density mostly 3 to 4 storey terraced shop-house type developments along the main roads and single, two and three story in the narrow alleys behind. Many of the houses are of timber construction. The area is essentially residential with supporting shops along the main roads and market stalls along some of the wider alleys behind. The area includes the Thai Chamber of Commerce and there are several shops supplying the extensive temple area across the khlong to the west.

The catchment is estimated to be about 10 ha with a population of some 4,000.

b) Survey Results

The survey results are presented in Table L20. Despite a relatively defined catchment and clear flow patterns the wastewater was found to be very weak with a normal weather BOD from the three 24 h composite samples of only 20 mg/l. The volatile solids were similarly high.

The first storm exhibited initial high solids concentrations of up to 5 times normal and BOD concentrations up to 3 times normal. The second storm was only recorded after a long delay and rainfall had ceased and there was consequently little variation in wastewater strength. The third storm produced wastewaters of more continuous high strength.

5) Commercial Area in Bang Kae, Th Phet Kasem, in the Nong Khaem Scheme Area

a) Catchment and Population

This is a highly compact commercial market area with stalls fronting shops and a department store in Bang Kae along Th Phet Kasem, and an extensive covered market including a new 2-storey open market building behind. Beyond this lies some mostly poor quality 2 and some 3 storey residential terraced buildings with open areas some of which are used as tips. To the south of the area there is a parallel road beyond which there are only minor developed areas. There is an extensive car sales area to the east of the area. Drainage is very poor to the back of the market and this and tipping has damaged the environment apart from the properties along Th Phet Kasem.

The catchment is likely to be about 10 ha but the population is likely to be more than the estimated 1,000 swelled with non-residents working or shopping at the market.

b) Survey Results

The survey results are presented in Table L21. Normal weather BOD from the three 24 h composite samples averaged 65 mg/l. Wastewater strengths were typical for Bangkok but might have been expected to be higher from this busy market area. Volatile solids were again high.

The two storm events exhibited the expected high initial solids but, as at Th Banthat Thong, one of the storms delivered wastewaters 3 times stronger than the other. Again this may be due to higher market and restaurant activity during the early evening.

6) Developing Residential and Industrial Catchment in Ratburana Scheme Area

a) Catchment and Population

This is a developing industrial area with mixed medium and low density development and mostly small factories located in the side roads amongst residential properties. There are vacant lots in the west of the area but the area is fully developed in the east where there are 4 to 5 floor terraced properties along the main road with shops at ground level. There is a busy covered market towards the east and a large hospital in the west towards the sampling location. Behind the main road there are mostly 3 floor residential terraces and single 2 storey houses in the Soi to the west.

The catchment is very approximately estimated to be about 10 ha with a population of 1,000

b) Survey Results

Normal weather BOD from the three 24 h composite samples averaged 48 mg/l, typical of those elsewhere in Bangkok and with the same high proportion of volatile solids. Details are indicated in Table L22. The two storms exhibited the expected variations in wastewater strength but these were not very marked.

(3) Comparison with Previous Wastewater Analyses in the Drains

Limited information is available for comparison described in Section 3.1.1 and summarized as follows:

i) 8 samples in Yannawa catchment by wastewater scheme contractor in 1995: average BOD 69 mg/l, ranging between 14 and 214 mg/l,
ii) 9 samples in Lumpini at 2 locations by JICA expert in 1998: average BOD 43 and 152 mg/l with a maximum of 250 mg/l.

Together with the results of this Study, these indicate generally weak and very variable wastewater quality.

(4) Interpretation

1) Average Wastewater Quality

The average wastewater quality in normal weather derived from the Study Team and Counterpart Team is given in the Table 4.2.2.1. This indicates the average wastewater quality to be generally very weak but variable from place to place and also from time to time at some locations. The average quality from all locations is similar to that of the Si Phraya WWTP records.

2) Seasonal Variation

Comparison of wet and dry season normal weather wastewater quality at Soi Song Phra catchment in the Si Phraya area and in Charoen Krung Soi 77 in the Yannawa area in the first survey are presented in Table L9 and L12. These indicate little variation in BOD but solids concentrations in the wet season were twice those in the dry season.

3) Daily Variation

During the first survey considerable variation in wastewater strength was found in the Soi Song Phra and Charoen Krung Soi 77 catchments as

indicated in Tables L9 and L12. The smaller Charoen Krung catchment found the normally expected pattern with higher day time and lower night time strengths although these differences varied considerably. The wastewater strength at Soi Song Phra also varied throughout the day but there was no clear daily pattern.

4) Unit Flows and Loads

Unit flows and loads are derived from the first survey results and population and are presented in Table 4.2.2.2. Unit flows are calculated as Flow divided by Population and expressed in l/c/d. Unit loads are calculated as Unit Flow times BOD concentration and expressed in g/c/d:

i) The very high unit flow in the Si Phraya catchment area is likely to be due to the catchment being more extensive than apparent from field investigation. Although the unit BOD load lies within an expected range, it is derived from the unit flow and so cannot be taken as representative,
ii) The very low unit flows and loads in the Yannawa catchment area must be due to other wastewater outlets from the drains, probably to the adjacent khlong, although none were observed during the field investigation,
iii) The high unit flow and very low unit load in the proposed Khlong Toey East catchment area suggests that surface water is entering the drain together with other outlets for wastewater. The catchment was flooded shortly before the survey, but no surface water inlets or alternative wastewater outlets were apparent during the field investigation.

The results of the drain survey cannot therefore be used directly to derive unit flows and loads. They indicate the need for much more extensive investigation of the drainage network, and the temporary closure of all outlets to the catchment other than the one to be used for monitoring. Only by this means can the catchment area be defined and the contributing population ascertained.

5) Wastewater Strength and First Flush Loads During Storms

Flows in the combined drains may increase considerably during storms with the addition of storm water. Normally wastewater strengths increase at the start of the storm due to the lifting of deposited sediment from the drain floor and then reduce as these transferred sediments pass and wastewaters are diluted with storm water. The average and range of storm event analyses are taken from Tables L9, L12 and L17 to L22 and presented in Table 4.2.2.3.

Pollutant loads may be derived as the product of flow and concentration. The first survey indicated large increases in flow and concentration during the storm events and load variations are calculated in Table 4.2.2.4. These indicate increases of up to 10 times average BOD loads and up to 80 times average suspended solids loads.

No flows were measured during the second survey but the expected pattern in wastewater strength was found. However, the variation in strength was smaller during most storm events due to the extent of the storms. On a number of occasions wastewaters were found to be of very different strengths during the two storm events. This may be partly explained by the times of day when the storms occurred.

Table 4.2.2.4 Survey of First Flush Loads from Storm Events

Location	Date	Peak Flow (max/avr)	Peak BOD Conc. (max/avr)	Peak BOD Load (peak flow x peak load) (max/avr)	Peak SS Conc. (max/avr)	Peak SS Load (peak flow x peak load) (max/avr)
Drain in Si Phraya Catchment	30.10.99	2.8	1.7	5	30	83
Drain in Yannawa Catchment	18.11.99	6.8	1.4	10	4	29

The Meteorological monitoring station at the Queen Sirikit Convention Center recorded 2.0 and 4.0 mm/h between 16.00 and 18.00 on 30 October with no rain before or after, and 5.8 mm/h between 18.00 and 19.00 on 18 November with no rain before or after. These represent significant but short storms. The 1996 – 1998 records indicate that rainfall in excess of 5 mm/h occurs 60 times a year, on average about once a week and up to once every other day during the wettest months. Rainfall intensities of 7.6 and 0.3 mm/h were recorded for the storm event of 20 June 1999 with no rainfall before or after, but no meteorological records of the later storms monitored in the survey were available for reporting. Annual rainfall information is included in Section 2.1.3.

6) Volatile Solids

The consistently high proportion of volatile solids (VSS) was unexpected and unexplained. Lower volatile to total solids (VSS/TSS) ratios were expected in the combined drains of Bangkok due to biological decomposition in the drains and by the low VSS/TSS ratio of the sludge

analyses. Some samples were analysed at an alternative laboratory and these confirmed the high VSS determined by the subcontractor.

7) Heavy Metals

The heavy metal concentrations measured in the wastewater presented in Table 4.2.2.5 are all within acceptable limits not to impair wastewater treatment processes.

(5) Overview of Survey Results

The surveys undertaken in this Study provide a valuable data base which significantly extends the knowledge of wastewaters in Bangkok. The fact that the wastewater analyses generally conform to the quality records at Si Phraya WWTP provides confidence in their general applicability to wastewaters in the combined drains in other parts of the city. However they also demonstrate the wide variability in wastewater quality both in place and time, and some of these variations cannot readily be anticipated.

The main parameter for planning and designing future wastewater services is BOD. However, the surveys demonstrate that the concentrations of other parameters relate to BOD as expected in municipal wastewaters notwithstanding the high VSS. This is important as it indicates the wastewaters to be readily bio-degradable and so treatable by conventional processes.

The key need for the surveys for this Master Plan is to forecast WWTP loadings and consequent sludge production. This is assessed and evaluated in Chapter 6. The low wastewater strength in the Bangkok drains does not well relate to normal unit pollution loads experienced around the world, and a means to account for this difference is proposed in Section 6.1.1.

Storm events monitored in the surveys provide useful information on the wastewater load and strength variation during storms and in particular first flush loads. These are important in relation to determining peak flow factors for interceptor sewer designs, but more storm event monitoring is considered necessary for this purpose.

The completion and commissioning of the Yannawa and Ratanakosin wastewater schemes will enable new wastewater data to be acquired at the new WWTP inlets. This will greatly add to the data obtained from the Study surveys and allow assumptions necessary for this Study to be re-assessed.

4.3 Sludge Qualities and Characteristics

4.3.1 Objectives and Methods

(1) Objectives

The objectives of the survey is to assess the qualities of the sludge cakes produced at the Central WWTPs, the Community WWTPs and the NSTPs, which are being operated at the present. Their suitability for agricultural use is the main interest in this Study.

(2) Methods

1) Sampling

The survey included the sampling and analysis of sludge cakes produced from the belt press dehydrators at the Si Phraya Central WWTP, the Huay Kwuang Community WWTP, the Nong Khaem NSTP and the On-Nut NSTP.

Sludge samplings for measurement and analysis took place during the first site survey period (October to November in 1998) and the second site survey period (June to July in 1999).

2) Measurement and Analysis

The measurement and analysis conducted were categorized into:

- General properties like moisture, total dry solids, volatile solids,
- Carbon and nutrient substances like nitrogen, phosphorus, potassium,
- Heavy metals like cadmium, copper, mercury, etc., and
- Pathogens and parasites.

The measurement and analysis were undertaken basically in accordance with the "Standard Methods for Examination of Water and Wastewater, 19th Edition," issued by the American Water works Association (AWWA), as detailed in Table 4.3.1.1.

Environment and Laboratory Co., Ltd., the subcontractor, under the supervision of the JICA Study Team, undertook the measurement and analysis. The BMA Counterpart Team, and the Department of Microbiology and the Department of Parasitology, Faculty of Public Health, Mahidol University, also, undertook analyses for bacteriological aspect and pathogens, and parasites.

4.3.2 Sampling and Measurement/Analysis

(1) Schedule of Sampling and Measurement/Analysis

The sampling and measurement/analysis were undertaken over the two periods, according the schedule shown in Table 4.3:2.1. The measurement and analysis in the Second Survey focused on the heavy metals.

Table 4.3.2.1 Schedule of Sampling and Measurement/Analysis

Location \ Survey		First survey		Second survey		
		First time	Second time	First time	Second time	Third time
Si Phraya Central WWTP	Sampling data	19-Oct-98 (Rainy)	12-Nov-98 (Fine)	21-June-99	23-June-99	25-June-99
	Analyzed items	(A), (B), (C)	(A), (B), (C)	(C)	(C)	(C)
Huay Kwuang Community WWTP	Sampling data	16-Oct-98 (Rainy)	9-Nov-98 (Fine)	23-June-99	24-June-99	25-June-99
	Analyzed items	(A), (B), (C)	(A), (B), (C)	(C)	(C)	(C)
Nong Khaem NSTP	Sampling data	16-Oct-98 (Rainy)	9-Nov-98 (Fine)	1-July-99	2-July-98	5-July-98
	Analyzed items	(A), (B), (C)	(A), (B), (C)	(C)	(C)	(C)
On-Nut NSTP	Sampling data	16-Oct-98 (Rainy)	9-Nov-98 (Fine)	1-July-99	2-July-99	5-July-99
	Analyzed items	(A), (B), (C)	(A), (B), (C)	(C)	(C)	(C)

Note: The categories of measurement and analysis are as follows:
(A): Sludge general properties like moisture, dry solids, volatile solids,
(B): Carbon and nutrient substances like nitrogen, phosphorus, potassium, and
(C): Heavy metals like cadmium, copper, mercury, etc.

In addition, bacterial examinations were conducted by the Counterpart Team and the Department of Microbiology, Faculty of Public Health, Mahidol University. Also, the parasitological examinations were undertaken by the Department of Parasitology, Faculty of Public Health, Mahidol University, for sludge samples taken in June 1999.

(2) Results of Measurement/Analysis

All the results of measurements and analyses, and examinations are presented in:

- Table 4.3.2.2 for the measurements and analyses of general properties and nutrients,
- Table 4.3.2.3 for the measurements and analyses of heavy metals,

- Table 4.3.2.4 for the bacterial examination, and
- Table 4.3.2.5 for the parasitological examinations.

Table 4.3.2.4 Results of Bacterial Examination

Examined Items \ Sludge sources		Si Phraya Central WWTP	Huay Kwuang Community WWTP	Nong Khaem NSTP	On-Nut NSTP
Total coliform (MPN/Wet-g)	*Dates*	*June 21, 99*	*June 23, 99*	*July 1, 99*	*July 1, 99*
	Results	11×10^4	33×10^4	920×10^5	$1,600 \times 10^5$
	Dates	*June 23, 99*	*June 24, 99*	*July 2, 99*	*July 2, 99*
	Results	27×10^4	140×10^4	$1,600 \times 10^5$	$2,400 \times 10^5$
	Dates	*June 25, 99*	*June 25, 99*	*July 5, 99*	*July 5, 99*
	Results	33×10^4	110×10^4	920×10^5	$1,600 \times 10^5$
Fecal coliform (MPN/Wet-g)	*Dates*	*June 21, 99*	*June 23, 99*	*July 1, 99*	*July 1, 99*
	Results	8×10^4	26×10^4	220×10^5	79×10^5
	Dates	*June 23, 99*	*June 24, 99*	*July 2, 99*	*July 2, 99*
	Results	17×10^4	70×10^4	130×10^5	170×10^5
	Dates	*June 25, 99*	*June 25, 99*	*July 5, 99*	*July 5, 99*
	Results	22×10^4	33×10^4	110×10^5	130×10^5
Fecal Streptococcous (Direct count, CFU/g) (Oct 19 to Nov 2, 98)	1st.	0	0	9.4×10^5	0
	2nd.	2.5×10^3	4.5×10^3	10.3×10^4	10.9×10^2
	3rd.	4.9×10^3	2.3×10^3	2.6×10^5	1.0×10^3
Fecal Streptococcous (Direct count, CFU/g) (Nov 9 to Nov 30, 98)	1st.	2.4×10^3	2.5×10^3	1.7×10^6	1.7×10^6
	2nd.	1.7×10^2	1.0×10^2	1.1×10^5	2.2×10^5
	3rd.	6.3×10^2	2.1×10^2	5.0×10^4	6.9×10^4
Fecal Streptococcous (Enrich method) (Oct 19 to Nov 2, 98)	1st.	+	+	+	+
	2nd.	+	+	+	+
	3rd.	+	+	+	+
Fecal Streptococcous (Enrich method) (Nov 9 to Nov 30, 98)	1st.	+	+	+	+
	2nd.	+	+	+	+
	3rd.	+	+	+	+

Source: The BMA Counterpart Team and the Department of Microbiology, Faculty of Public Health, Mahidol University

Table 4.3.2.5 Results of Parasitological Examination

Sampling date	Sludge sources	Parasites Found
1st. Nov. 9-12, 98	Si Phraya	*Hookworms eggs*
	Huay Kwuang	Not Found
	Nong Khaem	*Opisthorchis viverrini egg, Hookworms egg, Phaneropsolus bonnei eggs*
	On-Nut	*Opisthorchis viverrini egg, Hookworms egg, Phaneropsolus bonnei,Haplorchis sp.egg*
2nd. Nov. 23, 98	Si Phraya	Not Found
	Huay Kwuang	*Hookworms eggs*
	Nong Khaem	*Opisthorchis viverrini egg, Hookworms egg, Haplorchis sp.egg, Phaneropsolus bonnei*
	On-Nut	*Opisthorchis viverrini egg, Hookworms egg, Haplorchis sp.egg, Phaneropsolus bonnei*
3rd. Nov. 30, 98	Si Phraya	Not Found
	Huay Kwuang	Not Found
	Nong Khaem	*Opisthorchis viverrini egg, Haplorchis sp.egg*
	On -Nut	*Opisthorchis viverrini egg, Haplorchis sp.egg*

Source: The Department of Parasitology, Faculty of Public Health, Mahidol University.

4.3.3 Interpretation

(1) Sludge Solids Contents

The sludge moisture contents are distributed between 70 and 85 %, indicating that the dehydrators in the respective plants are being operated under the normal performance as a filter of belt press type, as shown in Table 4.3.3.1.

The volatile solids ratio (VS ratio) of the sludge at the Si Phraya WWTP was found to be almost 50 %. This figure is lower than expected from the volatile suspended solids (VSS) in the inlet sewage, which is around 70 % in the normal weather. The extremely light-loading of the biological treatment system might account for the relatively low VS ratio.

The VS ratio of sewage sludge at the Huay Kwang Community WWTP indicated high values, because it is of a separate-sewer system. It is reasonable that the NSTPs showed the higher VS ratio, considering its origin sources.

Table 4.3.3.1 Summary of Sludge Solids Contents

Measured items \ Sludge categories		Si Phraya Central WWTP	Huay Kwuang Community WWTP	NSTPs	Exemplary Sewage Sludge in Japan
Moisture (%)(1)	Nr. of sample	2	2	4	61 - 87
	Minimum	83.6	82.5	75.2	
	Maximum	85.8	85.3	82.3	
	Average	84.7	83.9	79.3	
Total solid (%)(1)	Nr. of sample	2	2	4	13 - 39
	Minimum	14.2	14.6	17.7	
	Maximum	16.4	17.5	24.9	
	Average	15.3	16.1	20.8	
Volatile solid (%)(2)	Nr. of sample	2	2	4	10 - 70
	Minimum	44.8	55.6	72.2	
	Maximum	55.5	56.6	82.8	
	Average	50.2	56.1	76.1	

Note: Units: (1); Weight by Wet-weight, (2); Weight by Dry weight.

(2) Nutrients Elements

Table 4.3.3.2 shows that almost all sludges are in a suitable range for agricultural use in terms of the carbon content, the nitrogen content and other nutrient items.

(3) Heavy Metals

When sludge aims to be used for agricultural application, toxic substances like heavy metals are regulated in a certain limit to prevent the human health and natural resources pollution such as land soil, water resources, etc.

If the measured figures shown in Table 4.3.3.3 are compared with the current Japanese Standards, mercury (Hg) in all sludge from BMA and copper (Cu) in the Si Phraya WWTP are beyond the limits on the average basis. The sludge from the Si Phraya WWTP exceeds the limit of nickel (Ni) as well as copper (Cu) on the average basis in comparison with the tentative standards proposed by AIT. Furthermore, mercury (Hg) in the sludge from the NSTPs is beyond the limit set by AIT in the maximum base.

The records shown in Table 4.3.3.3 include the data measured in the past. In this Study, these were referred as only the probable data that may occur in the future. Present industrial effluent standard should be strengthened, and establishment of new wastewater quality regulations to protect WWTPs from heavy metal intrusion will be required.

Table 4.3.3.2 Summary of Nutrient Contents

Measured items \ Sludge categories		Si Phraya Central WWTP	Huay Kwuang Community WWTP	NSTPs	Quality[1] Standard in Japan
Carbon (C) (%)	Nr. of sample	2	2	4	higher than 35 (as organic matter)
	Minimum	24.7	9.1	43.5	
	Maximum	33.8	43.5	59.9	
	Average	29.3	26.3	52.4	
Nitrogen (N) (%)	Nr. of sample	2	2	4	higher than 2
	Minimum	2.9	3.7	2.8	
	Maximum	3.9	4.0	4.6	
	Average	3.4	3.8	3.9	
Alkalinity (%)	Nr. of sample	2	2	4	less than 25
	Minimum	0.56	2.1	0.88	
	Maximum	0.70	2.2	2.7	
	Average	0.63	2.1	1.8	
Phosphorus (as P_2O_5) (%)	Nr. of sample	2	2	4	higher than 2
	Minimum	1.7	2.9	0.95	
	Maximum	2.2	3.7	2.1	
	Average	2.0	3.3	1.5	
Potassium (as K_2O) (%)	Nr. of sample	2	2	4	not specified
	Minimum	0.04	0.38	0.01	
	Maximum	0.10	0.43	0.38	
	Average	0.07	0.41	0.15	
C/N ratio (-)		8.7	6.8	13.5	less than 10

Note:

Units: Weight by Dry weight.

1): The quality standard for sewage sludge fertilizer, which was set by the Central Committee of Agricultural Cooperative.

The intrusion of heavy metals reportedly might be caused by small industries in certain kind of categories like electroplating, dying, battery manufacturing, etc. In terms of mercury, laboratories in hospitals, research and development institutions, etc. may be also suspicious. Judging from the high concentration of mercury in not only Central WWTP but also NSTPs and Community WWTP, it might be possibly that there is an illegal connection or occasional inflow of some wastewater besides night soil directs to septic tanks.

Consequently, careful consideration for heavy metal intrusion to Central WWTPs, Community WWTPs as well as NSTPs is identified to be the prerequisite for agricultural use of sludge in BMA area.

Table 4.3.3.3 Summary of Heavy Metal Contents

Sludge categories / Measured items		Si Phraya Central WWTP	Huay Kwuang Community WWTP	NSTPs	Standards of sludge fertilizer: Japanese Standards	Standards of sludge fertilizer: Tentative Standards proposed by AIT
Cadmium (Cd) (mg/kg)	Nr. of sample	5	5	10	5[1)]	20
	Minimum	0.5	0.5	0.5		
	Maximum	4.5	2.6	3.9		
	Average	1.7	1.5	1.5		
Chromium (Cr) (mg/kg)	Nr. of sample	5	5	10	Not specified	1,000
	Minimum	102	43	4.2		
	Maximum	751	96	47		
	Average	542	68	30		
Copper (Cu) (mg/kg)	Nr. of sample	5	5	10	600[2)]	900
	Minimum	61	69	57		
	Maximum	1,728	598	334		
	Average	944	320	203		
Lead (Pb) (mg/kg)	Nr. of sample	5	5	10	Not specified	1,000
	Minimum	53	63	21		
	Maximum	210	350	51		
	Average	138	183	38		
Nickel (Ni) (mg/kg)	Nr. of sample	5	5	10	Not specified	200 (400[3)])
	Minimum	30	15	0.5		
	Maximum	520	34	29		
	Average	297	26	14		
Zinc (Zn) (mg/kg)	Nr. of sample	5	5	10	1,800[2)]	3,000
	Minimum	146	165	66		
	Maximum	949	1,296	690		
	Average	615	650	400		
Mercury (Hg) (mg/kg)	Nr. of sample	5	5	10	2[1)]	25 (10[3)])
	Minimum	0.5	1.1	0.1		
	Maximum	14.7	12.0	35		
	Average	7.0	6.3	13		

Note:
Units: Weight by Dry weight,
1): The standard values are specified in the Fertilizer Control Law in Japan,
2): The standard values are specified in the Quality Standard of Organic Fertilizer set by Japan Ministry of Agriculture and Forestry in Japan,
3): AIT has proposed the alternative standards in the Seminar of this Study on September 10th, 1999.
4): The schematic procedures of the measurement and analysis for Japanese standards are shown in the "SUPPORTING REPORT M".

(4) Bacteria and Parasites

Among the sludge sources from which samples were taken, only the Huay Kwuang Community WWTP is equipped with digestion process. However, the effect of digestion in the reduction of pathogens and parasites could not be seen from the examination results.

(5) Need for Regular Monitoring of Sludge Quality

While twice-period samplings and measurements for sludge quality determination were carried out in this Study, some items' values were seen to fluctuate widely. Therefore, long-term monitoring on a regular basis is called to identify the background qualities.

4.4 Sludge Demand and Marketing Surveys

4.4.1 Agricultural Demand Surveys

(1) Background

The major expansion of wastewater treatment facilities proposed in central Bangkok will generate a large amount of sludge. As part of planning to deal with this, BMA engaged AIT to undertake a feasibility study into the agricultural use of sewage and night soil sludge. This followed an earlier Master Plan for sludge disposal reported in 1995. The AIT feasibility study which reported in 1998 identified considerable potential for disposal of sludge on farm land in Bangkok and the neighboring provinces. In this Study, methods of sludge treatment and disposal are extended beyond those of the AIT study, both in scope and planning horizon, as requested by BMA.

BMA plans to dispose of two forms of sewage and night soil sludge products: a digested and dewatered sludge cake, and a compost made by mixing sludge with farm residues such as coconut husks. The sludge cake would be offered free while composted sludge would be sold at a low price. To help determine the demand for these products, two surveys were undertaken, the first of Kaset Tamboons (Extension Officers of Department of Agricultural Extension), and the second of farmers.

(2) Survey of Extension Officers of Department of Agricultural Extension

1) Survey Objectives

The objectives of the survey were:

i) To obtain information on the existing use by farmers of chemical and organic fertilizers,

ii) To obtain information on farmers' acceptance and attitude towards using sludge products as a soil conditioner,
iii) To obtain information on what incentives would encourage farmers to use sludge products.

2) Selection of Provinces

As all sludge will be produced in Bangkok, the target survey areas were chosen adjacent to Bangkok Metropolitan Region (BMR). These were the provinces of Samut Sakhon, Nakhon Pathon, Nontha Buri, Pathum Thani, and Chacheng Sao. The chosen provinces are shown in Figure 4.4.1.1. They are in different topographical and physical locations and therefore allow survey of sludge applications to various crop types and terrain.

3) Survey Results and Conclusion

The responses to the questions in the survey are given in Table 4.4.1.1. The table shows the number of respondents, by province:

i) Using various types of fertilizer and planting various crops,
ii) Using specified information sources,
iii) Having experience of and using sewage sludge.

Important conclusions to be drawn from these statistics include:

i) 83 % of farmers would accept sewage sludge without charge,
ii) 18 % of farmers would accept sewage sludge if they had to pay for it.

(3) Survey of Farmers

1) Objectives of the Survey

The aim of this survey, undertaken by the Study Team, was to target farmers who are considered to have the greatest direct demand for sludge end-products such as compost. The objectives of the study were:

i) To determine (1) the possibility of introducing the use of Bangkok sewage sludge in farming, (2) farmers' acceptance and attitude towards sewage and human waste sludge;
ii) To determine (1) the market demand for sewage sludge as an alternative organic fertilizer in farming, (2) tentative costs of mixed compost sludge;
iii) To understand farmers' experience in using organic fertilizers.

The survey report is attached at Supporting Report A.

2) Survey Area and Target Group

Respondents to the questionnaire were 122 farmers who were using organic fertilizers on their farms. Target areas were selected to be near the source of BMA sewage sludge. The chosen areas comprised 41 villages in 11 districts, in Bangkok suburbs where agricultural activities remain, as well as in Nontha Buri and Chachengsao provinces.

3) Results and Conclusions

The responses to three important areas concerning types of preferred sewage sludge, intention to buy compost, and application of night soil to farms, are shown in Table 4.4.1.2. The results of these and other areas of the farmers' survey are used in Sections 4.4.2 to 4.4.4 below in the derivation of demand for sludge and sludge compost.

The main crops in the survey area were fruit trees, vegetables, flowers and field crops, and the average farm size was 1.29 hectares. Fruit trees were the predominant crop and about 53 % of the respondents were small farmers who had less than 0.8 hectares. Some 94 % of farmers used both chemical and organic fertilizers in fruit and vegetable and flower plantations. The amount of the most widely used chemical fertilizer was less than 1,250 kg per hectare. Most farmers spent more on chemical fertilizer than organic fertilizers. They also bought compost and did not use freely available human waste.

About 73 % of respondents had no knowledge of sewage sludge application. However, about 62 % in Bangkok and 65 % in Chacheng Sao would be interested in using it if it reduced fertilizer cost and achieved the same productivity. In Nontha Buri the proportion interested was much lower. Main reasons given for not accepting sludge products were uncertainty about the quality and their lack of knowledge about using it. Mixed sludge compost was preferred by most respondents, at an acceptable price of less than 1 Baht per kg.

Night soil was not a preferred fertilizer among Thai farmers due to the cultural bias that it was dirty and smelly. Only a few respondents used it (with fruit trees) and only one respondent used it for field crops.

To convince farmers to use sludge in place of other organic fertilizers, demonstrations are required in many areas, in which Extension Officers would play a lead role. Community or village leaders can be influenced to use it and thereby promote it among other farmers. Most Thai farmers would follow those who successfully apply new methods on their farms.

4.4.2 Demand Survey for Sludge Compost

In order to forecast the market size and demand of the wastewater and nightsoil sludge use for agricultural purposes in Thailand, the demand and market surveys were conducted. The demand survey is defined as a study to estimate the potential demand of sludge compost from the organic fertilizer demand study by means of statistical approaches. The market survey is defined as a study to estimate the current market size of sludge compost by means of micro approaches such as direct interviews to producers, retailers and end users.

All calculations were done based on ton dry solid sludge per day or t DS/d. The following basic assumptions were applied in the estimation;

- Compost is made of wastewater sludge or nightsoil sludge without digestion.
- 1 t sludge with 80 % moisture content is mixed with 0.5 t bulking materials with 15 % moisture content, which comes 1.00 t compost with 44 % moisture content. This implies that 0.2 t DS comes to 1.00 t compost, which means that the weight of compost becomes 5.0 times of the weight of dry sludge, as shown in Table 4.4.2.1.
- Sludge is applied only in the form of compost, based on the observation of the market taste. Thais are not familiar with liquid and cake of sludge and the survey to farmers shows 76.2 % of farmers prefer compost to solid, as shown in Table 4.4.1.2 (Table A.3.8 in Supporting Report A).

(1) Demand for Agricultural Use

This is the major demand segment and the potential demand size was estimated in the following 3 ways:

a. 1998 AIT Report (Table 4.4.2.2 (A))
b. First Survey to Agriculture Promotion Experts (Table 4.4.2.2 (B))
c. Interview Survey to Compost Manufacturers (Table 4.4.2.2 (C))

These estimations were summarized in Table 4.4.2.5 to compare the results and assumptions. The estimation was done in the following equation:

Potential demand = Target agricultural land area x Dry sludge application rate
x Ratio of farmers that are willingly to pay for sludge

Target agricultural land area was decided by selecting provinces and target crop and the area was calculated from Agricultural Land Use Statistics issued by Min. of Agriculture and Cooperatives in 1996. The target provinces within approximately 100 km radius from Bangkok were selected for (a) and (b), while 16 provinces within approximately 150 km radius were selected for (c) since the

compost manufacture mentioned they sometimes transport their compost even over 300 km by truck.

For sludge application rate, 5 t DS/ha/y was adopted from recommendation in the 1998 AIT Report, except estimation (c), in which 1.88 t DS/ha/y was used based on the figure mentioned by compost manufacturers.

For the ratio of farmers that are willing to pay for sludge, 20 % and 18 % are used for (a) and (b) from each survey result. Forty-seven percent is used for (c), which was obtained from the average figure of the Second survey results.

As shown in Table 4.4.2.5, it was concluded that 487 t DS/d could be the approximate potential demand scale of sludge compost in the nearby provinces.

(2) Demand for Public Parks (Table 4.4.2.3 (A))

Queen Sirikit Park is the only case where wastewater sludge is used for planting. They use sludge from Si Phraya WWTP and Huay Kwuang Community TP for flower nursing and have had good results. Three t/d of sludge cake is being applied for 3.36 ha flower beds and trees. This rate is applied for all 12 public parks in BMA, of which total park area is 286.6 ha, and the potential sludge demand was estimated at 7.68 t DS/d.

(3) Demand for Road and Green Zone (Table 4.4.2.3 (B))

Road green zone is another possible target area to apply sludge compost particularly in the initial experimental stage. According to the BMA land use plan, the road green zone occupies 213 ha, which needs sludge compost for soil conditioning at the rate of 5 t DS/ha/y, the recommended figure by the 1998 AIT report. The potential demand in BMA area is calculated by the same ratio and was resulted in 2.92 t DS/d. This potential demand could be much bigger, if nearby provinces use the compost as well.

(4) Demand for Golf Course (Table 4.4.2.4)

The Study Team made telephone interviews to 14 golf courses and had one meeting interview to the Royal Golf & Country Club. All of these golf courses are negative to use organic fertilizer including sludge compost, since they are rather quality conscious to smoothen grass and are not interested in cost and soil condition even for trees around golf course. Although sludge compost could be used at the development stage, this demand is very limited and therefore it is concluded that there is no potential demand from golf courses.

(5) Estimation of Overall Potential Demand

Since there is no statistic data available for sales volume of organic fertilizer and production capacities of these manufacturers are mostly small and medium scale, it is extremely difficult to estimate the demand size of organic fertilizer and compost. However, the Study Team tried to forecast by statistical approaches based on the results from the interview surveys. As shown in Table 4.4.2.5, the estimated value of the sludge compost demand is around 500 t DS/d, which is much larger than the wastewater and nightsoil sludge produced in 2020.

4.4.3 Marketing Survey for Sludge Compost

(1) Interview Survey to Fertilizer retailers (Table 4.4.2.6)

Five fertilizer retailers at Taevet Flower Market and another five retailers at Chatuchak Weekend Market were interviewed. The following are the findings and conclusions:

1) Findings

- Price range of chemical fertilizer is 20 to 30 Bahts/kg. These are 16-16-16, 46-0-0,13-0-46, 12-24-12 and so on from the best seller.
- Organic fertilizer has 2 kinds, compost and pellet.
- Price range of compost are 1.00 to 4.25 Bahts /kg, but mostly between 1 to 2 Bahts/kg. Raw materials are cow manure and garbage. Chicken manure compost is limited due to supply shortage.
- 2 kinds of pellet are identified. One is 50 Bahts/kg. Another is 15 Bahts/kg, made from chicken manure.
- BMA used to sell garbage fertilizer at 0.67 Bahts/kg long time ago, which was very popular by its cheap price and quality. Some people know that this included nightsoil.
- One shop has a problem to sell Korean compost at 15 Bahts/kg. Never has been sold for one year since too expensive.
- Even under this tropical condition, continuous supply of fertilizer is necessary for any kinds of flower, plant and tree to have healthy grow.
- All interviewees recognize possibility of wastewater sludge compost and said that it can be sold in the market if the price is competitive enough and the government makes proper PR and provides adequate education.

2) Conclusions

- There is a possibility of selling sludge compost fertilizer, possibly pellet as well.
- The target compost price should be less than 1 Bahts/kg. For pellet, probably around 10 Bahts/kg, but in a small scale.
- Need continuous effort to educate people.

(2) Interview Survey to Compost Manufacturers

The Study team made an interview survey to compost manufacturer, 12 compost factories are scattered in Thailand, which are owned by a whisky and beverage manufacturer. Their business activities were summarized as follows:

- The compost is made of whisky slop and bagasse, a waste of whisky and sugar cane, respectively. The operation started 7 years ago.
- The average annual production amount is 6,000 t, which varies depending on demand. The sales price ranges between 1,600 to 2,000 Bahts /t.
- These are no association of organic fertilizer or compost.
- The major users are farmers of fruit trees, since they are rather rich, compared to rice farmer and others. They use compost as a soil conditioner.
- The recommended consumption rate of their compost is 1 to 2 t/rai/year, which is around 3,000 Bahts/rai/year. Since the average sales from rice production is 10,000 Bahts/rai/year (5,000 x 2 times a year), rice farmers cannot afford to buy compost.
- Human waste is not used in Thailand.
- Ministry of Agriculture and Cooperatives started their campaign to promote organic fertilizer, instead of chemical fertilizer, one year ago. But, they just gave it as free of charge and no follow-up activities and survey have done yet. So, nobody knows what is happening after that. Their promotion is weak. The most critical constraint to expand the market of organic fertilizer is to educate farmers.
- Their compost factories are just located next to whiskey factories and their compost is transported by large-scale farmers and farmer's cooperatives. In case that customers request to transport the compost to their farm, the company asks transportation companies, which cost 3,500 Bahts for 200 km by 13 t truck, which means 0.001346 Bahts/kg/km. They often transport compost over 300 km or more, since transportation cost is not high.
- Chicken manure pellet is getting popular not only among city people but farmers, since easy to use.
- BMA fertilizer was popular, which consists of garbage and nightsoil. BMA was only one manufacturer.

- It might be possible to sell or give sewage sludge itself as a raw material of compost to compost manufacturers after appropriate safety treatments such as pasteurization and sterilization.

This information was used to estimate the potential demand of sludge compost, as shown in Table 4.4.2.2 (C).

(3) Telephone Survey to Compost Manufacturers

In order to estimate the existing market scale of organic fertilizer, the Study team tried to make a list of manufacturers and their production capacity by telephone interview survey. Table 4.4.2.7 shows relatively large-scale 5 producers with the total production capacity of 271,000 t/y, which is equivalent to 149 t DS/d. In addition, Table 4.4.2.8 shows producers registered at Ministry of Industries. Their total production capacity operating in the Central, East and West regions is 266,346 t/y or 146 t DS/d.

(4) Investigation for Agricultural Use of Nightsoil

All nightsoil sludge produced at both NSTPs have been used at public schools and district offices for planting and gardening. The volume is estimated at the level of 28 t DS/d.

(5) Second survey to farmers (Table 4.4.2.9)

The Second Survey to farmers indicates the strong potential interest in sludge compost. Although the numbers of respondents are limited, that is, 86, 58, and 7 for fruit, vegetables/flowers, and field crops, respectively, the Survey shows that 42, 52 and 43 % are interested in sludge compost to apply their fruit, vegetables/flowers and field crops, respectively, even if they have to pay. (See Table 4.4.1.2.) Based on this survey results and their actual application rate of organic fertilizers, the aggregate demand capacity of organic fertilizers within 10 provinces was estimated as around 1.08 Million t/y or 2,375 Million Bahts/y, which is equivalent to 594 t DS/d. If half of this amount is substituted by sludge compost, all sludge produced from WWTPs and NSTPs in 2020 will be completely absorbed for agricultural use.

The current market sizes of compost, animal manure, NS sludge and chemical fertilizer are also estimated as shown in Table 4.4.2.9. These are calculated as follows;

Sales amount in weight =Target area x fertilizer application rate from the survey

Sales amount in Baht =Sales amount in weight x average price of fertilizer from the survey

The results are summarized in Table 4.4.2.10.

(6) Estimation of Current Sales Volume of Compost Fertilizer (Table 4.4.2.10)

The current market size of compost was estimated at least 323 t DS/d by means of total of compost manufacturers operating in the nearby provinces. From the second survey, the approximate current market size of compost is estimated around 594 t DS/d. Since the supply amount reaches the level of 300 t DS/d in 2020 and the market size will certainly expand due to improvement of quality and quantity of agricultural products in the Bangkok region, there is an appropriate market size existing to absorb all wastewater and nightsoil sludge in the form of compost, if the sales price meet with the market need and the proper guideline of sludge compost is successfully introduced.

4.4.4 Conclusions

Based on this demand and market survey, the following conclusions can be drawn:

a. Compost made from wastewater sludge is acceptable as an organic fertilizer, which means that the BMA can give or sell sludge to compost manufacturers.
b. Although most of people say that nightsoil is not used for agriculture in Thailand, there is some evidence of nightsoil use in agriculture, e.g., BMA fertilizer including nightsoil was popular, nightsoil sludge from NSTPs is currently used at schools and district offices, 26 % of farmers in the Second survey have applied nightsoil (Table 3.17 of Supporting Report A). Therefore, nightsoil sludge would be also accepted in the market.
c. It is recognized by some groups of people, but not much by farmers, that sludge can be useful for agriculture. The key factors to penetrate the sludge market in the agricultural sector are (1) safety, (2) cost and (3) education of farmer.
d. The estimated potential demand at present could be around 500 t DS/d, while the estimated supply amount in 2020 is 300 t DS/d. The demand consists of agriculture sector, public parks, and road/green zone.
e. Market survey shows the current market size is at least 320 t DS/d, since this is the total amount of compost manufacturers and users identified in this survey. Since obviously there should be many missing compost companies not registered in MOI file, the real market size could be much larger than this figure.
f. In addition, the estimation from the Second Survey indicates the current compost market size in nearby 10 provinces is approximately 600 t DS/d, which implies that there is a possibility to use up all sludge produced in 2020.

g. Compost is recommended first, since this is an acceptable form in the current market, compared to liquid and cake form. Pellet would be unacceptably expensive and the market would be only a niche business, therefore this could not be an option in this Master Plan.
h. The target production cost of compost is 1.5 Bahts/kg and the sales price at the market place should be lower than 2 Bahts/kg.
i. Fruit tree, vegetable/flower and crop farming is the most prioritized area, since their yield is likely to be at affordable level to purchase compost.
j. According to the estimation from the Second survey, 6,520 Million Bahts are used for chemical fertilizer annually in the nearby 10 provinces, while 2,375 Million Bahts and 1,731 Million Bahts are used for compost and animal manure, respectively. In order to save import of chemical fertilizer, organic fertilizer should be much more encouraged to use.
k. The most important success factor to introduce the sludge compost into the agricultural sector is the proper guidance and education of farmers for which the appropriate promotion mechanism has to be developed, possibly together with Ministry of Agriculture and Cooperatives. The first step could be to apply the sludge compost to public parks and road green zone to show the positive effect of the sludge compost on trees and flowers.

4.5 Reclaimed Wastewater Reuse Survey

4.5.1 Introduction

The existing Si Phraya Central WWTP generates 20,000 m^3/d of treated wastewater, of which 200 m^3/d is reused in the plant for washing treatment equipment, toilet flushing, car washing and floor cleaning. Treated wastewater is also used for road cleaning and plant watering on the streets under the control of the district offices. The current ongoing 6 schemes, some under construction, will generate approximately 983,500 m^3/d in total of treated wastewater in the early years of the 21st century when they will be complete. In addition, new sewerage treatment systems are proposed in this Master Plan for areas in the suburbs by the year 2020.

When all of these sewerage schemes are completed, a huge amount of treated wastewater will be generated and discharged into khlongs, canals and rivers, and it is very important to consider reuse of treated wastewater in view of conservation of natural resources.

In order to make an efficient reuse plan in this Master Plan Study, an investigation into the future potential of wastewater reuse by public and private organizations was conducted.

The locations for survey were objectively selected from among public organizations or institutions and private sector entitles that consume large quantities of water, have experience of wastewater reuse and have the potential for future use, for example:

i) Wastewater Treatment Plants and Nightsoil Treatment Plants
ii) District Office
iii) Public Transportation Depot
iv) Public Building
v) Large Private Building
vi) Hotel
vii) Hospital
viii) Others (Stadium, Large garden, etc.)
ix) Irrigation
x) Industrial Estate and Factory

4.5.2 Public Wastewater Reuse Survey

(1) Wastewater Treatment Plants and Night Soil Treatment Plants

1) Si Phraya Central WWTP

At the Si Phraya WWTP, both secondary treated wastewater and wastewater that is additionally treated with a sand filter are reused. Of this, 80 to 180 m^3/d is generated by secondary treatment only and 1 to 20 m^3/d by additional sand filter. The latter is used in-plant for the washing of plant facilities and equipment, and the former is used for watering plants along the streets. Neighboring district offices that are responsible for watering roadside plants manage and control the application. The water quality for these applications is generally BOD 7-10 mg/l.

2) Huay Kwuang Community WWTP

Of the secondary treated wastewater used at the Huay Kwuang WWTP, 6 m^3/d twice a week is used for washing equipment, 4 m^3/d for watering the garden and 2 m^3/d for cleaning floors. The volume of reuse is equivalent to 0.5 % of the total volume of treated wastewater at this treatment plant.

3) Nong Khaem NSTP

At the Nong Khaem NSTP, the newest plant was constructed seven years ago. Over 90 % of the water used in the plant is treated wastewater produced by secondary treatment and subsequent sand filtering with a treatment capacity of 600 m^3/d.

The total amount of treated wastewater reuse is 420 m^3/d.

The main objective of treated wastewater reuse are as follows:

i) Floor cleaning
ii) Washing the filter cloth
iii) Washing the drum screen, etc.

The volume of treated wastewater is as follows:

i) For i) and iii) above: 120 m^3/d
ii) For ii) above: 300 m^3/d

The total amount of treated wastewater reuse is 420 m^3/d.

For comparison, the public water supply amount to this NSTP is 35 m^3/d, of which 12 m^3/d is for office use, 20 m^3/d is for chemical preparation, and 3 m^3/d is for laboratory use.

4) On-Nut NSTP

A night soil treatment plant including 3 sand filters is provided at On-Nut. However, the sand filters are not currently in use due to their age. The water needed for operation and maintenance as well as for living needs is from groundwater and khlong water.

The water usage of each plant is shown in Table 4.5.2.1.

(2) District Offices

The current water use conditions in some typical District Offices are summarized in Table 4.5.2.2. Volumes and frequencies of use are averaged as follows:

i) Road Plant Watering

Dry season: 15 $m^3/d/100$ ha (twice a day at night)
Rainy season: 7.5 $m^3/d/100$ ha (once a day at night)

ii) Road cleaning

Existing urban areas: 6 $m^3/d/$ 100 ha (once a week in the daytime)
Suburban areas: 2 $m^3/d/$ 100 ha (once a week in the daytime)

Table 4.5.2.2 shows that there is little difference in water consumption for road plant watering and road cleaning between urban and suburban areas. Accordingly, the volume of water to be used will not vary dramatically in the future even if the area is further urbanized. The volume of water to be used for road cleaning will increase as urbanization progresses and the network of roads expands.

(3) Public Transportation Depot

The investigation also covered the conditions of water use for public transport where a large volume of water is generally consumed for cleaning vehicles, etc. The Bangkok Mass Transit Authority (BMTA) operates public buses in Bangkok and currently owns 4,098 buses. These buses are stationed at 33 depots scattered in the city, and each depot consumes approximately 70 m^3 of public water for cleaning buses every day in the rainy season and every other day in the dry season. Four depots located in the suburban areas use khlong water for cleaning buses and other miscellaneous uses.

The Bangkok Mass Transit System (BTS) is developing a new transport system scheduled to commence operation by the end of 1999. There will be 35 train coaches, which will need washing once every 3 days. The water consumption for washing each coach is assessed to amount to 1 m^3, and the Chatuchak depot will amount to 15 m^3/d for washing train cars.

The State Railway of Thailand (SRT) has 100-year history. At each depot, a fairly large volume of water is being used, although reclaimed wastewater is not used.

Water usage data for each public transport service is given in Table 4.5.2.3.

The location of depots are dispersed widely, and water consumption is comparatively low. Of these, the State Railway of Thailand (SRT), which has been in operation for more than 100 years and has a comparatively large water consumption, uses public water and is not likely to require reclaimed wastewater.

(4) Public Building

Water consumption in the BMA building and district offices was investigated. In most cases, the water source is public water. There is no reuse of treated wastewater from septic tanks. Water usage data for each public building is given in Table 4.5.2.4.

4.5.3 Private Sector Reuse Survey

(1) Large Buildings

Surveys were conducted of five large-scale condominiums and office buildings having floor space of about 10,000 m^2. All of these are Level of Standard B of the Building Effluent Standards. The facilities in these buildings conduct primarily anaerobic treatment. There is no full-time operator for the facilities, and water quality measurement is not required. Reclaimed wastewater is not being reused. Water usage data for each of the buildings is provided in Table 4.5.3.1.

The Rama IV project is a roadside plant-watering project organized by a group of private firms. Since 1997, treated wastewater from the ESSO building has been used to water the plants in the green zone along Rama IV Road. The group of firms operates and maintains the watering equipment. Details of the project are as follows:

- ESSO building wastewater treatment system capacity: 135 m^3/d
- Volume of water used to sprinkle the green zone (about 500 m) in the middle of the road in front of ESSO building: 18 m^3/d
- Electricity charge for the pump machine: 10 Baht/d

(2) Hotel

Water use surveys were conducted for four large and prominent hotels in Bangkok. These hotels showed large-scale water consumption of around 1000 m^3/d. The water sources are the public supply water and river water. Each of the three hotels on the Chao Phraya River (the Oriental Bangkok, the Shangri-La and the Royal Orchid Sheraton) has facilities for treatment of river water to the quality level of public water. During the season when there is no salt water contamination, Chao Phraya River water is used after treatment. When the river water level falls or salt water is detected with conductivity of more than 600 micro-Siemen, for example, especially in the dry season, public supply water is used. As an example of river water treatment systems, the one at the Sheraton Hotel is introduced in Figure 4.5.3.1.

Water discharge from the hotels is regulated by Building Effluent Standards. For hotels of 200 rooms or more, Level of Standard A is applied. The regulated effluent quality is BOD 20 mg/l and SS 30 mg/l or less. The hotel owner must submit a report to the local official (Environmental and Sanitary Subdivision, District Office, BMA) at least once a month. The hotels are subject to controls equivalent to those applying to wastewater treatment plants. Water usage data for each hotel is provided in Table 4.5.3.2.

(3) Hospitals

Surveys were also conducted for five hospitals, which are subject to the same kind of strict regulation as is applied to hotels. Hospitals of 30 beds or more are Level of Standard A in the Building Effluent Standards. As was the case with the hotels discussed above, effluent quality should be at the same level as at public wastewater treatment plants. Of the five hospitals surveyed, three reused reclaimed wastewater. This water is mostly used for sprinkling plants, but at the Ramathibodi Hospital, secondary treatment wastewater is softened and used for flushing toilets in the two new buildings. Water usage data for each hospital is provided in Table 4.5.3.3.

(4) Others (Stadium, Large garden, etc)

Surveys were conducted of four large parks and golf courses. All of those surveyed were supplied with groundwater. This is primarily used for watering the grass which covers the majority of each site. The amount of water used per hectare of green field at public parks was 40 m^3/d. The water usage for each park and golf course is provided in Table 4.5.3.4 and 4.5.3.5.

Water discharge from buildings is regulated by Building Effluent Standards. Two Effluent Building Standards are the National Environmental Quality Act and the Act of Building Control (see Table 4.5.3.6 and 4.5.3.7).

4.5.4 Khlong Purification Reuse Survey

The khlongs in the city of Bangkok are a developed network. The city is originally wetlands, and there have always been many khlongs. The traditional means of transportation was by boat, and khlongs were the transportation routes. As the automobile replaced the boat as the primary means of transportation, khlongs were filled in and made into roads. Soi is said to indicate a road that was originally a waterway. There are many khlongs that have been narrowed or closed off by being filled in.

In the wet season, the river water level rises, and it is common for khlongs to overflow as storm water enters the upstream khlongs. To prevent this flooding, many dikes, floodgates and pump facilities have been provided in the urban area to control the influx and discharge of water. These facilities have greatly reduced flood damage.

In the dry season, the floodgates are also used to control the influx of salt water to the khlongs that results from high tides when river water levels are low. There has been some improvement with the implementation of the Khlong Water Quality Improvement Project. However, problems such as khlongs containing only sewage, offensive odors from the khlongs, and sludge buildup still remain.

As it is hoped that treated wastewater can be used to purify the khlongs, on-site investigations of khlongs were conducted. The results of the investigations are summarized below:

- The water level of the Chao Phraya River falls in the dry season. There is also less water coming from upstream of the khlongs. Consequently khlong water levels fall, and in places khlongs contain only sewage.
- In the urban area, closed-off khlongs may be seen in places. Where effluent pipes are connected directly to the khlongs, they are seen to contain pitch-black sludge.

- There are also places where little water flows into particularly narrow khlongs from upstream, leaving the khlongs to contain only sewage and turning them into drains.
- There are also places where khlongs have been covered over and turned into covered conduits.
- There are many ponds in city parks that are not connected to khlongs so as to prevent pollution from khlong discharge. The water source is groundwater.
- There are many khlongs in the suburbs that dry up in the dry season. This is due to the closing of the King's Dike, which is located upstream, in order to provide water to the agricultural region outside the King's Dike.

Sewage lines are currently being installed. When this project is completed, the sewage load will not be discharged to the khlongs, so the khlongs will become cleaner. Project details are provided below:

- Installation of an intercepting trunk sewers and connection of existing branch sewers to the intercepting sewers
- Construction of wastewater treatment plants

However, if just this project is implemented, the following issues will remain with respect to khlong purification:

- Reconnection to sewers of drains that are currently connected directly to khlongs
- Completion of septic tanks and their thorough and proper operation and maintenance to prevent the discharge of raw sewage into the khlongs
- Strategies to prevent leakage from old sewer lines to the khlongs (i.e., replacement or repair)
- Thoroughness in city cleaning and garbage collection to prevent the pollutant load from the roads from entering the khlongs when it rains.
- Strategies to prevent the pollutant load from un-sewered areas from entering the khlong network
- Means of maintaining water levels in the khlongs to maintain their self-purification capability

4.5.5 Irrigation Reuse Survey

Currently, the amount of agricultural land in the Bangkok region is 56,424 ha (use of land in 1996). Central Bangkok is an urban area, and agricultural land is primarily at the east and west edges of the city. Produce includes fruits and vegetables.

The Chao Phraya Dam is located midway up the Chao Phraya River, where it releases water at a rate of at least 100 m^3/s. It is mandated that this volume of

water be released for various uses, including irrigation, household use, water transport, prevention of odors in city khlongs, livestock and the prevention of salty tidal water from entering the khlongs. Irrigation water is supplied from the Chao Phraya River through the khlongs. The Royal Irrigation Department is responsible for managing the khlongs.

Almost every year in the dry season, the irrigation water supply is insufficient and a water shortage problem develops. Because salt water from the ocean in the south enters the khlongs easily when there is a reduced flow in the rivers and khlongs, there is much farmland in the southern part of Bangkok abandoned due to salination.

There is, therefore, a potential demand for treated wastewater from wastewater treatment plants as irrigation water. The problem is water quality. The Royal Irrigation Department has prepared water quality standards for irrigation (see Table 4.5.5.1). FAO guidelines are applied for each crop (see Table 4.5.5.2 and 4.5.5.3).

Table 4.5.5.4 shows a comparison between the irrigation standards for reclaimed wastewater reuse and the results of the recent survey of the treated wastewater from the Si Phraya WWTP.

The organic principles expressed by BOD and other indicators are within the limits of the standards. Investigation of the 6th item, heavy metal, revealed a presence lower than the standard limit by a factor of ten, and it is assumed that other heavy metals not investigated are also an insignificant issue. Toxic substances such as phenol, which were not investigated, are primarily found in industrial wastewater, so they are not considered as a potential problem outside of industrial areas. Some nutrients not in the standards may affect certain crops, but there should be no problem if the water is used after dilution with khlong water.

4.5.6 Industrial Reuse Survey

Industrial factories can be divided into three categories: individual factories (mainly small scale), industrial parks or areas developed by the private sector, and industrial estates developed by the public sector. As of 1996, there were a total of 44,500 factories spread throughout the Bangkok area. Many individual factories are very small-scale operations engaged in machinery, battery, electroplating, and the like. There are also large-scale dying factories. There are several mini industrial areas operated by private companies and there are two large-scale industrial estates (Bangchan and Lat Krabang) managed by the Industrial Estate Authority Thailand (IEAT). The total number of companies in these estates and industrial areas is 400, and the total area is 604 ha. An overview is provided in

Table 4.5.6.1. Due to difficulties in acquiring land and securing a supply of water for industrial use, there are few plans to build new factories.

An industrial water supply system has not been established yet in Thailand. The water for each private factory or industry is supplied from its own well or public water supply systems. The great majority of industries have been supplied by groundwater due to ease and economy.

The water source for the two large industrial estates is groundwater. As of 1994, the volume of use was 24,100 m^3/d. Simply compared to the groundwater abstract of BMA as a whole, 458,607 m^3/d(1992), industrial wastewater accounts for a mere 5 % of the total groundwater used. However, the subsidence effect on the land near the point of abstraction is probably not as small as the number would indicate.

Currently, the water tariff for groundwater is 3.5 Baht/m^3. Due to more effective water tariff collection based on the restriction of groundwater use and an increase of the water tariff itself, it is envisaged that acquisition of water for industrial purposes will become more difficult in the future.

Surveys were conducted at three industrial sites discharging 2,000 m^3/d or more of wastewater. For the two textile factories surveyed, the water source was groundwater, and for the food factory, the water source was the public water supply. In the food factory, treated wastewater is used for washing the cartons used for shipping chickens. Water usage data for each factory is provided in Table 4.5.6.2.

4.5.7 Requested Water Quality and Preferable Reuse Water Charge

Survey results are shown in Table 4.5.7.1.

No water tariffs are paid for water used for watering plants at Queen Sirikit Park. Rain water and khlong water are used for watering plants at a golf course. At golf courses, there is no incentive to pay for water because even in a water shortage, the grass does not die for about a month. Therefore it seems unreasonable to consider charging for water for watering plants in public places, whether public or privately owned. The water quality level will be determined in line with the intended use.

If the charge for building miscellaneous water is less than the water charge of 14 Baht/m^3, there is demand. The water quality level will be determined in line with the intended use.

When supplying reclaimed wastewater for irrigation, it must meet RID Irrigation standards and must additionally be colorless, odorless, and hygienic. It would be impossible to charge for it.

Regarding industrial use water, there are strict water quality requirements and the industrial water charge is around 3.5 Baht/m^3 to 7 Baht/m^3.

4.5.8 Analysis of Survey Results

The results of the reclaimed wastewater reuse survey may be divided into six categories. First, possible uses of reclaimed wastewater would be for miscellaneous use in buildings, for plant watering, and for khlong purification. The plant watering application can be further divided into the following two general categories: roadside plant watering/road cleaning and plant watering (parks, golf courses, etc.). Additionally, there are possibilities for agricultural and industrial use.

Table 4.5.8.1 compares the current water source, demand, related problems, and demand for reclaimed wastewater for each category of potential demand for reclaimed wastewater. There are problems associated with the water source for each category, which illustrates the potential demand that exists for reclaimed wastewater.

Special characteristics of each category are analyzed as follows. For the category of water for miscellaneous use in buildings, water circulates within the public water supply system, thus differing from the other water uses in character. In this case, the amount of public water used is reduced, with the beneficial effect of saving water and aiding drought mitigation. Water for the other categories is discharged after use out of the system. If water that has been used is once reused, there is no change in the use of public water as a whole. Here, the primary purposes of water use are watering plants and supplying water to the khlongs. Both of these can be considered as contributing to environmental improvement in the city. The former contributes to green area expansion (because it does not rain during the dry season, it is impossible to expand green areas without securing a water source). The latter contributes to water environmental purification by increasing the flow of water in the khlongs.

As irrigation water, reclaimed wastewater contributes to drought mitigation, and as industrial water it contributes to preventing land subsidence.

Table 4.5.8.2 shows the results of analyzing each potential area of demand for reclaimed wastewater in terms of drought mitigation, environmental improvement (green area expansion and water environmental purification) and land subsidence prevention. The results are graphically expressed in Figure 4.5.8.1. About 1 % of

the treated wastewater from the Si Phraya WWTP is used for roadside plant watering. There are public and private projects underway to try and use reclaimed wastewater for miscellaneous uses in buildings and for plant watering (in building's gardens).

CHAPTER 5 EXISTING ORGANIZATION AND INSTITUTION

5.1 Scope, Autonomy and Overall Organization of Bangkok Metropolitan Administration (BMA)

The BMA is the administrative authority for the Bangkok Metropolitan Area which currently covers some 1,569 km^2. It is classified as an independent public authority but is subject to the overall jurisdiction of the Minister of the Interior as well as the Bangkok Metropolitan Assembly, the elected governing body. The elected Governor is the BMA's chief executive and is assisted by four deputy governors who between them administer 14 departments and 50 district offices (see Figure 5.1.1.1 for BMA's existing organization).

One of the chief responsibilities of the BMA is management of the city's output of wastewater and night soil which is the main concern of this Study.

5.2 Detailed Organization and Functions of BMA

The management of the city's output of wastewater and night soil is the responsibility mainly of the Departments of Drainage and Sewerage (DDS), and Public Cleansing, respectively. Other departments involved include (1) Policy and Planning, (2) City Planning, (3) Finance and (4) Law Enforcement. Some functions in these areas are delegated to the 50 district offices.

5.2.1 Department of Drainage and Sewerage

The main purpose of the DDS is to plan, design, construct, operate and maintain the facilities for drainage and sewerage in the BMA area. The Director General (DG) heads the department assisted by three Deputy Director Generals who are responsible nominally for administration, operations and technical areas of the department's work. The main facilities involved in wastewater treatment are described in Chapter 3. DDS has eight divisions:

i) Office of the Secretary Division,
ii) Drainage Information Division,
iii) Main System Development Division,
iv) Drainage Control System Division,
v) Drainage System Division,
vi) Canal System Division,
vii) Water Quality Management Division, and
viii) Mechanical Division.

The main functions of these divisions are summarized below (see Figure 5.2.1.1 for the divisional organization).

(1) Office of the Secretary Division

This division supports all DDS divisions in the following areas: secretarial services; personnel administration, finance (including payroll); preparation of regulations and contracts; and general legal advice. The division consists of five subdivisions: Secretariat, Administration, Legal, Personnel, and Finance.

(2) Drainage Information Division (DID)

The prime objective of DID is to continually monitor the Chao Phraya river and the canal system throughout Bangkok and protect the city from flooding by controlling pumping stations and water gates according to telemetered data received. A secondary objective is to update, store, analyze and report data on the canal system and on the Geographical Information System (GIS) for the drainage system, as planned and when required.

(3) Main System Development Division

The main objective of this division is to plan, design and implement facilities such as sewers and pumping stations to improve flood control. There are five subdivisions: Administration, Project Management, and Drainage System Development 1, 2, and 3.

(4) Drainage Control System Division

This division's objective is to operate and maintain pumping stations, water gates, and automatic screens. There are 416 pumps in 90 pumping stations, 60 water gates and 50 automatic screens in the BMA area. Portable electric and diesel pumps are installed temporarily to control local flooding. The division has three subdivisions: Drainage Control, Drainage Engineering and Administration.

(5) Drainage System Division

The job of this division is to plan and ensure the cleanliness and proper operation of all sewer lines for effective drainage of flood water and wastewater. There are 950 km of main sewers up to 6 m in diameter, and 2600 km of small sewers up to 60 cm in diameter in the sois (alleys). The DSD has responsibility for main sewers while district offices clean the small soi sewers; they can ask DSD for assistance. The division comprises three subdivisions: Sewer Maintenance, Sewer Engineering and Administration.

(6) Canal System Division

The objective of this division is to plan, control, operate, maintain and improve the canal system and the retention ponds. There are 250 canals of total length 750 km and seven retention ponds (with a total area of 833 raise) to be increased to 17 in due course. Five subdivisions perform the division's work: Canal Engineering, Canal Maintenance 1 and 2, Retention Pond Maintenance, and Administration. A major problem is pollution of canals by garbage.

(7) Water Quality Management Division

The Water Quality Management Division (WQMD) was set up to manage water quality in the BMA area, and to resolve specific pollution problems. It is therefore responsible for wastewater disposal and the management of Central and Community WWTPs. Specifically, WQMD has to:

i) Study and resolve wastewater problems by designing, constructing and controlling wastewater treatment and disposal systems;
ii) Ensure the efficient and effective operation and maintenance of wastewater treatment and disposal facilities; and
iii) Monitor and control the quality of water entering the environment and in public water courses.

WQMD comprises five subdivisions: Technical, Water Quality Management Centers 1, 2, and 3, and Administration. The Water Quality Management Centers (WQMCs) were set up to ensure the efficient and effective operation and maintenance of all WWTPs, and to plan and implement additional or improved facilities, in each area of BMA. At present the existing Community WWTPs and the Central WWTP at Si Phraya report to the Water Quality Management Division (WQMD): the former to individual officers in the three Water Quality Management Centers (WQMCs) and the latter to the head of WQMC2.

A complete listing of WWTPs for each WQMC is given in Table 5.2.1.1 below:

Table 5.2.1.1 Water Quality Management Centers and their WWTPs

Subdivision	WWTP in operation	WWTP under construction
Water Quality Management Center 1 (NE area)	Huay Kwuang; Pibun Wattana; King Rama IX; Tung Song Hong 1 & 2; Ram In Pa; Ta Sai; Bang Bua;	Ratanakosin*; Din Daeng* (BMA Stage 1);
Water Quality Management Center 2 (SE area)	Si Phraya*; Bon Kai; Khlong Toey; Bang Na; Klong Chan; On-Nut; Rom Klao; Hua Mark	Yannawa* (BMA Stage 2)
Water Quality Management Center 3 (West Bank)	Buddhamontol Sai 2	Nong Khaem* / Phasi Charoen* (BMA Stage 3); Ratburana* (BMA Stage 3)

Source: Water Quality Management Division, Department of Drainage and Sewerage
Note: * Central WWTPs

One Community WWTP at Din Daeng remains to be handed over to BMA from the National Housing Authority.

(8) Mechanical Division

The prime objective of the Mechanical Division is to provide mechanical and electrical engineering services to DDS for installing, and carrying out major repairs on, electric and diesel pumps. The division also services and repairs cranes and vehicles belonging to DDS. There are about 1,000 pumps in the DDS system. In addition to haulage vehicles, there are 10 mobile cranes for pump installation and major repair and 13 mobile generators. There are four subdivisions: Stores and Supplies, Pump Services, Maintenance, and Administration.

5.2.2 Department of Public Cleansing

The aims of the Department of Public Cleansing (DPC) are: to manage the collection, treatment (where possible) and disposal of solid waste and night soil; to keep streets and public places clean; and to maintain vehicles and equipment used by the division. DPC collaborates with district offices in providing a service to the general public and the public and private sectors (see Figure 5.2.2.1 for the current organization chart).

(1) Night Soil Control Division

The main objective of the Night Soil Control Division (NSCD) is to collect and dispose of night soil in the BMA area. NSCD collects night soil with its own vehicles and staff, and by delegating to district offices which handle between 85 % and 90 % of the total amount. Night soil is processed at two treatment plants, one

each at On-Nut and Nong Khaem with a maximum design capacity of 600 m^3/d each.

(2) Public Cleansing Service Division

Solid waste produced in Bangkok is collected by the Cleansing Sections of the 50 BMA district offices and the Public Cleansing Service Division. This division collects solid waste from hospitals, health centers, markets, government buildings, public places and in emergency situations, and assists District offices. It also provides emergency water services and keeps roads washed and clean

(3) Garbage Disposal Division

This division is nominally responsible for operating the garbage disposal plants at On-Nut and Nong Khaem. However, neither plant is operational and the two sites are now used solely as transfer stations. They receive, with a third transfer station at Tha Raeng, more than 8,500 tons of solid waste daily from BMA districts and Public Cleansing Division, which is then collected by local contractors and delivered to sanitary landfill sites belonging to the contractors. The division also collects medical wastes using its own trucks from hospitals and medical clinics for disposal at the 20 t/d incinerator at On-Nut.

(4) Technical and Planning Division

This division is responsible for collecting and analyzing data to support BMA planning and the coordination with district offices, and for research.

(5) Office of the Secretary Division

The Office of the Secretary Division provides general office and financial services to the department.

5.2.3 Other Departments of BMA

The Department of Law Enforcement supervises and enforces laws, bylaws, and city ordinances, and manages the city police force. The Department of Policy and Planning collects and stores statistical and technical data in order to formulate policies, master plans and projects for the development of the city. The Department of City Planning undertakes urban planning for the metropolitan area under the Town and Country Planning Act 1975 while complying with national policy on land use and zoning.

The Department of Permanent Secretary for the BMA provides the secretariat for senior BMA executives and administers some BMA services not allocated to any

other department. One of these is the Environmental Policy and Promotion Division (EPPD). In existence for only a year, it will be the central body for developing and implementing environmental policies for the BMA area. But its TOR does not mention the responsibility to ensure: (1) the proper functioning of subsidiary units responsible for pollution control and especially the control of water quality, e.g. Water Quality Management Division in DDS, and Environment Sections in District offices; (2) the training of such units where necessary; and (3) the need to coordinate the work of EPPD with these subsidiary units. Also, there should be more emphasis on enforcement of the legislation. The Study Team questions the need for BMA to set additional standards for environmental quality when PCD has already done so. If there are gaps, they should be filled by PCD and not BMA.

The Department of Public Works (DPW) has responsibility for all public works in the BMA area including major infrastructural projects and general building control. Finally, the Department of Finance sets the financial policy, regulations and procedures for BMA, and ensures that these are followed by other BMA departments. It consolidates the accounts and undertakes treasury management for BMA

5.2.4 District Offices

District offices usually comprise ten sections: Administration, Registration, Education, Revenue, Environment and Sanitation, Finance, Public Works, Law Enforcement (Police), Community Development, and Public Cleansing. All are supported functionally and financially by the appropriate department or division in BMA head office. Few activities are contracted out although there are plans for this. Each office has an Environment and Sanitation Section which inspects and tests pollution point sources such as restaurants, factories and apartment blocks for on site treatment facilities. Districts have no laboratories so that samples are sent to WQMD for analysis. Regulations are often not followed but there are very few prosecutions for these offenses. This is attributed to a police force which is ineffective in applying public health and environmental law. The Public Cleansing Section cleans streets, and collects garbage and night soil, the latter by vacuum trucks (provided by BMA) and transported to one of the two night soil treatment plants. Illegal collection and dumping of night soil in canals is a major problem and another example of poor enforcement of the law.

5.3 Other Institutions relevant to Drainage, Sewage and Environmental Aspects

There are a number of additional institutions at national and regional levels, some recently formed, which have major responsibilities in wastewater management and environmental protection. These include:

i) National Environment Board
ii) Environment Fund
iii) Pollution Control Committee
iv) Ministry of Science, Technology and Environment
v) Office of Environmental Policy and Planning
vi) Pollution Control Department
vii) Department of Environmental Quality Promotion
viii) Wastewater Management Authority.

Their interaction with Bangkok metropolitan, regional municipal, provincial and district administrations in BMR is outlined in Figure 5.3.1.1. The most important of these in the context of this Study are briefly examined below.

5.3.1 Pollution Control Department

(1) Principles and Functions

The Pollution Control Department (PCD) was established in June 1992 under a Royal Decree resulting from the Enhancement and Conservation of the National Environmental Quality Act (1992) (NEQA) to assist the National Environment Board (see 5.4.1 below) to perform its duties.

The functions of PCD are summarized as follows:

i) To formulate national policy and plans for environmental quality conservation and promotion with respect to pollution control
ii) To formulate and recommend environmental quality standards and emission / effluent standards
iii) To formulate the environmental management plan to control, remedy and prevent pollution
iv) To monitor and report annually on national environmental quality
v) To develop appropriate systems, methodologies and technologies to better manage water quality, air quality, noise, hazardous substances and solid waste
vi) To respond to public complaints concerning pollution

(2) Organization

The PCD has seven divisions which include Water Quality Management Division (WQMD). This has the mandate for wastewater management which requires it to

perform the functions in item(1) to maintain water quality, particularly by establishing surface water quality standards and effluent standards from pollution sources, and ensuring that these are enforced.

(3) Achievements to Date

First established in 1992, PCD has appointed more than 60 professional staff. WQMD has created 8 subdivisions and set up its own laboratory as well as monitoring stations in 25 river basins. It also monitors the efficiency of WWTPs revealing serious O&M problems in at least 50 % nationally. Minimum standards have been established for effluent and surface water, and are published with other pollution standards in the 4th edition of Building Effluent Standards on Pollution Control in Thailand (see Data Book F for a summary). In late 1996 PCD issued the BMR Wastewater Management Plan which includes significant areas of BMA but not the inner core of Bangkok. From this, the Samut Prakan Wastewater Management Project was selected; operation is expected to begin in stages in 1999-2000 with final completion around 2002.

PCD has implied jurisdiction over Wastewater Management Authority (WMA) because WMA should develop WWTP systems in accordance with PCD's policies and plans, but has no direct authority as both entities report to MOSTE. Currently, there is some difference of opinion on which projects in BMR should have priority. WMA have selected two projects because of their better prospects for cost recovery, while PCD's priorities are based more on environmental considerations. MOSTE is attempting to reconcile the two positions.

(4) Funding and Cost Recovery

The establishment of a viable wastewater sector is dependent on effective systems for financing and cost recovery. Since GOT and related subsidies will be insufficient even if there is a strong economic recovery, other sources must be found. Two other main sources should be tapped for successful development of the sector: private capital through equity participation in public / private partnerships or joint ventures; and recovery of recurrent costs (O&M) and some or all capital costs through an appropriate tariff structure and recovery system. It is now a priority to agree and implement the method of charging the service fee to provide the basis for future expansion of the wastewater treatment and disposal system.

5.3.2 Wastewater Management Authority

(1) Responsibilities, Powers and Strategies

The Wastewater Management Authority (WMA) is a state enterprise established by Royal Decree in July 1995 under the Ministry of Science, Technology and Environment (MOSTE).

The objective of WMA is to set up a "central wastewater treatment system" within "wastewater management areas" which are Bangkok Metropolis and the provinces of Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, and Samut Sakhon.

The main responsibilities and powers of WMA are, in wastewater management areas:

i) The ability to undertake property transactions;
ii) To survey, plan, design, construct, operate, manage and maintain "central wastewater treatment systems";
iii) To make joint agreements to achieve efficient wastewater treatment;
iv) To collect service charges and fees for wastewater treatment;
v) To establish limited (public) companies to operate wastewater treatment.

The main strategies identified for the WMA are: (1) to set up enterprises and utilize modern technology for treating wastewater to reduce the deteriorating condition of the rivers and khlongs in the Bangkok Metropolitan Region; (2) to create awareness and understanding among the general public for environmental quality and conservation; and (3) to form cooperative alliances in wastewater management with other organizations.

(2) Achievements to Date

A corporate plan has been prepared with PCD as the implementing agency. WMA believe that the PCD Master Plan is too ambitious because of the likely funds limitation even with private sector involvement. WMA are also reviewing and trying to resolve O&M problems in WWTPs constructed by PWD, at the request of provincial governments. However, their mandate is primarily in BMR and this is where their initial efforts should be directed.

5.3.3 Metropolitan Waterworks Authority

The Metropolitan Waterworks Authority (MWA) was established as a state enterprise under the Ministry of the Interior, according to the MWA Act of 1967, replacing four previous water supply agencies. The MWA's main job is: to survey for and procure raw water sources, and acquire raw water for treatment; and to

produce, distribute and sell treated water in the Bangkok Metropolis and the neighboring Provinces of Nonthaburi and Samut Prakan.

MWA's policies and objectives are summarized as follows:

i) To provide good service and adequate supply of water to customers;
ii) To be self-financing for both O&M and expansion of facilities; water tariffs to be adjusted appropriately and fairly so that interest payments and capital repayments may be made [but there is no independent regulation of tariffs other than the Ministry of Finance];
iii) To control water losses at the level allowing MWA to deliver a good service to customers, although the water loss is tending to increase;
iv) To increase water production from surface water to substitute for groundwater abstraction (currently there are 81 deep wells in operation yielding 162,000 m^3/d;
v) To increase management efficiency by reorganizing MWA and reducing work processes and staff;
vi) To divide all MWA units into cost centers or profit centers, so that expenses and financial performance may be analyzed and controlled as in an efficient private company;
vii) To increase participation of the private sector in MWA in appropriate areas, which should lead eventually to a complete privatization of the organization.

The method of water revenue collection is relevant to WWT funding because the preferred way of collecting the sewerage service fee is to collaborate with MWA. MWA has devised a tariff structure based on three user categories which comprises a volume based unit charge increasing progressively according to volume used, and a fixed (meter) charge based on meter size.

MWA has reported several management and organizational issues which are relevant to this Study and are summarized here:

i) As a state enterprise, MWA is governed by regulations and procedures which seriously inhibit efficient operation, especially in personnel management which do not encourage or reward good performance, despite relatively good pay; it is estimated that MWA is 25-30 % over staffed;
ii) Inability to expand services promptly due to shortage of the capital needed and existing debt;
iii) Extremely high water losses at 42 % which will need substantial funding to reduce to the more acceptable 30 %;
iv) An urgent need for more surface water;
v) An urgent need for more demand side management to save water.

A MWA Subcommittee has concluded that a major program to improve efficiency and attract private capital and technical expertise is needed, to allow the achievement of the policies and objectives itemized above. The proposed program is apparently being considered by the Board of Directors.

5.3.4 Industrial Estate Authority of Thailand (IEAT)

The Industrial Estate Authority of Thailand (IEAT), a state enterprise, was set up under the Ministry of Industry in 1979 to establish industrial estates in designated areas. The IEAT is empowered to establish the necessary infrastructures including water supply systems, drainage systems and wastewater treatment plants, and to charge service fees for the use of these facilities. Private industrial estate development is also permitted, providing the developer can meet certain conditions. Once a license to operate has been issued by the Ministry of Industry, the developer, usually a joint venture between Thai and foreign investors (who provide the technical expertise), will pay IEAT a fixed and variable fee for the privilege of owning, developing and running the estate.

There are three reasons for briefly reviewing IEAT's achievements: (1) the joint management of water supply and sewage disposal; (2) the negotiation and management of arrangements for private sector participation in the O&M of water supply, wastewater disposal, drainage and flood control, and solid waste disposal; and (3) setting and collecting service fees; all of which could guide the development of a viable wastewater sector in the future.

IEAT now operates 29 industrial estates throughout the country. In 1994, in five of these estates, IEAT contracted out for five years the operation and maintenance of water supply, wastewater treatment, solid waste, drainage and flood control, in return for which the company is paid about 17 % of revenue received from companies on the estate. IEAT collects the service charge from factories, pays for investment and major repairs, decides charges, and liaises with related entities.

IEAT plans to form a new joint venture subsidiary company, with a successful international bidder, which in 1999 will take over all aspects of industrial estates management, including revenue collection, waste disposal and assets management. This company would be a leader in the operation and maintenance of utilities and would probably bid for the O&M of individual BMA Central WWTPs when these are offered, and also for the O&M of individual MWA and PWA water treatment plants.

5.4 Laws and Regulations

The main laws relevant to environmental protection and the control of wastewater collection, treatment and disposal in Bangkok Province are:

1) The Enhancement and Conservation of National Environmental Quality Act (NEQA) (1992)
2) Organization Division of Pollution Control Department, Ministry of Technology, Science and Environment Royal Decree (1992)
3) The Wastewater Management Authority Establishment Royal Decree (1995)
4) The Bangkok Metropolitan Administration Service Administration Regulations Act (1985 amended in 1991 and 1996)
5) The Industrial Estate Authority of Thailand Act (1979 amended in 1996)
6) The Factory Act (1992)
7) The Public Health Act (1992)
8) The Thai Waters Navigation Act (1913 last amended in 1992)
9) The Building Control Act (1979 last amended 1992)
10) The Revolutionary Party Notice No. 286 (1972)
11) The Office of the Prime Minister Procurement Regulations (1992 last amended in 1996)
12) The Private Participation in State Work or Business Operation Act (1992)
13) The Metropolitan Waterworks Authority Act (1967 amended in 1992)

Laws (1) to (5) give the duty and powers to state agencies, including BMA, to treat wastewater from the public and to make charges while laws (6) to (10) prescribe the duty of private individuals or entities not to discharge wastewater or pollutants into the environment. Laws (11) and (12) control the participation of the private sector in state activities. Law (13) governs the operation of the Metropolitan Waterworks Authority in supplying treated water to the provinces of Bangkok, Nonthaburi and Samut Prakan, included because of the linkage between water supply and sewage disposal.

5.4.1 Environmental Laws

The Enhancement and Conservation of National Environmental Quality Act (NEQA) 1992 (referred to as the Environmental Act) is the central environmental legislation in Thailand. It provides for the management of wastes, including wastewater, from point sources including industries, and promotes decentralization by making local governments responsible for dealing with pollution control and waste management.

The Environmental Act establishes two bodies to strengthen environmental protection: the National Environment Board (NEB) comprising the Prime Minister

and the Cabinet, and the Environmental Fund supervised by the NEB which is to fund environmental projects through grants to GOT agencies and low interest loans to the private sector for improving the environment. The NEB has can prescribe environmental standards, and in doing this is advised by the Pollution Control Committee (PCC) established for this purpose.

The Environmental Act identifies priority areas for environmental conservation and pollution control using the terms "Environmental Conservation Area" and "Pollution Control Zone". Under subsidiary legislation, the former Office of the National Environment Board is replaced by one office and two departments, all reporting to MOSTE:

(1) The Office of Environmental Policy and Planning (OEPP), responsible for policy formulation and planning, local and international coordination, and for administering the Environmental Fund;
(2) The Pollution Control Department (PCD), responsible for initiating pollution control projects and the development of methodology, and for monitoring and enforcing the provisions of the Environment Act; and
(3) The Department of Environmental Quality Promotion (DEQP), responsible for public education and campaigns to promote environmental protection and enhancement; and for training the government and private sectors.

5.4.2 Laws related to Drainage and Sewerage

(1) The Bangkok Metropolitan Administration Service Administration Regulations Act (1985, 1991 and 1996)

The BMA is the administrative authority for the metropolitan area, and its organization, administration, powers and duties are set out in this Act. The Act prescribes 27 functions for BMA, many of which impact on wastewater generation, treatment and disposal. However, the specific provision of sewage and night soil collection, treatment and disposal services is omitted. BMA can, subject to approval from the BMA Assembly and Minister of Interior: establish a company or hold a share of a company; and entrust public services and the collection of revenue to a company in place of BMA. BMA can also collect service charges by issuing BMA ordinances, which have to be approved by the BMA Assembly.

(2) The Wastewater Management Authority Establishment Royal Decree (1995)

The Wastewater Management Authority (WMA) was established by Royal Decree as a state owned enterprise under MOSTE to help to ensure efficient wastewater disposal in the BMR and any other areas prescribed by Cabinet (see also 5.3.2

above). Through this Decree, WMA has more responsibility and authority for the efficient and effective management of wastewater than any other agency.

(3) The Industrial Estate Authority of Thailand Act (1979 amended in 1996)

By this Act, the Industrial Estate Authority of Thailand (IEAT), a state enterprise, is set up under the Ministry of Industry to establish industrial estates in designated areas and to have exclusive jurisdiction over all business activities in such estates (see also 5.3.4 above).

(4) The Factory Act (1992)

The Factory Act of 1992 is administered by the Ministry of Industry and concerns, among other things, the regulation of industrial wastes. This requires individual site treatment and disposal according to prescribed methods and standards, thereby regulating the quality of industrial wastewater which may be discharged to street drains and khlongs.

(5) The Building Control Act (1979 last amended 1992)

Under the Ministry of Interior, this Act, extended to environmental protection, requires property owners to construct toilets, bathrooms and proper drainage for buildings, and generally to comply with the Environmental Act concerning the discharge of wastewater into natural water courses.

5.4.3 Other relevant Regulations

(1) The Public Health Act (1992)

The Public Health Act is mainly concerned with sanitation and cleanliness, and is not the governing law for wastewater systems. However, this Act is said to be frequently used in the districts to enforce anti-pollution measures because it is thought to be stronger than the Environmental Law, also of 1992.

(2) The Metropolitan Waterworks Authority Act (1967 amended in 1992)

This Act provides for the establishment of the Metropolitan Waterworks Authority, responsible for sourcing and distributing water within Bangkok, and Nonthaburi and Samut Prakan provinces. The Act is included here because of the normal close technical and organizational relationship between sewage disposal and water supply, but this is not the case in Thailand at present.