JAPAN INTERNATIONAL COOPERATION AGENCY

THE KINGDOM OF THAILAND
BANGKOK METROPOLITAN ADMINISTRATION

THE STUDY FOR THE MASTER PLAN ON SEWAGE SLUDGE TREATMENT/DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK IN THE KINGDOM OF THAILAND

FINAL REPORT

Vol. I EXECUTIVE SUMMARY

OCTOBER 1999

NIPPON KOEI CO., LTD.

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LIST OF REPORTS

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(as of October 1998)

PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Government of Japan decided to conduct the master plan study on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Keisuke Okazaki, Nippon Koei Co., Ltd. to the Kingdom of Thailand, four times between September 1998 to October 1999. In addition, JICA set up an advisory committee headed by Mr. Haruki Takahashi, Japan Sewage Works Agency, between September 1998 and October 1999, which examined the study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of the Kingdom of Thailand, and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared the final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

October, 1999

Kimio Fujita
President
Japan International Cooperation Agency

October, 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

LETTER OF TRANSMITTAL

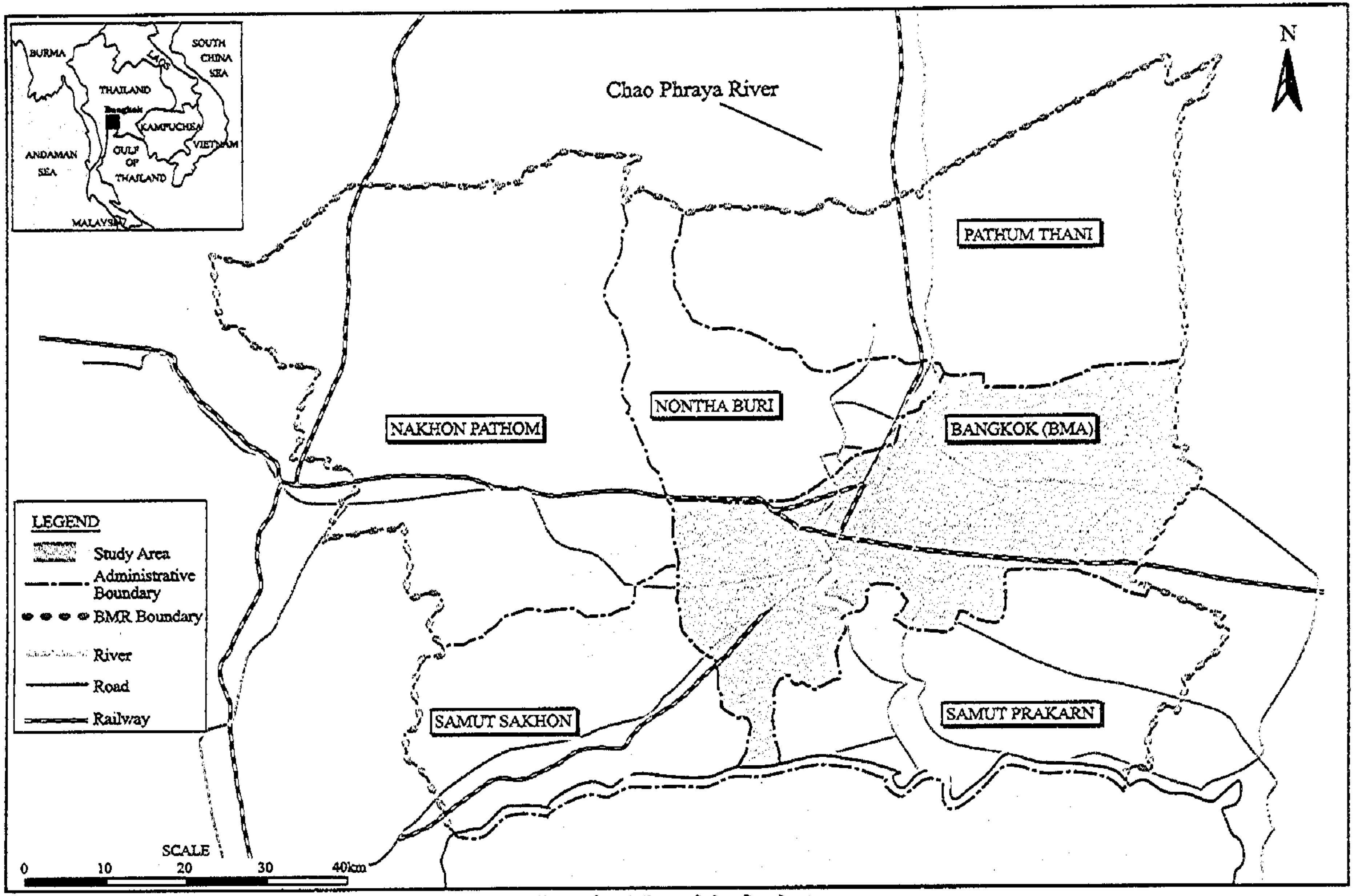
It is with great pleasure that we submit to you the Final Report of the Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok completed by the Study Team with cooperative efforts of the Bangkok Metropolitan Administration (BMA) and other parties concerned. The report has been prepared for the Government of the Kingdom of Thailand in implementing the effective sewage sludge treatment/disposal and reclaimed wastewater reuse plan in the BMA area.

The report consists of four volumes of the Executive Summary, Main Report, Supporting Report and the Data Book. The Executive Summary presents the outline of the study results and the Main Report gives all the study results regarding sewage sludge treatment/disposal and reclaimed wastewater reuse. The Supporting Report describes sludge reuse survey for agriculture, proposed wastewater treatment and disposal system, and standards and principles for application of wastewater sludge to agricultural land. The Data Book compiles useful reference data relevant to the Study.

Taking this opportunity, on behalf of the Study Team, I would like to express my heartfelt gratitude to the personnel from JICA, Advisory Committee, Ministry of Foreign Affaires, Ministry of Construction, Embassy of Japan in Thailand and JICA Thai Office and Thai officials from Steering Committee comprised of relevant government agencies who extended the kind assistance and cooperation for the entire study period to the Study Team. The Study Team hopes that the results of this study contribute to the future implementation of sludge treatment/disposal and reclaimed wastewater reuse projects in Thailand and to socioeconomic development of Thailand.

Yours faithfully,

Keisuke Okazaki
Team Leader
The Study for the Master Plan on
Sewage Sludge Treatment/Disposal
and Reclaimed Wastewater Reuse in Bangkok



Location Map of the Study Area

1. INTRODUCTION

1.1 Background of the Study

1. The BMA, in compliance with the national and regional development plans and revised edition of the Feasibility Study of Bangkok Sewerage System Project 1982 carried out by JICA, began planning the establishment of wastewater disposal facilities. Since commissioning the first scheme – the Si Phraya interceptor sewer and wastewater treatment plant in 1994 – nine further wastewater schemes were planned. When completed in the beginning of 21st Century, these will generate large amount of sewage sludge and plans are now required for its disposal.

1.2 Objective of the Study

2. The objective of the Study is:
   - To formulate a master plan for the year 2020 for effective sewage sludge treatment/disposal in the BMA area,
   - To determine for viable reclaimed wastewater reuse plan in the BMA area and
   - To transfer technical knowledge to Thai counterpart personnel during the course of the Study.

1.3 The Study Area

3. The Study area mainly covers the 50 District of the entire BMA area (1,569 km^2) controlled by Bangkok Metropolitan Administration (BMA).

2. GENERAL CONDITIONS OF THE STUDY AREA

2.1 Natural Conditions

4. Bangkok is situated on the flat deltaic plain of the Chao Phraya River, a part of the Lower Central Plain of Thailand. General ground levels in the city are 1 – 2 m above Mean Sea Level (MSL). Monthly rainfall varies from 9.1 mm in January to 344.2 mm in September. Total annual mean rainfall is 1,496 mm and there are 125 average rainy days each year. Storms are usually intense and occur as squalls across the city. The theoretical 2 year maximum storm intensity is 61 mm/h.

2.2 Socioeconomic Conditions

5. The BMA area now has an estimated population of 7.5 million although records account for only 6 million, explained by the under-recording of migrants. The Study Team investigated a number of population forecast studies and these are compared in Figure 2.2.1.

6. The Metropolitan Water Authority (MWA) serves water to BMA and parts of neighboring provinces. It has a major treatment plant in Bang Khen and three other plants drawing water from the Chao Phraya and Ta Chin River producing 4.5 million m^3/d. It also has minor groundwater sources. There are plans to develop the Maha Sawat treatment plant including damming the Ta Chin River to produce 4 million m^3/d and to produce a total of 8.2 million m^3/d in 2017. MWA currently provide 1,342,000 customers with 945,000 million/year over an area of 1,100 km^2 and supplies are increasing at 4 % pa.

7. The Central Government and BMA budget for environment had increased by 19.9 % and 29.9 % per annum during 1992 to 1997, respectively, out of which 88 % was invested for wastewater. Due to the economic crisis, however, the overall national budget has dropped by 16.2 % in the 1998 Thai Fiscal Year and the total environmental development budget and the BMA's environment budget have decreased more sharply by 50.3 % and 69.5 %, respectively.

3. EXISTING SEWERAGE SYSTEM IN BANGKOK

3.1 Existing and Ongoing Wastewater Treatment System and Facilities in BMA

8. In the early 1990s, BMA embarked on a major program of wastewater treatment schemes to improve water quality in the khlongs and in the Chao Phraya River. The initial project in Si Phraya became operational in 1994 and currently six further schemes are being implemented. These will be completed by 2003 and will provide services over a total area of 192 km^2, treating 980,000 m^3/d of wastewater from an initial design population of 2.2 million. When fully developed, these schemes will treat 1,330,000 m^3/d from an ultimate population of 3.4 million. The main features of the schemes are shown in Table 3.1.1.

3.2 Existing Night Soil Treatment System

9. Night soil services areas in BMA are separated into two zones: Nong Khaem and On-Nut. Based on the tariff collection records, the total collected night soil in the whole of BMA is calculated as 1,019 m^3/d, resulting in 13 % of the collection ratio on the population base. On the other hand, the actual quantities treated at NSTPs are 450 m^3/d (400 to 500 m^3/d) and 200 m^3/d at Nong Khaem and On-Nut, respectively. Accordingly, the actual collection ratio of night soil is regarded to remain at 8.4 % on the whole. The maximum design capacity of each of the NSTP is 600 m^3/d. However, these are not being operated at their full capacity.

3.3 Existing Sludge Treatment/Disposal System

10. At the present, only the Si Phraya Central WWTP is working in BMA as the central wastewater treatment system. Community wastewater treatment systems are under operation at 14 places in BMA. Besides, the night soil treatment plant is also in existence at Nong Khaem and On-Nut. The quantities of sludge generated from all these souses at the present area estimated at 17.9 t DS in total.

3.4 Existing Wastewater Quality

11. Influent wastewater quality records are only available from Si Phraya WWTP and Huay Kwuang WWTP, one of the largest community treatment plants. Wastewater was also analyzed by a JICA resident expert in BMA I Lumphini in 1998, by the contractor for the Yannawa wastewater scheme in 1995 and by the BMA. These results are summarized in Table 3.4.1.

4. FIELD SURVEYS AND INVESTIGATIONS

4.1 Influent and Treated Effluent Quality and Quantity at WWTP

12. The results of the surveys are summarized in Tables 4.1.1 and 4.1.2. The Si Phraya WWTP records indicated very weak wastewater. The 1998 population of the service area is estimated as 95,000 and the survey data would, therefore, yield average unit flows and loads of 121 l/c/d and only 3 g/c/d BOD. However, these unit flows and loads are not considered representative.

13. The Huay Kwuang WWTP wastewater was also found to be weaker than the values in the WWTP records, but the strength was generally more typical of municipal sewage. An investigation of the served population and metered water

consumption indicated that wastewater flows were only half the water supply. Using water consumption and BOD records from the WWTP, a unit flow of 183 l/c/d and unit load of 45 g/c/d may be derived.

4.2 Wastewater Quality and Flow Rate in the Drainage System

14. The initial survey was undertaken to assess unit flows and loads from flow and concentration surveys in defined catchment areas. Three smaller catchments were selected: i) a commercial catchment in Soi Song Phra catchment area, ii) a mixed residential and commercial catchment in Thanon Charoen Krung Soi 77 in the Yannawa catchment area, iii) a residential catchment in Soi Wachirathun Sahit 31, Sukumvit Soi 101/1 in the proposed Khlong Toey East catchment area.

15. The survey results are presented in Table 4.2.1 and 4.2.2 and indicate generally weak and very variable wastewater quality both in the time and place. These indicate the wastewater to be readily treatable and having a high proportion of volatile solids. The storm event surveys indicated increases in load of up to 10 times average BOD and up to 80 times average suspended solids at the beginning of storms.

4.3 Sludge Quantities and Characteristics

16. The sludge moisture contents measured are distributed between 70 to 85 %, indicating that the dehydrators in respective plants are being operated under the normal performances as belt press types. The volatile solids ratio (VS ratio) of the sludge at the Si Phraya WWTP was measured as some 50 %. The C/N ratio, the carbon content, the nitrogen content, etc. show that all sludge is almost suitable range for agricultural use.

17. If the measured figures of heavy metals shown in Table 4.3.1 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 bases. The sludge from the Si Phraya WWTP are beyond the limit of nickel (Ni) as well as copper (Cu) on the average bases in the comparison with the tentative standards proposed by AIT. Furthermore, mercury (Hg) in the sludge from the NSTP is beyond the limit set by AIT on the maximum base.

4.4 Sludge Demand and Marketing Surveys

18. Two kinds of interview surveys were conducted, first to agricultural experts from Ministry of Agriculture and Co-operatives in the neighboring 5 provinces, and second to farmers in the two provinces together with the BMA area. Both surveys show positive response on sludge compost, although they depend on chemical fertilizer more than organic one now. The estimation shows that 6.5 Billion Baht/year is used for chemical fertilizer in nearby 10 provinces, whole 2.4 and 1.7 Billion Baht/year is used for compost and animal manure.

19. The potential demand size of sludge compost in the area was estimated by statistical approaches, which indicates that the total demand is equivalent to 498 t DS/d, consisting of 487 for agricultural use, 8 for public parks and 3 for road green zone. This is 1.64 times bigger than the total amount of wastewater and night soil sludge produced in 2020, that is, 303 t DS/d.

20. The current market size of compost in the area was estimated from production capacity of identified compost manufactures, that is at least 323 t DS/d equivalent. Another estimation of compost market size from the survey to farmers shows 594 t DS/d equivalent or 1 million t/year is currently used in the area.

21. Wastewater and night soil sludge compost is acceptable for agricultural use and their market size seems large enough to absorb all sludge produced in 2020. The success factors are safety, cost, band education to farmers. The target production cost of compost is 1.5 Baht/kg and the sales price at the market place should be lower than 2 Baht/kg. Fruit tree, vegetable/flower, and crop farming are the most prioritized areas, since their yield is likely to be at an affordable level to purchase compost.

4.5 Reclaimed Wastewater Reuse Survey

22. Treated wastewater is being reused on-site in wastewater treatment plants and night soil treatment plants. At the Nong Khaem NSTP, 90 % of water used is reclaimed wastewater. Only treated wastewater from the Si Phraya WWTP is used outside the plant. One percent of the treated wastewater volume is used for watering roadside plants and road cleaning. Table 4.5.1 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.

5. EXISTING ORGANIZATION AND INSTITUTION

5.1 Bangkok Metropolitan Administration (BMA)

23. BMA is the administrative authority for the Bangkok Metropolitan Area covering some 1,569 km^2 and is responsible for managing the city's output of wastewater and night soil. The two departments with major responsibilities in these areas are the Departments of Drainage and Sewerage (DDS), and Public Cleansing (DPC). Other departments provide supervision and support in functions such as planning and finance, law enforcement, staff training and the recently established environmental policy and promotion.

5.2 Laws and Regulations

24. A large but overlapping body of legislation now exists: to empower state agencies to treat wastewater and establish central wastewater treatment systems, to require the private sector to treat wastewater, to empower state agencies to regulate effluent, to monitor environmental quality; to empower organizations to collect a wastewater treatment charge, and to allow private participation in state business activities. The Enhancement and Conservation of National Environment Quality Act of 1992 is the main environment for protecting the environment. This could partially account for the present poor enforcement of environmental law which should be addressed as a matter of urgency.

6. PLAN OF FUTURE WASTEWATER AND NIGHT SOIL SLUDGE TREATMENT AND DISPOSAL

6.1 Establishment of Future Wastewater Disposal System

25. Wastewater flows and loads are determined separately for domestic, commercial and institutional, and industrial wastewaters. Domestic wastewater flow forecasts are based on MWA water consumption forecasts of 256 l/c/d throughout the Master Plan period. A unit domestic load 40 g/c/d is proposed derived from a review of past studies and projects, text book figures and data from the Study Team survey.

26. The low strength of the wastewater at Si Phraya WWTP and elsewhere in the drains must be due to BOD reduction in the large flat combined drains designed for storm flows. This will be due to de-composition of organic matter and dilution from groundwater infiltration and the khlongs. As a result, BOD Reduction Factor is introduced to account for the losses in BOD between wastewater entering the drain and delivery at the WWTP. Figure 6.1.1 indicates the range and variability of BOD concentration in the combined drains and at Si Phraya WWTP. From this figure, 110 mg/l is selected to represent the normal maximum BOD strength wastewater and it is assumed that this will be equivalent to average wastewater quality at the WWTP when the new wastewater schemes are in operation. The average wastewater BOD concentration at the entry to the drains forecast from load and flow predictions for the proposed wastewater schemes is derived from Table 6.1.2 is 160 mg/l. To reduce this to 110 mg/l at the WWTP gives 30 % BOD Reduction Factor.

27. The main criterion for the selection of new areas requiring public wastewater facilities must be the degree of urbanization as indicated by forecasts of population density and planned development in the BMA Land Use Plan. This identified 13 future wastewater scheme areas which, together with the three planned schemes, constitute the strategic plan. Priority areas for public wastewater services are determined by numerical evaluation of development criteria together with khlong water quality as in indicated in Figure 6.1.3.

6.2 Plan of Future Night Soil Treatment System

28. The night soil generation rate of 1.0 l/c/d has been applied to this Study. Total population in BMA is based on 11,856,000 people in 2020. The quantity of night soil collected in the whole of BMA has been computed, assuming that the collection ratio of night soil would attain to 20 % in 2020, on the basis of population number. This has resulted in daily 2,445 m^3 of collected night soil in BMA in 2020, being followed by the stepwise increases of collection ratio, like 16 % in 2005, 17 % in 2010 and 18 % in 2015.

6.3 Plan of Reclaimed Wastewater Reuse

29. Reuse for agriculture and industry is judged to be premature, irrigation being applied outside the urban area and quality requirements for industrial use being high. Priorities were considered for the remaining categories of : 1)watering road

plants/road cleaning, 2) miscellaneous water for buildings, 3) watering plants for parks and golf courses, and 4) purification of khlongs.

30. The target volume of reclaimed wastewater to be used as miscellaneous water for buildings would be about 1 % of the total treated wastewater volume, and as it would be used cyclically, it would reduce public water consumption and aid in drought mitigation. Likewise, about 1 % of the total treated wastewater volume would be used for watering plants along roads and in parks. The remaining roughly 99 % would be used for khlong purification. Table 6.3.1 shows the amount of reclaimed wastewater reuse in 2020.

7. DEVELOPMENT PLAN OF SLUDGE TREATMENT/DISPOSAL

7.1 Frameworks of Sludge Treatment/Disposal Development

31. The target year for the sludge treatment/disposal system is set for 2020 consisting short term (to attain within the quarter term of the targeted period) and long term (to attain within the target year) strategies. The generation rate of sludge was established as 1.0 kg-DS/kg-BOD for the wastewater sludge and the sludge from the small community WWTP was derived from the AIT report.

32. To calculate the night soil sludge generation rate, 1.0 l/c/d of the collected night soil rate is used. In addition, 100 % of the removal of SS and 50 % the biomass generation to BOD has been assumed. The sludge generation rate from night soil treatment is calculated as 14.8 g-DS/c/d. Giving 20 % allowance against the large fluctuation in the characteristics of collected night soil, 18 g-DS/c/d has been derived.

33. Taking into account of the 30 % Reduction Factor as mentioned previously, total sludge generation has been estimated at 302 t DS/d in 2020 that is equivalent to around daily 30,200 m^3 at 1 % concentration. The sludge generated from the central WWTP will account for 83 % of total sludge in BMA in 2020.

34. According to the sludge characteristic analysis, heavy metals such as mercury, copper and nickel were identified, and especially mercury in the sludge from the NSTPs was found to be beyond the limit set by AIT. Subsequently, risk evaluation study was carried out. The results of calculation is given in Table 7.1.1.

7.2 Basic Scheme of Sludge Treatment/Disposal

35. For ultimate disposal option, 1) landfill disposal and 2) agricultural reuse were proposed. For the case of 1), Kampansaen in Nakhon Pathom Province currently being used for solid waste disposal site, and this site is the most promising for the future sludge landfill having a capacity of some 38 million m^3.

36. Standards and regulations for landfilling of sludge have not been provided in BMA. On the basis of developed countries' experience, the dewatered-type sludge with some 85 % moisture is desirable as the minimum pre-requisite for the sludge disposal. Concerning hazardous substance contents of sludge, like heavy metals, organic solvents, organic chlorides, etc., it is strongly recommended that certain adequate limits be enacted to enhance "Green Disposal".

37. The standards and regulations related to agricultural use of sludge have not been furnished in Thailand. Proper standards and regulations must be furnished to promote the use of sludge fertilizer, and to protect the natural environment and human health.

38. To set out the ultimate sludge disposal scheme, a number of assumptions have been made, and three scenarios of ultimate sludge disposal are presented as shown in Table 7.2.1.

39. Figure 7.2.2 shows a total of six options of possible sludge treatment process for the both landfill disposal and agricultural use, incorporating digestion and incineration process. These options have been compared economically by estimating relevant treatment costs including facilities construction, operation and maintenance cost and recovering cost.

7.3 Proposed Sludge treatment/Disposal Scheme in BMA

40. Figure 7.5.2 shows the entire scheme and its mass quantities in 2020. Three scenarios have emerged under the consideration for the critical parameters, which are needed for the sludge treatment/disposal and for the extent of demands in beneficial uses. Scenario 1 is "Full Agricultural Use" consisting 65 % is for agricultural use, 35 % is for landfill. Scenario 2 is "Incineration Introduction" consisting 9 % out of total sludge for landfill after 2010. Scenario 3 is "50 % agricultural Use", only 50 % of the sludge which suitable quality for agricultural

use , which is equivalent to 33 % of total are used for sludge compost, and the rest of sludge is disposed to landfill site and total landfill sludge together with the sludge of non-suitable quality for agriculture use is 67 % of total generated sludge.

41. The landfill sludge disposal sludge, which is tentatively assumed high-risk sludge, is proposed to be treated and be disposed by the system summarized in Table 7.5.1 for scenario 1,2, and 3. Figure 7.5.3 shown the dynamic lines of both landfill sludge and agricultural use sludge in 2020 for the Scenario 1.

42. The agricultural use sludge, which is tentatively assumed low-risk sludge, is proposed to be treated and be disposed by the system summarized in Table 7.5.2 for Scenario 1,2, and 3. The sludge from respective Central WWTPs, NSTPs and Community WWTPs are dewatered at the job-site and are transported into the composting plants.

7.4 Recommendation

43. For either the case of landfill or agricultural use, the following key factors should be kept in mind.
- Management of sewage inflow
- Promotion of environmental-friendly landfill
- Promotive organizations and dissemination for compost marketing
- Reassessment of Generated Sludge quantity and construction schedule

8. PRELIMINARY COST ESTIMATION AND FINANCIAL ECONOMIC EVALUATION

8.1 Preliminary Cost Estimation

44. As mentioned in the previous section, Options A2, L1, L2 and L4 were selected to make comparative cost analysis for sludge treatment/disposal. The unit cost for sludge treatment/disposal after dewatering in WWTP is – 2,969, 8,539, 2,156, and 1,399 Baht/t DS respectively, as shown in Table 8.1.2. Minus figure of Option A2 means that this process can make a profit by selling compost, indicating a possibility of privatization.

45. The financial analysis includes (1) wastewater treatment systems, (2) sludge treatment systems, (3) reclaimed wastewater reuse systems and (4) night soil

treatment systems. The wastewater treatment system has a breakeven point at the WW charge rate of 4.06 Baht/m³, which is 7 times higher that the present rate. The overall treatment system is largely affected by WW charge rate, nor much by other factors. The overall system has a breakeven point at the WW charge rate of 4.04 Baht/ m³. The total initial investment cost up to the year 2020 was estimated to be 2,029 Mil. US$, 2,034 Mil. US, and 2,023 Mil. US$ for Scenario 1, 2, and 3, respectively.

46. The pre-feasibility study of the overall sludge treatment system for the representative scenarios is carried out. For Scenario 1, the financial calculation includes all sludge treatment processes after WWTPs for low risk sludge and after STC for high risk sludge, i.e., composting, digesting, landfill, and transportation, in which 38 % of sludge is dumped after digestion and the rest is composted without digestion. The construction costs of STC are excluded in the financial calculation, since these roles should belong to the BMA. FIRR on investment is calculated at 10.92 %. The sensitivity analysis indicates that 10 % change of the compost plant construction cost affects approximately 1.6 % change in FIRR.

47. For Scenario 2, 25 % of the high risk sludge is assumed to be incinerated and dumped after 2010, in which FIRR becomes 7.22 % due to the heavy cost burden of incineration. In Scenario 3, half of the low risk sludge cannot be sold in the compost market and is therefore dumped in a well-equipped landfill site without digestion. FIRR of Scenario 3 becomes 1.94 %, which shows the system is quite sensitive in terms of cost recover by selling compost.

9. ORGANIZATION AND INSTITUTIONAL PLAN

9.1 Legislation and its Enforcement

48. Existing legislation is considered adequate for regulating the sector and for encouraging the development of new wastewater treatment and night soil processing facilities. However, there are too many laws covering similar subject areas and some rationalization and consolidation of the law and implementing agencies is necessary.

9.2 Overall Organization of the Water and Sewage Sectors

49. Effective and efficient regulation of the water and sewage sector is promoted, which will be essential when the private sector becomes a bigger player. It is also proposed that the management of sewerage should be closely linked with drainage and flood control. The present segregation of sewerage and water supply results in under funding and lack of attention for sewerage development, as well as increased operating and maintenance costs in aggregate.

9.3 Wastewater User Charge

50. An early decision on the collection of service charges and fees from users of public WWTP facilities is recommended. This charge would develop revenues for BMA under 'Polluter Pays' principle and would encourage polluters to reduce pollution loads. This Study proposed the application of a user charge based on volume of water consumption and BOD load and separate fee for commercial users.

10. IMPLEMENTATION PLAN

51. It is assumed in this Master Plan that BMA will wish to contract out the majority of construction works and will require international aid to fund many of the components of the Master Plan. However, some privately financed schemes may be arranged where the contractor funds procurement and is paid through operational charges.

52. The main options for construction contracts concern the scope of the contractor's tasks. These may be either traditional construction contracts with an engineer appointed for the works design and supervision, or design and construct "Turnkey" contracts where the contractor also designs the works to an outline specification.

11. INITIAL ENVIRONMENTAL EXAMINATION

53. The conclusion of the IEE is that a further environmental study at the level of Environmental Impact Assessment (EIA) is required for feasibility study (F/S). The following points are to be included in the TOR of the EIA study, as these are sensitive issues to be taken care of :

- Public Health Condition

- Ground Water Pollution
- Flora and Fauna
- Landscape
- Water Pollution
- Soil Contamination

12. RECOMMENDATIONS

54. In the course of the Study many problems and constraints were identified which will need to be resolved for the plan to be successfully implemented, and BMA will need to give the execution of the plan high priority maintaining a high degree of flexibility and enthusiasm.

The followings are recommendations to be resolved as a prerequisites and/or in the course of implementation of sludge treatment and disposal development programs.

- Improvement to the wastewater collection system
- Re-evaluation of heavy metals by monitoring, establishment of standards and
- Re-evaluation of reclaimed wastewater reuse issue after completion of proposed WWTP
- Organization and instiiutional issues regarding DDS and DPC

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ON
SEWAGE SLUDGE TREATMENT/DISPOSAL AND RECLAIMED
WASTEWATER REUSE IN BANGKOK
IN
THE KINGDOM OF THAILAND

FINAL REPORT

EXECTIVE SUMMARY

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List of Tables

List of Figures

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List of Abbreviations

Symbol	Description	Symbol	Description
AIT	Asian Institute of Technology	DSD	Drainage System Division
AS	Activated Sludge	DWF	Dry Weather Flow
ASP	Activated Sludge Plant	EC	E Coil
BMA	Bangkok Metropolitan Administration	EIA	Environmental Impact Assessment
BMR	Bangkok Metropolitan Region	F/C	Foreign Currency
BMTA	Bangkok Mass Transit Authority	FIRR	Financial Internal Rate of Return
BOD	Biochemical Oxygen Demand	F/M	Feed to Micro-organism Ratio
BOO	Build, Operate, and Own	F/S	Feasibility Study
BOT	Build, Operate, and Transfer	GIS	Geographic Information System
BTS	Bangkok Mass Transit System Public Co., Ltd.	GDP	Gross Domestic Product
C/N	Carbon to Nitrogen Ratio	GOT	Government of Thailand
COD	Chemical Oxygen Demand	GW	Ground Water
CWTP	Central Wastewater Treatment Plant	ICB	International Competitive Bidding
DDS	Department of Drainage and Sewerage (BMA)	IEAT	Industrial Estates Authority of Thailand
DEQP	Department of Environmental Quality Promotion	IEE	Initial Environmental Examination
DG	Director General	IFI	International Funding Institution
DID	Drainage Information Division	IMF	International Monetary Fund
DO	Dissolved Oxygen	JICA	Japan International Cooperation Agency
DPC	Department of Public Cleansing	L/C	Local Currency
DPW	Department of Public Works (in BMA)	LS	Lump Sum
DS	Dry Solids	MLSS	Mixed Liquor Suspended Solids

Symbol	Description	Symbol	Description
JV	Joint Venture	RID	Royal Irrigation Department
MOI	Ministry of Industry	SAPROF	Special Assistance for Project Formation
MOSTE	Ministry of Science, Technology and Environment	SBR	Sequential Batch Reactor
MSL	Mean Sea Level	SRT	State Railway of Thailand
MSW	Municipal Solid Waste	SS	Suspended Solids
MWA	Metropolitan Waterworks Authority	STC	Sludge Treatment Center
NEB	National Environment Board	TDS	Total Dissolved Solids
NEQA	National Environment Quality Act	TFY	Thai Fiscal Year
NESDB	National Economic and Social Development Board	TOR	Terms of Reference
NHA	National Housing Authority	TSS	Total Suspended Solids
NS	Night Soil	US EPA	United States Environment Protection Agency
NSCD	Night Soil Control Division	VAT	Value Added Tax
NSTP	Night Soil Treatment Plant	VLR	Vertical Loop Reactor
O&M	Operation and Maintenance	VS	Volatile Solids
OECF	Overseas Economic Cooperation Fund	VSS	Volatile Suspended Solids
PCC	Pollution Control Committee	WMA	Wastewater Management Authority
PCD	Pollution Control Department, Ministry of Science, Technology and Environment	WQMD	Water Quality Management Division
PR	Public Relations	WW	Wastewater
PSP	Private Sector Participation	WWTP	Wastewater Treatment Plant
PV	Permanganate Value	WWTS	Wastewater Treatment System
PWA	Provincial Waterworks Authority		

List of Units

Symbol	Description
Extent	
ha	hectares
km^2	square kilometers
rai	1 rai = 1,600 m^2
Length	
cm	centimeters
km	kilometers
m	meters
mm	millimeters
Currency	
US$	United State Dollars
	US$ 1.0 = J¥ 120 = Baht 36
J¥	Japanese Yen
B	Thai Bahts
Time	
d	day
h	hour
yr	year
Volume	
l	liter
kl	kiloliters
l/c/d	liter per capita per day
m^3	cubic meters
m^3/d	cubic meters per day
m^3/hr	cubic meters per hour
m^3/min	cubic meters per minute
$m^3/c/y$	cubic meters per capita per day
Nm^3	Normal cubic meters

Symbol	Description
Weight	
g/c/d	grams per capita per day
kg	kilograms
mg	milligrams
mg/l	Milligrams per liter
t	ton
t/d	ton per day
t DS/d	ton Dry Solid per day
Energy	
kcal	kilocalories
kj/kg	kilo joules per kilogram
kPa	kilo Pascals
kW	kilo Watt
Mj/kg	Mega joules per kilogram
MN/m^2	Mega Newton per square meters
Mpa	Mega pascals
Others	
M or Mil	Million
MD	Man Day
ppm	parts per million
Khlong or klong	Canal
pers.	Persons

CHAPTER 1 INTRODUCTION

1.1 Authorization

Based on the Scope of Work agreed between the Bangkok Metropolitan Administration (BMA) of the Kingdom of Thailand and the Japan International Cooperation Agency (JICA), JICA made a contract with Nippon Koei Co. Ltd. to conduct the Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok (the Study).

JICA, the official agency of the Government of Japan responsible for implementation of technical cooperation programs, undertook the Study in accordance with the relevant laws and regulations in force in Japan and in close cooperation with the authorities of the Government of the Kingdom of Thailand. The BMA acted as a counterpart agency to the Japanese Study Team and as a coordinating body in relation to other relevant organizations for smooth implementation of the Study.

1.2 Background of the Study

Water quality conservation and provision of wastewater facilities were a major commitment of the 7th National Socioeconomic Development Plan (1992 - 1997; "the National Plan"). This led to plans for the implementation of wastewater collection and treatment facilities, strengthening of water quality control and canal water quality improvement in the 4th Bangkok Metropolitan Administration Development Plan (1992 - 1996).

The BMA, in compliance with the national and regional development plans and revised edition of the Feasibility Study of Bangkok Sewerage System Project 1982 carried out by JICA, began planning the establishment of wastewater disposal facilities. Since commissioning the first scheme - the Si Phraya interceptor sewer and wastewater treatment plant in 1994 - nine further wastewater schemes are now under construction (six schemes) or planned (three schemes). When completed in the beginning of 21st Century, these will generate large amounts of sewage sludge and plans are now required for its disposal.

Meanwhile, as a result of rapid urbanization and industrial development in the metropolitan region there is an increasing demand for water. Due to the severe drought in 1993, the Metropolitan Waterworks Authority (MWA) was obliged to cut water intake by 25 percent, so saving water and finding new water resources is therefore required. Thus, the efficient reuse of reclaimed wastewater has also become necessary.

Taking such circumstances into consideration, the Government of the Kingdom of Thailand therefore requested the Government of Japan to conduct a study of these issues. Subsequently the JICA Study Team was formed to carry out the Study for the Master Plan on Sewage Sludge Treatment/Disposal and Reclaimed Wastewater Reuse in Bangkok.

1.3 Objectives of the Study

As part of wastewater management in the Bangkok Metropolitan area, BMA is now planning and implementing nine wastewater collection and treatment systems. When these plans have been completed the sludge to be generated will require proper treatment and disposal. Hence, the objectives of this Study are:

- To formulate a master plan for the year 2020 for effective sewage sludge treatment/disposal in the BMA area,
- To determine a viable reclaimed wastewater reuse plan in the BMA area and
- To transfer technical knowledge to Thai counterpart personnel during the course of the Study.

1.4 The Study Area

The Study area mainly covers the 50 districts of the entire Bangkok City area (1,569 km^2) controlled by the BMA.

1.5 Organization of the Study

(1) Japanese Organization

The Japanese organization consists of the Study Team under JICA direction and the Advisory Committee set up at JICA headquarters.

<u>Study Team</u>

Mr. Keisuke Okazaki	Team Leader
Mr. Keith Hitchcock	Sewage Treatment Planner
Mr. Tadashi Shoji	Sludge Treatment Disposal/Environment Expert
Mr. Toshiki Naka	Reclaimed Wastewater Reuse Planner
Mr. John A. L. Chettoe	Organization/Institution Expert
Mr. Toru Ishibashi	Economic/Financial Expert
Mr. Tsutomu Yamamoto	Facility Designer/Cost Estimator
Mr. Shigenobu Hibino	Coordinator

JICA Advisory Committee

Mr. Haruki Takahashi	Chairman
Mr. Tsuyoshi Yanagi	Member

(2) Thai Organization

Steering Committee

1.	Deputy Bangkok Governor	Advisor of the committee
2.	Ms. Hansa Sanguannoi Assistant Secretary to Bangkok Governor	Advisor of the committee
3.	Mr. Sutat Weesakul Chairman Board Committee of Flood Protection and Management	Advisor of the committee
4.	General Director of the Department of Drainage and Sewerage	President of the committee
5.	Deputy of General Director of the Department of Drainage and Sewerage	Committee member
6.	Expertise of Sewerage System	Committee member
7.	Director of the Department of Public Cleansing	Committee member
8.	Representative of the Department of Policy and Planning of BMA	Committee member
9.	Ms. Preeda Parkpian Environmental Engineering Program, Asian Institute of Technology	Committee member
10.	Ms. Orawan Sirirapiriya Chulalongkorn University	Committee member
11.	Mr. Suwit Chumnumsiriwat Sanitary Engineering Program Faculty of Public Health Mahidol University	Committee member
12.	Mr. Chart Chiemchaisri Environmental Engineering Program Faculty of Engineering Kasetsart University	Committee member
13.	Representative of Office of Environmental Policy and Planning Ministry of Science Technology and Environment	Committee member

14.	Representative of Department of Agricultural Promotion Ministry of Agricultural and Co-operatives	Committee member
15.	Representative of Department of Public Works Ministry of Interior	Committee member
16.	Representative of Wastewater Management Authority	Committee member
17.	Director of Water Quality Management Division Department of Drainage and Sewerage	Committee member and Secretary
18.	Chief of Technical Subdivision Water Quality Management Division	Committee member and Secretary

Counterparts

Ms. Apinan Jaruchaiyakul	Chief of Technical Subdivision, DDS, BMA
Mrs. Suthimol Kessomboon	Sanitary Engineer DDS, BMA
Ms. Ubolwan Boontavee	Scientist, DDS, BMA
Ms. Chantana Rirattanapong	Scientist, DDS, BMA
Ms. Sermsook Pakkattang	Sanitary Scientist, DDS, BMA
Ms. Prayoon Chanya	Sanitary Scientist, DDS, BMA
Mr. Kitchapat Yinhirum	Civil Engineer
Mr. Prasith Inthachom	Civil Engineer
Mr. Suwapan Chiemrungsi	Civil Engineer
Mr. Kosit Srijaeng	Scientist

CHAPTER 2 GENERAL CONDITIONS OF THE STUDY AREA

2.1 Natural Conditions

(1) Topography

Bangkok is situated on the flat deltaic plain of the Chao Phraya River, a part of the Lower Central Plain of Thailand. General ground levels in the city are 1 - 2 m above Mean Sea Level (MSL).

(2) Meteorology

Bangkok experiences a tropical humid climate influenced by the Southwest and Northeast monsoon. There are three main seasons, a hot season from February to April, a wet season from May to October, and a cool season from November to January. The average monthly temperature ranges from 25.6 to 29.7°C.

(3) Hydrology

Monthly rainfall varies from 9.1 mm in January to 344.2 mm in September. Total annual mean rainfall is 1,496 mm and there are 125 average rainy days each year. Storms are usually intense and occur as squalls across the city. The theoretical 2 year maximum storm intensity is 61 mm/h.

(4) Geology and Hydrogeology

The upper geological strata comprise a series of clays overlying sand at a depth of between 21 and 25 m. There are eight aquifer layers above the bedrock of between 50 m and 550 m. Groundwater abstraction has resulted in severe subsidence but this is now being restricted.

(5) Drainage and the Canal System

Because of the low lying flat topography, many areas of BMA are liable to flooding. The urban drainage system comprises large concrete pipes and culverts draining to a network of canals (khlongs) and a sophisticated flood control system has been developed. The drainage system is also used to dispose of wastewater but the flat topography and high groundwater makes it less suitable for this purpose. Many drains are therefore surcharged and silted and the khlongs have become heavily polluted. Facilities have recently been installed to improve khlong water.

2.2 Socioeconomic Conditions

(1) Population and Population Forecasts

The BMA area now has an estimated population of 7.5 million although records account for only 6 million, explained by the under-recording of migrants. The Study Team investigated a number of population forecast studies and these are compared in Figure 2.2.1. The population forecasts carried out by BMA in the 1998 Wastewater User Charge Feasibility Study are used in this Study extrapolated from 2017 to 2020 and project a population for 2020 of 11.9 million.

(2) City Planning and Land Use

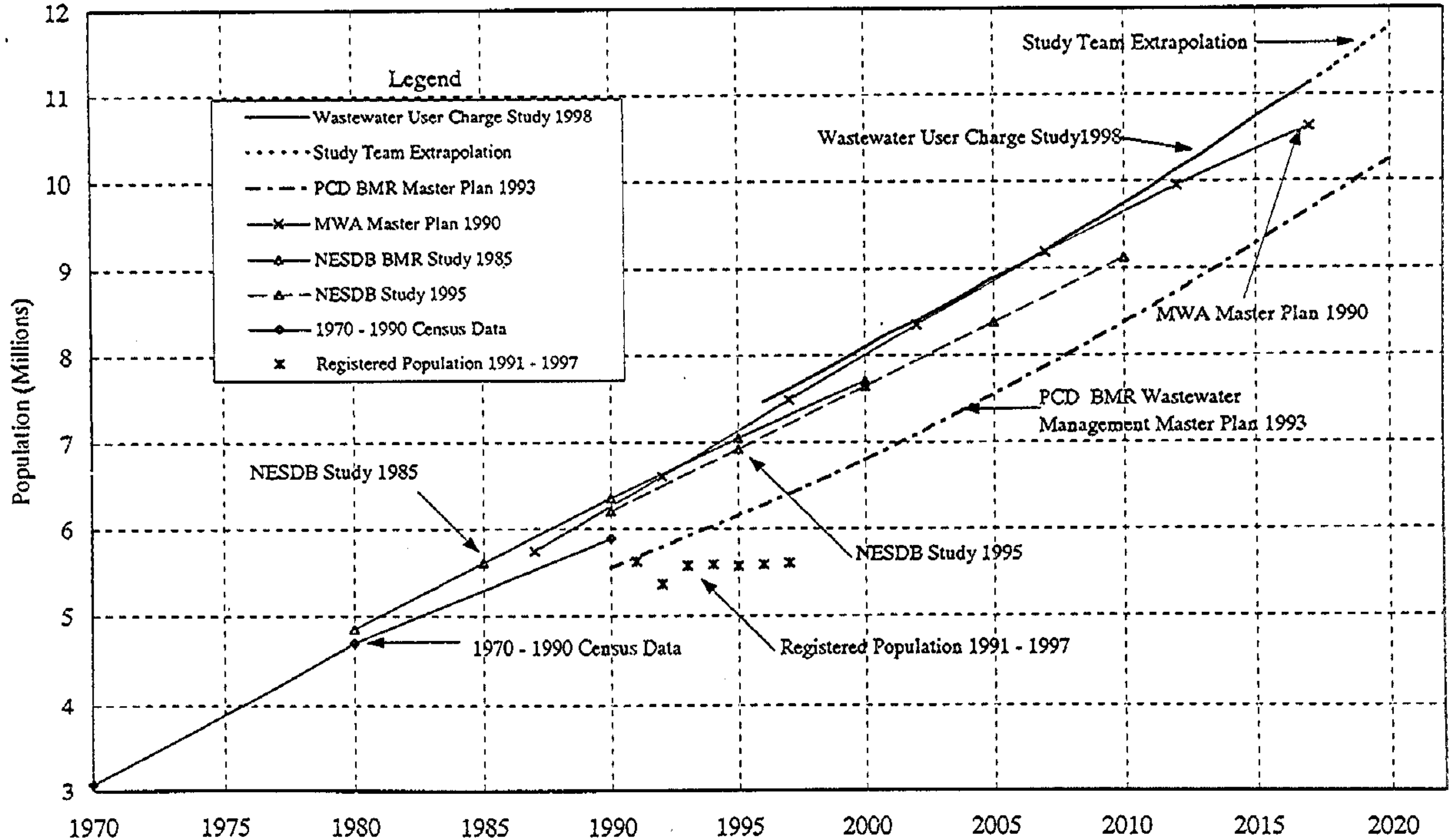
BMA City Planning Department have prepared a Land Use Plan for the period 1997-2017 to accommodate forecast growth in the city. Extensive expressway and mass transit systems are being implemented to cope with the city's traffic congestion. However, industry is being encouraged to develop outside the BMA area to limit migration to the capital and provide employment in the regions.

(3) Water Supply and Consumption

The Metropolitan Water Authority (MWA) serves BMA and parts of neighboring provinces. It has a major treatment plant in Bang Khen and three other plants drawing water from the Chao Phraya and Ta Chin Rivers producing 4.5 million m^3/d. It also has minor groundwater sources. There are plans to develop the Maha Sawat treatment plant including damming the Ta Chin River to produce 4 million m^3/d and to produce a total of 8.2 million m^3/d in 2017. MWA currently provide 1,342,000 customers with 945,000 million m^3/yr over an area of 1,100 km^2 and supplies are increasing at 4 % pa.

(4) Solid Waste Disposal

BMA collects 8,315 m^3/d of solid waste from 635,000 properties, 37 % of those in the BMA area, which is disposed of in two major sanitary landfills and a 1,000 m^3/d composting plant. Over the past ten years the amount of solid waste collected has doubled and this is expected to double again over the next fourteen years. Solid waste disposal is undertaken by contractors on 5 year term contracts.



THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 2.2.1 COMPARISON OF POPULATION PROJECTIONS IN BMA AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	

(5) Public Health

Poor sanitary conditions prevail in many parts of Bangkok but BMA's current program of wastewater schemes should result in significant improvements. Available records indicate no epidemics of water related diseases in recent years.

(6) Economic Development Plan and Index

The economic crisis in Thailand started on July 2, 1997 after the Thai Government decided to introduce a floating Thai Baht, after which the Thai Baht sharply depreciated from 25.79 to 56 Baht/US$ in January 1998. Shortly after the economic crisis, the Government agreed to follow the IMF Guidelines to obtain a loan to reform the its economy with significant government budget cuts, an increase of VAT from 7 % to 10 %, and an order to close 42 finance companies.

During this period, the real GDP annual growth rate has become negative and is estimated to be -0.4 % and -7.0 % in 1997 and 1998, respectively. However, due to Government efforts and political stability, the Thai economy has been recovering gradually, showing positive fundamental economic indicators, e.g., (1) the acceptable annual inflation rate is 5.6 % in 1997 and is estimated 9.2 % in 1998, which is less than the expected rate, (2) the exchange rate has become stable at around 36 Baht/US$, (3) the trade balance has been in surplus by a sharp increase in exports, i.e., 28.0 % and 57.5 % in 1997 and in 1998 (up to July).

(7) Financial and Economic Conditions in the Area of Environmental Preservation

The Central Government and BMA budget for environment had increased by 19.9 % and 29.9 % per annum during 1992 to 1997, respectively, out of which 88 % was invested for wastewater. Due to the economic crisis, however, the overall national budget has dropped by 16.2 % in the 1998 Thai Fiscal Year and the total environmental development budget and the BMA's environment budget have decreased more sharply by 50.3 % and 69.5 %, respectively. This is considered as an exceptional but unavoidable budget allocation in the condition of economic crisis.

(8) Administrative Boundaries

The BMA area is divided into districts and subdistricts. The districts have recently been rearranged from 38 into 50 new district areas.

CHAPTER 3 EXISTING SEWERAGE SYSTEM IN BANGKOK

3.1 Existing and Ongoing Wastewater Treatment Systems and Facilities in BMA

(1) Public Wastewater Services Program

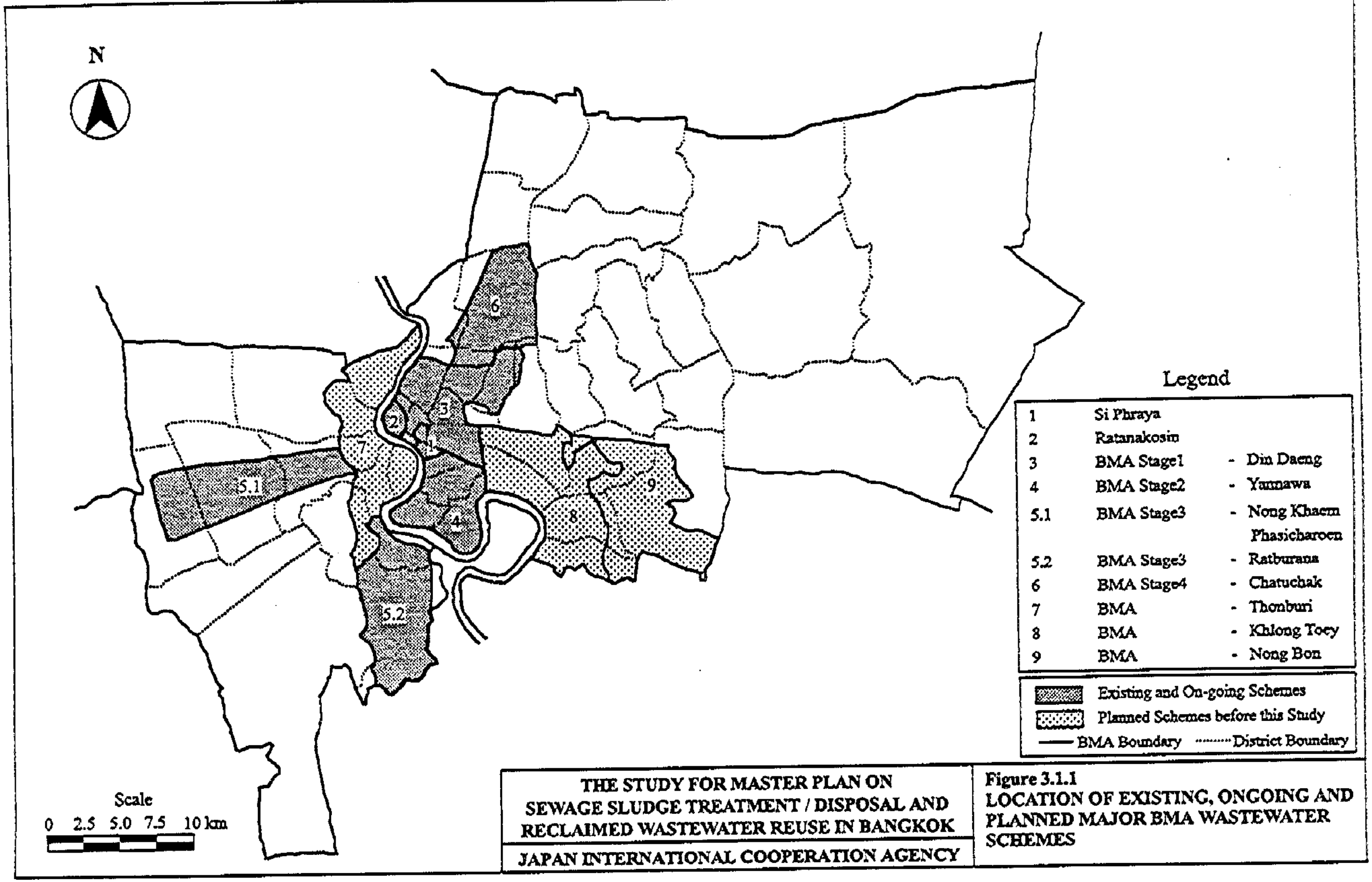
In the early 1990s, BMA embarked on a major program of wastewater treatment schemes to improve water quality in the khlongs and in the Chao Phraya River. The initial project in Si Phraya became operational in 1994 and currently six further schemes are being implemented. These will be completed by 2003 and will provide services over a total area of 192 km^2, treating 980,000 m^3/d of wastewater from an initial design population of 2.2 million. When fully developed, these schemes will treat 1,330,000 m^3/d from an ultimate population of 3.4 million. The locations and main features of these schemes are shown in Figure 3.1.1 and Table 3.1.1.

The Si Phraya Wastewater Scheme serves a population of 120,000 in an area of 2.7 km^2 in the older part of the city and includes a 2.3 km interceptor sewer. The treatment plant is fully housed with biological treatment facilities on three floors. The plant is not fully effective due to weak influent which has an average BOD of only 61 mg/l.

The ongoing wastewater treatment plant schemes are designed to the wastewater and treated effluent quality criteria shown in Table 3.1.2.

The interceptor or diversion chambers are hydraulically designed to accept 5 x Dry Weather Flow (DWF) into the interceptor sewers and to allow excess flows to pass to the khlongs. The Wastewater Treatment Plants (Central WWTPs) are designed to give preliminary treatment (screening and grit removal) to 5 x DWF, and full treatment to 1.5 x DWF initially and to 2.5 x DWF in future.

The Central WWTPs adopt various forms of the activated sludge treatment process including de-nitrification and phosphorous removal by biological or chemical processes. Sludge is required to be pressed to a cake of at least 20 % dry solids (DS) and thickeners and belt presses are to be used for this purpose. The WWTPs at Yannawa and Ratburana will accept a total of 1,400 m^3/d of night soil and this is to be screened and added to the sludge streams for thickening and de-watering.



THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 3.1.1
LOCATION OF EXISTING, ONGOING AND PLANNED MAJOR BMA WASTEWATER SCHEMES

Table 3.1.1 Existing and Ongoing Major BMA Wastewater Schemes

Name	Si Phraya	Ratanakosin	Din Daeng BMA Stage 1	Yannawa BMA Stage 2	Nong Khaem BMA Stage 3	Ratburana BMA Stage 3	Chatuchak BMA Stage 4
Service Area (km^2)	2.7	4.1	37.8	28.5	42.9	42.3	33.4
Design Population							
Phase 1	120,000	160,000	697,000	560,000	178,000	177,000	430,000
Year	2009	2011	1990	1992	1992	1992	2020
Phase 2			1,080,000	900,000	450,000	375,000	
Year			2015	2020	2020	2020	
Design Capacity							
Dry Weather Flow							
Phase 1 (m^3/d)	30,000	40,000	341,000	200,000	157,000	65,000	150,000
Phase 2 (m^3/d)			463,000	360,000		130,000	
Main Treatment Process	Activated Sludge Contact Stabilization	2 stage Activated Sludge	Conventional Activated Sludge	Activated Sludge Sequential Batch Reactor	Activated Sludge Vertical Loop Reactor	Activated Sludge Vertical Loop Reactor	Activated Sludge type not decided
WWTP Site Area (ha)	0.3	0.64	2.72	3.2	8.32	1.41	1.12
Current Status	Operational	Contract suspended	Contract suspended	Under construction	Under construction	Under construction	Contract to be awarded
Expected Completion		1999	Not known	1999	2001	2001	2003

Table 3.1.2 Specified Wastewater Quality and Treated Effluent Quality Requirements for BMA Wastewater Schemes

Parameter	Wastewater Influent Quality Assumed for Design Criteria		Treated Effluent Quality (mg/l)
	Phase 1 (mg/l)	Phase 2 (mg/l)	
BOD	150	200	20
Suspended Solids	150	200	30
N (total)	30	35	10
N (NH_3)	-	-	5
P	8	10	2
DO	-	-	5

Fourteen Community WWTPs were constructed by the National Housing Authority (NHA) and all but one have now been taken over by BMA. These were designed with separate sewerage systems for a total of 26,000 m^3/d from a population of 133,000. Treatment is generally provided by conventional or extended aeration activated sludge plants.

(2) Wastewater Treatment System of Private Sectors

All private properties are required to have septic tanks or community plants for treatment.

Small private houses must have septic tanks to accept toilet wastes and these generally have outlets to the drains or khlongs. Other domestic wastewater pass directly to the drains.

Larger properties, housing estates and industries are required to provide WWTPs to treat wastewater to prescribed quality standards which mostly require biological treatment.

3.2 Existing Night Soil Treatment Systems

(1) Existing Night Soil Collection

Night soil service areas in BMA are separated into two zones: Nong Khaem and On-Nut. Based on the tariff collection records, the total collected night soil in the whole of BMA is calculated as 1,019 m^3/d, resulting in 13 % of the collection ratio on the population base. On the other hand, the actual quantities treated at NSTPs are 450 m^3/d (400 to 500 m^3/d) and 200 m^3/d at Nong Khaem and On-Nut, respectively. Accordingly, the actual collection ratio of night soil is regarded to remain at 8.4 % on the whole.

The collection of night soil is undertaken by both districts and BMA. The operation and maintenance of NSTP at On-Nut is undertaken directly by BMA but that at Nong Khaem is by subcontractor.

(2) Existing Night Soil Treatment

The maximum design capacity of each of the NSTPs is 600 m^3/d. However, these are not being operated at their full capacity. Apart from the shortage of the vehicles for night soil collection, one of reasons is that the treatment plants have suffered from problems with mechanical components, resulting in only limited capacity.

Besides the Nong Khaem and the On-Nut NSTP, other night soil treatment schemes are ongoing along with the Central WWTP construction projects at Yannawa and Ratburana. In either Central WWTPs, collected night soil will be treated together with sewage sludge, after screened and stored in tank.

3.3 Existing Sludge Treatment/Disposal Systems

(1) Current Sludge Generation and Treatment/Disposal

At the present, only the Si Phraya Central WWTP is working in BMA as the central wastewater treatment system. Community wastewater treatment systems are under operation at 14 places in BMA. Besides, the night soil treatment plant is also in existence at Nong Khaem and On-Nut. The quantities of sludge generated from all those sources at the present are estimated at 17.9 t DS/d in total.

(2) Current Ultimate Disposal

Sludge cakes from the Si Phraya Central WWTP and the Huay Kwuang Community WWTP are used for sludge fertilizer or soil conditioner in nearby parks, after mixed with ash, coconut husk, or soil. Sludge cake from the On-Nut NSTP is also used in city parks. Most of sludge cakes from the Nong Khaem NSTP are disposed off the nearby dumping site, except for a small part being utilized for agricultural land.

(3) Ongoing Sludge Treatment/Disposal Schemes

Respective Central WWTPs under ongoing status, i.e.: Ratanakosin, Din Daeng, Yannawa, Nong Khaem, Ratburana and Chatuchak have been planned to construct sludge treatment facilities in each site. The Nong Khaem Sludge Treatment Center (STC) is also ongoing. This is designed collectively to treat sludge generated from the above Central WWTPs with the maximum capacity of 120 t

DS/d. This scheme has been delayed due to contractual problems but it is reported that the operation will be inaugurated in 2001.

3.4 Existing Wastewater Quality

Influent wastewater quality records are only available from Si Phraya WWTP and Huay Kwuang WWTP, one of the largest community treatment plants. Wastewater was also analyzed by a JICA resident expert in BMA in Lumphini in 1998, by the contractor for the Yannawa wastewater scheme in 1995 and by the BMA. These results are summarized in Table 3.4.1. Further wastewater quality data was obtained in the Study and is presented in Chapter 4. This shows the wastewater to be generally very weak and variable. Higher strength wastewater is recorded at Huay Kwuang WWTP as this catchment has a separate sewerage system which is only used in small parts of the city.

Table 3.4.1 Summary of Wastewater Quality Analyses from BMA WWTP Records and Previous Drain Surveys

Survey	Location	Type of Sewerage	TSS			BOD			COD		
			min (mg/l)	**avr (mg/l)**	max (mg/l)	min (mg/l)	**avr (mg/l)**	max (mg/l)	min (mg/l)	**avr (mg/l)**	max (mg/l)
BMA Records	Si Phraya WWTP*	Combined				37	**61**	89			
	Huay Kwuang WWTP*	Separate	89	**182**	295	160	**246**	400	200	**402**	657
	Other Community WWTPs inspected**	Separate	50	**54**	57	170	**225**	280		**450**	
Yannawa Project Contractor	Yannawa drains (4 locations)	Combined	21	**166**	411	26	**69**	214	56	**210**	365
JICA Expert Study	Lumphini drains (2 locations)	Combined	20	**55**	130	34	**135**	300			

Note:
* monthly averages of weekly analyses over 43 months from October 1995 to April 1999
** typical values available

CHAPTER 4 FIELD SURVEYS AND INVESTIGATIONS

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

(1) Surveys Undertaken at Si Phraya and Huay Kwuang WWTPs

Surveys were undertaken by the Study Team in the wet and dry seasons in October and November 1998 and in the wet season in June and July 1999, and by the Counterpart Team in the dry season in January and February 1999.

The surveys included sampling and analysis and flow measurement of the incoming sewage and treated effluents at Si Phraya Central WWTP and Huay Kwuang Community WWTP during normal weather and storm events. Samples were analyzed for TSS, VSS, BOD and COD and heavy metals. The requirements for the three surveys varied. The initial survey included flow measurements in order to assess unit flows and loads, the Counterpart Team survey contributed additional wastewater analyses and the second Study Team survey investigated wastewater and effluent quality at Si Phraya WWTP since this plant receives flows from the combined drainage system and is of more relevance to this Study.

(2) Survey Results from Si Phraya and Huay Kwuang WWTPs

The results of the surveys are summarized in Tables 4.1.1 and 4.1.2.

The Si Phraya Central WWTP records indicate very weak wastewater. The 1998 population of the service area is estimated as 95,000 and the survey data would therefore yield average unit flows and loads of 121 l/c/d and only 3 g/c/d BOD. However, these unit flows and loads are not considered representative.

The Huay Kwuang Community WWTP wastewater was also found to be weaker than the values in the WWTP records, but the strength was generally more typical of municipal sewage. An investigation of the served population and metered water consumption indicated that wastewater flows were only half the water supply. Using water consumption and BOD records from the WWTP, a unit flow of 183 l/c/d and unit load of 45 g/c/d may be derived.

The heavy metal concentrations measured in the wastewater are all within acceptable limits and would not impair biological treatment processes.

Table 4.1.1 Summary of Flow and Wastewater and Treated Effluent Quality at Si Phraya WWTP

Source	Weather	Average Flow (m^3/d)	TSS min (mg/l)	TSS avr (mg/l)	TSS max (mg/l)	VSS min (mg/l)	VSS avr (mg/l)	VSS max (mg/l)	BOD min (mg/l)	BOD avr (mg/l)	BOD max (mg/l)	COD min (mg/l)	COD avr (mg/l)	COD max (mg/l)
Inlet Wastewater	Normal Weather	11,500	10	**34**	89	18	**22**	29	8	**41**	82	30	**92**	154
	Storm Event		30	**59**	65	23	**38**	60	26	**41**	66	87	**126**	189
Treated Effluent	Normal Weather		1	**5**	10				2	**6**	8	10	**24**	64

No. of Samples :

Wastewater TSS, BOD and COD : 26 spot + 3 composite in Normal Weather, 24 spot during Storm Events
VSS : 3 composite in Normal Weather, 24 spot during Storm Events

Effluent TSS, BOD and COD : 8 spot + 3 composite
VSS : 3 composite

Table 4.1.2 Summary of Flow and Wastewater and Treated Effluent Quality at Huay Kwuang WWTP

Source	Weather	Average Flow (m^3/d)	TSS min (mg/l)	TSS avr (mg/l)	TSS max (mg/l)	BOD min (mg/l)	BOD avr (mg/l)	BOD max (mg/l)	COD min (mg/l)	COD avr (mg/l)	COD max (mg/l)
Inlet Wastewater	Normal Weather	1,330	12	**96**	164	102	**170**	240	190	**305**	412
	Storm Event	4,720	70	**711**	1,325	120	**370**	615	285	**1,111**	1,799
Treated Effluent	Normal Weather		1	**4**	8	5	**15**	32	29	**39**	60

No. of Samples :

Wastewater 26 spot in Normal Weather, 4 spot during Storm Event

Effluent 8 spot in Normal Weather

4.2 Wastewater Quality and Flow Rate in the Drainage System

(1) Surveys Undertaken

The initial survey was undertaken to assess unit flows and loads from flow and concentration surveys in defined catchment areas. Three smaller catchments were selected:

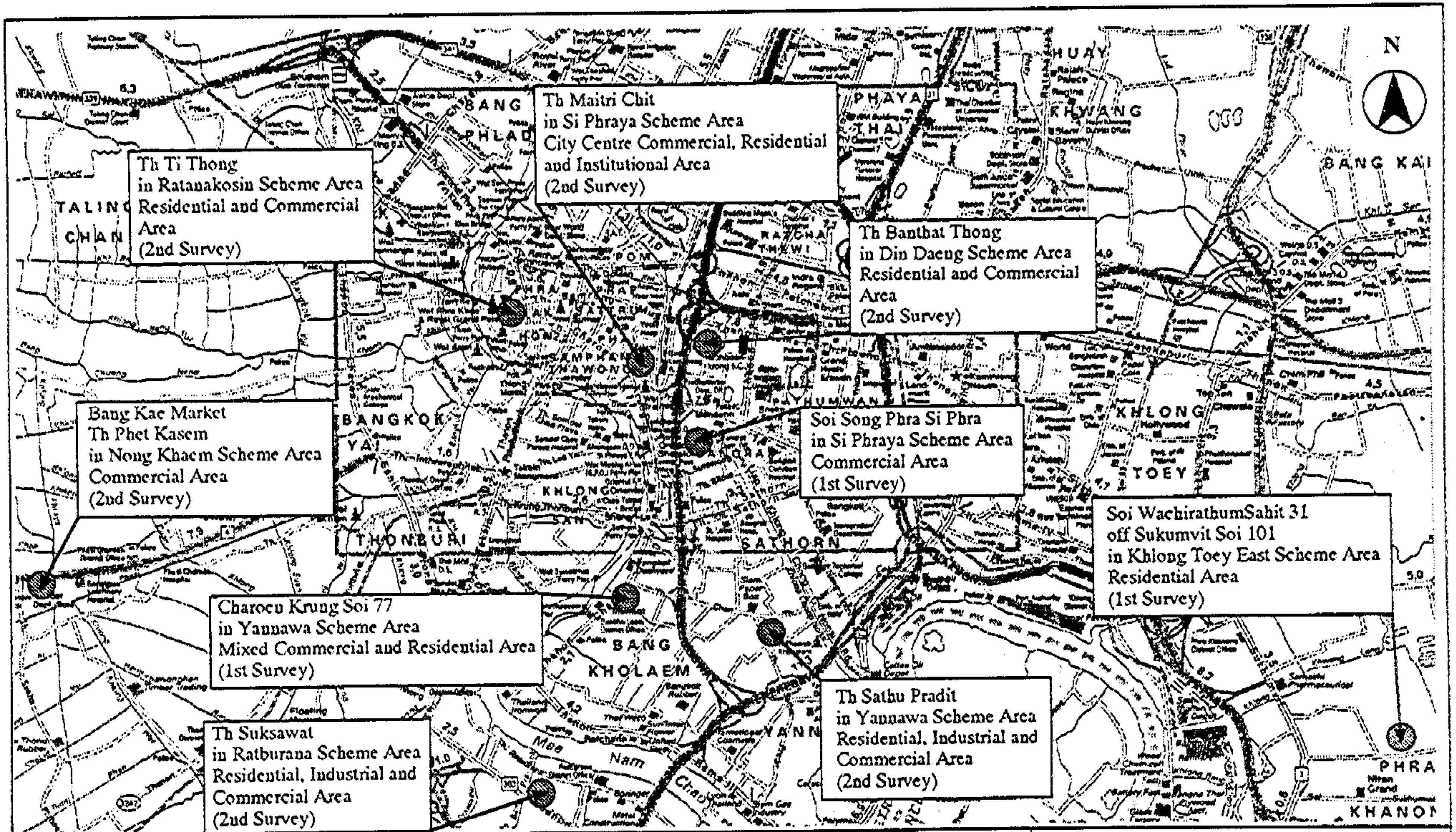
i) a commercial catchment in Soi Song Phra in the Si Phraya catchment area,
ii) a mixed residential and commercial catchment in Thanon Charoen Krung Soi 77 in the Yannawa catchment area,
iii) a residential catchment in Soi Wachirathun Sahit 31, Sukumvit Soi 101/1 in the proposed Khlong Toey East catchment area.

The locations of these sampling points are indicated in Figure 4.2.1. The Counterpart Team survey also analyzed samples from these locations.

The second survey was required to make more representative assessments of wastewater quality and sampling locations were selected for larger catchments in each of the existing and ongoing wastewater scheme areas:

i) a high density city center catchment with residential, commercial and institutional development in Th Maitri Chit in the Si Phraya scheme area,
ii) a medium density residential, industrial and commercial area in Th Sathu Pradit in the Yannawa scheme area,
iii) an older medium density residential and commercial catchment in Th Banthat Thong in the Din Daeng scheme area,
iv) a traditional residential catchment in the older part of the city in Th Ti Thong in the Ratanakosin scheme area,
v) a market area catchment at Bang Kae in the Nong Khaem scheme area,
vi) a developing residential and industrial catchment in the Ratburana scheme area in Th Suksawat.

Difficulties were encountered in finding suitable sampling locations in both surveys. The majority of manholes inspected were found to contain stagnant wastewater and flow patterns were often un-traceable and sometimes varied in direction. The implications on wastewater transfer for the new wastewater schemes are discussed in Section 6.1.1.



THE STUDY FOR MASTER PLAN ON
SEWAGE SLUDGE TREATMENT / DISPOSAL AND
RECLAIMED WASTEWATER REUSE IN BANGKOK

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 4.2.1
SEWAGE QUALITY AND FLOW SURVEY
LOCATIONS IN THE DRAINAGE SYSTEM

(2) Wastewater Quality and Quantity

The survey results are presented in Tables 4.2.1 and 4.2.2 and indicate generally weak and very variable wastewater quality both in time and place. They indicate the wastewater to be readily treatable and having a high proportion of volatile solids. Unit flows and loads were calculated from the survey data and are presented in Table 4.2.3. These indicated very large variations between the catchments. Extremely high and low values are most probably due to uncertainties concerning the catchment boundaries, contributing populations and actual water consumption. The storm event surveys indicated increases in load of up to 10 times average BOD and up to 80 times average suspended solids at the beginning of storms.

The wastewater quality data obtained form the Study surveys provides valuable data base which significantly extends the knowledge of wastewaters in the combined drains in Bangkok. It is used for forecasting loads to future WWTPs and consequent sludge production in Chapter 7 and will also be available for the planning and design of new wastewater services.

4.3 Sludge Qualities and Characteristics

(1) Objectives and Methods

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. The 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). 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).

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, took the analysis for bacteriological aspect and pathogens, and parasites.

Table 4.2.1 Summary of Wastewater Quality Analyses from the Drains in Normal Weather

Survey	Wastewater Scheme Area	Location	No. & type of samples	TSS			VSS			BOD			COD		
				min (mg/l)	avr (mg/l)	max (mg/l)	min (mg/l)	avr (mg/l)	max (mg/l)	min (mg/l)	avr (mg/l)	max (mg/l)	min (mg/l)	avr (mg/l)	max (mg/l)
First Study Team and Counterpart Team Surveys	Si Phraya	Song Soi Phra	24 spot	7	37	73				48	83	120	72	169	378
	Yannawa	Charoen Krung Soi 77	24 spot	4	33	143				34	100	150	94	188	306
	Khlong Toey	Soi Wachirathum Soi 31	8 spot	11	25	35				30	42	53	77	93	129
Second Study Team Survey	Si Phraya	Th Maitri Chit	2 comp.	55	89	122	44	65	85	47	52	56			
	Yannawa	Th Sathu Pradit	2 comp.	32	33	33	25	26	27	36	51	66			
	Din Daeng	Th Banthat Thong	2 comp.	45	61	76	39	44	49	27	37	47			
	Ratanakosin	Th Ti Thong	2 comp.	19	21	23	18	20	21	18	20	21			
	Nong Khaem	Bang Kae Market	2 comp.	43	45	47	38	39	39	53	65	77			
	Ratburana	Th Suksawat	2 comp.	43	48	53	35	37	39	39	48	57			
All Locations			68	4	44	143	18	39	85	18	55	150	72	150	378

Table 4.2.2 Summary of Wastewater Quality Analyses from the Drains during Storm Events

Survey	Wastewater Scheme Area	Location	No. of spot samples	TSS			VSS			BOD			COD		
				min (mg/l)	avr (mg/l)	max (mg/l)	min (mg/l)	avr (mg/l)	max (mg/l)	min (mg/l)	avr (mg/l)	max (mg/l)	min (mg/l)	avr (mg/l)	max (mg/l)
First Study Team and Counterpart Team Surveys	Si Phraya	Song Soi Phra	8	19	**174**	835				25	**46**	120	112	**144**	255
	Yannawa	Charoen Krung Soi 77	8	44	**64**	142				82	**82**	129	180	**260**	449
Second Study Team Survey	Si Phraya	Th Maitri Chit	24	23	**69**	336	22	**46**	189	24	**58**	111	82	**151**	400
	Yannawa	Th Sathu Pradit	36*	22	**78**	340	15	**38**	140	17	**48**	141	44	**134**	291
	Din Daeng	Th Banthat Thong	24	16	**48**	192	12	**33**	77	8	**64**	150	32	**156**	288
	Ratanakosin	Th Ti Thong	36*	11	**36**	125	8	**26**	70	14	**33**	66	16	**93**	189
	Nong Khaem	Bang Kae Market	24	38	**64**	134	22	**41**	84	24	**80**	204	126	**216**	416
	Ratburana	Th Suksawat	24	28	**58**	147	15	**37**	76	20	**67**	126	79	**188**	315
All Locations			184	11	74	835	8	37	189	8	60	204	16	168	449

Note:
* in one of the three storm events sampling was delayed until 6 h after the commencement of the storm

Table 4.2.3 Determination of Unit Flows and Loads from Survey Data

Location	Estimated Population	Measured Flow (m^3/d)	Measured BOD (mg/l)	Flow per Capita (l/c/d)	BOD per Capita (g/c/d)
Si Phraya WWTP	95,000	11,450	22	121	3
Huay Kwuang WWTP	11,995	1,330	146	111	16
Si Phraya Catchment Area	1,463	965	76	660	50
Yannawa Catchment Area	1,022	54	90	53	5
Khlong Toey East Catchment Area	284	101	34	356	12

(2) Results and Interpretation

The sludge moisture contents measured are distributed between 70 to 85 %, indicating that the dehydrators in respective plants are being operated under the normal performance as belt press types. The volatile solids ratio (VS ratio) of the sludge at the Si Phraya WWTP was measured as some 50 %. The C/N ratio, the carbon content, the nitrogen content, etc. show that all sludge is almost suitable range for agricultural use.

If the measured figures of heavy metals shown in Table 4.3.1 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 the comparison with the tentative standards proposed by AIT. Furthermore, mercury (Hg) in the sludge from the NSTPs is beyond the limit set by AIT on the maximum base.

The records shown in Table 4.3.1 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 4.3.1 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".

Source: JICA Study Team

The intrusion of heavy metals reportedly might be caused by small industries in certain kind 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 in existence that the illegal connection or occasional inflow of some wastewater besides night soil directs to septic tanks.

As for bacteria and parasites, among the sludge sources from which sample 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 examinations of this time.

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

(1) Agricultural Demand Survey

Two kinds of interview surveys were conducted, first to agricultural experts from Ministry of Agriculture and Co-operatives in the neighbouring 5 provinces, and second to farmers in the two provinces together with the BMA area. Both surveys show positive response on sludge compost, although they depend on chemical fertilizer more than organic one now. The estimation shows that 6.5 Billion Baht/year is used for chemical fertilizer in nearby 10 provinces, while 2.4 and 1.7 Billion Baht/year is used for compost and animal manure.

(2) Demand Survey for Sludge Compost

The potential demand size of sludge compost in the area was estimated by statistical approaches, which indicates that the total demand is equivalent to 498 t DS/d, consisting of 487 for agricultural use, 8 for public parks and 3 for road green zone. This is 1.64 times bigger than the total amount of wastewater and nightsoil sludge produced in 2020, that is, 303 t DS/d. The demand survey is summarized in Table 4.4.1.

(3) Marketing Survey for Sludge Compost

The current market size of compost in the area was estimated from production capacity of identified compost manufacturers, that is, at least 323 t DS/d equivalent. Another estimation of compost market size from the survey to farmers shows 594 t DS/d equivalent or 1 million t/yr is currently used in the area. The marketing survey is summarized in Table 4.4.2.

Table 4.4.1 Supply and Demand Estimation

	Estimated amount (t DS/d)	Sludge application rate (t DS/ha/y)	No. of target provinces	Ratio of willingness to pay (%)	Target crops			Remarks
					Fruit trees	Vege. and flowers	Field crops	
Expected supply								
From all WWTPs in 2020	259.0							
From all NSTPs in 2020	44.0							
Total	**303.0**							
Potential demand								
Agricultural use								
From the past report								
AIT 1998 report	416	5.00	9	20	O	O		
From the JICA study team								
1st survey to Kaset Thambon	435	5.00	10	18	O	O		
Interview to compost manufacturer	610	1.88	16	47	O			
Final estimation of sludge compost demand	487							Average
Public parks in BMA	8							
Road green zones in nearby 10 provinces	3							
Golf courses	0							
Total potential demand	**498**							

Table 4.4.2 Supply and Market Estimation

	Estimated size (t DS/d)	Estimated size (t/y)	Estimated size (Mil. B/y)	Average price (B/t)	Remarks
Expected supply					
From all WWTPs in 2020	259.0				
From all NSTPs in 2020	44.0				
Total	**303.0**				
Estimated current market size in nearby 10 provinces					
Market size estimation 1 (From interview and statistic surveys)					
Registered compost manufacturers in MOI	146.3				
Telephone interviews to compost manufacture	148.9				
Current NS use at schools/districts	28.0				
Total	**323.2**				No double counting
Market size estimation 2 (From the 2nd survey)					
Compost market size	**593.6**	1,080,620	2,375	2,198	
Animal manure		835,624	1,731	2,071	
NS sludge	**207.5**	378,607	0	0	Free of charge
Chemical		656,618	6,520	9,930	

(4) Conclusions

Wastewater and nightsoil sludge compost is acceptable for agricultural use and their market size seems large enough to absorb all sludge produced in 2020. The success factors are safety, cost, and education to farmers. The target production cost of compost is 1.5 Baht/kg and the sales price at the market place should be lower than 2 Baht/kg. Fruit tree, vegetable/flower, and crop farming are the most prioritized areas, since their yield is likely to be at an affordable level to purchase compost.

4.5 Reclaimed Wastewater Reuse Survey

(1) Current Conditions of Reuse

Treated wastewater is being reused on-site in wastewater treatment plants and night soil treatment plants. At the Nong Khaem NSTP, 90 % of water used is reclaimed wastewater. Only treated wastewater from the Si Phraya WWTP is used outside the plant. One percent of the treated wastewater volume is used for watering roadside plants and road cleaning.

(2) Survey of Current Conditions

A survey of current conditions was conducted to determine the current level of use and potential for future use. The survey covered the following 11 areas:

Wastewater Treatment Plants and Night Soil Treatment Plants
District Offices
Public Transportation Depots
Public Buildings
Large Private Buildings
Hotels
Hospitals
Others (stadiums, large gardens, etc.)
Khlongs
Irrigation
Industrial Estates and Factories

Effluent regulations are particularly strict, under Building Control Regulations, for hotels and hospitals, which have on-site plants equal to public wastewater treatment plants. Of the nine sites surveyed, reclaimed wastewater is used on-site in five cases for watering plants. In two large hospitals, double pipes are employed for a portion of the buildings, with reclaimed wastewater being used for flushing toilets. Also, treated wastewater from a large private building on Rama IV Road has been used since 1997 to water plants along a 500 m stretch of the road.

(3) Survey Analysis

By analyzing the survey results, the possible areas of reclaimed wastewater reuse can be broken down into the following categories:

i) Plant Watering (green expansion through reuse of wastewater),
ii) Building Miscellaneous Water (conservation of public water through recycling),
iii) Purification of Khlongs water environmental improvement through discharge of wastewater).

Plant Watering can be further divided as follows:

i) Road Plant Watering/Road Cleaning,
ii) Plant Watering (parks, golf courses etc.).

In addition to these, there are:

i) Agricultural Use (conservation of irrigation water through reuse of wastewater), and
ii) Industrial Use (prevention of land subsidence by reducing the abstraction of groundwater through reuse of wastewater).

Table 4.5.1 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.

Table 4.5.1 Reclaimed Wastewater Reuse by Each Item (1998)

Potential Demand for Reclaimed Wastewater	Forecast Demand for Reclaimed Wastewater (Public WWTP)		Type of Reuse	Drought Mitigation		Environmental Improvement: Green Area Expansion		Environmental Improvement: Environmental Purification	Land Subsidence
				Public	Private	Public	Private		
	(m^3/d)	%		(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d)	(m^3/d)
Road Plant Watering/Cleaning Road	**180**	**0.9**	Reuse		-	180[4]	18[5]	-	-
Buildings Miscellaneous Water	(20)	(0.1)	Recycle	20[2]	250[3]		-	-	-
Plant Watering (Parks, Golfcource etc.)	-	-	Reuse		-	-	50[6]	-	-
Purification of Khlong	**19,820**	**99.1**	Discharge		-		-	19,820	-
Agricultural Water	-	-	Reuse		-		-	-	-
Industrial Water	-	-	Reuse		-		-	-	-
Total	**20,000[1]**	**100.0**		20[2]	250[3]	180	68	19,820	-

Note :

1) Total value does not include the R.Q. of U.B. because it is recycled in Si Phraya WWTP.

2) used for washing filter cloth etc. in the Si Phraya WWTP.

3) used for toilet flushing etc. in Ramathibodi, Siriraj Hospital.

4) from Si Phraya WWTP

5) from Esso building for Rama IV Road plant watering.

6) from on-site buildings for plant watering.

CHAPTER 5 EXISTING ORGANIZATION AND INSTITUTION

5.1 Bangkok Metropolitan Administration (BMA)

BMA is the administrative authority for the Bangkok Metropolitan Area covering some 1,572 km^2 and is responsible for managing the city's output of wastewater and night soil. The two departments with major responsibilities in these areas are the Departments of Drainage and Sewerage, and Public Cleansing. Other departments provide supervision and support in functions such as planning and finance, law enforcement, staff training and the recently established environmental policy and promotion.

(1) Department of Drainage and Sewerage (DDS)

This department plans, designs, constructs, operates, and maintains the facilities for sewerage and drainage (including the canals or khlongs) in the Bangkok Metropolitan Area. In particular, the Water Quality Management Division (WQMD) is responsible for controlling water quality and resolving pollution problems, and therefore manages all public wastewater treatment plants as well as monitoring the quality of all water entering the environment. Many of its functions are delegated, under WQMD's supervision, to the 50 district offices.

(2) Department of Public Cleansing (DPC)

The Department of Public Cleansing manages the collection, treatment (where appropriate) and disposal of solid waste and night soil. It also cleans streets and public places. About 90 % of the night soil and garbage is collected by district offices. The night soil is processed at two treatment plants before being trucked to final destinations. Garbage is trucked to transit stations and from there to landfill by private contractors.

(3) District Offices

The 50 district offices deliver BMA services locally, collect revenue, keep records and monitor and enforce regulations, inadequately in environmental matters as is discussed below. All are supported functionally and financially by the appropriate body in BMA head office. Few activities are contracted out, although there are plans for this.

5.2 Other Institutions relevant to Drainage, Sewage and Environmental Aspects

Several bodies at national and regional levels have major policy, regulatory and executive roles in the sector. The most important of these are: the National

Environment Board, Environment Fund and Pollution Control Committee; Pollution Control Department, Office of Environmental Policy and Planning, Department of Environmental Quality Promotion, and Wastewater Management Authority; the last being responsible (at present only nominally) for developing and operating central wastewater treatment systems in the Bangkok Metropolitan Region. The considerable powers given to these entities represents a major change in the role of central environmental protection agencies from advisory to active management.

The Industrial Estate Authority of Thailand (IEAT) establishes industries in dedicated areas and has to develop and operate all necessary infrastructure, including water and sewage treatment, thus providing a useful precedent for future development of sewerage and water supply, especially in its use of the private sector. The Metropolitan Waterworks Authority (MWA) procures, acquires, treats and distributes water in Bangkok and two neighboring provinces. Unusually, it has almost no connection with sewerage management and is separate from BMA.

5.3 Laws and Regulations

A large but overlapping body of legislation now exists: to empower state agencies to treat wastewater and establish central wastewater treatment systems, to require the private sector to treat wastewater, to empower state agencies to regulate effluent, to monitor environmental quality, to empower organizations to collect a wastewater treatment charge, and to allow private participation in State business activities. The Enhancement and Conservation of National Environmental Quality Act of 1992 is the main environmental legislation, but even now is not widely accepted at district level as the main instrument for protecting the environment. This could partially account for the present poor enforcement of environmental law which should be addressed as a matter of urgency.

5.4 Privatization

For some time BMA has relied on the private sector to provide certain services that can be delivered, it is thought, more economically and more effectively outside government. These services are provided largely through service contracts, although there have been some management contracts and joint ventures. This trend should be extended and expanded, with proper thought given to regulation.

CHAPTER 6 PLAN OF FUTURE WASTEWATER AND NIGHT SOIL SLUDGE TREATMENT AND DISPOSALS

6.1 Establishment of Future Wastewater Disposal System

(1) Establishment of Design Basis

Wastewater flows and loads are determined separately for domestic, commercial and institutional, and industrial wastewaters.

Domestic wastewater flow forecasts are based on MWA water consumption forecasts of 256 l/c/d throughout the Master Plan period. A unit domestic load 40 g/c/d is proposed derived from a review of past studies and projects listed in Table 6.1.1, text book figures and data from the Study Team survey. Population forecasts in each proposed service area are derived from the 1998 Wastewater User Charge study.

Forecasts of commercial and institutional flows and loads are taken from the 1993 Master Plan investigations with an additional allowance for flows from educational establishments.

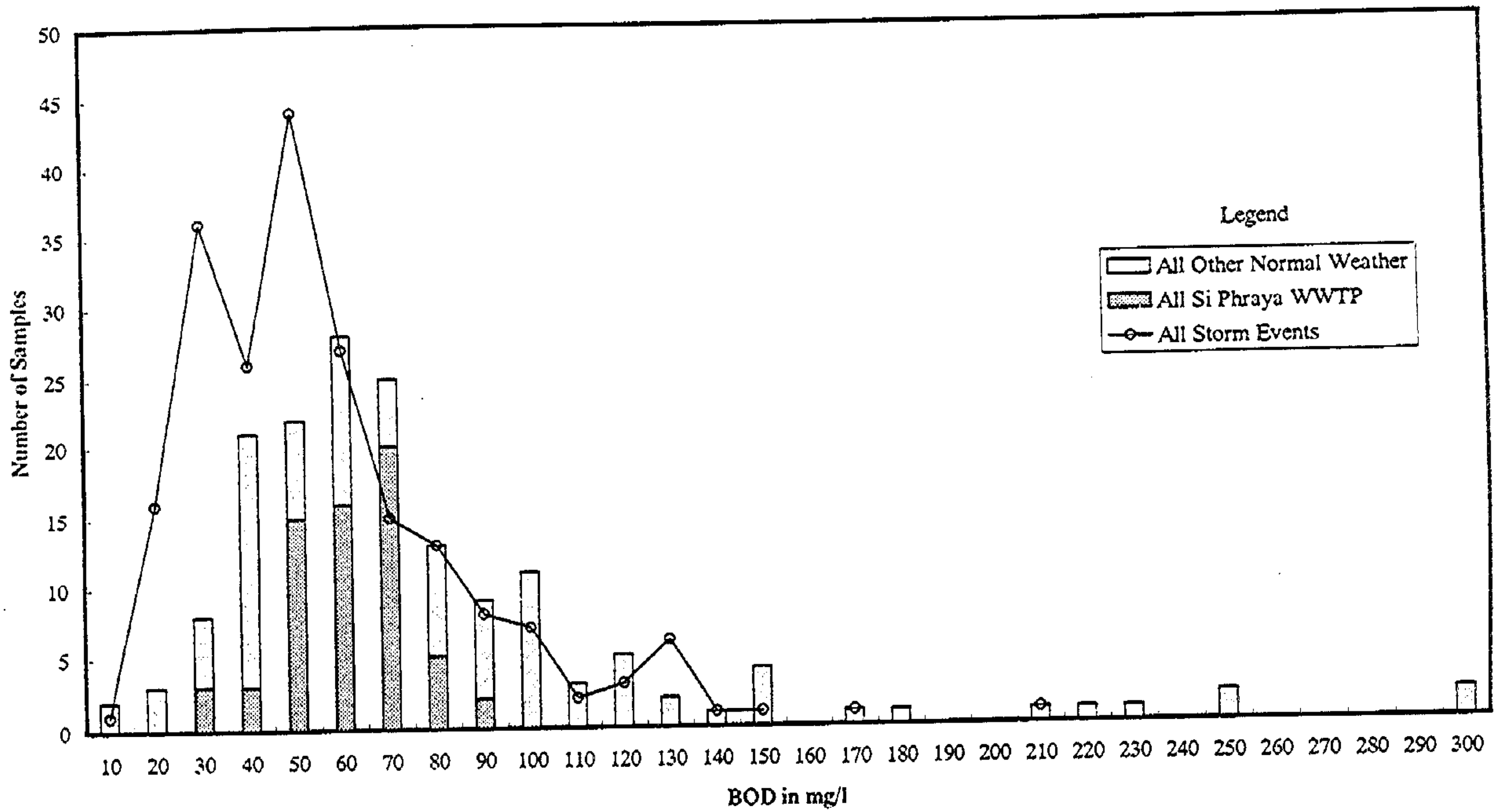
The low strength of the wastewater at Si Phraya Central WWTP and elsewhere in the drains must be due to BOD reduction in the large flat combined drains designed for storm flows. This will be due to de-composition of organic matter and dilution from groundwater infiltration and the khlongs. When the new wastewater schemes are in operation, wastewaters in the combined drains will be drawn down into the interceptor sewers resulting in faster flows with less opportunity for biological de-composition, and inflows from the khlongs will also be stopped. As a result there will be less reduction in wastewater strength than at present. A BOD Reduction Factor is introduced to account for the losses in BOD between wastewater entering the drain and delivery at the WWTP. Figure 6.1.1 indicates the range and variability of BOD concentration in the combined drains and at Si Phraya WWTP. From this figure, 110 mg/l is selected to represent the normal maximum BOD strength wastewater and it is assumed that this will be equivalent to average wastewater quality at the WWTP when the new wastewater schemes are in operation. The average wastewater BOD concentration at the entry to the drains forecast from load and flow predictions for the proposed wastewater schemes is derived from Table 6.1.2 is 160 mg/l. To reduce this to 110 mg/l at the WWTP gives a 30 % BOD Reduction Factor in the drainage system and this value is adopted in this Study.

Table 6.1.1 Domestic Unit Flow and Load Determinations and Forecasts (1/2)

Source	DWF per Person (l/c/d)	Peak Flow for Intercepor (xDWF)	BOD per Person (g/c/d)	Comment
Si Phraya (existing)	250	1	16	Flow from WWTP design capacity. BOD from measured BOD concentration. Includes non-domestic flow.
Ratanakosin (on going)	250	n.a.	n.a.	Flow from WWTP capacity. Includes non-domestic flow.
Din Daeng (BMA 1) (on going)	410	5	82	Flow based on 100% water consumption records. Peak from Contract Spec. BOD based on Spec. Concentration of 200 mg/l.
Yannawa (BMA 2) (on going)	357 (Ph 1) 400 (Ph 2)	5	54 (Ph 1) 80 (Ph 2)	DWF from Spec. total flow and popn. Peak from Spec. BOD from Spec. concentrations of 150 and 200 mg/l. Includes non-domestic flow.
Nong Khaem (BMA 3) (on going)	376	5	56 (Ph 1) 75 (Ph 2	Flow from Spec. Peak from Spec. BOD from Spec. concentration. Includes non-domestic flow.
Ratburana (BMA 3) (on going)	376	5	56 (Ph 1) 75 (Ph 2	Flow from Spec. Peak from Spec. BOD from Spec. concentration. Includes non-domestic flow.
Chatuchak (BMA 4) (before contract)	376	5	56 (Ph 1) 75 (Ph 2)	DWF from Spec. total flow and popn. Peak from Spec. BOD from Spec. concentrations of 150 and 200 mg/l. Includes non-domestic flow.
Plan for Khlong Toey and Thonburi (1998)	376	5	56 (Ph 1) 75 (Ph 2)	Flow from SAPROF study for OECF based on: 256 l/c/d domestic + 120 l/c/d non-domestic as above. Peak from BMA. BOD based on BMA concentration criteria of 150 and 200 mg/l.
PCD BMR Wastewater Management Master Plan (1993)	200 (1990) 220 (2000) 240 (2010) 260 (2020)	3	30	Flow based on 80% of forecast water consumption from MWA. BOD not explained

Table 6.1.1 Domestic Unit Flow and Load Determinations and Forecasts (2/2)

Source	DWF per Person (l/c/d)	Peak Flow for Intercepor (xDWF)	BOD per Person (g/c/d)	Comment
PCD BMR Wastewater Management Plan (1996)	209-512 (1997) 222-516 (2001) 239-542 (2006) 257-570 (2011) 277-599 (2016)	5 for small upstream areas reducing to 2 for large down-stream areas.	35 (1996) 50 (2016)	Water consumption forecasts from MWA and Provincial Waterworks Authority (PWA). No explanation for BOD in available reports. Assumes that wastewater is equal to water consumption.
MWA Master Plan for Water Supply (1990)	190/230 (1987) 200/242 (1997) 210/254 (2007) 220/260 (2017)			Water demand not wastewater forecasts for Central Business Districts/outside Central Business Districts. These are exclusive of government, commercial and industrial demands
Current MWA planning (1998)	256 (to 2017)			Domestic water demand only. This is as later planned BMA Schemes where 120 l/c/d is added for non-domestic flow.
Wastewater User Charge Study (1998)	as PCD BMR Master Plan above			
NESDB Water Quality Management Study (1988)			48	53 mg/l at source, 48 mg/l at the drain due to losses in septic tank
Sludge Master Plan Survey (1988) in Huay Kwuang WWTP Catchment	183		45	Based on metered water consumption and measured BOD concentration in 1996. This is considered the most relevant indication of unit flow and load although no septic tanks are provided in this catchment.



THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 6.1.1 DISTRIBUTION OF WASTEWATER BOD FROM COMBINED DRAINS
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 6.1.2 Forecasts of Wastewater Flows and Loads for Proposed New Service Areas (1/2)

Future Master Plan Service Area	Area	Forecast Population			Forecast Domestic Flow			Forecast Domestic BOD			Forecast Commercial and Institutional Flow			Forecast Commercial and Institutional BOD		
		2000	2010	2020	2000	2010	2020	2000	2010	2020	2000	2010	2020	2000	2010	2020
	(km^2)	(x1000)	(x1000)	(x1000)	($x10^3 m^3/d$)	($x10^3 m^3/d$)	($x10^3 m^3/d$)	(t/d)	(t/d)	(t/d)	($x10^3 m^3/d$)	($x10^3 m^3/d$)	($x10^3 m^3/d$)	(t/d)	(t/d)	(t/d)
Thonburi South	22.3	534	549	565	136.7	140.5	144.6	21.4	22.0	22.6	7.0	7.2	7.4	1.0	1.0	1.1
Thonburi Central	17.5	355	376	400	90.9	96.3	102.4	14.2	15.0	16.0	15.2	16.1	17.1	3.0	3.2	3.4
Thonburi North	11.4	175	193	216	44.8	49.4	55.3	7.0	7.7	8.6	9.0	9.9	11.1	3.2	3.5	3.9
Khlong Toey West	25.7	333	369	406	85.2	94.5	103.9	13.3	14.8	16.2	13.3	14.7	16.2	4.0	4.4	4.9
Khlong Toey East	31.9	278	354	453	71.2	90.6	116.0	11.1	14.2	18.1	3.4	4.3	5.5	0.5	0.6	0.8
Total planned	**108.8**	**1675**	**1841**	**2040**	**428.8**	**471.3**	**522.2**	**67.0**	**73.7**	**81.6**	**47.9**	**52.2**	**57.3**	**11.7**	**12.7**	**14.1**
Bang Sue	19.7	327	359	391	83.7	91.9	100.1	13.1	14.4	15.6	7.6	8.3	9.1	2.1	2.3	2.5
Huay Kwuang	15.3	164	228	317	42.0	58.4	81.2	6.6	9.1	12.7	12.2	17.0	23.6	4.6	6.4	8.9
Wang Thong Lang	35.7	274	361	478	70.1	92.4	122.4	11.0	14.4	19.1	4.2	5.5	7.3	0.6	0.8	1.0
Bung Kum	42.8	256	362	512	65.5	92.7	131.1	10.2	14.5	20.5	2.5	3.5	5.0	0.2	0.3	0.4
Total proposed	**113.5**	**1021**	**1310**	**1698**	**261.3**	**335.4**	**434.8**	**40.9**	**52.4**	**67.9**	**26.5**	**34.3**	**45.0**	**7.5**	**9.8**	**12.8**
TOTAL	**222.3**	**2696**	**3151**	**3738**	**690.1**	**806.7**	**957.0**	**107.9**	**126.1**	**149.5**	**74.4**	**86.5**	**102.3**	**19.2**	**22.5**	**26.9**

Table 6.1.2 Forecasts of Wastewater Flows and Loads for Proposed New Service Areas (2/2)

Future Master Plan Service Area	Area	Forecast Industrial Flow			Forecast Industrial BOD			Forecast Total DWF			Forecast Total BOD			Forecast BOD at WWTP			Forecast Total Sludge		
		2000	2010	2020	2000	2010	2020	2000	2010	2020	2000	2010	2020	2000	2010	2020	2000	2010	2020
	(km²)	(x10³ m³/d)	(x10³ m³/d)	(x10³ m³/d)	(t/d)	(t/d)	(t/d)	(x10³ m³/d)	(x10³ m³/d)	(x10³ m³/d)	(t/d)	(t/d)	(t/d)	(t/d)	(t/d)	(t/d)	(t DS/d)	(t DS/d)	(t DS/d)
Thonburi South	22.3	35.2	46.2	60.7	6.2	8.1	10.7	178.9	193.9	212.7	28.6	31.1	34.4	20.0	21.8	24.1	20.0	21.8	24.1
Thonburi Central	17.5	21.1	27.7	36.4	2.6	3.4	4.5	127.2	140.1	155.9	19.8	21.6	23.9	13.9	15.1	16.7	13.9	15.1	16.7
Thonburi North	11.4	6.7	8.8	11.5	0.8	1.1	1.4	60.5	68.1	77.9	11.0	12.3	13.9	7.7	8.6	9.8	7.7	8.6	9.8
Khlong Toey West	25.7	26.4	34.7	45.5	2.6	3.4	4.5	124.9	143.9	165.6	19.9	22.6	25.6	13.9	15.8	17.9	13.9	15.8	17.9
Khlong Toey East	31.9	19.4	25.5	33.4	2.0	2.6	3.4	94.0	120.4	154.9	13.6	17.4	22.3	9.5	12.2	15.6	9.5	12.2	15.6
Total planned	**108.8**	**108.8**	**142.9**	**187.5**	**14.2**	**18.6**	**24.5**	**585.5**	**666.4**	**767.0**	**92.9**	**105.0**	**120.2**	**65.0**	**73.5**	**84.1**	**65.0**	**73.5**	**84.1**
Bang Sue	19.7	9.8	12.9	16.9	2.0	2.6	3.4	101.1	113.1	126.1	17.2	19.3	21.5	12.0	13.5	15.1	12.0	13.5	15.1
Huay Kwuang	15.3	11.3	14.8	19.5	1.2	1.6	2.1	65.5	90.2	124.3	12.4	17.1	23.7	8.7	12.0	16.6	8.7	12.0	16.6
Wang Thong Lang	35.7	6.6	8.7	11.4	0.8	1.1	1.4	80.9	106.6	141.1	12.4	16.3	21.5	8.7	11.4	15.1	8.7	11.4	15.1
Bung Kum	42.8	6.8	8.9	11.7	0.7	0.9	1.2	74.8	105.1	147.8	11.1	15.7	22.1	7.8	11.0	15.5	7.8	11.0	15.5
Total proposed	**113.5**	**34.5**	**45.3**	**59.5**	**4.7**	**6.2**	**8.1**	**322.3**	**415**	**539.3**	**53.1**	**68.4**	**88.8**	**37.2**	**47.9**	**62.3**	**37.2**	**47.9**	**62.3**
TOTAL	**222.3**	**143.3**	**188.2**	**247.0**	**18.9**	**24.8**	**32.6**	**907.8**	**1081.4**	**1306.3**	**146.0**	**173.4**	**209.0**	**102.2**	**121.4**	**146.4**	**102.2**	**121.4**	**146.4**

Note:
Domestic flow at 256 l/c/d
Domestic BOD at 40g/c/d at drain entry throughout
Commercial and Institutional flow from 1993 PCD BMR Master Plan basic data, projected flows proportional to population + allowance for educational establishments
Commercial and Institutional BOD derived in the same way as flow but no BOD allowance for educational establishments
Industrial flow from1993 PCD BMR Master Plan basic data, projected flows proportional to forecast growth in manufacturing GDP of 2.76% pa
Industrial BOD in the same way as flow
BOD reduction in Drainage system assumed at 30 %
Sludge production at 1.0 kg/kg BOD

Future wastewater schemes are recommended to be of similar size or rather smaller than those of the current program, and same collection system (combined system) is recommended. A peak flow capacity of 5 x DWF has been assumed in the proposed schemes in this Study, but it is recommended that more flow and load investigations be undertaken which may suggest a lower factor is appropriate.

(2) Establishment of New Wastewater Schemes

The main criterion for the selection of new areas requiring public wastewater facilities must be the degree of urbanization as indicated by forecasts of population density and planned development in the BMA Land Use Plan. This identified 13 future wastewater scheme areas which, together with the three planned schemes, constitute the strategic plan. These areas are shown in Figure 6.1.2. The scheme areas generally serve populations of up to 500,000 and compare with those in the 1993 Master Plan although boundaries are adjusted.

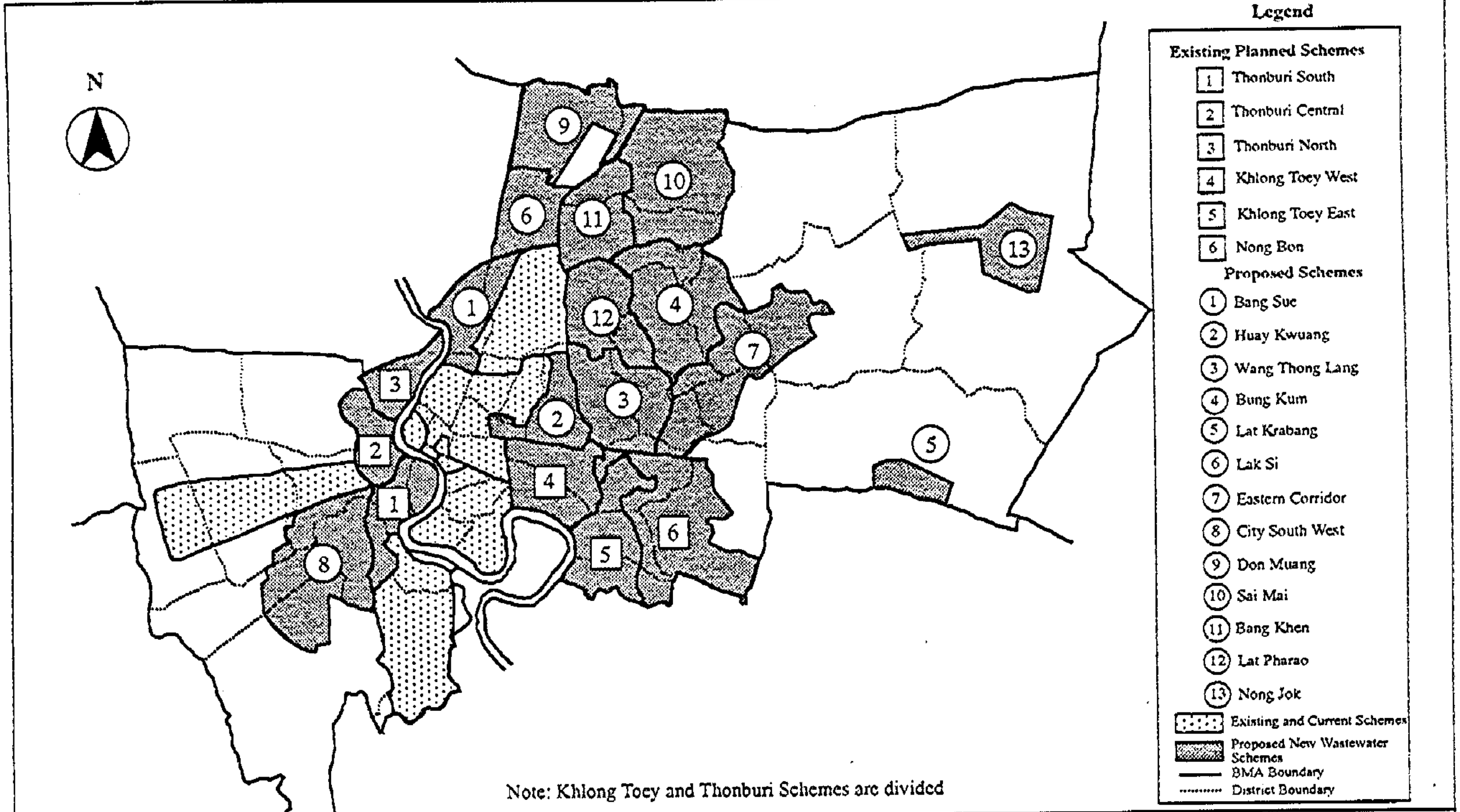
Priority areas for public wastewater services are determined by numerical evaluation of development criteria together with khlong water quality as indicated in Figure 6.1.3. This analysis justifies the priority for schemes in the Khlong Toey and Thonburi areas but not for the Nong Bon scheme. Second priority is given to newly proposed schemes in Bang Sue, Huay Kwuang, Wang Thong Lang and Bung Kum, and these are proposed to be implemented within the Master Plan period.

(3) Wastewater Treatment Plants

Wastewater flows and loads are forecast for the planned and proposed schemes in Table 6.1.2. Small footprint compact housed plants similar to those of the existing and ongoing schemes will be necessary for most schemes due to difficulties and high costs of land acquisition. However, single level plants are recommended wherever possible.

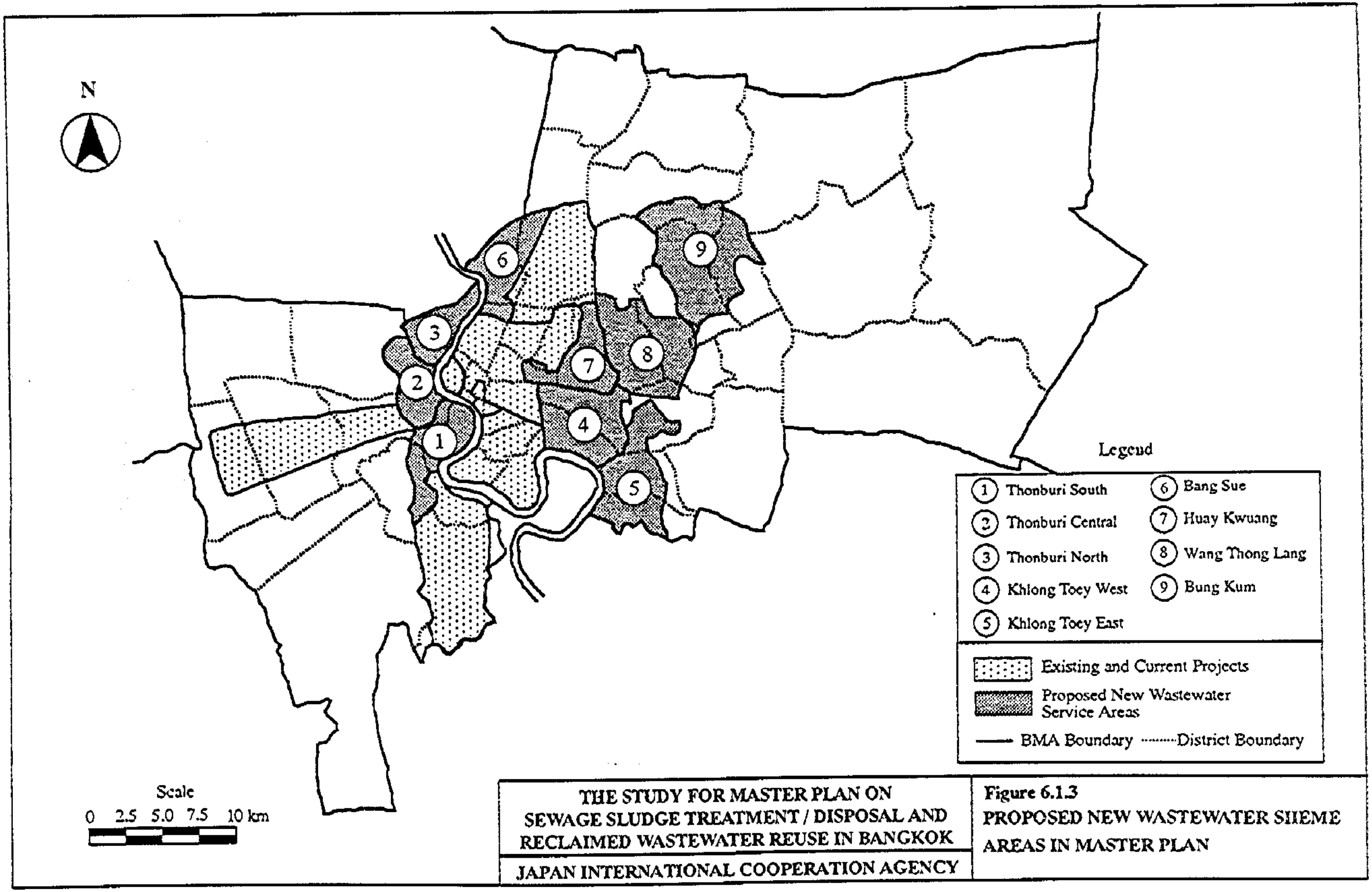
(4) Wastewater Collection Systems

The wastewater collection systems will comprise new interceptor chambers on the existing drainage system, and interceptor sewers to convey the diverted wastewater to the Central WWTP. The main report includes provisional layouts for the main interceptor sewers.



Note: Khlong Toey and Thonburi Schemes are divided

THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 6.1.2 PROPOSED STRATEGIC WASTEWATER MASTER PLAN
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK

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Figure 6.1.3
PROPOSED NEW WASTEWATER SHEME AREAS IN MASTER PLAN