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. III SUPPORTING REPORT

OCTOBER 1999

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A. SLUDGE SURVEY FOR AGRICULTURAL REUSE

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1. Introduction

The Bangkok domestic sewage sludge includes wastewater, night soil, oil and grease from the Bangkok metropolitan area. The Bangkok Metropolitan Administration (BMA) has aimed to introduce the concept of reusing Bangkok sewage sludge in farming. It is expected that Bangkok sewage sludge will be an alternative source of organic matter to replace commercial organic fertilizers. The reuse of the sludge is based on environmentally sound and low-cost technologies, and is appropriate in the current economic crisis of the country.

The small waste water treatment plants of Bangkok have produced sewage sludge from domestic waste disposal. Sludge produced by these plants will be transported to the central sewage sludge treatment plants located around the Bangkok vicinity for digestion and dewatering. The BMA plans to introduce two forms of sewage sludge, namely, cake or solid sludge, and compost made of sludge mixed with farm residues such as coconut husks. The solid sewage sludge is given free of charge to farmers while the compost made by mixing sludge and farm residues will be sold at a low cost. The introduced sewage and night soil sludge has met the standards of the BMA to ensure that agricultural products produced by using the sewage sludge instead of organic compost will be safe for human consumption.

To attract farmers to replace the organic fertilizers they use with Bangkok sewage sludge, the sewage sludge source should be easily accessible and the price of mixed sludge compost should be lower than the market price of purchased compost. In addition, quality of sewage sludge should satisfy farmers.

Some constraints on using sewage sludge in farming have been anticipated. These include a requirement for a large storage facility, a seasonal demand for sludge, labour requirements, transportation and cultural bias.

Therefore, a research study of market demand for the sewage sludge in farming areas adjacent to Bangkok, where the sewage sludge can be easily obtained, was launched. This was to investigate the feasibility of the introduction of sewage sludge in the Thai farming system.

2. Objectives of the Survey

The main objectives of the survey are as follows:

- To find out the possibility of introducing the use of the Bangkok sewage sludge in farming, farmers' acceptance and attitude towards sewage and human waste sludge;
- To find out the market demand for sewage sludge as an alternative organic fertilizer in farming and tentative costs of the mixed compost sludge;
- To understand farmers' experiences in using organic fertilizers.

3. Survey Area and Target Group

The main and only source of sewage sludge is from Bangkok. Therefore, the target survey areas should be adjacent to Bangkok. These selected areas included Bangkok suburbs where agricultural activities still remain, Nonthaburi and Chachoengsao provinces. Twenty villages in the three selected provinces were targeted to conduct the field survey.

The target group was purposely defined as farmers who were using organic fertilizers on their farms. Paddy farmers were excluded from the survey because organic fertilizers were not used in paddy fields. It was planned that about 100 farmers would be interviewed, that five respondents would be interviewed per village, and ten villages would be selected in each province.

4. Methodologies

A social survey using questionnaires was conducted. Interviewers consisted of graduate and undergraduate students from the Department of Geography, Kasetsart University. Interviewers brought with them samples of sewage sludge in the solid and compost mixed forms to show respondents during the interview to introduce the sewage sludge to farmers and find out their opinions about it. The research consisted of the following steps:

1) Prepare questionnaires:
   A questionnaire was prepared based on the previous study of AIT and the objectives of the study. Discussion of and final decision on the questionnaire were made among the principal researcher and the JICA Study Team.

2) Select survey areas:
The districts and villages of the survey provinces were selected using topographic maps. Selection of the survey areas was based on agricultural land use and proximity to access roads.
3) Pretest of the questionnaire:
Two graduate students pretested the questionnaire on 6 February 1999. After conducting the pretest, some questions were rewritten to make them clearer. All interviewers were briefed about the questionnaire and the research objectives before conducting the field survey.
4) Conduct field survey:
Graduate students supervised the undergraduates in the field survey. Interviewers were divided into three groups. After interview, each questionnaire was checked for its correctness. The total respondents interviewed were 129. The questionnaires with incomplete answers were discarded making final number of 122 respondents to be processed and analysed. The survey was conducted in four working days on 6-12 February in the 41 villages as follows:

Provinces	Districts	Sub-districts	Willages (#)
Bangkok	Nong Khaem	Nong Khaem	5 (# 4, 6, 7, 8,10)
	Nong Chok	Nong Chok	3 (# 2, 7, 11)
		Sai Kong Din	1 (# 3)
		Khlong Sib Song	2 (# 4, 11)
		Khu Piew Nuea	1 (# 8)
		Khok Faek	1 (# 6)
	Onnuch Road		
	Pravate		1 (Seri village)
	Suan Luang	Suan Luang	3 (# 2, 6, 8)
	Lad Krabang	Lad Krabang	2 (# 6, 7)
Nonthaburi	Mueng	Bangrak Noi	2 (# 3, 5)
	Bang Buathong	Bangrak Yai	2 (# 4, 5)
		Lahan	1 (# 3)
	Bang Kruay	Sala Klang	2 (# 1, 3)
		Plai Bang	1 (# 3)
	Sai Noi	Sai Noi	4 (# 2, 3, 6, 12)
Chachoengsao	Mueng	Bang Phai	4 (# 7, 8, 9, 10)
		Don Thong	2 (# 7, 9)
	Bang Khla	Sao Cha Ngok	2 (# 2, 3)
		Samed Nuea	2 (# 5, 7)

5) Processing and data analysis:
The data were processed and analysed by using the statistical package SPSS for Windows. The percentile, means and cross-tabulation were used for producing analytical tables and report.
6) Prepare the field survey report.

5. Timing

The research study project was conducted during four weeks in February, 1999.

6. Limitations to the Study

- Purposive selection called for respondents using organic fertilizers. It was hard to find five such respondents in some villages especially in Bangkok and Nonthaburi provinces where urban land use has expanded.
- The limited numbers of farmers in the Bangkok area have caused difficulty in conducting interviews; moreover, farmers were absent during the survey.
- Since the BMA has recently changed the district boundaries and more new districts have been established, it was found out that respondents were confused as to which district they belonged to.
- Thai farmers usually have difficulty in memorizing the quantity of fertilizers they purchased and applied in their farms. Many respondents had difficulty in responding to questions on the quantities of fertilizers applied.

7. Results and Analysis

7.1 Respondents' Information

Total number of respondents was 122. The number of respondents from Bangkok was slightly higher than those from the other two provinces (Table A.1.1). Most Bangkok farmers were in the district (Amphoe) of Nong Khaem (17.2%), while most Nonthaburi farmers were from the districts of Bang Bua Thong and Bang Kruay (Table A.1.2). It was difficult to find farmers who practiced organic fertilizers available at the time the survey was conducted; as a result, interviewers could find only one respondent in a village in most survey areas of Bangkok as shown in Table A.1.3.

Table A.1.1 Number of Respondents by Provinces

Provinces	Number of respondents	
	No.	%
Bangkok	42	34.40
Nonthaburi	40	32.80
Chachoengsao	40	32.80
Total	122	100.00

Table A.1.2 Number of Respondents by Provinces and Districts

Provinces	Number of respondents	
	No.	%
Bangkok		
-Nongkhaem	21	17.20
-Nongchork	8	6.60
-Prawate	4	3.28
-Suanluang	7	5.74
-Latkrabang	2	1.64
Nonthaburi		
-Muang	8	6.60
-Bangbuathong	12	9.80
-Bangkruay	11	9.00
-Sainoi	9	7.40
Chachoengsao		
-Muang	20	16.40
-Bangkhla	20	16.40
Total	122	100.00

Table A.1.3 Number of Respondents by Villages (1/2)

Villages	Number of respondents	
	No.	%
Bangkok		
1) Amphoe Nongkhaem		
a. Tambon Nongkhaem		
1.Mu4	7	5.74
2.Mu6	4	3.28
3.Mu7	4	3.28
4.Mu8	3	2.46
5.Mu10	3	2.46
2) Amphoe Nongchork		
a. Tambon Nongchork		
1.Mu2	1	0.82
2.Mu7	1	0.82
3.Mu11	1	0.82
b. Tambon Sai Kong Din		
4.Mu3	1	0.82
c. Tambon Khlong Sipsong		
5.Mu4	1	0.82
6.Mu11	1	0.82
d. Tambon Khu Phung Nuan		
7.Mu8	1	0.82
e. Tambon Khokyack		
8.Mu6	1	0.82
3) Amphoe Prawate		
1.Mu Ban Seri	4	3.28
4) Amphoe Suanluang		
1.Mu2	2	1.64
2.Mu6	2	1.64
3.Mu8	3	2.46
5) Amphoe Latkrabang		
1.Mu6	1	0.82
2.Mu17	1	0.82
Nonthaburi		
1) Amphoe Muang		
a. Tambon Bangraknoi		
1.Mu3	1	0.82
2.Mu5	8	6.56

Table A.1.3 Number of Respondents by Villages (2/2)

Villages	Number of respondents	
	No.	%
2) Amphoe Bangbuathong		
a. Tambon Bangrakyai		
1.Mu4	7	5.74
2.Mu5	2	1.64
b. Tambon Lahan		
3.Mu3	2	1.64
3) Amphoe Sainoi		
a. Tambon Sainoi		
1.Mu2	1	0.82
2.Mu3	3	2.46
3.Mu6	2	1.64
4.Mu12	3	2.46
4) Amphoe Bangkrauy		
a. Tambon Plaibang		
1.Mu3	3	2.46
b. Tambon Salaklang		
1.Mu1	7	5.74
2.Mu3	1	0.82
c. Chachoengsao		
1) Amphoe Muang		
a. Tambon Bangphai		
1.Mu7	1	0.82
2.Mu8	2	1.64
3.Mu9	10	8.20
4.Mu10	1	0.82
b. Tambon Donthong		
5.Mu7	2	1.64
6.Mu9	4	3.28
2) Amphoe Bangkhla		
a. Tambon Sao Changok		
1.Mu2	7	5.74
2.Mu3	3	2.46
b. Tambon Samet Nuan		
3.Mu5	6	4.92
4.Mu7	4	3.28
Total	122	100.00

7.2 Agriculture

Three main types of crops in the survey areas were fruit trees, vegetables and flowers, and field crops. Among the three types, fruit tree plantations were found in every province (Table A.2.1). Vegetables and flowers were found more in Nonthaburi. These fruits included banana, mango and coconut plantations in Bangkok. Fruit trees in Nonthaburi and Chachoengsao included bananas, mango, coconut, guava, lychee and lemon. The field crops were corn and beans.

Table A.2.1 Distribution of Respondents by Types of Crops and Provinces

Provinces	Types of crops							
	Fruit tress		Vegetable and flowers		Field crops		Total	
	No.	%	No.	%	No.	%	No.	%
Bangkok	33	60.00	19	34.55	3	5.45	55	100.00
Nontbaburi	24	50.00	21	43.75	3	6.25	48	100.00
Chachoengsao	29	59.18	18	36.73	2	4.08	49	100.00
Total	86	56.57	58	38.16	8	5.26	152	100.00

Note: Multiple answers

The average farm size in the survey area was 8.039 rai per family. The minimum farm size was half a rai reported by a respondent in Bangkok, while the maximum farm size was 110 rai reported by a respondent in Chachoengsao. Half of the total respondents (53.3%) had farms of 5 rai or less, and only 4% had more than 20 rai (Table A.2.2). Most farmers in the survey areas had small farms. Only one respondent in Chachoengsao had farms larger than 40 rai (Table A.2.3). The major crop type of the survey area was fruit trees while vegetables and flowers were the second major crop. Very few farmers planted field crops. Fruit trees were only found in the largest size farm group. Vegetables, flowers, and field crops were planted in the area of less than 20 rai (Table A.2.4).

Table A.2.2 Distribution of Respondents by Farm Sizes

Farm sizes (rai)	Number of respondents	
	No.	%
Lowest through 5	65	53.28
5.1-10	34	27.87
10.1-15	13	10.66
15.1-20	5	4.10
20.1-40	4	3.28
40.1 through highest	1	0.82
Total	122	100.00

Table A.2.3 Distribution of Respondents by Farm Sizes and Provinces

Farm sizes (rai)	Provinces							
	Bangkok		Nonthaburi		Chachoengsao		Total	
	No.	%	No.	%	No.	%	No.	%
Lowest through 5	20	47.62	28	70.00	17	42.50	65	53.28
5.1-10	14	33.33	8	20.00	12	30.00	34	27.87
10.1-15	6	14.29	3	7.50	4	10.00	13	10.66
15.1-20	1	2.38	1	2.50	3	7.50	5	4.10
20.1-40	1	2.38	0	0.00	3	7.50	4	3.28
40.1 through highest	0	0.00	0	0.00	1	2.50	1	0.82
Total	42	100.00	40	100.00	40	100.00	122	100.00

Table A.2.4 Distribution of Respondents by Types of Crops and Farm Size

Farm sizes (rai)	Types of crops											
	Fruit trees		Vegetables and flowers		Field crops		Fruit tress and vegetables and flowers		Fruit trees and field crops		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Lowest through 5	50	64.94	31	63.27	5	83.33	4	44.44	0	0.00	90	63.38
5.1-10	16	20.78	10	20.41	1	16.67	3	33.33	1	100.00	31	21.83
10.1-15	4	5.19	7	14.29	0	0.00	2	22.22	0	0.00	13	9.15
15.1-20	2	2.60	1	2.04	0	0.00	0	0.00	0	0.00	3	2.11
20.1-40	4	5.19	0	0.00	0	0.00	0	0.00	0	0.00	4	2.82
40.1 through highest	1	1.30	0	0.00	0	0.00	0	0.00	0	0.00	1	0.70
Total	77	100.00	49	100.00	6	100.00	9	100.00	1	100.00	142	100.00

Note: Multiple answers

Most farmers who planted fruit trees, vegetables and flowers, and field crops used both chemical and organic fertilizers on their farms (Table A.2.5). Applying organic fertilizer alone was found more in fruit trees than other crops. And it was found that the number of farmers who used organic fertilizer alone was higher than that of those using chemical fertilizers alone. Like other agricultural areas, chemical fertilizer was widely used and was preferred. Most respondents (80.61%) used in the amount of not more than 200 kg of chemical fertilizer per rai. Animal waste and compost were mostly found less than 200 kg per rai per year. Only two respondents applied human waste (Table A.2.6). Minority of respondents applied more than 200 kg of fertilizer per rai per year, and few respondents applied more than 600 kg. Most farmers bought the compost, while some of them made their own (Table A.2.7). More farmers in Bangkok made their own compost. Other types of fertilizers included residues from coconuts, beans, and castor oil seeds. The average amount of coconuts mixed in compost was 125 kg/rai/year; however, the average amount of beans was only 50 kg/rai/year.

Table A.2.5 Distribution of Respondents by Types of Crops and Fertilizers Used

Types of crops	Types of fertilizers used							
	Organic fertilizer		Chemical fertilizer		Both		Total	
	No.	%	No.	%	No.	%	No.	%
Fruit trees	21	24.42	2	2.33	63	73.26	86	100.0
Vegetables and flowers	4	6.90	2	3.45	52	89.66	58	100.00
Field crops	0	0.00	0	0.00	7	100.00	7	100.00
Total	25	16.56	4	2.65	122	80.79	151	100.00

Note: Multiple answers

Table A.2.6 Distribution of Types and the Amount of Fertilizer Used in kg/rai/year

Types of fertilizer used	Amount of fertilizers used in kg/rai/year											
	Lowest-200		200.1-400		400.1-600		600.1-800		800-highest		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Compost	30	54.55	10	18.18	7	12.73	5	9.09	3	5.45	55	100.0
Animal waste	37	69.81	8	15.09	3	5.66	2	3.77	3	5.66	53	100.0
Human waste	2	100.0	0	0.0	0	0.0	0	0.0	0	0.0	2	100.0
Chemical fertilizers	79	80.61	10	10.20	4	4.08	2	2.04	3	3.06	98	100.0
Compost+manure	0	0.0	0	0.0	0	0.0	1	100.0	0	0.0	1	100.0
Compost+chemical fertilizers	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	1	100.0
Manure+ chemical fertilizers	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	1	100.0
Compost+manure+chemical fertilizers	1	100.0	0	0.0	0	0.0	0	0.0	0	0.0	1	100.0
Others	4	100.0	0	0.0	0	0.0	0	0.0	0	0.0	4	100.0

Table A.2.7 Distribution of Respondents by Sources of Compost Used and Provinces

Provinces	Sources of compost used							
	Make own		Buy		Both		Total	
	No.	%	No.	%	No.	%	No.	%
Bangkok	12	28.57	29	69.05	1	2.38	42	100.00
Nonthaburi	7	17.50	31	77.5	2	5.00	40	100.00
Chachoengsao	4	10.00	33	82.5	3	7.50	40	100.00
Total	23	18.85	93	76.23	6	4.92	122	100.00

Among the types of fertilizers, most farmers spent more on chemical fertilizers than other types. The prices paid ranged from 5 Bahts to 15 Bahts per kg and more. It was found that the prices of animal waste and compost were not costly. Most of them were less than 3 Bahts per kg. Very few farmers paid all types of fertilizers higher price than 15 Bahts per kg (Table A.2.8). Human waste was costless. The prices of residues from coconuts and castor oil seeds were less than 5 Bahts; while, from beans were higher than 15 Bahts.

Table A.2.8 Distribution of Cost of Fertilizers by Types

Cost of fertilizers (Baht/kg)	Types of fertilizers							
	Compost		Animal waste		Chimical fertilizers		Others	
	No.	%	No.	%	No.	%	No.	%
Lowest through 1	35	66.04	11	26.19	0	0.00	0	0.00
1.1 - 3	6	11.32	19	45.24	0	0.00	1	33.33
3.1 - 5	5	9.43	9	21.43	2	2.00	1	33.33
5.1 - 10	3	5.66	3	7.14	52	52.00	0	0.00
10.1 - 15	1	1.89	0	0.00	42	42.00	0	0.00
15.1 through highest	3	5.66	0	0.00	4	4.00	1	33.33
Total	53	100.00	42	100.00	100	100.00	3	100.00

Most respondents had the suppliers transport fertilizers for them. They did not face the difficulty of transportation. However, respondents in Nonthaburi were diffierent from those in the other two provinces. The percentages of transport of fertilizers by suppliers, farmers, or both were found not much different (Table A.2.9). This means that many farmers in Nonthaburi could afford to transport fertilizers themselves. Regarding the methods of applying organic fertilizers, Table A.2.10 showed that almost all farmers in the survey areas applied organic fertilizers manually.

Table A.2.9 Distribution of Respondents by Transportation of Fertilizers and Provinces

Provinces	Transportation of fertilizers							
	By supplier		By farmer		Both		Total	
	No.	%	No.	%	No.	%	No.	%
Bangkok	15	50.00	12	40.00	3	10.00	30	100.00
Nonthaburi	12	36.36	10	30.30	11	33.33	33	100.00
Chachoengsao	30	83.33	4	11.11	2	5.56	36	100.00
Total	57	57.57	26	26.26	16	16.16	99	100.00

Table A.2.10 Distribution of Respondents by Methods of Applying Organic Fertilizers and Provinces

Provinces	Methods of applying organic fertilizers							
	Manually		Using equipment		Both		Total	
	No.	%	No.	%	No.	%	No.	%
Bangkok	40	95.24	1	2.38	1	2.38	42	100.00
Nonthaburi	40	100.00	0	0.00	0	0.00	40	100.00
Chachoengsao	35	87.50	2	5.00	3	7.50	40	100.00
Total	115	94.26	3	2.46	4	3.28	122	100.00

7.3 Experience with and Acceptance of Sludge

The survey aimed to find out experience and acceptance of farmers in using sludge as organic fertilizer in farming. The available sludge consisted of sewage sludge and night soil (NS).

7.4 Sewage Sludge

Table A.3.1 shows that the majority of respondents had never heard about using sewage sludge in farming. The Bangkok respondents were found to be more aware of using it in farming (Table A.3.2).

Table A.3.1 Distribution of Respondents Who Heard About Sewage Sludge by Provinces

Provinces	Number of respondents who heard about sewage sludge					
	Yes		No		Total	
	No.	%	No.	%	No.	%
Bangkok	16	38.1	26	61.9	42	100.0
Nonthaburi	7	17.5	33	82.5	40	100.0
Chachoengsao	10	25.0	30	75.0	40	100.0
Total	33	27.05	89	72.95	122	100.0

Table A.3.2 Distribution of Respondents Who Aware of Using Sewage Sludge in Farming by Provinces

Provinces	Number of respondents who aware of using sewage sludge in farming					
	Yes		No		Total	
	No.	%	No.	%	No.	%
Bangkok	14	50.00	2	40.00	16	48.48
Nonthaburi	5	17.86	2	40.00	7	21.21
Chachoengsao	9	32.14	1	20.00	10	30.30
Total	28	100.0	5	100.0	33	100.0

When the samples of sewage sludge was introduced to respondents to find out if it was an acceptable replacement for organic fertilizers, it was found that more than half of the respondents in Bangkok and Chachoengsao would like to use it in farming. However, only 27.50% of total respondents from Nonthaburi accepted the sludge, while most of them were undecided or refused it (Table A.3.3). From Table 3.4, most farmers (77.78%) who would like to apply the sludge held small farms of less than 10 rai.

Table A.3.3 Distribution of Respondents Who Will Use Sewage Sludge in Farming by Provinces

Provinces	Number of respondents who will use sewage sludge in farming							
	Yes		No		Undecided		Total	
	No.	%	No.	%	No.	%	No.	%
Bangkok	26	61.90	8	19.05	8	19.05	42	100.00
Nonthaburi	11	27.50	10	25.00	19	47.50	40	100.00
Chachoengsao	26	65.00	5	12.50	9	22.50	40	100.00
Total	63	51.64	23	18.85	36	29.51	122	100.00

Table A.3.4 Distribution Of Respondents Who Will Use Sewage Sludge in Farming by Farm Sizes

Farm sizes (rai)	Number of respondents who will use sewage sludge in farming							
	Yes		No		Undecided		Total	
	No.	%	No.	%	No.	%	No.	%
Lowest through 5	30	47.62	12	52.17	2	13.33	44	43.56
5.1-10	19	30.16	8	34.78	7	46.67	34	33.66
10.1-15	8	12.70	3	13.04	2	13.33	13	12.87
15.1-20	3	4.76	0	0.00	2	13.33	5	4.95
20.1-40	2	3.17	0	0.00	2	13.33	4	3.96
40.1 through highest	1	1.59	0	0.00	0	0.00	1	0.99
Total	63	100.00	23	100.00	15	100.00	101	100.00

The main reason of refusing sewage sludge was that most respondents, especially in Nonthaburi (70.97%), were not sure about its quality. Many respondents from Chachoengsao and Bangkok indicated that they did not know how to use the sludge in farming. It seemed that transportation was not the problem (Table A.3.5). Time and labour requirements in preparing the sludge as organic fertilizers were also not major problems. Farmers who planted fruit trees were more concerned about time and labour than those who planted vegetables and flowers (Table A.3.6). Other reasons for not using sludge included not being interested, being afraid of the large quantities required, and satisfaction with animal waste as good and easy to use.

Table A.3.5 Distribution of Respondents With Reasons for Not Using Sewage Sludge in Farming by Provinces

Reasons for not using sewage sludge in farming	Provinces							
	Bangkok		Nonthaburi		Chachoengsao		Total	
	No.	%	No.	%	No.	%	No.	%
Don't know how to use	5	23.81	3	9.68	7	30.43	15	20.00
Not sure about quality	13	61.90	22	70.97	9	39.13	44	58.67
No transportation	0	0.00	0	0.00	1	4.35	1	1.33
No time/labour	2	9.52	3	9.68	3	13.04	8	10.67
Others	1	4.76	3	9.68	3	13.04	7	9.33
Total	21	100.00	31	100.00	23	100.00	75	100.00

Table A.3.6 Distribution of Respondents With Reasons for Not Using Sewage Sludge in Farming by Types of Crops

Reasons for not using sewage sludge in farming	Types of crops							
	Fruit tree		Vegetable and flowers		Field crops		Total	
	No.	%	No.	%	No.	%	No.	%
Don't know how to use	11	23.40	5	14.71	1	33.33	17	20.24
Not sure about quality	25	53.19	21	61.76	2	66.67	48	57.14
No transportation	1	2.13	0	0.00	0	0.00	1	1.19
No time/labour	7	14.89	2	5.88	0	0.00	9	10.71
Others	3	6.38	6	17.65	0	0.00	9	10.71
Total	47	100.0	34	100.0	3	100.0	84	100.0

The main reason for accepting the sludge in farming was that most respondents would like to try something new on their farms (Table A.3.7). They also would like to reduce cost in agricultural investment. Less than 20% of the total respondents who would try the sludge indicated that by using it, the soil would be improved.

Table A.3.7 Distribution of Respondents With Reasons for Accepting Sewage Sludge in Farming by Provinces

Reasons for accepting sewage sludge in farming	Provinces							
	Bangkok		Nonthaburi		Chachoengsao		Total	
	No.	%	No.	%	No.	%	No.	%
Reduce cost	10	31.25	1	9.09	8	21.62	19	23.75
Want to try something new	16	50.00	7	63.64	25	67.57	48	60.00
Shortage of animal waste	0	0.00	1	9.09	0	0.00	1	1.25
Improve soil condition	6	18.75	2	18.18	4	10.81	12	15.00
Total	32	100.00	11	100.00	37	100.00	80	100.00

When the samples of sludge were shown to respondents in order to find out the type preferred, almost all respondents in Chachoengsao and all in Nonthaburi indicated that the sludge mixed compost was preferable while Bangkok farmers preferred both types (Table A.3.8). The mixed compost sludge was also preferable for all crops (Table A.3.9).

Table A.3.8 Distribution of Respondents by Types of Preferred Sewage Sludge and Provinces

Provinces	Types of preferred sewage sludge							
	Solid		Mixed compost sludge		Both		Total	
	No.	%	No.	%	No.	%	No.	%
Bangkok	12	46.15	12	46.15	2	7.70	26	100.00
Nonthaburi	0	0.00	11	100.00	0	0.00	11	100.00
Chachoengsao	1	3.85	25	96.15	0	0.00	26	100.00
Total	13	20.63	48	76.19	2	3.17	63	100.00

Table A.3.9 Distribution of Respondents by Types of Preferred Sewage Sludge and Types of Crops

Types of crops	Types of preferred sewage sludge							
	Solid		Mixed compost sludge		Both		Total	
	No.	%	No.	%	No.	%	No.	%
Fruit trees	11	22.00	37	74.00	2	4.00	50	100.00
Vegetables and flowers	7	22.58	24	77.42	0	0.00	31	100.00
Field crops	1	25.00	2	50.00	1	25.00	4	100.00
Total	19	22.35	63	74.12	3	3.53	85	100.00

About half of the total respondents from Bangkok and Chachoengsao indicated that they were interested in buying the mixed compost sludge, while more than half of the respondents (62.50%) from Nonthaburi were not interested or undecided (Table A.3.10). The percentage of respondents who would like to buy the mixed sludge was higher among those who planted vegetables and flowers (51.72%). For those who planted fruit trees, about 41.86% indicated an interest in buying sludge, and the rest refused it or were undecided (Table A.3.11). Most farmers (38.18%) who would be willing to buy sewage sludge to replace their organic fertilizer indicated that they would pay not more than B1 per kg (Table A.3.12). And 30.91% of them would be willing to pay at the price of not more than B2.

Table A.3.10 Distribution of Respondents Who Would Buy Mixed Compost Sludge by Provinces

Provinces	Types of preferred sewage sludge							
	Solid		Mixed compost sludge		Both		Total	
	No.	%	No.	%	No.	%	No.	%
Bangkok	21	50.00	10	23.81	11	26.19	42	100.00
Nonthaburi	15	37.5	16	40.00	9	22.50	40	100.00
Chachoengsao	20	50.00	13	32.50	7	17.50	40	100.00
Total	56	45.90	39	31.97	27	22.13	122	100.00

Table A.3.11 Distribution of Respondents Who Would Buy Mixed Compost Sludge by Types of Crops

Types of crops	Types of respondents who would buy mixed compost sludge							
	Yes		No		Undecided		Total	
	No.	%	No.	%	No.	%	No.	%
Fruit trees	36	41.86	30	34.88	20	23.26	86	100.00
Vegetables and flowers	30	51.72	17	29.31	11	18.97	58	100.00
Field crops	3	42.86	3	42.86	1	14.29	7	100.00
Total	69	45.70	50	33.11	32	21.19	151	100.00

Note: Multiple answers

Table A.3.12 Distribution of Sludge Prices that the Respondents Willing to Pay

Sludge prices that the respondents willing to pay (Baht)	Number of respondents	
	No.	%
Lowest through 1	21	38.18
1.1-2	17	30.91
2.1-3	5	9.09
3.1-5	6	10.91
5.1-10	3	5.45
10.1 through highest	3	5.45
Total	55	100.00

If the BMA provided the solid sewage sludge free of charge, interested farmers would have to mix it with other compost before applying it to their plants. Majority of the respondents who planted all crop types were interested in this (Table A.3.13). However, most farmers from Nonthaburi were not interested in sludge even if it was free of charge. Only 22.5% mentioned that they would like to have it (Table A.3.14). Among those who were not interested, most farmers (44.44%) who planted fruit trees mentioned that they lacked time and labour to prepare it while most who planted vegetables and flowers pointed out that they were not sure about its quality (Table A.3.15). The majority of farmers in Bangkok (55.56%) and Nonthaburi (42.42%) who were not interested in it mentioned that they were not sure about the quality while those in Chachoengsao (55.56%) lacked time and labour (Table A.3.16).

Table A.3.13 Distribution of Respondents Interested in Applying Sewage Sludge If Given Free of Charge by Types of Crops

Types of crops	Number of respondents interested in applying sewage sludge if given free of charge							
	Yes		No		Undecided		Total	
	No.	%	No.	%	No.	%	No.	%
Fruit trees	40	46.51	28	32.56	18	20.93	86	100.00
Vegetables and flowers	27	46.55	21	36.21	10	17.24	58	100.00
Field crops	4	57.14	2	28.57	1	14.29	7	100.00
Total	71	47.02	51	33.77	29	19.21	151	100.00

Note: Multiple answers

Table A.3.14 Distribution of Respondents Interested in Applying Sewage Sludge If Given Free of Charge by Provinces

Provinces	Number of respondents interested in applying sewage sludge if given free of charge							
	Yes		No		Undecided		Total	
	No.	%	No.	%	No.	%	No.	%
Bangkok	26	61.91	9	21.43	7	16.67	42	100.00
Nonthaburi	9	22.50	19	47.50	12	30.00	40	100.00
Chachoengsao	20	50.00	14	35.00	6	15.00	40	100.00
Total	55	45.08	42	34.43	25	20.49	122	100.00

Tables A.3.15 Distribution of Respondents with Reasons for Not Applying Sewage Sludge If Given Free of Charge by Types of Crops

Reason for not applying sewage sludge if given free of charge Provinces	Types of Crops							
	Fruit trees		Vegetables and flowers		Fields crops		Total	
	No.	%	No.	%	No.	%	No.	%
No transportation	3	5.56	3	8.11	0	0.00	6	6.38
No time/labour	24	44.44	11	29.73	0	0.00	35	37.23
Not sure about quality	19	35.19	13	35.14	2	66.67	34	36.17
Others	8	14.81	10	27.03	1	33.33	19	20.21
Total	54	100.00	37	100.00	3	100.00	94	100.00

Tables A.3.16 Distribution of Respondents With Reasons for Not Applying Sewage Sludge If Given Free of Charge by Provinces

Reason for not applying sewage sludge if given free of charge Provinces	Provinces							
	Bangkok		Nonthaburi		Chachoengsao		Total	
	No.	%	No.	%	No.	%	No.	%
No transportation	1	5.56	1	3.03	3	11.11	5	6.41
No time/labour	5	27.78	10	30.30	15	55.56	30	38.46
Not sure about quality	10	55.56	14	42.42	6	22.22	30	38.46
Others	2	11.11	8	24.24	3	11.11	13	16.67
Total	18	100.00	33	100.00	27	100.00	78	100.00

7.3.2 Night Soil (NS)

Concerning the use of NS, or human waste, in farming, Table A.3.17 shows that most respondents (more than 70%) did not favour this type of organic fertilizer. Less than 30% of total respondents applied it, and the percentage of Bangkok farmers (28.57%) who applied it was slightly higher than those in the other two provinces (25%). From Table A.3.18, among those who applied NS, it was found that this type of fertilizer was applied more to fruit trees (53.66%). Only one farmer (2.44%) who planted field crops used NS. Though there was no expense for using NS as a fertilizer, it was not favored due to several reasons. The major reason given by most respondents from all provinces was that it was dirty and smelly (Table A.3.19). The Bangkok respondents mentioned that they had better alternative. Respondents in Nonthaburi said that there was a shortage of supply. The Chachoengsao respondents also mentioned about the shortage of supply and the difficulty of the use.

Table A.3.17 Distribution of Respondents Who Applied Human Waste on Their Farms by Provinces

Provinces	Number of respondents who applied human waste on their farms					
	Yes		No		Total	
	No.	%	No.	%	No.	%
Bangkok	12	28.57	30	71.43	42	100.00
Nonthaburi	10	25.00	30	75.00	40	100.00
Chachoengsao	10	25.00	30	75.00	40	100.00
Total	32	26.23	90	73.77	122	100.00

Table A.3.18 Distribution of Respondents Who Applied Human Waste on Their Farms by Types of Crops

Types of crops	Number of respondents who applied human waste on their farms					
	Yes		No		Total	
	No.	%	No.	%	No.	%
Fruit trees	22	53.66	64	58.18	86	56.95
Vegetables and flowers	18	43.90	40	36.36	58	38.41
Field crops	1	2.44	6	5.45	7	4.64
Total	41	100.00	110	100.00	151	100.00

Note: Multiple answers

Table A.3.19 Distribution of Reasons for Not Applying Human Waste by Provinces

Reasons for not applying human waste	Provinces							
	Bangkok		Nonthaburi		Chachoengsao		Total	
	No.	%	No.	%	No.	%	No.	%
Dirty/smelly	17	45.95	15	44.12	18	37.50	50	42.02
Difficult to use	4	10.81	5	14.71	9	18.75	18	15.13
No supply	5	13.51	7	20.59	9	18.75	21	17.65
Have better alternative	10	27.03	3	8.82	8	16.67	21	17.65
Others	1	2.70	4	11.76	4	8.33	9	7.56
Total	37	100.00	34	100.00	48	100.00	119	100.00

8. Conclusion and Recommendation

The average farm size in the survey areas was 8.039 rai per family. More than half of the respondents were small farmers who had less than 5 rai. Fruit trees were the major crop found in the areas. Most farmers used both chemical and organic fertilizers in fruit and vegetable and flower plantations. The amount of chemical fertilizer which was the most widely used was less than 200 kg per rai. Only a few respondents applied human waste in farming.

Most farmers spent more of their agricultural investment on chemical fertilizer more than other types of fertilizer. They also bought compost while NS cost nothing. The price they paid for chemical fertilizer ranged from 5 Bahts to 15 Bahts. The prices of animal waste ranged from 1 Baht -3 Bahts. Suppliers of fertilizers would provide transportation service to farmers.

Regarding the introduction of sewage sludge application, most respondents had never heard about it. When it was introduced to them, it was found out that more than half of the respondents in Bangkok and Chachoengsao were interested in using it because they wanted to try something new and they expected it would lower their agricultural cost. However, the response to the sludge in Nonthaburi was much lower than the other two provinces. The main reasons for not accepting the sludge were that they were not sure about the quality and they lacked knowledge about using it.

The mixed compost sludge was the preferred type indicated by most respondents. The most acceptable price was less than 1 Bahts per kg. The reasons for refusing to use sludge were lack of time and labour and uncertainty about the quality.

NS was not a preferred fertilizer among the Thai farmers due to the cultural bias that it was dirty and smelly. Only a few respondents were found who used it with the fruit trees, and only one farmer used it for field crops.

In conclusion, the introduction of sludge in farming is more welcome in Bangkok and Chachoengsao than in Nonthaburi. The provision of the sludge for free of charge could be launched in Bangkok and Chachoengsao. However, the mixed compost sludge is more interesting to farmers especially those who plant vegetables and flowers. The price of the sludge mixed is strongly recommended at 1 Baht per kg.

To convince farmers to replace the sludge with other types of organic fertilizer, there should be a demonstration programme to promote its use in many areas. Community or village leaders can be influenced to use it so as to promote it among other farmers. Most Thai farmers would follow those who successfully apply some innovation on their farms. Information on quality, types, use, price and sources of sludge should be widely disseminated to farmers along with the demonstration programme.

B. FORECAST RATE OF GROWTH IN INDUSTRIAL WASTEWATER

B. FORECAST RATE OF GROWTH IN INDUSTRIAL WASTEWATER

The 1993 PCD BMR Master Plan investigated the extent of wastewater producing industries in each district to establish industrial wastewater flows in 1990. It assumed that these would increase in proportion with Gross Domestic Product (GDP) which was forecast to be 3.33% pa throughout the period 1990 - 2020.

The 1996 PCD BMR Plan estimates industrial wastewater in the BMA region to be very much less than in that of the 1993 Master Plan (135,900 m^3/d in 2001 compared with 475,980 m^3/d in 2000 or 29%), and to increase at a much lower rate of ((167,410 m^3/d in 2016 / 129,570 m^3/d in 1997)$^{1/19}$ - 1 = 1.4% pa). The earlier Master Plan is considered to be more reliable concerning the base data as there is reference to industrial wastewaters in each district.

GDP has been growing faster than predicted in the 1993 Master Plan. Current available records and forecasts are indicated in Table B.1 and forecast growths for each decade are presented in Table B.2.

The overall growth over the 30 year period is forecast to be 402% equivalent (calculating growth year on year from Table 6.2.4 ie 1.190 x 1.080 x 1.136 x ......x1 .045 - 1) to an average annual growth rate of 5.52% ((4.02 + 1)$^{1/30}$ - 1). This compares with 167% increase forecast in wastewater flow over the 30 year period in the PCD BMR Master Plan at 3.33% pa ((1.0333)^{30} - 1)

It is considered unlikely that industrial wastewater production will increase by as much as GDP in the sector for the following reasons:

- Industries are required to fully treat their own wastes and there should therefore be no need to discharge their effluents to the drainage system if there is a convenient khlong nearby.
- Industries are being encouraged by the government to locate outside the BMA area by tax breaks and duty exemptions.
- Industries are being encouraged to locate in industrial estates with independent wastewater collection and treatment facilities. Existing industrial estates and those currently being developed will provide for 221 factories and four further industrial parks are being planned in the BMA region.
- A higher proportion of new industries are likely to be of a type producing little or no industrial wastewater than the older industries.
- Enforcing wastewater quality standards is likely to result in waste

minimisation including using less water and re-cycling which will produce smaller quantities of wastewater.

Table B.1 GDP Growth Records and Forecasts

Source		Year	Annual GDP Growth (%)
NESDB National Accounting Division - from Records (Manufacturing Sector in Bangkok Province) Growth calculated from Actual GDP		1990-1	19.0
		1991-2	8.0
		1992-3	13.6
		1993-4	4.3
		1994-5	12.7
		1995-6	10.6
		1990-6	81.4 over 6 years = 11.2% pa
NESDB Analysis and Projection Division (National Forecasts Sector)	Short Term Forecasts	1996-7	-0.4
		1997-8	-7.0
		1998-9	+0.5
		1999-2000	2.6
		2000-1	3.5
		2001-2	4.2
		1002-3	4.4
	Long Term Forecasts	2003-6	6.1
		2007-11	6.2
		2012-6	5.0
		2017-20	4.5

Table B.2 Calculated Forecast Growth in Manufacturing GDP

Period	Annual Growth (%)	Growth over Decade (%)
1990-2000	6.1	81.4
2000-2010	5.5	71.1
2010-2020	4.9	61.6

The Study Team have discussed the likely effects of these factors with various Divisions in NESDB concerned with urban planning and industrial policy and the environment, with the pollution control department in MOSTE, and the Department of Industrial Works office at the MOI who are concerned with waste monitoring and Cleaner

Production manufacturing techniques. Although NESDB recognise that these effects will be significant, they have no forecasts concerning the changes in types of industry nor the success of the policy to move industry away from Bangkok or into serviced industrial parks. Nevertheless it is evident that the growth in industrial wastewater is likely to be much less than the 5.52% pa forecast growth in manufacturing GDP.

Another forecasting option would be to assume industrial wastewater would increase in proportion to population. For the proposed new wastewater scheme areas this would amount to 1.65% pa (ie $(3{,}738{,}000 \text{ in } 2020 / 2{,}696{,}000 \text{ in } 2000)^{1/20} - 1$), but a faster rate of growth would be more appropriate in view of the potential for industrial development in the region. A growth rate of half the forecast growth in GDP in the sector or 2.76 % pa (i.e. 5.52% pa/2) would be 67% higher than forecast population growth (ie 2.76/1.65) and this is considered the most appropriate estimate for this Study.

This represents a rather lower quantity of industrial wastewater than forecast industrial water demand by MWA in 2020 based on their planning assumption that non-domestic water will amount to 120 l/c/d. MWA figures indicate that 32% of water supply will be for non-domestic use (120 l/c/d in (256 + 120) l/c/d) compared with 27% derived from the flow and load calculations for the proposed new wastewater scheme areas derived in Table 6.1.3.1 (industrial flow of 247,000 m^3/d plus commercial and institutional flow of 102,300 m^3/d in total of 1,307,100 m^3/d in 2020).

There is reason for MWAs forecasts to have a higher proportion of non-domestic water supply since much of industrial water supply will be treated and discharged independently. It should be noted that all industries within the MWA service area will be obliged to use MWA supplies rather than groundwater due to the damaging effects of subsidence caused by ground water abstraction. The Study Team's forecast industrial wastewater growth are therefore broadly compatible with MWA forecasts.

C. SIZE OF WASTEWATER SERVICE SYSTEMS

C. SIZE OF WASTEWATER SERVICE SYSTEMS

1. Review of Options

1.1 Options Available

The options available range between

- very small pre-fabricated WWTPs for each property
- small community separate sewerage systems and Community WWTPs
- large public wastewater schemes comprising major sewerage and Central WWTPs serving major areas of the city
- very large public wastewater schemes comprising major sewerage and WWTPs such that two or three schemes would serve the whole of the city

1.2 Experience within BMA

BMA has experience of most of these options. Individual large properties such as hotels have individual pre-fabricated "package" WWTPs privately operated, they have inherited small community wastewater services from the National Housing Authority (NHA) serving populations of generally between 2,000 and 20,000 and they are implementing a programme of wastewater schemes serving between 100,000 and 1 million persons. The 1996 PCD BMR Wastewater Management Plan proposes three very large wastewater schemes to serve all future urban areas.

1.3 Management and Operational Control

Each option requires a different management arrangement. Private WWTP facilities need to be managed by the property owners or occupants and operated by themselves or contracted out. They need to be regulated by government institutions both at the design and construction stage to ensure that the WWTP facilities are suitable, and on a regular basis afterwards to ensure that they are being properly operated. In Bangkok, regulations are in place for WWTPs for larger properties and the provision of WWTP facilities is enforced during planning and construction. However, operation performance is not generally monitored.

The larger BMA wastewater schemes implemented in the current programme are planned to be individually managed initially by the project contractors before take over by BMA staff. Each will require a significant permanent staff and independent day to day management. However, there should be some coordinated operational management to share facilities such as expensive maintenance and laboratory equipment.

Very large wastewater schemes such as proposed in the 1996 PCD BMR Wastewater Management Plan could be independently managed.

1.4 Costs of Construction and Operation

Generally, larger public wastewater schemes are found to be more cost effective than smaller schemes, but in Bangkok, the difficulties in acquiring land for WWTP sites and pumping stations may distort this. Trunk sewerage to take wastewaters from a central area to where space is available for a WWTP may increase construction costs significantly.

Very large wastewater schemes can only be implemented in stages. It is important that real environmental benefits are realised by the early component schemes without much additional investment to accommodate the needs of future schemes.

The costs of small private WWTP facilities are difficult to assess because it is difficult to separate building and land costs if the plant is housed in a basement, and power supplies and waste plumbing items. Operational costs are also difficult to assess separately but must be much greater than unit costs for larger WWTPs if the plant is operated properly. The cost of proper treated wastewater quality and sludge disposal monitoring is also a major task and cost for small plants.

2. Evaluation

Major wastewater schemes would appear most appropriate but limited by available investment funds such that the new schemes will realise immediate benefits. This is essentially a continuation of the current programme but with catchment populations of generally between 200,000 and 500,000 above there would be little financial benefit. This in accordance with the 1993 PCD BMR Wastewater Management Master Plan proposals although some smaller areas are proposed due to increases in forecast population. The new wastewater scheme areas proposed should more readily allow for incremental development. The new schemes should allow for adoption into the very large wastewater schemes of the 1996 PCD BMR Plan only where the costs of doing so are small.

D. SELECTION OF TYPE OF SEWERAGE

D. SELECTION OF TYPE OF SEWERAGE

1. Options

The main choice lies between continuing with the interceptor sewerage system adopted in the current wastewater schemes, or the construction of new independent separate foul sewerage systems.

2. Use of Combined Drainage System

The construction cost of an Interceptor Sewers and the continued use of the existing Combined Drainage system is much less than that of installing a completely new Separate Foul Sewers complete with new property connections. However, there are technical constraints.

- The existing drains are generally large with flat gradients. Wastewater generally moves sluggishly through the drains and is often stagnant. It often putrefies causing sewer gas and foul odours in the city through un-sealed manholes.
- The water levels in the khlongs often do not allow the drains to discharge freely and sometimes khlong water flows backs up the drains hindering the flow of wastewater.
- Solids in the wastewater precipitate resulting in deposits in the drains which are difficult to remove increasing the likelihood of flooding.
- Flooding from the drains with polluted with wastewater is more environmentally unsatisfactory and causes risks to public health.

Much of the drainage system is heavily silted which greatly hinders wastewater flow as well as reduces the capacity for carrying storm water. The flat gradients of the drains requires regular and extensive maintenance if they are to be fully effective.

The requirements are properly managed operation and maintenance, in particular:

- comprehensive records of septic tanks including location, size, population served and any special difficulties,
- regular septic tank emptying initiated by BMA rather than the property owner,
- compulsory use of grease traps for restaurant kitchen wastes,
- comprehensive records of the drainage system including detailed plans and condition,
- systematic drainage cleaning programme adjusted to clear particular areas especially prone to silting,

- repairs to the drainage system particularly where damage allows soil to be washed into the drains.

3. Option for Future Upgrading

Interceptor Sewerage may readily be converted for use as part of a new Separate Sewerage system by using them as trunk sewers and installing new secondary sewers and property connections upstream. This upgrading would generally make almost full use of the initial scheme investment.

Conversation to a Separate Sewer system could readily be implemented incrementally and could therefore be carried out in particular sensitive areas where the Combined Drains are found to be particularly unsuitable for wastewater conveyance.

4 Evaluation

In view of the nature of the existing drainage systems, the Separate Sewer system is generally preferred for all new development. However the continued use of the Combined Drains is a much lower cost option and is appropriate subject to

- improvements in the hydraulic operation in sensitive areas to establish effective and consistent flow patters, and continuous falls in drain level,
- subsequent conversion to Separate Sewerage in particular sensitive locations where, despite efforts, the drains fail to convey wastewaters satisfactorily and sewer gas release continues,
- improved maintenance of the drainage system and renovation where necessary,
- improved operation and regulation of septic tanks and use of grease traps.

E. PEAK FLOW FACTOR FOR INTERCEPTOR SEWER DESIGN

E. PEAK FLOW FACTOR FOR INTERCEPTOR SEWER DESIGN

1. Current Practice and Previous Recommendations

Variations in wastewater flow are accommodated by providing capacity for a multiple of average Dry Weather Flow (DWF).

For all the current ongoing schemes, a Peak Flow Factor of 5 x DWF has been selected. This allows a DWF with a BOD concentration of 100 mg/l to be diluted 5 timer to 20 mg/l on discharge to the Khlong. Interceptor Sewer capacities are sized for these flows and the hydraulic design of the Interceptors or Diversion Chambers arranged to control the quantity of wastewater entering the Interceptor Sewer to this amount.

The 1993 PCD BMR Wastewater Management Master Plan proposed a Peak Factor of 3 for interceptor sewers and 2.5 for separate sewerage.

2. Criteria for Determination

The key issues are:

- the need to accommodate the first flush of storm flows which will carry high pollution loads from the sediments deposited in the drains and to limit the pollution load in the overflow,
- the provision of a margin to allow for the poor assessments of flows to each Interceptor Chamber due to the difficulties of identifying sub-catchment boundaries, and poor hydraulic separation in the Interceptor Chambers due to the flat topography which limits hydraulic control,
- the marginal cost of providing additional sewer capacity and limits on available funds for the project.

a) Environmental Considerations

The condition of the khlong waters is described in Section 2.1.5 of the Main Report (Volume II) and Data Book S (Volume IV). All are rated as Class 5 waters, the worst quality, according to the PCD Standards included in Appendix D and there are no specific targets for improvement.

The average measured wastewater quality is about 60 mg BOD/l established in Section 6.1 of the Main Report (Volume II), and the average forecast from the future schemes derived from Table 6.1.3.1 in Section 6.1.3 is 112 mg/l (146.4 t/d in 1306,300 m^3/d). A Peak Flow Factor of 5 would dilute this future wastewater to 22 mg/l under steady state conditions, and to 37 mg/l with a Peak Flow Factor of 3.

An analysis of the hydrological data and BMA drainage design given in Supporting Report F to this Appendix indicates that the typical number of spills per drainage outfall would be 99 per year with a Peak Flow Factor of 5, and that this would increase to 113 per year for a Factor of 3.

The need to divert the first flush of sediment from the drains to the Interceptor Sewer is the main consideration. The storm event data from the survey of the wastewaters in the drains indicates large increases in pollution loads at the beginning of storms as indicated in Section 4.2 of the Main Report (Volume II).

These indicate increases of up to 10 times average BOD loads and up to 80 times average suspended solids loads. However it is more important to divert treatable wastewater BOD to the Interceptor Sewer system than silt deposits and mineralised organic matter.

b) Cost Considerations

The additional costs of providing greater sewer capacity are assessed in Table E.1 This assumes that sewer capacity is approximately proportional to pipe cross section area and determines the savings which would result from smaller pipes if the peak capacity were reduced from 5 x DWF to 4 or 3 x DWF. This indicates that a cost saving of about 4% would be achieved if the Peak Factor were reduced from 5 to 4 x DWF, and 8% if it were reduced from 5 to 3 x DWF. There is a significant increase in cost when the sewer size requires construction by slurry shield tunneling for diameters above 2.5 m as indicated in this table.

Table E.1 Comparative Costs of Sewers for Peak Flow Capacity

5 x DWF			4 x DWF				3 x DWF			
Dia (m)	Cross Section Area (m^2)	Cost (US$/m)	Cross Section Area (m^2)	Dia (m)	Cost (US$/m)	Cost Saving (%)	Cross Section Area (m^2)	Dia (m)	Cost (US$/m)	Cost Saving (%)
0.5	0.20	1710	0.16	0.50	1710	0	0.12	0.40	1640	4
1.0	0.79	2050	0.63	0.90	1980	3	0.47	0.80	1910	7
2.0	3.14	2740	2.51	1.80	2610	5	1.89	1.50	2400	12
3.0	7.07	6370	5.66	2.80	6180	3	4.24	2.30	2950	54

Note:
Unit costs from OECF SAPROF Study for Khlong Toey and Thonburi Wastewater Schemes, 1998
Assume micro-tunnel up to 300 mm dia., slurrey shield pipe jack to 800 mm dia.,
earth pressure balance pipe jack to 2.5 m and slurry shield tuneling for larger sizes.

F. DETERMINATION OF DRAIN OVERFLOW SPILL FREQUENCIES WITH DIFFERENT PEAK FLOW FACTORS

F. DETERMINATION OF DRAIN OVERFLOW SPILL FREQUENCIES WITH DIFFERENT PEAK FLOW FACTORS

1. Approach

Rainfall in Bangkok generally occurs in intense local storms as described in Chapter 2 Section 2.1.3 of the Main Report (Volume II).

Hydrological data and drainage design criteria were investigated to give an indication of the overflow frequencies from the Interceptor Chambers with different Peak Flow Factors. For this purpose a set of typical conditions are assumed as follows:
a medium density residential area
a wastewater flow in the interceptor sewer of 1 x DWF
an assumed combined drain length to the interceptor chamber of 1 km at 1 m/s
the drains are full and have no capacity for storm flow storage

2. Drainage Design

BMA DDS currently design urban drains based on theoretically based rainfall intensity hyetographs. Storm return periods of 5 years are adopted for the main drains and 2 years for subsidiary drains. An appropriate range of run-off coefficients are adopted to suit different land use. BMA DDS are aware that many older parts of the drainage system provide a lesser degree of flood protection.

3. Hydrological Information

Meteorological data is available from Meteorological Department for Bangkok includes

- maximum 15 minute rainfall intensity in each day from Bang Na Meteorological Station
- hourly rainfall intensities in each day from Khlong Toey Meteorological Station
- three hourly rainfall intensities in each day from Khlong Toey Meteorological Station.

Rainfall data was collected for the past three years and the hourly intensity data examined to assess overflow frequencies.

The hyetograph for a 2 year storm return period used by BMA DDS includes 60 mm/h at 1 hour. The rainfall records included 2 storms during the 33 month period when rainfall exceeded this intensity which is consistent with the hyetograph.

4. Calculation

For the typical conditions, the design run-off coefficient is 50%, and the time of concentration 30 min. (10 min for entry plus 1000 m ÷ 1 m/s for time in the drain = 27 min, approx 30 min).

The design hyetograghs show rainfall intensities for 30 min. to be 50% higher than those for 1 hour. It is therefore assumed that actual rainfall intensities for 30 min. will be 50% higher than those for 1 hour.

For the planned and proposed major wastewater schemes are predicted to produce DWFs in service areas as shown in Table F.1 from the forecasts given in Table 6.1.3.1. These are expressed in the same terms as rainfall intensity.

Table F.1 Forecast Wastewater DWF per Unit Area

Scheme	DWF in 2020 (m^3/d x 1000)	Area (km^2)	DWF/Area (m^3/d x 1000/km^2)	DWF/Area (mm/hour)
Khlong Toey West	165.7	25.7	6.45	0.27
Khlong Toey East	154.9	31.9	4.86	0.20
Thonburi North	78.0	11.4	6.84	0.29
Thonburi Central	155.9	17.5	8.90	0.37
Thonburi East	212.7	22.3	9.54	0.40
Bang Sue	126.1	19.7	6.40	0.27
Huay Kwuang	124.2	15.3	8.12	0.34
Wang Thong Lang	141.1	35.7	3.95	0.16
Bung Kum	147.8	42.8	3.45	0.14
Total	1307.1	222.3	5.88	0.25

For the purposes of this exercise the average DWF/unit area is taken as typical.

Table F.2 determines the rainfall intensity that can be accommodated.

Table E.2 Interceptor Sewer Capacity for Storm Flow

Peak Flow Factor (x DWF)	Wastewater DWF/area (mm/h)	Interceptor Sewer Capacity (a) (mm/h)	Remaining Storm Flow Capacity (b) (mm/h)	Equivalent Rainfall at 50% run-off (c) (mm/h)	Equivalent 1 hour Rainfall Intensity (d) (mm/h)
3	0.25	0.75	0.50	1.0	0.7
4	0.25	1.00	0.75	1.5	1.0
5	0.25	1.25	1.00	2.0	1.3

(a) DWF/area x Peak Flow Factor

(b) Sewer capacity - DWF

(c) Storm flow capacity ÷ 50% run-off

(d) 1 hour rainfall = 30 min rainfall ÷ 150%

The 1 hour rainfall intensity data over the period January 1996 - September 1998 gives the following:

- Total no of storms: 412 = 150 per year
- Total no of storms with less than 0.7 mm/h hourly intensity: 103 = 25%
- Total no of storms with less than 1.0 mm/h hourly intensity: 118 = 29%
- Total no of storms with less than 1.3 mm/h hourly intensity: 139 = 34%

Higher intensity storms will result in overflows to the khlongs under these typical circumstances as shown in Table E.3.

Table E.3 Number of Overflow Spills Under Typical Conditions

Peak Flow Factor (x DWF)	Storms contained within sewer (%)	Storms exceeding sewer capacity (%)	Number of overflow spills per year (a)
3	25	75	113
4	29	71	107
5	34	66	99

(a) % storms exceeding sewer capacity x total storms of 150 per year

5 Conclusion

This simple analysis demonstrates that the majority of storms will cause overflows to the khlongs and that the number of spills from the interceptor sewer chamber overflows will be similar for Peak Flow Factors between 3 and 5 x DWF.

G. WASTEWATER TREATMENT REQUIREMENTS

G. WASTEWATER TREATMENT REQUIREMENTS

1. Treatment Capacity

The later BMA ongoing wastewater schemes (Yannawa, Nong Khaem and Ratburana, and Chatuchak) are all to provide

- screening and grit removal (preliminary treatment) of all incoming flows up to 5 x DWF,
- full treatment (biological treatment) of flows up to 1.5 x DWF in the first phase and with provision for increasing this to 2.5 x DWF in the second phase.

Preliminary treatment of all incoming flows is in accordance with international practice.

Full biological treatment should be provided for all wastewater in dry weather. Wastewater flows can generally rise to 2.5 x DWF in medium sized catchments and this might be expected in new proposed wastewater schemes in Bangkok in due course. However, it is likely that lower wastewater flows will be delivered initially and it is appropriate that a smaller full treatment capacity should be provided until such time as there is evidence that the wastewater flows have increased. The initial WWTP should be designed to allow for development in capacity.

2. Extent of Wastewater Treatment

BMA set their own criteria for treated effluent quality from their Central WWTPs. The treated effluent quality standards of the ongoing schemes are described in Table G.1. These require full biological treatment including nitrogen and phosphorous removal but no further treatment. BMA require a better effluent quality from their Central WWTPs than required from industries, large buildings and housing estates as listed in the Laws and Standards on Pollution Control and included in Data Book. The main difference is the need for nutrient removal.

Table G.1 BMA Current Project Treated Wastewater Effluent Quality Standards

Parameter	Average Effluent Quality Standard (mg/l)
BOD	20
Suspended Solids	30
N (total)	10
N (NH_3)	5
P	2
DO	5

The need for biological treatment of all wastewaters is not in question. The options for biological treatment are essentially

- treatment of organic material to a 20/30 standard (20 mg/l BOD and 30 mg/l suspended solids),
- additional nitrification and de-nitrification to remove nitrogen standard of 5 mg/l,
- additional biological or chemical treatment to remove phosphorous typically to a standard of 2 mg/l.

Further (tertiary) treatment may be provided to remove more solids (especially helminths) and BOD, and rapid gravity sand filters are commonly used for this purpose.

Disinfection (usually chlorination, hypo-chloride dosing or ultra-violet treatment) may also be required to remove bacteria.

Nitrification and de-nitrification is a relatively simple addition to most activated sludge processes. Biological phosphorous removal requires more complex plant and sophisticated control, and chemical phosphorous removal is expensive for medium and large WWTPs.

The need for nutrient removal is to avoid eutrophication and high weed growth in the khlongs. Water hyacinth is a key indicator of excessive nutrients and this may be observed at some locations. However, the JICA Feasibility Study on the Purification of Khlong Water in Bangkok, 1989 makes no reference to the need for nutrient removal. Nevertheless a number of international experts have advised BMA on the need for nutrient control and in view of the small flows in the khlongs, the Study Team consider nutrient removal to be desirable. However, the need for skilled and experienced WWTP operators for such plants must be recognized.

Further treatment would be required to remove pathogenic organisms only if the treated effluent were discharged into waters to be used for un-restricted irrigation, recreation or fishery purposes (Class 3 or better), and the Bangkok khlongs cannot be expected to be used for this purpose. Further treatment is not therefore recommended except for treated effluents to be used for particular re-use purposes described in Section 6.5 of the Main Report (Volume II).

If an external regulation authority were empowered to ensure compliance to the standards, it would be appropriate to introduce maximum quality standards in addition to the average standards BMA set for themselves.

3. Sludge Treatment

Wastewater sludges in the ongoing schemes are required to be de-watered to a sludge cake of at least 20% dry solids content. There is no requirement for sludge stabilisation except at Nong Khaem and Chatuchak WWTPs where anaerobic digestion is proposed.

Sludge digestion is discussed in Section 6.2.2 of the Main Report (Volume II).

II. SIZE AND LOCATION OF PROPOSED CENTRAL WASTEWATER TREATMENT PLANT SITES

H. SIZE AND LOCATION OF PROPOSED CENTRL WASTEWATER TREATMENT PLANT SITES

1. Land Requirements

1.1 Existing and Ongoing Scheme Central WWTPs

The present WWTPs are all compact multi-storey plants with treatment processes on several floors. Plant sizes and flows are indicated in Table H.1.

Table H.1 Land Areas for WWTP Sites for Current Schemes

Wastewater Scheme	DWF (1,000 m^3 /d)	WWTP Area / No. of Floors (ha/no)	WWTP Area per DWF (ha/1,000 m^3/d)
Si Phraya	30	0.30 / 4	0.010
Ratanakosin	40	0.64	0.016
Din Daeng	463	2.72 / 2	0.006
Yannawa	360	3.20 / 4	0.009
Nong Khaem	157	8.32 (open)	0.053
Ratburana	130	1.41	0.011
Chatuchak	150	1.12	0.008

1.2 Treatment Process Selection

The main element of the WWTP and the largest componant is the biological treatment plant. For the purposes of this Study, the WWTP plant sizes are based on the use of the Sequential Batch Reactor Activated Sludge Process modified for nutrient removal. This process is considered because it is one of the simpler forms of biological nutrient removal process and is used in the Yannawa WWTP. Further discussion of the treatment process selection and plant sizing is included in Report I. Other forms of biological treatment are available which take less space but these generally cannot remove phosphorous and some are unsuitable for nitrogen removal. If these processes are to be used, phosphorous must be removed chemically by the addition of alum or other readily available additives and, although chemical phosphorous removal is planned for the Nong Khaem and Ratburana WWTPs, biological nutrient removal is recommended by the Study Team for large capacity WWTPs. The main options for more compact biological treatment are the Submerged Biological Aerated Filter process and the Deep Shaft Activated Sludge Process.

Submerged Biological Aerated Filters (SBAF)

This is a very compact process developed for housed WWTPs where there is very limited space available and is now in use at a number of WWTPs in developed countries. SBAF is a fixed film process in which the active bio-mass is held in a medium in an aerated reactor and this avoids the need for clarifiers to continuously separate and re-cycle the activated sludge. Waste activated sludge is periodically removed by taking SBAF units out of commission and back-washing, and the back-wash thickened or co-settled with the wastewater. The process requires primary sedimentation or at least extensive preliminary treatment to safeguard the SBAF media from blockages.

The process may be adapted for nitrification and de-nitrification using a 2-stage process but this takes more space. Phosphorous must be removed chemically in a primary settlement stage.

The process may require as little as 25% of that for a conventional activated sludge treatment plant, but the overall WWTP site would more typically be about 50% of that for a conventional activated sludge plant or as little as 30% in a housed plant without vehicle access between the units..

Deep Shaft Activated Sludge Process

This process has been developed both to save space and to improve aeration efficiency, and is now used at a number of plants in developed countries where the soils are convenient for shaft construction. The Deep Shaft process is a conventional activated sludge plant but with a very deep reactor tank or shaft in which the mixed liquor is continuously rotated around a vertical wall. The arrangement allows better use to be made of the air which is drawn down the shaft with the wastewater flow and breaks into smaller bubbles as it rises and the pressure is reduced. Conventional clarifiers are required to separate and return the activated sludge.

The process may be sized for nitrification and de-nitrification may be achieved using an additional anoxic reactor tank upstream, but phosphorous must be removed chemically.

The process may reduce the biological plant size by about 40% of a conventional activated sludge plant but the overall WWTP site would be more typically 70 to 80% of that for a conventional plant.

1.3 Assessment of Land Required for Future Central WWTPs

Less compact plants than those of the current schemes are preferred if land land can be made available. An assessment of the land requirements for future WWTP sites for the schemes proposed to be implemented during the Master Plan period is indicated in Table H.2. These are based on 0.10 ha per thousand m^3/d DWF for conventional open WWTPs drawn from the Study Team's experience, 0.035 ha per thousand m^3/d DWF for single storey compact plants and 0.021 ha per thousand m^3/d DWF for 2-storey housed plants established from the indicative plant sizing and layouts for the proposed Thonburi South WWTP shown in Figures 6.1.3.2 land 6.1.3.3 in the Main Report (Volume II).

Table H.2 Assessment of Land Required for Future WWTP Sites

Wastewater Scheme	DWF (1,000 m^3/d)	WWTP Site Area required for		
		Conventional Open Plant (ha)	Compact Single Storey Plant (ha)	Housed 2-Storey Plant (ha)
Thonburi South	213	21	7.5	4.5 (3.4 for 3-storey plant
Thonburi Central	156	16	5.5	3.3
Thonburi North	78	8	2.8	1.7
Khlong Toey West	166	17	5.9	3.5
Khlong Toey East	155	16	5.5	3.3
Bang Sue	126	13	4.5	2.7
Huay Kwuang	124	12	4.4	2.6
Wang Thong Lang	141	14	5.0	3.0
Bung Kum	148	15	5.3	3.2

2. Land Acquisition

BMA and other government offices own significant areas of land but these are generally developed and required for other purposes and so unavailable for new WWTPs. Although there is often agricultural or undeveloped land available in suitable locations, BMA have great difficulty in acquiring land for public utility purposes. There are procedures for compulsory land purchase by government offices but these are not currently used by BMA for wastewater projects. The consequences of these difficulties are often:

- very high land purchase costs,
- prolonged land purchase procedures,
- WWTP sites being selected in less suitable locations with consequent higher engineering costs.

Due to these difficulties, the major existing WWTP and those currently under construction are compact multi-storey plants with treatment process units located on a number of floors as indicated in Table H.1.

It is evident from this that land acquisition arrangements should commence well in advance of scheme implementation.

3. Identification of Possible Central WWTP Sites

Ideally sites are required in the centre of the service area, in undeveloped land, adjacent to a suitable khlong for disposal of treated effluent, and with road access. Since the land is generally flat and the major sewers will need to be tunneled, locating WWTPs at the low point in the catchment is not critical. Furthermore, some undeveloped low areas are liable to flooding and should remain undeveloped to provide flood relief storage.

Field inspections were made to identify suitable WWTP locations together with inquiries at BMA and district offices. Sites proposed in the 1993 PCD BMR Wastewater management Master Plan were also considered. The outcome of these investigations are indicated in Table H.3 which also indicates the type and size of plant which may be accommodated. Further investigation will be necessary to establish whether these sites may be acquired.

Table H.3 Possible WWTP Sites for Proposed New Wastewater Schemes

Proposed Wastewater Scheme Area	Proposed WWTP Site Location	Current Use of Site	Area of Site (ha)	WWTP Type and Area (ha)	Present Owners of Site
Thonburi South (Option 1)	N side of Th.Chom Thong 800m. W of Th. Somdet Phra Chao Taksin	Plantation area with few poor houses	3 - 4	3 – Storey Housed (3.4)	District has not identified owners
Thonburi South (Option 2)	At bend of Khl. Chao Khannang by Malee Drinks factory	Plantation area with few poor medium quality houses	5 - 6		
Thonburi Central	Adjacent to Khlong Bangkok Yai and Railway	Plantation area with few timber houses but no road access	Very large, 20 - 50	Open Plant (16)	Many families typically owning 0.1 – 0.5 ha each
Thonburi North (Option 1)	On Th.Phrapin Kloa adjacent to Khlong Bangbumroo	Mostly unused, small open market and a few shacks	10	Single Storey Housed (2.8)	Sinakron Bank (1.2 ha) and several families (6 own 0.9 ha)
Thonburi North (Option 2)	On Th.Phrapin Kloa behind Nitaya Supermarket	New small restaurant but mostly undeveloped	4		Not investigated
Khlong Toey West	Bangkok Port (Livestock Union Commerc.)	Slum housing	11	Single Storey Housed (5.9)	Port Authority

Table II.3 Possible WWTP Sites for Proposed New Wastewater Schemes (cont.)

Proposed Wastewater Scheme Area	Proposed WWTP Site Location	Current Use of Site	Area of Site (ha)	WWTP Type and Area (ha)	Present Owners of Site
Khlong Toey East	Land between Bang Na Expressway and Khlong Bang Na	Agricultural	5	2 - Storey Housed (3.3)	District unable to advise
Bang Sue	On Khl. Lad Yeo by Wat Matchan Tikan	Dense plantation area with poor houses either side	Difficult to assess 2-5	2 - Storey Housed (2.7)	Not investigated
Huay Kwuang (Option 1)	N of Th. Rama IX between Khl. Huay Kwuang and Th. Mitmitree	Agricultural	8	Single Storey Housed (4.4)	TOA Paint Co.
Huay Kwuang (Option 2)	By Thailand Cultural Bentre S of Th. Tiemruamit	Agricultural	40		Osatit family own 6 ha
Wang Thong Lang (Option 1)	N of Th. Piachautit	Agricultural	100 – 200	Single Storey Housed (5.0)	Surasak Meesawan family
Wang Thong Lang (Option 2)	N of Khl. Kacha adjacent to Th. Ram-khambaeng Soi 26	Agricultural	12		Osatanuklor family and Kijserm Thong Co. Ltd
Bung Kum (Option 1)	Between Th. Nungjan, Soi Suka and Th. Daset Varamin	Wooded and undeveloped (recommended by District)	6	Single Storey Housed (5.3)	Dr. Sompriyapat
Bung Kum (Option 2)	N of District office	Agricultural	30		Not investigated

Compact WWTPs are likely to be necessary for all but the Thonburi Central WWTP. Although larger sites can be identified for Huay Kwuang, Wang Thong Lang and Bung Kum in agricultural or undeveloped area, district offices have indicated that these sites will be difficult to obtain, that prices will be very high, and that WWTP sites should therefore be of minimum size.

I. WASTEWATER TREATMENT PLANT PROCESSES

I. WASTEWATER TREATMENT PLANT PROCESSES

1. Selection of Options

The choice of treatment processes in the ongoing projects is proposed by the bidder an approved by BMA during bid evaluation before awarding the contract. The process streams must satisfy the assumed wastewater quality, and the treated wastewater and sludge quality standards specified in the contract. This procedure ensures that the selected processes are cost-effective. This is particularly appropriate in relation to nutrient removal as processes are currently being rapidly developed and bidders will search for the most cost-effective process. Proposals for Central WWTP processes in this Master Plan are therefore provisional.

2. Review of Options

2.1 Preliminary and Primary Treatment

Primary sedimentation is generally not recommended for tropical WWTPs due to high sewage temperatures and consequent gas release and from septic sludge which can lift settled sludge from the tank floor. For this reason it has not been included in the ongoing scheme WWTPs. Preliminary treatment (screening and grit removal) is therefore more important and there are a variety of proprietary plant options for these processes.

2.2 Biological Treatment

Nutrients may be removed by biological or chemical treatment processes. Removal of Nitrogen by nitrification and de-nitrification in the activated sludge process is now commonly practiced but biological removal of phosphorous requires more complex activated sludge processes and careful control. Phosphorous also be removed chemically by adding alum or other readily available chemicals which attach to phosphorous compounds and precipitate.

For large WWTPs biological phosphorous removal is desirable to avoid costly chemicals, but some chemical addition is often required to ensure effluent quality standards are compiled with.

Nutrient removal requires an enhanced Activated Sludge Process (ASP) as phosphorous removal by chemical treatment alone is not usually considered cost-effective for large WWTPs. There are a variety of nutrient removal ASP options. These differ in the configuration of the anoxic and anaeraobic reactor stages and mixed liquor re-cycling necessary for transfer of phosphorous to the sludge. Processes include:

- Bardenpho processes (there are a number of variants)
- UCT (University of Cape Town) process
- A/O and A/O² (Anoxic/Oxidation) processes
- Modified SBR (Sequential Batch Reactor) process
- VIP (Virginia Initiative Plant) process
- PhoStrip (a sidestream chemical process on the return activated sludge)

Of the four ongoing schemes with nutrient removal, the Yannawa Central WWTP includes the proprietary CASS system which is a modified SBR process adapted for nitrogen and phosphorous removal, and the Din Daeng, Nong Khaem and Ratburana Central WWTPs have conventional and VLR (Vertical Loop Reactor) ASPs which require chemical addition for phosphorous removal.

2.3 Sludge Treatment

The sludges are required to be thickened and de-watered to a cake prior to transport from the Central WWTP. Some liming of the sludges may be necessary for odour control of un-digested sludges.

Processes for thickening include:

- Gravity thickeners
- Rotating drum thickeners
- Belt presses
- Dissolved Air Flotation (DAF)
- Centrifuges

Process for sludge de-watering include

- Belt presses
- Centrifuges
- Plate presses
- Vacuum filters
- Sludge drying beds

Belt presses are used on all the current schemes.

3. Provisional Proposals

The following proposals are provisional since process selection will be made from the bidders' proposals and BMA acceptance. This provisional selection takes account of :

- the need for compact processes,

- ease of operation,
- use of similar processes on current schemes,
- procurement and operation costs.

The following process streams include non-process functions for completeness:

- Inlet pumping of full incoming flows
- Coarse screening with bar screens
- Fine screening with drum screens
- Screenings washing and compaction and discharge to skips for trucking from the WWTP
- Grit removal in vortex grit separators
- Grit washing and discharge to skips for trucking from the WWTP
- Flow measurement of all incoming flows
- Storm flow separation and discharge
- Flow division and pumping of full treatment flows to biological treatment units
- SBR ASP basins (combined ASP reactors and clarifiers)
- Flow measurement of full treatment flows
- Cascade discharge of treated effluent for final aeration
- DAF sludge thickeners for waste sludge from the SBR basins
- Sludge pumping to digestion plant if required at the WWTP
- Primary anaerobic sludge digestion if required
- Secondary sludge digestion if required
- Sludge de-watering by belt presses with polymer pre-conditioning
- Powdered lime added to sludge cake for odour control as necessary
- Sludge cake skipped for transport from the WWTP
- Air management and odour treatment for housed plants

The modified SBRASP process has been selected as being one of the simpler processes for biological nutrient removal and because it is already being installed at the Yannawa WWTP.

4. Process Design Parameters

4.1 Preliminary Treatment

Coarse bar screens are generally designed on the basis of the maximum velocity between the bars of 0.9 m/s.

Fine drum screens and vortex grit separators are propriety designed equipment and sizes are taken from manufacturers' catalogues.

4.2 Biological Treatment Plant

Typical F/M ratios for SBR ASP plants designed for nitrification, de-nitrification and phosphorous removal removal without prior primary treatment are 0.08 – 0.10 kg BOD /d per kg MLSS. A value of 0.09 kg/kg/d has been used in the provisional designs. MLSS is typically 2,000 – 3,000 mg/l and a value of 2,500 mg/l has been adopted in the provisional designs. A period of 2 h has been allowed for settling and decanting.

4.3 Sludge Treatment

Sludge treatment design parameters are proposed in Section 7.2.6 in the Main Report (Volume II).