6.2 Plan of Future Night Soil Treatment System

(1) Planning Conditions

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.

(2) Expansion Plan of Night Soil Collection and Treatment System

In 2020, the service area of night soil collection and treatment in BMA will be divided into four (4) service areas: Nong Khaem, On-Nut, Yannawa and Ratburana, as shown in Figure 6.2.1. This division of service areas has been planned in light of the location of NSTPs, their treatment capacity and the served population number of respective district.

The existing NSTPs at Nong Khaem and On-Nut are requested rehabilitated to work under their original capacity of 600 m^3/d to meet the quantities of collected night soil. The combined treatment of night soil in the Yannawa Central WWTP and in the Ratburana Central WWTP, which are in the ongoing and planned status, should be proceeded according to the following time-schedule planned by BMA:

1) Yannawa Central WWTP:
- 500 m^3/d up to 2000,
- 1,000 m^3/d up to 2016,

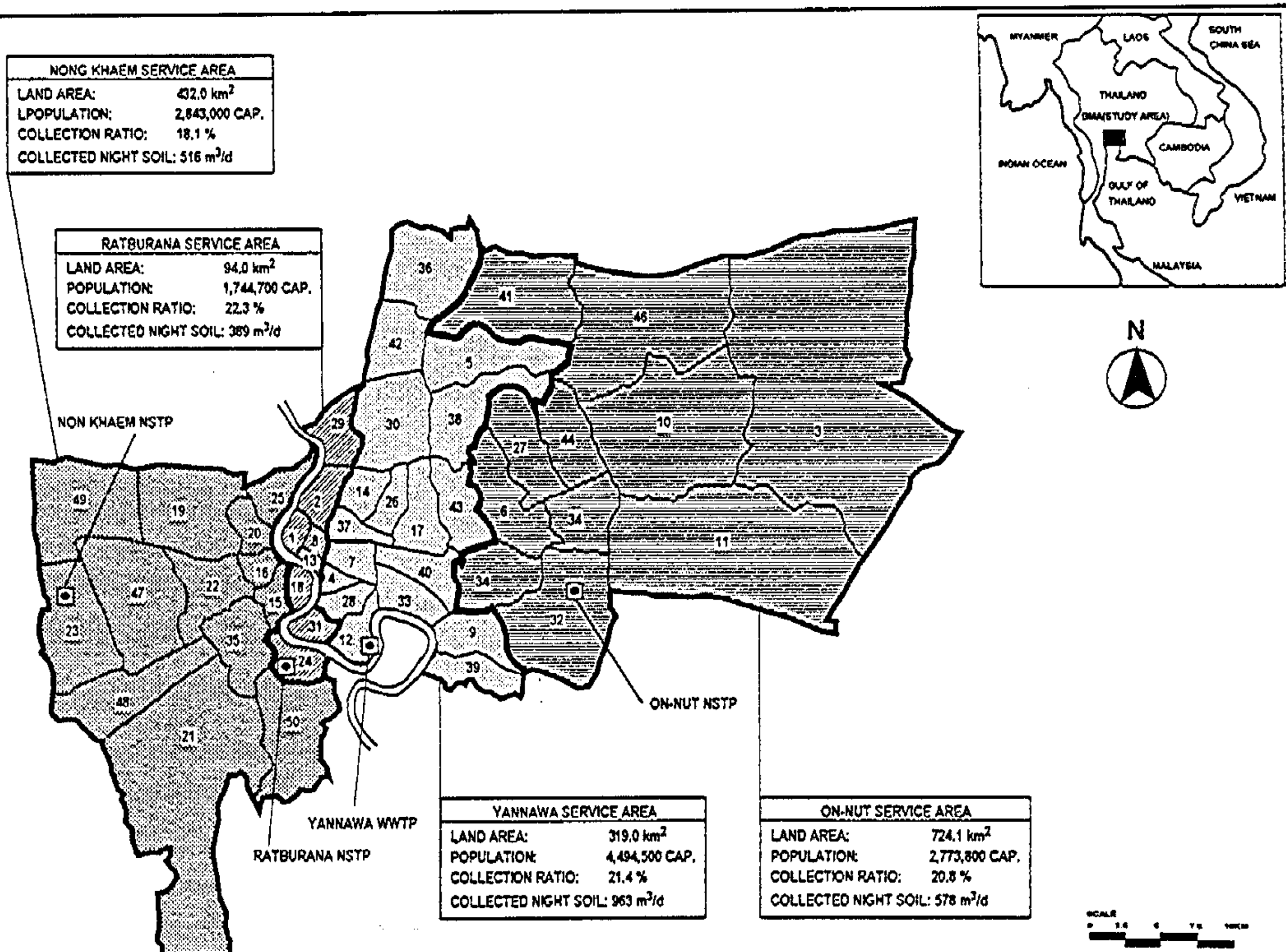
2) Ratburana Central WWTP:
- 260 m^3/d up to 2002,
- 400 m^3/d up to 2016,

6.3 Plan of Reclaimed Wastewater Reuse

(1) Policy for Prioritization

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.

NO	DISTRICT NAME
1	PHRA NAKHRON
2	DUSIT
3	NONG JOK
4	BANG RAK
5	BANG KHEN
6	BANG KAPI
7	PATHUMWAN
8	POM PRAP SATTRU PHAI
9	PHRA KHANONG
10	MIN BURI
11	LAT KRABANG
12	YAN NAWA
13	SAMPHANTHAWONG
14	PHAYA THAI
15	THON BURI
16	BANGKOK YAI
17	HUAY KWUANG
18	KHLONG SAN
19	TALING CHAN
20	BANGKOK NOI
21	BANG KHUN THIAN
22	PHASI CHAROEN
23	NONG KHAEM
24	RAT BURANA
25	BANG PHLAT
26	DIN DAENG
27	BUNG KUM
28	SATHORN
29	BANG SUE
30	CHATUCHAK
31	BANG KHO LAEM
32	PRAWET
33	KHLONG TOEY
34	SUAN LUANG
35	CHOM THONG
36	DON MUANG
37	RATCHATHEWI
38	LAT PHRAO
39	BANG NA
40	VADHANA
41	SAI MAI
42	LAK SI
43	WANG THONG LANG
44	KHANNA YAO
45	SAPHAN SUNG
46	SAM WA
47	BANG KAE
48	BANG BON
49	THAWI WATTANA
50	THUNG KRUE



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

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Figure 6.2.1
EXPANSION PLAN FOR NIGHT SOIL
COLLECTION AND TREATMENT IN 2020

Reuse option 1 is extremely practical, so a plan for reuse is to be created. Options 2 and 3 pose problems in terms of immediate implementation, so a study of their feasibility is to be made. Option 4 is proposed as an option for a case study.

(2) Reclaimed Wastewater Reuse Plan

1) Watering road plants and road cleaning

Public wastewater treatment plants are to be used as a new water source for the work of district offices. The survey revealed that about 30 m^3/d/100 ha (two times per day at night) is used for watering roadside plants and 10 m^3/d/100 ha (once a week in the daytime) is used for road cleaning. The quality of treated wastewater will be improved by sand filter. Target areas will be the 33 districts to which reclaimed wastewater from the 16 existing and planned wastewater treatment plants can be supplied. The volume of reclaimed wastewater to be used from each WWTP will range from 347 m^3/d/WWTP to 2,520 m^3/d/WWTP. The capacity of one reclaimed wastewater package is to be 300 m^3/d and 1 to 8 units will be installed at each WWTP.

2) Miscellaneous Water for Buildings

Target areas are new city development zones near wastewater treatment plants. The new city development zones will be equipped with a dual water supply system to provide separate water for kitchen use and for miscellaneous uses. The reclaimed wastewater will be supplied by pipeline. Sand filters and activated carbon filters will be added to raise the water quality of the reclaimed wastewater so that it can be used for many purposes including flushing toilets, washing cars and watering plants. According to preliminary calculations, reclaimed wastewater could be supplied at about 5 Baht/m^3, and would not be expensive compared to the public water tariff (14 Baht/m^3). The target water quality is proposed at SS 3 mg/l, BOD 5 mg/l, and COD 30 mg/l.

3) Watering Plants (parks, golf courses)

Target areas will be parks and golf courses that are located near WWTPs. Reclaimed wastewater will be supplied by tanker or pipeline. The assumed volume to be used in a park is about 40 m^3/d/ha (in the dry season). Preliminary calculations reveal that tanker transport will cost about 28 Baht/m^3. As this is very expensive compared to the groundwater tariff of 3.5 Baht/m^3, it will be difficult to find users by tanker. The target water quality is SS 6 mg/l or less and BOD 10 mg/l or less.

4) Purification of Khlongs

The 2.3 million m^3/d of treated wastewater can be used as a resource to purify the khlongs. The Khlong Toey East Catchment Area will be taken as a case study to examine the purification effect of treated wastewater in the khlongs. Reuse Plan is shown in Figure 6.3.1. The following two cases are considered:

Case 1: Khlong Pollution due to the load that flows from the sewer pipes when it rains.

In one day, a volume of treated wastewater equal to the volume of the khlongs will be released into the khlongs, pushing the sewage stagnating in the khlongs further downstream. Treated wastewater will be supplied to routes 4 and 6 to improve khlong water quality as follows: 12,300 m^3/d for route 4, and 12,600 m^3/d for route 6.

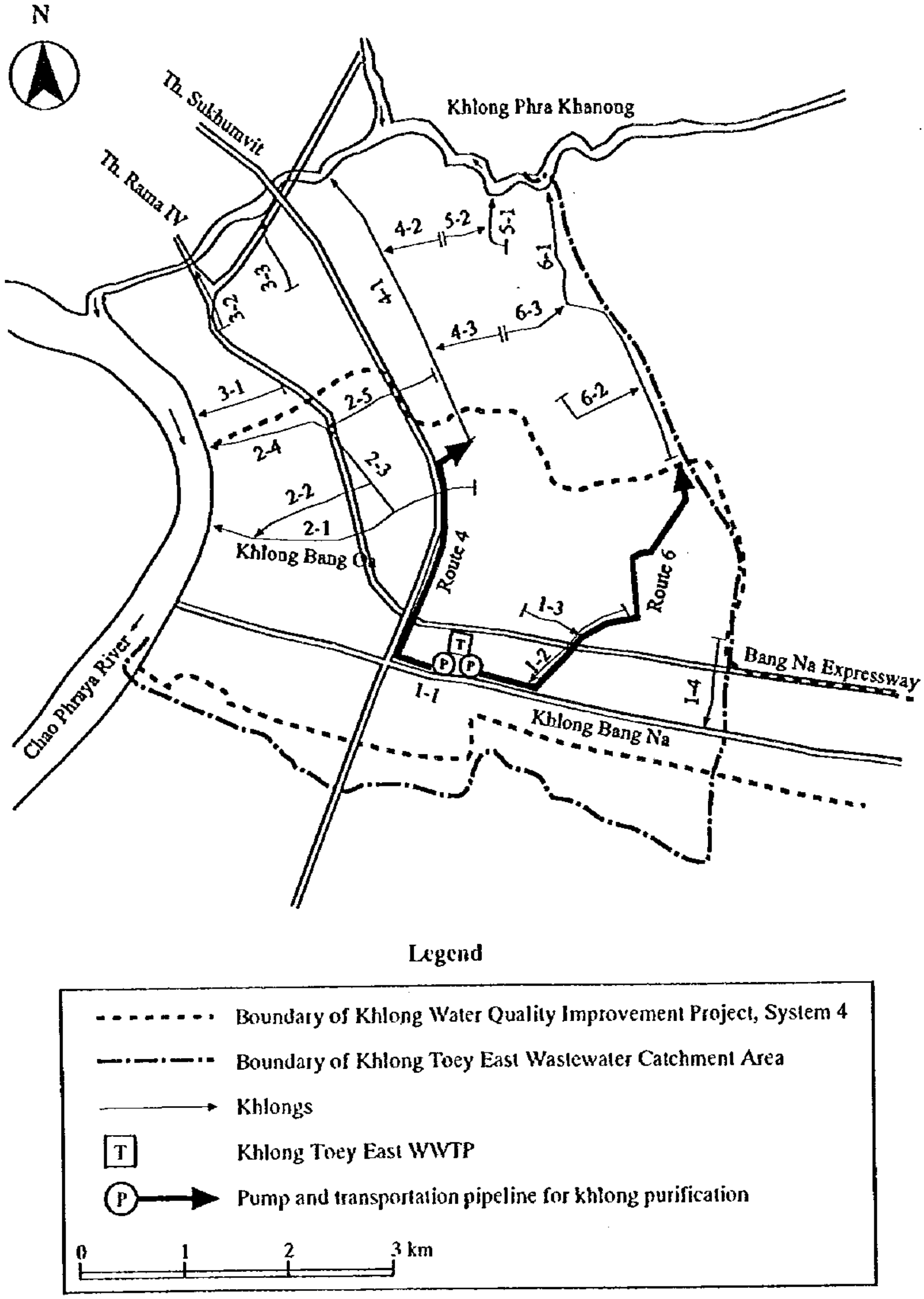
Case 2: Khlong Pollution from a portion of sewage that flows directly into the khlongs (estimated to be about 5 % of the total sewage volume).

The treated wastewater is supplied to dilute the khlong water. At a dilution ratio of 13 times, the khlong water is found to improve to 20 mg/l or less. Treated wastewater will be supplied to routes 4 and 6 as follows: 18,369 m^3/d for route 4, and 18,811 m^3/d for route 6.

In both cases, treated wastewater amounts to about 10 % of the khlong water volume.

(3) Conclusion

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. The following Table 6.3.1 shows the amount of reclaimed wastewater reuse in 2020.



THE STUDY FOR MASTER PLAN ON SEWAGE SLUDE TREATMENT / DISPOSALAND RECLAIMED WASTEWATER REUSE IN BANGKOK	**Figure 6.3.1** RECLAIMED WASTEWATER REUSE PLAN FOR KHLONG PURIFICATION (KHLONG TOEY EAST CATCHMENT AREA)
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 6.3.1 Reclaimed Wastewater Reuse by Each Item (2020)

Potential Demand for Reclaimed Wastewater	Forecast Demand for Reclaimed Wastewater		Drought Mitigation	Environmental Improvement	
				Green Area Expansion	Environ-mental Purification
	(m^3/d)	%	(m^3/d)	(m^3/d)	(m^3/d)
Road Plant Watering	**15,450**	**0.7**	-	15,450	-
Buildings Miscellaneous Water	(22,000)	(1.0)	22,000	-	-
Plant Watering	**3,900**	**0.2**	-	3,900	-
Purification of Khlong	**2,270,150**	**99.1**	-	-	2,270,150
Total	**2,289,500**	**100.0**	-	-	-

CHAPTER 7 DEVELOPMENT PLAN OF SLUDGE TREATMENT/ DISPOSAL

7.1 Frameworks of Sludge Treatment/Disposal Development

(1) Goal and Basic Strategies

The target year for the sludge treatment/disposal development in this Study is set for the year of 2020. The basic strategies to attain the goal of the sludge treatment/disposal development are categorized into:

1) The short-term (to attain within the quarter term of the targeted period):

The development of safe and sound treatment/disposal system to secure the function of sewerage systems, and

2) The long-term (to attain within the target year):

The inauguration and pursuit of "green disposal" and beneficial uses of sludge.

(2) Service Area for Sludge Treatment/Disposal

The sludge treatment/disposal development covers the sludge generated from three sources in BMA: the central wastewater treatment system, the community wastewater treatment system and the night soil treatment system.

(3) Projection for Sludge Generation

1) Sludge from Central WWTPs

The sludge to be derived from Central WWTPs may be classified into biological treatment sludge and phosphorus removal sludge. The sludge generation rate for incoming BOD (R1, kg-DS/kg-BOD) can be calculated by biomass amount after biodegradation and self-digestion and inorganic solid content. The representative value of influent BOD (So) is assumed to be 110 mg/l, which is derived from the evaluation of the influent sewage quality. The sludge generation rate (R1) of 0.58~0.77 is obtained, from the assumed operating conditions of the sewage treatment plant.

The quantity of sludge generated from phosphorus removal is calculated by assuming the dosage of aluminum coagulant is used for phosphorus removal. The sludge consisting of aluminum phosphate 3.9 mg/l per 1 mg-P/l is induced. To calculate the sludge generation, 110 mg/l of BOD used above and some 7 mg/l of phosphorus in representative sewage in BMA, as seen from the design report for the Nong Khaem WWTP, have been taken as representative ones. So that the sludge generation rate (R2) in phosphorus removal process is estimated at 0.25 kg-DS per kg-BOD_{inlet}.

From this discussion, the overall sludge generation rate (R = R1 + R2) in Central WWTPs, has been computed as 0.83~1.02 kg-DS/kg-BOD_{inlet} including both biological and phosphorus treatment sludge. Based on this examination, "1.0" of sludge generation rate (R1) has been adopted for this Study.

Meanwhile, the ongoing Central WWTPs in BMA and previous study has adopted different sludge generation rates (R1) ranging from 0.6 to 1.3 in their designs.

2) Sludge from Small Community Wastewater Treatment Plants

For the Community WWTPs at Huay Kwuang, the sludge generation rate of 36 g-DS/cap/d has been adopted according to its current sludge generation. For other Community WWTPs, 60 g-DS/cap/d has been derived from the AIT Feasibility Study, because the type of WWTPs is a separated-system.

3) Sludge from Night Soil Treatment Plants

The sludge generated from night soil treatment may be regarded as the suspended solid in night soil and surplus sludge, which is generated in biological treatment system for supernatant, containing a small amount of metal hydrate resulting from coagulant. On the average, Suspended Soils (SS) and BOD of collected night soil are seen as 13.4 g/l and 2.7 g/l, respectively, although they are widely varied.

To calculate the night soil sludge generation rate, 1.0 l/c/d of the collected night soil rate is used. In addition, 100 % for the removal of SS and 50 % the biomass generation to BOD_{inlet} has been assumed. The sludge generation rate from night soil treatment is calculated as 14.8 g-DS/cap/d (13.4 + (2.7 x 50/100) = 14.8). Giving 20 % allowance against the large fluctuation in the characteristics of collected night soil, 18 g-DS/cap/d (14.8 x 1.2 = 17.7, say 18) has been derived.

4) Overall Sludge Generation in BMA

The sludge quantities in the planned and proposed schemes of Central WWTPs are calculated by applying the generation rate of 1.0 kg-DS/kg-BOD_{inlet} as examined before. Meanwhile the sludge quantities for the existing and ongoing scheme are based on their design reports. The 30 % reduction in the influent of Central WWTPs has been applied for ongoing, planned, and proposed schemes.

Figure 7.1.1 shows the transition of the sludge generation from 2000 to 2020 of the target year. Total sludge generation will reach 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 WWTPs will account for 83 % of total sludge in BMA in 2020.

The night soil sludge quantity that occupies 42 % at present will decrease to 15 % in 2020. The current Community WWTPs will keep almost constant generation by year, account only for 4 to 7 % of total sludge.

(4) Sludge Characteristics

1) Sludge Solids Contents

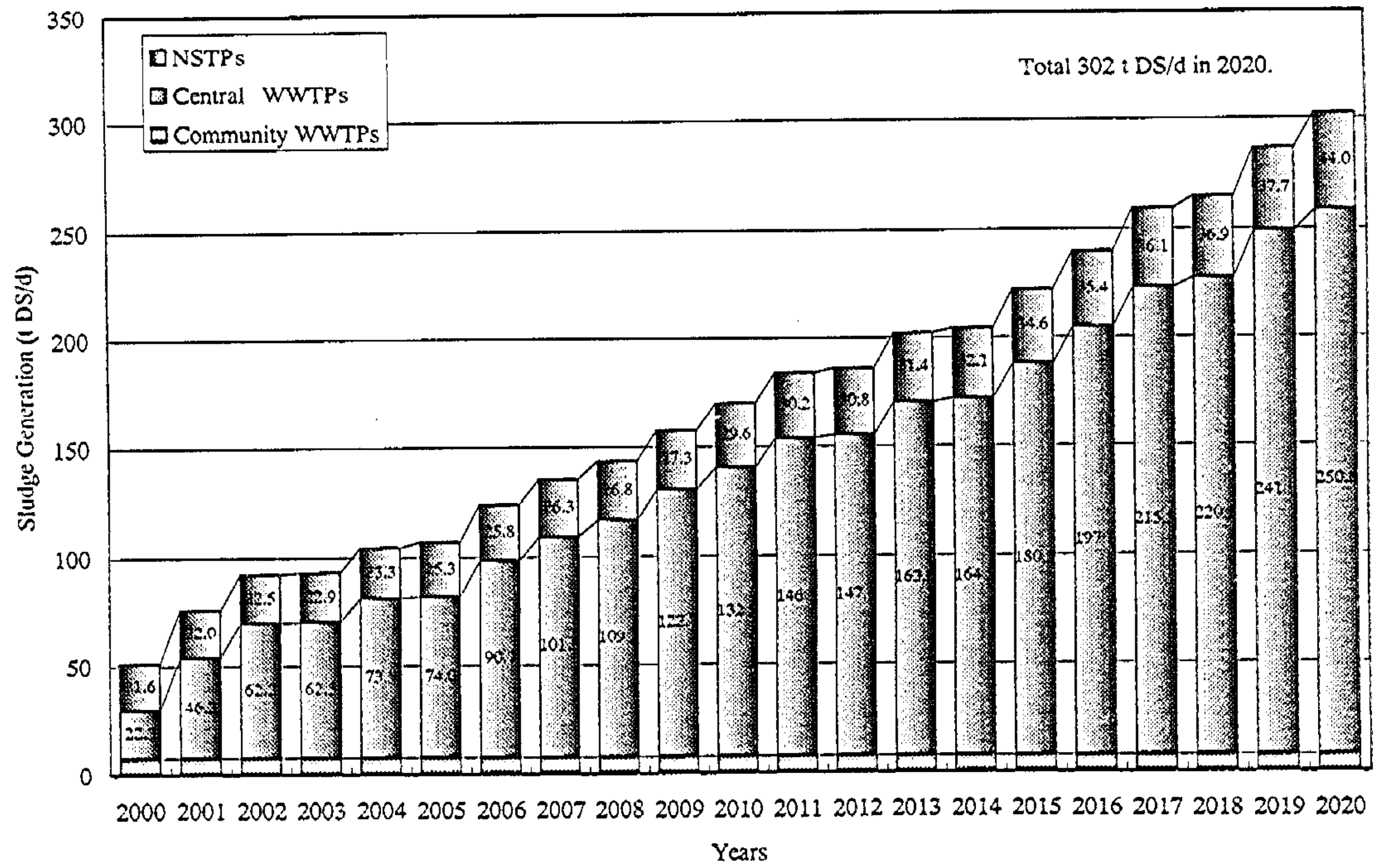
The volatile solids ratio (VS ratio) of the sludge at the Si Phraya WWTP was measured as some 50 %. The VS content of sewage sludge will further be lowered a little in the future in the wake of the sewerage development in BMA, due to aluminum or other metal hydrates sludge to be generated in the phosphorus removal process.

2) Nutrient Elements

The ratio of carbon content to nitrogen content (C/N ratio) and other items show that all the sludges are almost in a suitable range for agricultural use.

3) Heavy Metal Intrusion into Sewage

Mercury (Hg) in all sludge and copper (Cu) in the Si Phraya WWTP are beyond the limits on an average basis specified in the current Japanese Standards. 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 maximum limit set by AIT.



THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 7.1.1 TRANSITION OF SLUDGE GENERATION IN BMA
JAPAN INTERNATIONAL COOPERATION AGENCY	

There is no proper way to define the extent of heavy metal intrusion into sewerage. Nevertheless, this should be assessed in order to examine the future sludge disposal and sludge reuse. The risk evaluation method has been applied to evaluate the likelihood of possible inclusion of heavy metals in the catchment areas concerned.

This assessment has been undertaken using criteria such as the volume of industrial wastewater, the total number of industrial factories, likely loads from polluting industries, toxicity indicators and the future potential growth in this type of industrial sector. The results identified by this methodology, therefore, can only provide an indication of where sludge with the high-risk for heavy metal are likely to be discharged. Out of all industries, factories likely to discharge heavy metal-containing wastewater were extracted. Six most probable heavy metal-generating industries were selected and evaluated as shown in Table 7.1.1.

The service areas were ranked from highest to lowest rank of heavy metal intrusion. The Khlong Toey East service area has the highest risk. These risk ranking are used to decide the destinations for final disposal of sludge in this Study. The actual extent of heavy metal intrusion should be determined by monitoring, prior to and in the implementation stage.

7.2 Basic Scheme of Sludge Treatment/Disposal

(1) Ultimate Sludge Disposal Options

The options for ultimate disposal of sludge may be categorized into those that just dispose the sludge and those that reuse a portion of the sludge for some beneficial use, as follows:

1) Disposal Options

- Landfill disposal, and
- Ocean dumping.

Of disposal options, landfill disposal has been identified as the sole realistic option in BMA.

Table 7.1.1 Risk Evaluation of Heavy Metal Intrusion

Service Areas	Industry Categories												Total Weighting Point	Total Toxic Factory Number	Total Factory Number	Average Weight Point to One Factory	Toxic Factory Ratio to All Factories	Industrial Wastewater Ratio to Total Sewage	Toxicity Point at Present	Toxicity Index at Present	Potential Growth Index of Industrial Sector	Total Toxicity Index	Risk Ranking
	Dyeing		Machinery		Electro-plating		Cosmetic/ Tooth Paste		Battery		Printing												
Relative Rating by Industries	3		3		5		1		1		3												
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(C)= Σ (B)	(D)= Σ (A)	(E)	(F)= (C)/(D)	(G)= (D)/(E) x100	(H) (%)	(I)= (F)x(G) x(H)/100	(J)= 10/16 x(I)	(K)	(L)= (J)x(K)	
Si Phraya	0	0	99	297	4	20	1	1	7	7	4	12	337	115	1,040	2.9	11.1	48	15.6	9.7	2	19.4	8
Ratanakosin	0	0	68	204	44	220	1	1	11	11	7	21	457	131	1,173	3.5	11.2	30	11.7	7.3	3	21.9	6
Din Daeng	2	6	524	1572	12	60	7	7	44	44	43	129	1818	632	5,827	2.9	10.8	16	5.0	3.1	3	9.4	15
Yannawa	2	6	307	921	30	150	16	16	21	21	151	453	1567	527	5,305	3.0	9.9	31	9.2	5.7	3	17.2	9
Nong Khaem	1	3	204	612	30	150	7	7	14	14	81	243	1029	337	3,347	3.1	10.1	25	7.7	4.8	9	43.2	2
Ratburana	5	15	75	225	15	75	4	4	5	5	36	108	432	140	1,884	3.1	7.4	20	4.6	2.9	10	28.7	3
Chatuchak	1	3	148	444	4	20	3	3	17	17	2	6	493	175	902	2.8	19.4	6	3.3	2.0	3	6.1	16
Thonburi South	9	27	298	894	33	165	11	11	18	18	154	462	1577	523	5,726	3.0	9.1	29	8.0	5.0	4	20.0	7
Thonburi Central	4	12	165	495	7	35	2	2	11	11	20	60	615	209	1,927	2.9	10.8	23	7.3	4.6	3	13.8	10
Thonburi North	0	0	95	285	2	10	1	1	8	8	14	42	346	120	857	2.9	14.0	15	6.1	3.8	3	11.4	13
Khlong Toey West	1	3	154	462	1	5	10	10	11	11	22	66	557	199	2,032	2.8	9.8	27	7.4	4.6	6	27.8	4
Khlong Toey East	1	3	236	708	9	45	10	10	12	12	51	153	931	319	2,207	2.9	14.5	22	9.3	5.8	10	58.0	1
Bang Sue	0	0	85	255	3	15	3	3	13	13	4	12	298	108	1,207	2.8	8.9	13	3.2	2.0	5	10.0	14
Huay Kwuang	1	3	105	315	0	0	7	7	4	4	9	27	356	126	681	2.8	18.5	16	8.4	5.2	5	26.1	5
Wang Thong Lang	4	12	187	561	11	55	3	3	12	12	22	66	709	239	1,512	3.0	15.8	8	3.8	2.3	5	11.7	12
Bung Kum	0	0	127	381	1	5	1	1	14	14	4	12	413	147	778	2.8	18.9	8	4.2	2.7	5	13.3	11

Notes:

1) (A): Numbers of factories

2) (B): Weighting points, = (A) x (Relative Rating by Industries)

3) (H): Industrial wastewater amount to total wastewater amount derived from PCD Master Plan for the existing and ongoing projects and from Table 6.1.2 for proposed schemes.

4) (K): Estimated based on Land Use Plan for the target year of 2017.

Source: JICA Study Team

2) Beneficial Uses Options

In beneficial use options, certain substances in sludge like inorganic matters, organic matters, as well as nutrient elements are utilized for specific purposes.

- Organic fertilizer,
- Construction materials,
- Recovery of digestion gas, and
- Fuel in co-incineration.

Of them, the beneficial uses for construction material and fuel in co-incineration appear not to be realistic at the early development stage in BMA.

(2) Prioritized Ultimate Disposal Options

In the broader classification of disposal, the time-wise priority for sludge disposal may be concluded as follows:

1) In the short-term:

- To establish safe and sound landfill disposal, using the existing landfill sites at present,
- On the other side, to promote agricultural uses of as much sludge as possible in line with market demand of sludge compost, and
- To establish the recovery of digestion gas.

2) In the long-term:

- To progress the landfill more carefully in natural environment and human health,
- To continue and expand the effort for agricultural uses, and
- To promote maximum volume reduction and a various kind of beneficial uses, accompanied by technology research and development activities.

(3) Landfill Disposal Scheme

1) Prospect of Landfill Sites

Within or adjacent to BMA, there are several existing sites for landfill disposal in Kampangsaen, Lad Krabang, and Samuk Prakarn. Of them, Kampansaen in Nakhon Pathom Province being used mainly for municipal solid waste (MSW) is the most promising site having landfill capacity of some 38 million m^3. The sludge generated in BMA will be disposed here in the mode of "Co-Landfilling" with MSW. Given other existing and planned landfill sites besides this, this landfill capacity for BMA doesn't appear to be a shortage of within the target year of 2020.

2) Standards and Regulations of Landfill Disposal

In Japan, the sludge generated from public sewage treatment is handled with special care, almost equally to the industrial waste, since it possibly contains some hazardous substances. Accordingly, the sludge for landfilling is regulated to meet the following input requirements:

- To be dehydrated less than 85 % moisture, or to be incinerated less than 15 % ignition loss,
- To not contain hazardous substances like heavy metals and toxic solvents beyond the limits measured by the extraction examination using normal water.

If sludge contains hazardous substances, it is mandated to be treated so that they are less than the standard values, by using a proper method like cement solidification, incineration, pyrolysis, etc. Otherwise, sludge, is regulated to be disposed of in a strictly controlled type of landfill, which is perfectly isolated from the outside.

The normal sludge can be disposed in accordance with specified manners in controlled-type of landfill site, which is equipped with adequate storage structures, leachate seepage, leachate collection and treatment systems, water quality monitoring system, disaster-proof facilities, etc. The technical standard for inland landfilling specifies a 3.0 m layer depth for digested dehydrated sludge and 0.5 m layer depth for undigested dehydrated sludge.

In BMA, the landfilling input quality standard for sludge generated from sewerage system has not been established yet now, while the concerned bodies reportedly are starting the preparation works. Practical countermeasure for landfill disposal has not been established yet. Thus, BMA has not been prepared well to cope with increasing sludge generation at present, with respect to the provision of standards and regulations for landfill activities of sludge.

3) Sludge Properties Required for Landfill Disposal

Standards and regulations, which specify the qualities of landfill 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".

(4) Agricultural Use Scheme

1) Prospect of Agricultural Use

Experience in developed countries has indicated that one of the most ideal and promising options of sludge beneficial uses is the utilization as an organic fertilizer or a soil conditioner for agricultural lands. The term "Agricultural Uses" in this Study incorporates all kinds of application as fertilizer or soil conditioner in relation to agriculture, gardening, forestry, planting in park as well as turf-keeping in golf courses.

The sludge compost demand and marketing survey carried out by the Study Team revealed that the present daily demand for sludge compost at 600 t DS/day is two times larger than the projected sludge generation at about 300 t DS/day as of 2020.

2) Standards and Regulations of Agricultural Use

In Japan, in almost all cases, sludge is used for agriculture in the form of sludge compost, after properly treated in a composting process. Basically, such compost fertilizer is required to have certain qualities for the following items:

- Toxic substances like heavy metals,
- General properties like C/N ratio, organic matters, and

Moreover, management standards were set to protect the accumulation of heavy metals in the soil.

In the United States, the regulations implemented by the US Environmental Protection Agency (US-EPA) set the criteria for sludge quality and outline management practices that must be observed in land application of sludge. It also creates two classes with respect to pathogen reduction: Class A and Class B.

3) AIT Study in BMA

For the sludge generated in BMA, AIT had performed an extensive study to determine the feasibility of agricultural use of sludge, including the application experiment for grass, flowers, ornamental plants, and vegetables. From the Study standards for the application of sludge as well as monitoring in BMA were proposed.

4) Current Status and Issues in BMA

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. The standards and regulations should be established considering local requirements, conditions, and customs.

5) Sludge Properties Required for Agricultural Use

There are four possible forms of sludge that can be used for fertilizer: composted sludge, dried sludge, dewatered sludge, and incinerated sludge. To compare the four forms of sludge as fertilizer, the following items were evaluated: fertilizer value, handling and storage performance, production cost, and the influence to environment and human health. Based on a weighted point comparison, the composted sludge for sludge fertilizer is proposed as the best suitable sludge form in BMA.

(5) Conceptualization of Ultimate Sludge Disposal

To set out the ultimate sludge disposal scheme, a number of assumptions have been made:

1) Heavy metal contents:

It has been assumed that the sludge in the higher risk ranked service areas of more than or equal to the middle place (8th place: the Si Phraya Central WWTP) is regarded as the "High-Risk Sludge", which cannot be used for sludge fertilizer, and the sludge generated from the lower risk ranked service areas of less than the middle place is regarded as the "Low-Risk Sludge", which can be used for sludge fertilizer. Under this assumption, total amount of the high-risk sludge reaches 114 t DS/d in 2020, which is roughly equivalent to the design treatment capacity of 120 t DS at the Nong-Khaem Sludge Treatment Central (STC). Certain standards and regulations, which regulates the input quality of sludge for heavy metals for landfill disposal, are assumed to become effective after 2010 to promote environmentally friendly landfill.

2) Sales amount of sludge fertilizer:

Even though a large market demand for sludge fertilizer in and around BMA has been identified, the actual amount of sales in the future may be uncertain. It basically depends on the market principal of "Supply" and "Demand". However, to determine a disposal scheme in this Study, two cases were assumed: all of the low-risk sludge is consumed in the market, and; half of the low-risk sludge is consumed.

Under these assumptions, the following three scenarios of ultimate sludge disposal are presented, as shown in Table 7.2.1.

Table 7.2.1 Scenario for Ultimate Sludge Disposal in BMA

Scenario	Risk Categories for Heavy Metal		Remarks
	Low-Risk Sludge	High-Risk Sludge	
Scenario 1 (Full Agriculture Use)	All the sludges are used for organic fertilizer after composting.	All the sludges are disposed to the landfill site after dewatering.	
Scenario 2 (Incineration Introduction)	All the sludges are used for organic fertilizer after composting.	Up to 2009: All the sludges are disposed to the landfill site after dewatering. After 2010: 75 % of sludge are disposed to the landfill site after dewatering. The rest (25 %) is incinerated.	The incineration of sludge is assumed to be called for the period afterward 2010, under the following situations: A: Regulations or standards for the landfill disposal of heavy-metal-containing sludge are applied, B: Maximum volume reduction and beneficial uses of are needed.
Scenario 3 (50 % Agricultural Use)	50 % of sludge is used for organic fertilizer after composting. The rest (50 %) of sludge is disposed to the landfill site after dewatering.	All the sludge are disposed to the landfill site after dewatering.	The selling of sludge compost is limited to 50 % of the generation quantity of usable sludge.

- Scenario 1: (Full agricultural use)
  All the low-risk sludge will be consumed for sludge fertilizer.

- Scenario 2: (Incineration introduction)
  Incineration is introduced after 2010 for 25 % of high-risk sludge.

- Scenario 3: (50 % agricultural use)
  Half (50 %) of the sludge regarded as low-risk will be consumed for sludge fertilizer.

In these three scenario, it should be noted that:

- The share of the high-risk sludge amount (some 38 % in 2020) is tentatively adopted, based on the result of risk evaluation as previously mentioned. This percentage can be lowered by taking proper countermeasures to prevent heavy metal intrusion into sewerage,

- The actual portion of marketable sludge fertilizer is highly flexible by nature, depending on conditions like: the qualities and price of sludge fertilizer product, related technical and commercial promotions, etc.

The mass balances for these three scenarios are shown in Figure 7.2.1.

(6) Sludge Treatment Scheme

1) Selection of Sludge Treatment Process

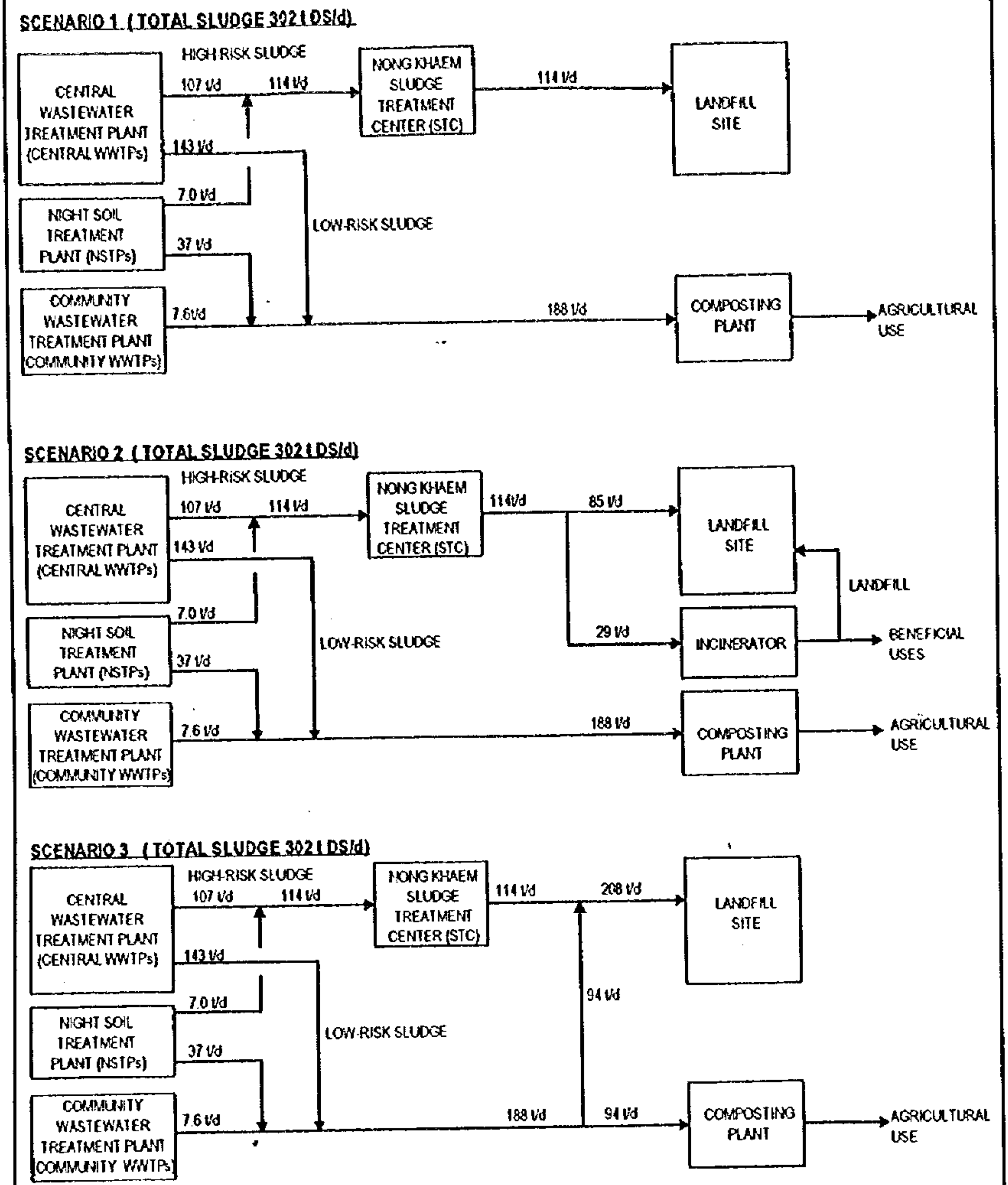
The required sludge properties in the respective ultimate disposal schemes are:

- Landfill disposal scheme: to be dewatered or incinerated,
- Agricultural use scheme: to be composted.

Figure 7.2.2 shows a total of six options of possible sludge treatment process for the both landfill disposal (named by "L" of the first letter) and agricultural use (named by "A" of the first letter), incorporating digestion and incineration process. To make the comparison between respective options, provisional sludge treatment facilities with the capacity of 20 t DS/d (2,000 m^3/d as 1 % slurry) has been assumed. These options have been compared economically by estimating relevant treatment costs including facilities construction, operation and maintenance cost, and recovering cost. The results are summarized in Table 7.2.2.

From the cost comparison, the following optimum processes were selected:

- Option L2 for landfill disposal:
- Option L1 for the introduction of incineration in the future:
- Option A2 for agricultural use:



Note :

1) The values of sludge flow are based on the generated sludge, without accounting the Dry Solids reduction in digestion and incineration.

2) The unit : Tonne Dry Sludge.

THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 7.2.1 SLUDGE MASS FLOW BALANCE IN BMA IN 2020
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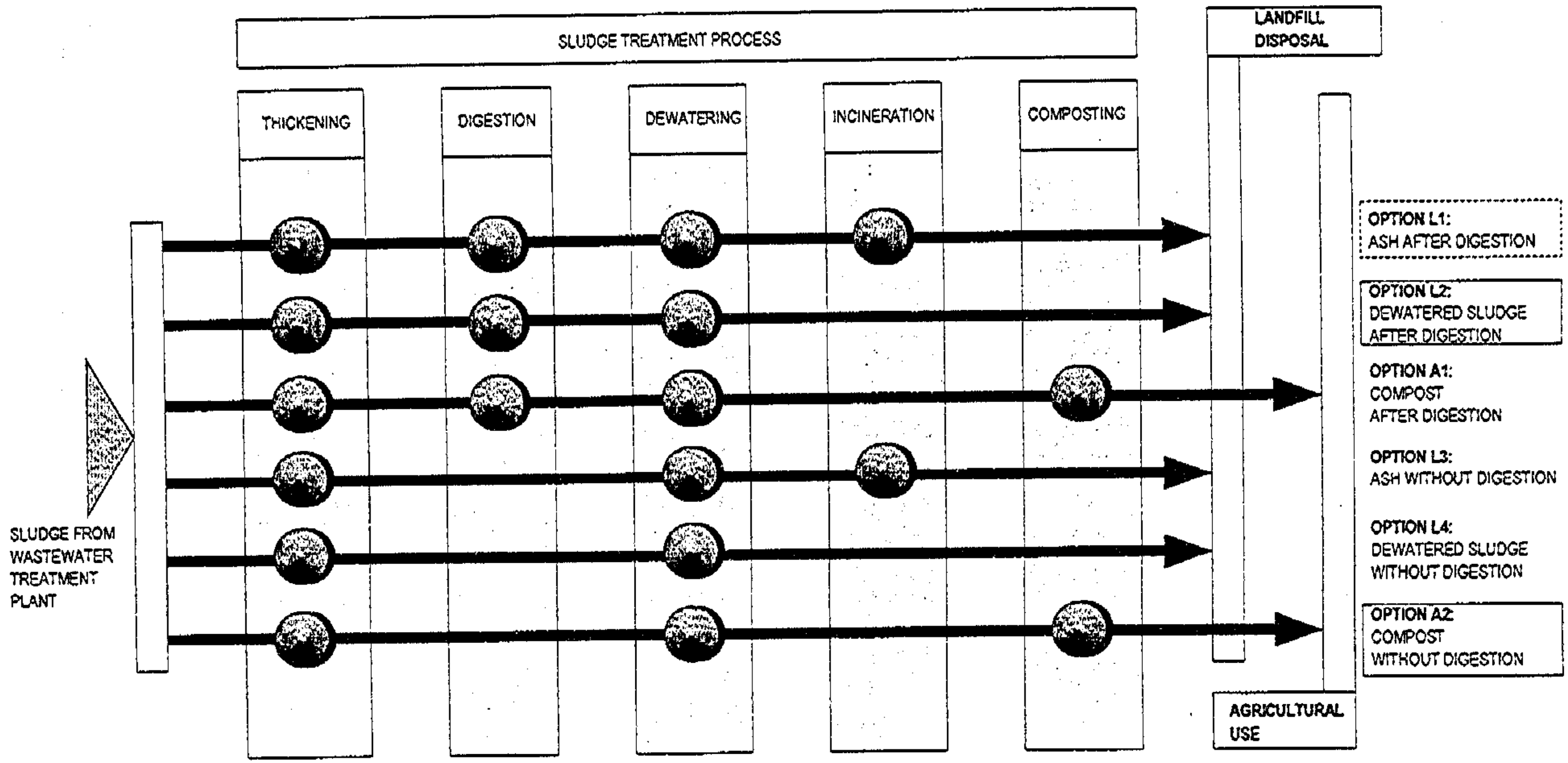


NOTE: THE SELECTED ALTERNATIVES ARE MARKED BY THE BOX ☐.

THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 7.2.2 OPTIONS OF SLUDGE TREATMENT PROCESS
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 7.2.2 Cost Comparison between Sludge Treatment Process Options

Options		Total treatment expenses (US$/d)	Ratio
Option L1	Landfill of ash: after Digestion and Incineration	8,500	100
Option L2	Landfill of dewatered sludge: after Digestion	3,120	37
Option L3	Landfill of ash: after Incineration	9,965	117
Option L4	Landfill of dewatered sludge: Neither digestion nor incineration	3,540	42
Option A1	Agricultural use of compost: after Digestion	1,843	22
Option A2	Agricultural use of compost: No digestion	430	5.1

Note: The total treatment expenses include construction, O & M and the recovering cost in each treatment step.

2) Unit Process Selection of Sludge Treatment

Diverse unit process like thickening, digestion, dewatering, incineration and composting are being used in sludge treatment. Different types of unit processes, which are widely prevalent in many countries, have been compared to select the most suitable one for BMA.

A relative weighting point method has been applied for the evaluation of each type, by using the following parameters, which are assessed by the raw point of 1 (inferior) to 5 (superior) by subjective types:

- General Performance reliability (relative weight rating: 6)
- Suitability for sludge properties in BMA (relative weight rating: 5)
- Easiness of operation and maintenance (relative weight rating: 4)
- Cost performance (relative weight rating: 3)
- Space requirement (relative weight rating: 2)

The most suitable ones for BMA in respective unit processes for sludge treatment are:

- Floatation thickener for thickening,
- Mesophilic digester for digestion,
- Belt-press dehydrator for dewatering,
- Multiple hearth or fluidized bed incinerator for incineration, and
- Horizontal fermenter for composting.

These conclusions, however, should be regarded as an exemplary direction, which is induced based on general conditions in BMA. It is highly recommended that the actual selection of unit processes take place on the basis of substantial and specific conditions and requirements of respective schemes.

(7) Sludge Transportation

The important requisites for sludge transportation is to transfer sludge effectively, economically and in a manner that is friendly to the environment. So, the emission of offensive odor is likely to be a serious concern in BMA. The emission of offensive odor can be solved to a certain level by adequate operation of the sewage treatment plant. Such expensive countermeasure as lime dosing or application of odor proof agent should be taken, unless contrivance measures in usual operation are effective.

Sludge in the form of liquid or solid-like cake is transported by different ways like: truck transportation, pipeline pumping, and barge transportation and railroad transportation.

7.3 Sludge Treatment Plan for Landfill Disposal

(1) General

Of sludge generated from BMA, the sludge assumed as the high-risk for heavy metal intrusion is ultimately disposed off for the landfill site. The sludge generated from the Central WWTPs up to the 8th place risk ranking is tentatively regarded as the high-risk sludge:

Meanwhile, the optimum sludge treatment process for landfill disposal thereof has been clarified as:

(Raw sludge) - [Thickening] - [Digestion] - [Dewatering] ----------------(Landfill)

In reality, on the other hand, the Sludge Treatment Center (STC) at Nong Khaem has already been ongoing toward the completion of 2001. Because this is equipped with the digestion process, which is essential for the optimum sludge treatment process for landfill disposal, all the high-risk sludges are assumed to be transported and treated at the Nong Khaem STC.

In Scenario 1 of sludge disposal, all the high-risk sludges are assumed to be disposed to landfill site after dewatered. In Scenario 2, the sludge equivalent to 25 % of the high-risk sludge is assumed to be incinerated after dewatered for the purpose of the countermeasure for the possible stringent landfill standards, the need of maximum volume reduction or possible beneficial uses of ash. In Scenario 3, 50 % of the low-risk sludge is assumed to be disposed to landfill site, after dewatered.

(2) Planning Conditions

According to the preliminary design, the sludge transportation to the Nong Khaem STC is planned by trucks after dewatering at respective Central WWTPs. The sludge treatment facilities for landfill disposal, therefore, are separately installed in respective Central WWTPs as well as in the Nong Khaem STC. The planning conditions thereof are summarized as follows:

- Sludge quantity in 2020:
  - Sludge form Central WWTPs: Total 11,400 m^3/d (as 99 % moisture content), (114 t DS/d)
  - Inlet sludge to incinerator: 120 t/d (as 80 % moisture content) (equivalent to 25 % of dewatered sludge after 2010 in Scenario 2)
- Sludge composition: VS 43 to 48 %
- Process performance:
  - VS removal in digestion: 50 %
  - Dewatered sludge moisture content: 80 %
  - Digestion gas generation: 0.6 Nm^3/kg-Removed VS
  - Generated heat: 5,000 kcal/Nm^3
  - Gas engine efficiency: 35 %
  - Power generation efficiency: 95 %

(3) Sludge Treatment Facilities at Central WWTPs

Employing floatation thickeners and belt press filters, sludge is treated to form a sludge cake. The following design parameters has been applied to determine their main dimensions:

- 130 kg-DS/m^2/d of surface loading for a floatation thickener, and
- 150 kg-DS/m/h of filtration rate for a belt-press filter.

(4) Nong Khaem Sludge Treatment Center (STC)

1) Main Specifications

The preliminary design has delineated the following outline of the ongoing Nong Khaem STC:

- Inlet sludge quantities: Total 120 t DS/d : 80 % moisture content, VS ratio 53 % (The sludge from the Nong Khaem Central WWTP is in the state of slurry)
- Slurry preparation system:
  - Sludge holding tank: Total 324 m^3
  - Gravity belt thickener: 2 units

- Sludge cake holding tank: Total 15,000 m^3
- Sludge mixing tank: Total 46 m^3

- Anaerobic digester: Total 45,000 m^3 (2 units)
- Belt press filter: 2.5m Width x 5 units
- Boiler and heat exchanger: Total 4,000 kW

High-risk sludge of total 114 t DS/d (in 2020) will be treated in these facilities. Figure 7.3.1 shows the flow diagram of the Nong Khaem STC based on the preliminary design, adding the incinerator being planned after 2010 and the digestion gas recovery system.

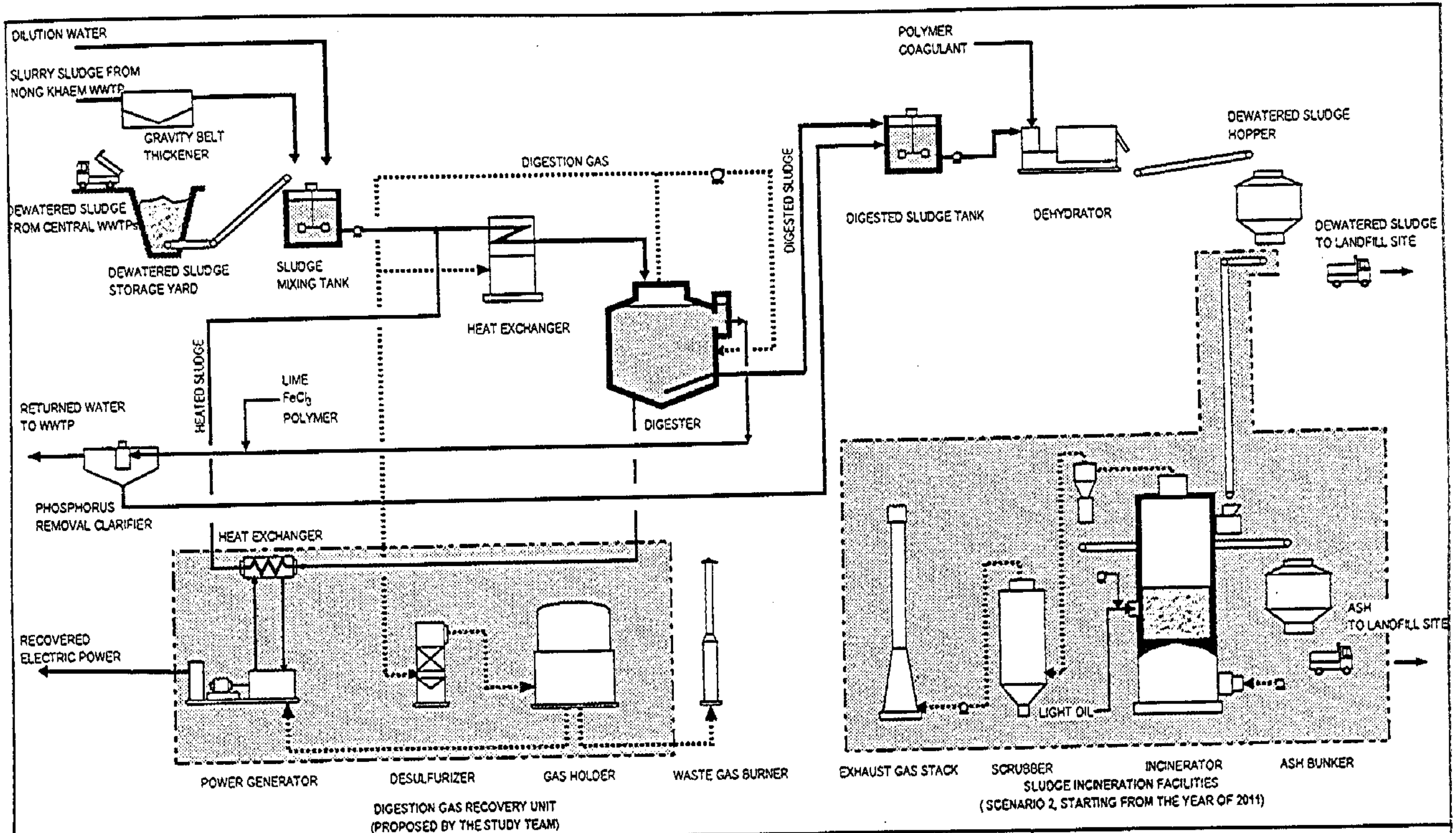
2) Sludge Transportation Alternatives

Although the Nong Khaem STC Scheme has already adopted truck haulage for transporting sludge from respective Central WWTPs, pipeline pumping may be seen as the alternative for sludge transportation.

a) Alternative T1: Truck Transportation (ongoing scheme)
(Raw Sludge)-[Thickening]-[Dewatering]-Truck Transp.--[Nong Khaem STC]

b) Alternative T2: Pipeline Transportation
(Raw Sludge) - Pipeline Transp. ----------------------------[Nong Khaem STC]

The daily expense of the pipeline transportation alternative is 87 % of that of truck transportation.



NOTE: THIS FIGURE SHOWS THE PRELIMINARY DESIGN OF THE FLOW DIAGRAM BEING PLANNED BY BMA AT PRESENT, EXCEPT FOR THE PART OF DIGESTION GAS RECOVERY AND INCINERATION.

THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	**Figure 7.3.1 FLOW DIAGRAM OF NONG KHAEM STC**
JAPAN INTERNATIONAL COOPERATION AGENCY	

It should be noted that the pipeline transportation needs more precise study on the cost effectiveness regarding dehydration and construction cost for the Chao Phraya River crossing. Because its fundamental scheme has been already endorsed by BMA, sludge transportation by trucks in the Nong Khaem Project appears to be going ahead at the moment. However, the pipeline transportation should be studied in detail in the future amendment.

(5) Power Generation by Digestion Gas

The Study Team recommends that the following facilities for generating power from the digestion gas be installed from the economical point of view:

- Digestion gas generation: 16,100 Nm^3/d (in 2020)
- Gas holder: 8,000 m^3 x 2 units
- Gas engine output: 1,370 kW (in 2020)
- Generated power: 700 kW x 2 units (in 2020)
- Power output: 1,300 kW

During power generation, the exhaust heat will be used to heat raw sludge prior to the digesters.

(6) Sludge Incineration

In Scenario 2 of sludge disposal, 25 % of the treated sludge at the Nong Khaem STC is incinerated assuming a fluidized-bed type incinerator is used, which is utilized widely throughout the worlds. The characteristics of the sludge incinerator are delineated as follows:

- Fluidized-bed furnace: 2 units
  Capacity 60 t Dewatered Sludge/d x 2 units
  Combustion temperature 700 to 900 °C
- Auxiliary facilities: Sludge feed equipment,
  Auxiliary combustion equipment,
  Fuel supply equipment,
  Ash storage hopper,
  Exhaust gas treatment equipment.

(7) Landfill Disposal Facilities

BMA should be provided with regulations for adequate input condition of sludge containing toxic substances, and standards to ensure proper disposal of sludge to landfill site.

Because the landfill site in BMA likely deals with not only sludge but also MSW, safe structure and practices against both solid waste and sludge should be furnished. At least, sludge should be disposed separated layers with proper depth using cover soil, since it contains a large portion of water and organic matters. The landfill disposal for sludge, also, should be well equipped with the proper facilities so as to prevent the possible negative impact on the environment and human-health.

7.4 Sludge Treatment Plan for Agriculture Use

(1) General

Of sludge generated from BMA, the sludge assumed as low-risk for heavy metal intrusion is used as organic fertilizer for agricultural use in the vicinities of BMA. The sludge generated from the Central WWTPs with risk ranking of 9th or beyond is tentatively regarded as the low-risk sludge:

The optimum treatment process of the sludge for agricultural use is:

(Raw sludge) - [Thickening] - [Dewatering] - [Composting]----(Organic fertilizer)

In Scenario 1 and 2 of sludge disposal, all the low-risk sludge are assumed to be used as organic fertilizer for agricultural use. In Scenario 3, on the other hand, 50 % of the low-risk sludge is assumed to be marketed as organic fertilizer and the rest disposed of to landfill site after dewatered.

(2) Planning Conditions

The planning conditions for the treatment facilities for the low-risk sludge are summarized as follows:

- Sludge quantity in 2020
  - Generated sludge form Central WWTPs: Total 14,300 m^3/d (as 99 % moisture content)
  - Generated sludge from NSTPs: Total 185 t/d (as 80 % moisture content)
  - Generated sludge from Community WWTPs: Total 36.5 t/d (as 80 % moisture content)
- Sludge composition: VS 50 to 60 %
- Process performance:
  - Dewatered sludge moisture content: 80 %
  - VS reduction at composting content: 50 %
  - Water evaporation: 50 %

(3) Sludge Treatment Facilities at Central WWTPs

1) Alternatives for Sludge Treatment

Almost all of the Central WWTPs in BMA are constrained to install their facilities within very limited land spaces. Aggregated sludge treatment facilities, which consist of thickener and dehydrator, can save the land space necessary for respective Central WWTPs and may reduce the treatment cost by scale-up effect. Thus, the economic feasibility of the following alternatives for sludge treatment facilities including sludge transportation has been examined.

- Alternative C1: Individual Treatment

(Raw Sludge) - [Thickening] - [Dewatering] --------------------(Dewatered Sludge)

- Alternative C2: Aggregated Sludge Treatment Facilities

(Raw Sludge)--Pipeline Transp--[Thickening]-[Dewatering]---(Dewatered Sludge)

The individual treatment alternative is by far more economically advantageous than the aggregated treatment alternative. So, the scale-up effect is not so significant, in case the aggregated facilities are limited to only thickening and dewatering. Therefore, the individual sludge treatment at respective Central WWTPs is recommended in this Study.

2) Main Specification of Sludge Treatment Facilities

Employing floatation thickeners and belt press filters, sludge is treated to form of sludge cakes at the individual Central WWTP. The following design parameters has been applied to determine their main dimensions:

- 130 kg-DS/m^2/d of surface loading for a floatation thickener, and
- 150 kg-DS/m/h of filtration rate for a belt-press filter.

(4) Sludge Composting Facilities

This Study has assumed tentatively to select the following dispersive scheme, envisaging that the actual places should be decided at the implementing stage:

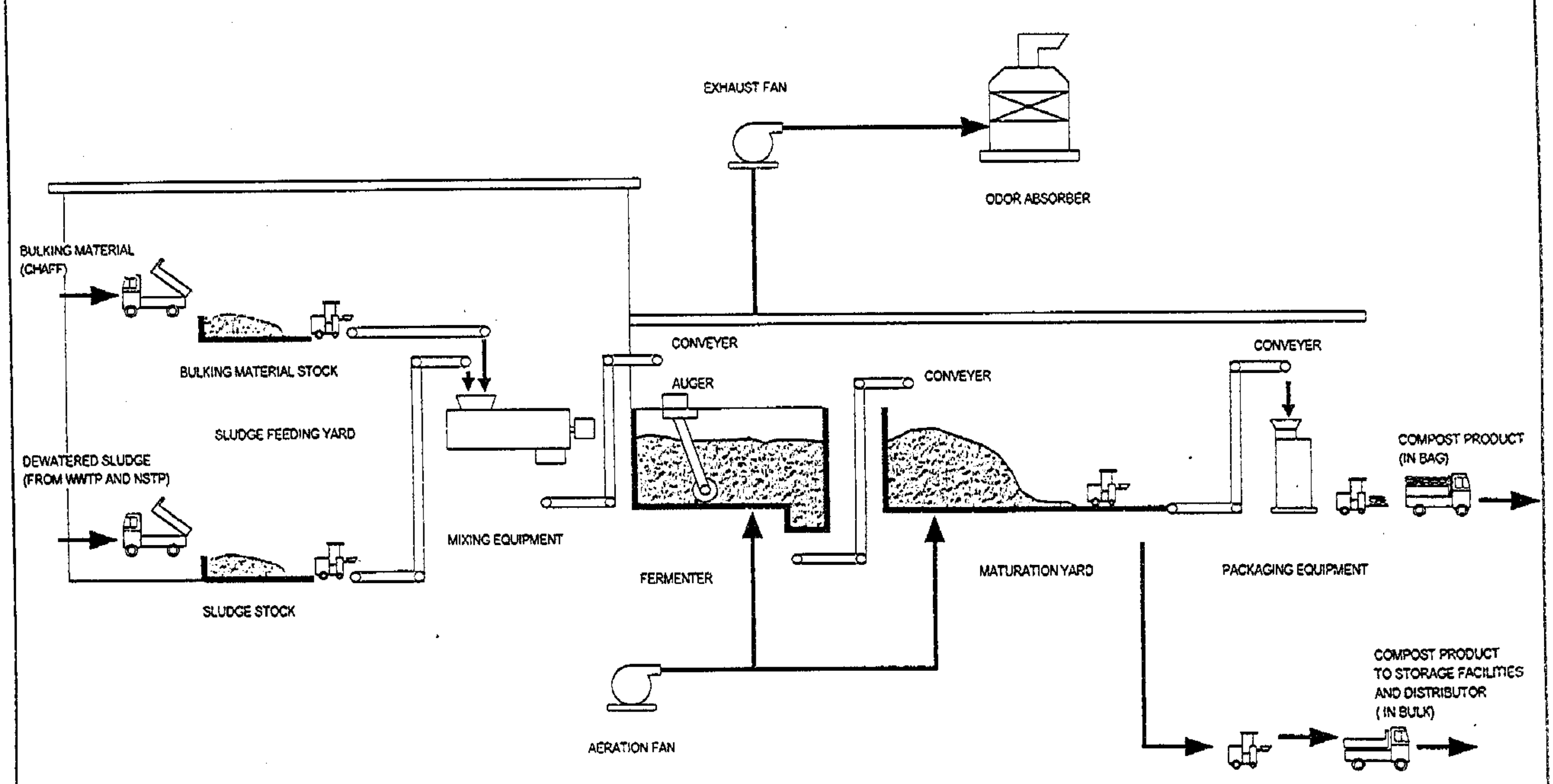
- North Plant: in the northern area of BMA,
- East Plant: in the eastern area of BMA, and
- West Plant: in the western area of BMA (including Nong Khaem)

Table 7.4.1 shows the tentatively allocated production capacity of composting plants.

Table 7.4.1 Production Capacity of Sludge Composting Plants

Name	Dewatered Sludge Input in 2020 (and Output in 2020)		Sludge Sources
	Scenario 1 and 2	Scenario 3	
North Plant	334 t Wet/d (334 t Product/d)	167 t Wet/d (167 t Product/d)	Bang Sue Chatuchak Din Daeng Community WWTPs
East Plant	218 t Wet/d (218 t Product/d)	109 t Wet/d (109 t Product/d)	Bung Kum Wang Thong Lang On-Nut (Night soil) Community WWTPs
West Plant	389 t Wet/d (389 t Product/d)	195 t Wet/d (195 t Product/d)	Thonburi North Thonburi Central Nong Khaem (Night soil) Yannawa (Sewage) Yannawa (Night soil) Community WWTPs

The horizontal-type fermenter attached with travelling paddle windrow devices is recommended for the sludge composting for BMA from the viewpoint of the compost quality and economical efficiency. Figure 7.4.1 show the outline of the proposed composting plant for BMA.



THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 7.4.1 FLOW DIAGRAM OF COMPOSTING PLANT
JAPAN INTERNATIONAL COOPERATION AGENCY	

7.5 Proposed Sludge Treatment/Disposal Scheme in BMA

(1) Overall Sludge Treatment/Disposal Flow

Figure 7.5.1 and Figure 7.5.2 shows the entire scheme and its mass flow 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. These parameters are the standards for agricultural use of sludge and for the input quality for landfill sludge, the needs for maximum volume reduction or beneficial uses of sludge and the demand for sludge compost.

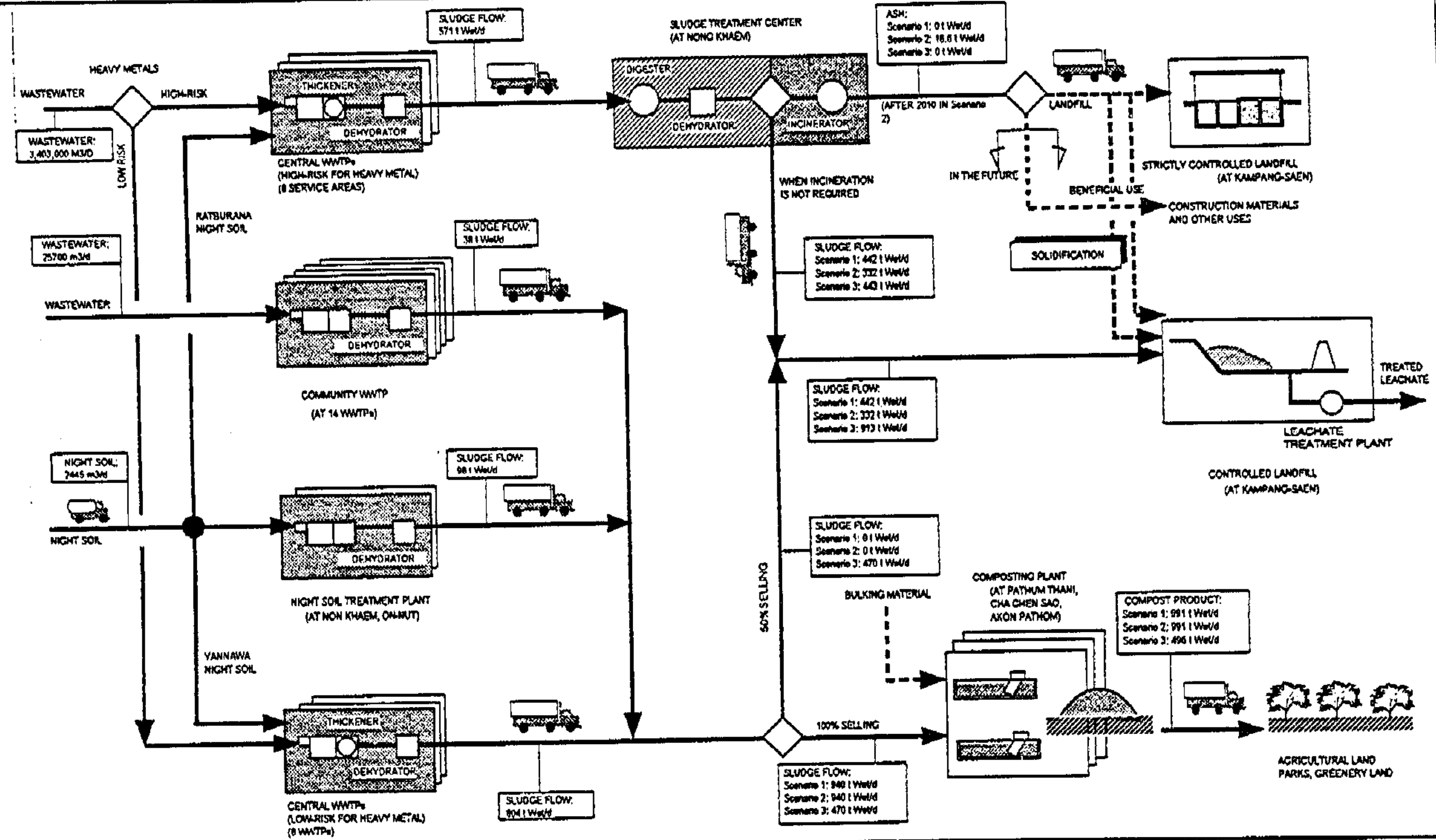
In Scenario 1, which is named "Full Agricultural Use", all the sludges meeting the standard quality (65 % of total generated sludge) are used for agricultural use. The rest of the sludge (35 % of total generated sludge) is disposed to landfill site. In Scenario 2, which is named "Incineration Introduction", out of the landfill disposal sludge, some 9 % of total generated sludge (equivalent to 25 % of the landfill sludge) is incinerated after 2010. The enforcement of the input quality standard for landfill sludge and the needs for maximum volume reduction or beneficial uses of sludge are assumed to justify the introduction of incineration.

In Scenario 3, which is named "50 % Agricultural Use", only 50 % of the sludge with suitable quality for agricultural use, which is equivalent to 33 % of total generated sludge, are used for sludge compost. This is the case which actual marketing of sludge compost would be constrained less than the maximum expected demand. 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.

Figure 7.5.3 shows the dynamic lines of both landfill sludge and agricultural use sludge in 2020 for Scenario 1.

(2) Proposed Treatment/Disposal System for Landfill Disposal Sludge

The landfill 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. In this system, the sludge generated in respective Central WWTPs is centralized to the Nong Khaem STC after dewatered and then goes to the Kampangsaen landfill site after treated. When night soil is treated after mixed with high-risk sludge in Central WWTP, the night soil sludge is regarded as high-risk sludge.



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

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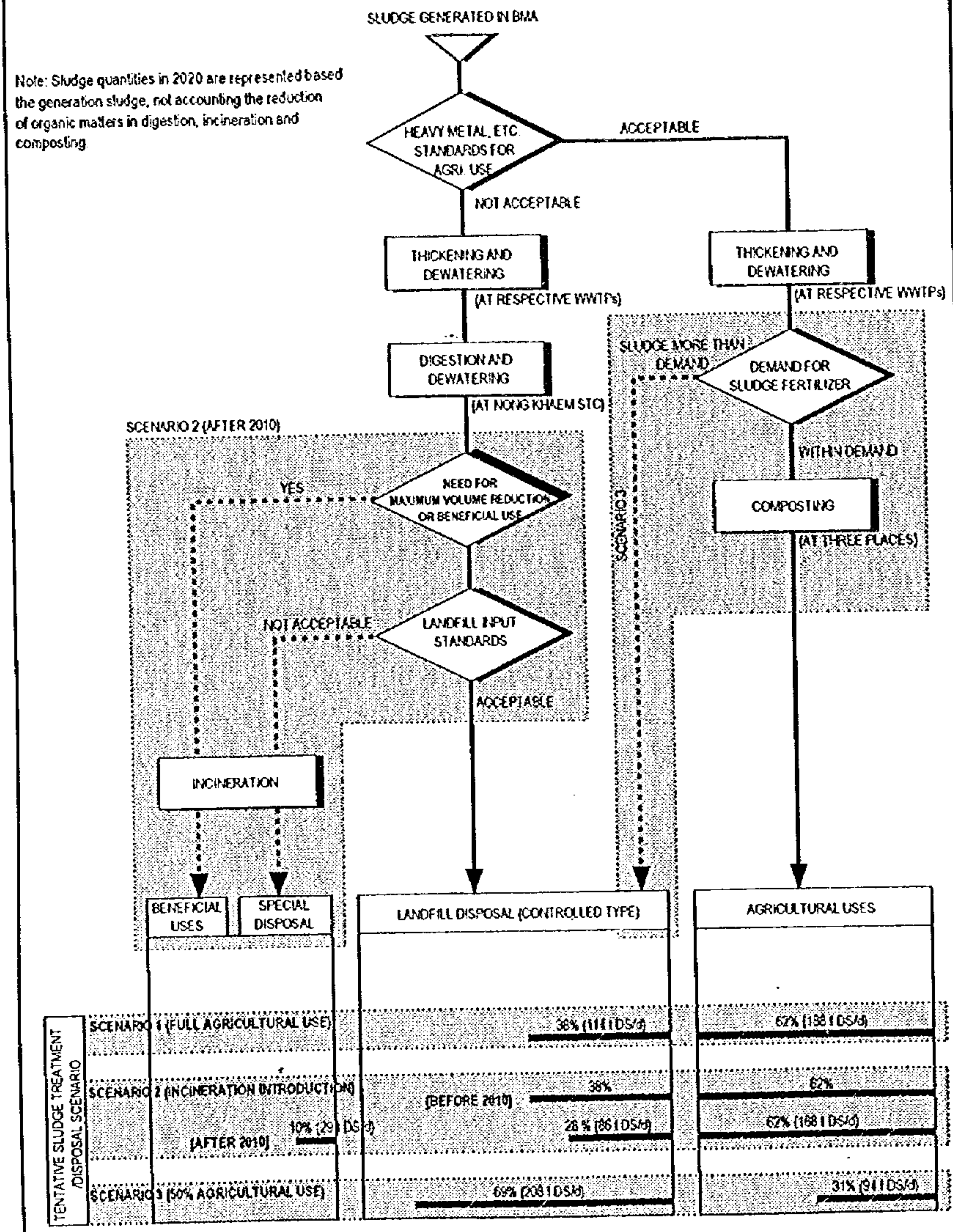
Figure 7.5.1
OVERALL SLUDGE TRETAMENT/ DISPOSAL FLOW DIAGRAM IN 2020



The sludge quantities are represented on the basis of generated sludge without the consideration for the reduction in digestion and composting process.

THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 7.5.2 CONCEPTUAL FLOW OF SLUDGE TREATMENT/DISPOSAL SCENARIOS
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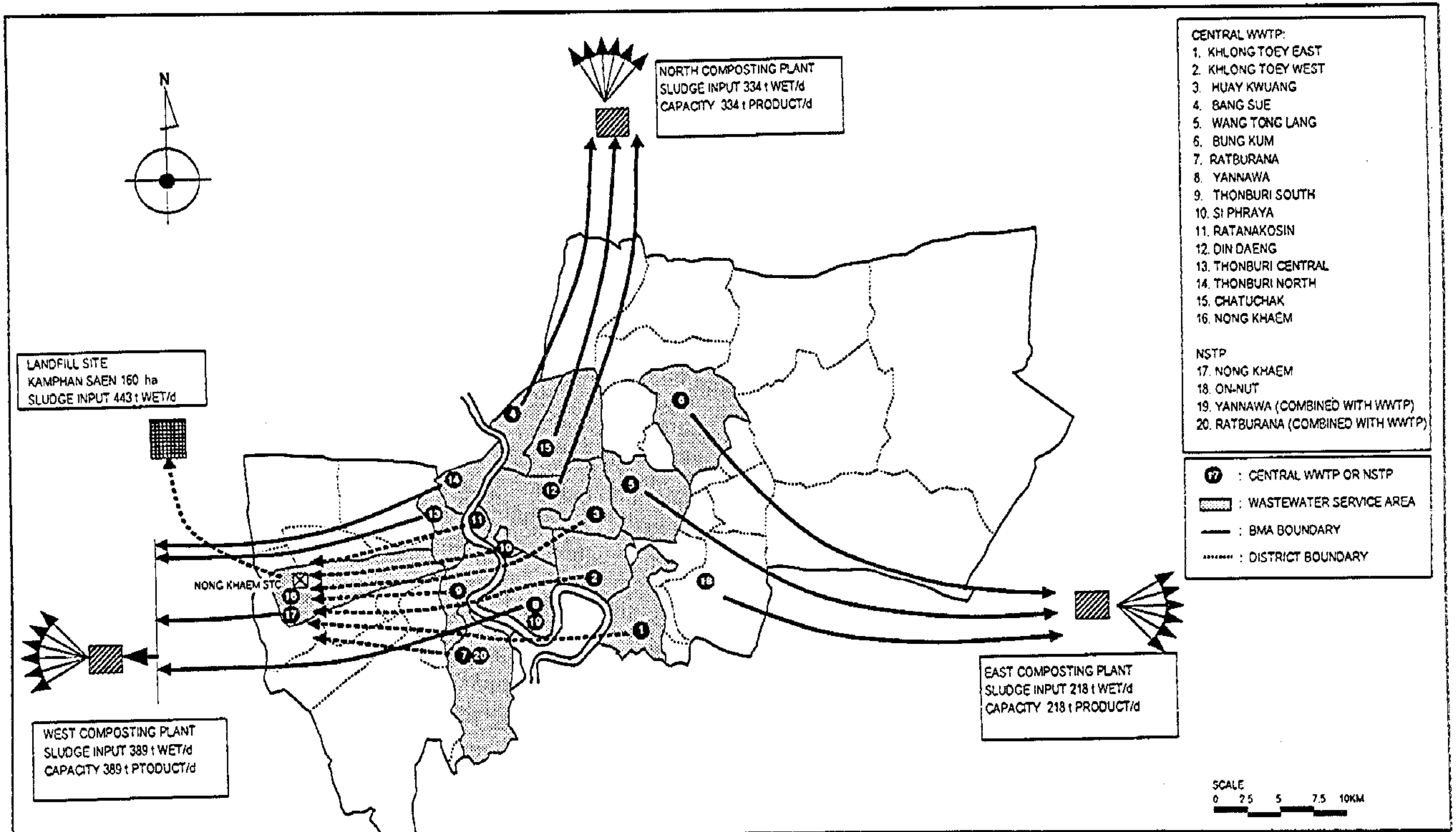

THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK

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Figure 7.5.3
SLUDGE DYNAMIC LINES IN 2020 (SCENARIO 1)

The Nong Khaem STC, which is an ongoing scheme, is equipped with cake receiving and storage, sludge dilution, sludge digestion and sludge dehydration facilities. Its capacity is scheduled to be 120 t DS/d. The Study Team recommends that the Nong Khaem STC be equipped with power generation units (expected total output 1,200 kW) utilizing digester gas from the economical point of view.

In the beginning, the sludge transportation by trucks will take place from Central WWTPs to the Nong Khaem STC in accordance with the ongoing scheme. The Study Team, however, recommend that pipeline transportation without dehydration at job-site be studied for the economical transportation in the future.

Table 7.5.1 Proposed Treatment/Disposal System for Landfill Disposal Sludge

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Activities / Treatment</th><th rowspan="2">Locations</th><th colspan="2">Facilities and Works</th></tr>
<tr><th>Scenario 1 / Scenario 3</th><th>Scenario 2</th></tr>
<tr><td>L-1</td><td>Sewage sludge thickening and dewatering</td><td>Central WWTPs (8 places)</td><td colspan="2">[L-1]: Thickeners and dehydrators</td></tr>
<tr><td>L-2</td><td>Sludge transport by trucks</td><td>Central WWTPs -> Nong Khaem STC</td><td colspan="2">[L-2]: Transport of dewatered sludge(quantity: 571 t Wet/d in 2020)</td></tr>
<tr><td rowspan="3">L-3</td><td rowspan="3">Sludge dilution, digestion, dewatering and incineration</td><td rowspan="3">Nong Khaem STC</td><td rowspan="2">[L-3A]: Dilution equipment, digester and dehydrator (capacity: 120 t DS/d in 2020)</td><td>[L-3B]: Dilution equipment, digester and dehydrator (capacity: 120 t DS/d in 2020)</td></tr>
<tr><td>[L-3C]: After 2010: Incineration added (capacity: 120 t Wet/d in 2020)</td></tr>
<tr><td colspan="2">[L-3D]: Power generator (capacity: 1400 kW in 2020)</td></tr>
<tr><td rowspan="2">L-4</td><td rowspan="2">Sludge transport</td><td rowspan="2">Nong Khaem STC→ Kampangsaen landfill site</td><td rowspan="2">[L-4A]: Transport of dewatered sludge (quantity: 403 t Wet/d in 2020)</td><td>[L-4B]: Transport of dewatered sludge (quantity: 302 t Wet/d in 2020)</td></tr>
<tr><td>[L-4C]: After 2010: Transport of ash (quantity: 16.6 t Wet/d in 2020) added</td></tr>
<tr><td rowspan="2">L-5</td><td rowspan="2">Landfill disposal</td><td rowspan="2">Kampangsaen landfill site</td><td rowspan="2">[L-5A]: Controlled landfill disposal (quantity: 443 t Wet/d in 2020)</td><td>[L-5B]: Controlled landfill disposal of dewatered sludge (quantity: 332 t Wet/d in 2020)</td></tr>
<tr><td>[L-5C]: After 2010: e.g. controlled landfill disposal of ash (quantity: 16.6 t Wet/d)</td></tr>
</table>

Note: The numbers marked by [ ] stand for the item number to specify a certain facility or work in this system.

Scenario 2 is featured by the introduction of an incinerator with the capacity of 110 t Wet/d after 2010, which is aimed at the mitigation measure for toxic materials like heavy metals, etc. correspondent to the implementation of the input quality control of landfill sludge. In this case, ash from the incinerator will be disposed in "strictly controlled-type" or "controlled-type" landfill site. Ash may be requested to receive the solidification process before disposal, depending on the quality standard to be enforced. Incinerator is, also, anticipated to play the role for the maximum volume reduction or the pre-treatment for some perspective sludge beneficial uses.

As for the landfill disposal, the Study Team has clarified that BMA has to prepare an adequate input control for sludge to be disposed in landfill site. Also, setting up a proper practice for sludge landfilling to be dedicated to wastewater sludge is needed.

(3) Proposed Treatment/Disposal System for Agricultural Use Sludge

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 sludges from respective Central WWTPs, NSTPs, and Community WWTPs are dewatered at the job-sites and are transported into the composting plants.

Total quantity of sludge compost will be around 940 t Product/d in 2020 in Scenario 1 and 2. In Scenario 3, its quantity will be limited to 470 t Product/d in 2020 due to the restriction of compost marketing and the rest of low-risk sludge will go to the Kampangsaen landfill site, directly from the respective sludge sources.

The composting plants are tentatively sited at the three locations in total, i.e. one in the northern area, one in the eastern area, and one in the western area of BMA. The actual location of the composting plant, however, should be studied more specifically prior to the implementation stage in light of the distance from compost consumption areas, the availability of bulking materials and operation staffs, and the environment conditions of the neighborhood.

The composting plant consists of sludge stockyard, fermenter, maturation yard, and odor control facilities. Among various types of composting processes, the Study Team deems the horizontal type to be the most suitable for BMA, as the results of comprehensive comparison including performance, easiness of operation and maintenance, space requirement, etc. Bulking materials necessary for sludge composting will be collected and transported to the composting plants from the nearby areas.

Table 7.5.2 Proposed Treatment/Disposal System for Agricultural Use Sludge

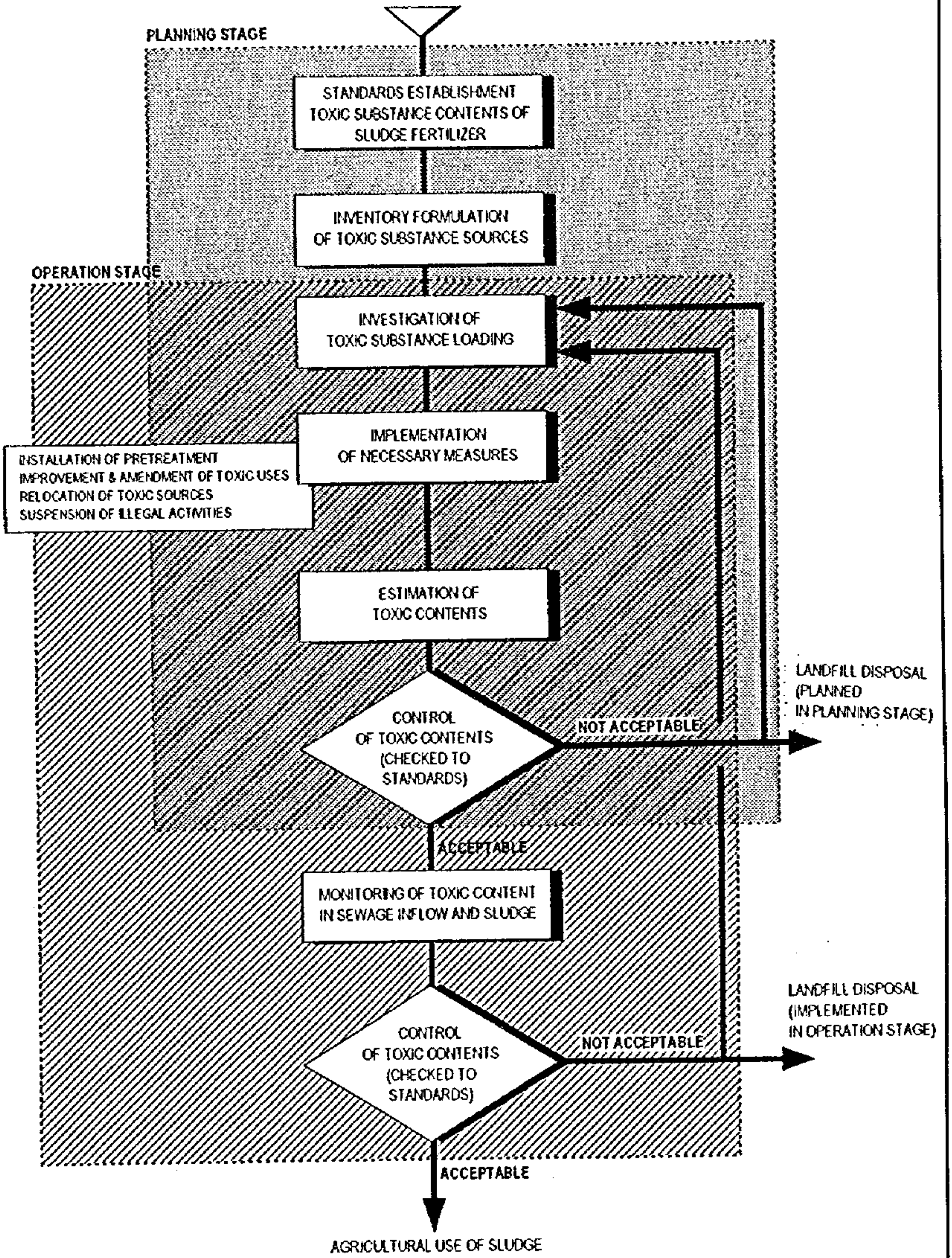
No.	Activities / Treatment	Locations	Facilities and Works	
			Scenario 1 / Scenario 2	Scenario 3
A-1	Sewage sludge thickening and dewatering	Central WWTPs (8 places)	[A-1]: Thickeners and dehydrators	
A-2	Sludge transport by trucks	Central WWTPs, NSTPs, Community WWTPs→ Composting Plants (3 places)	[A-2A]: Transport of dewatered sludge to North Plant (quantity: 334 t Wet/d in 2020)	[A-2D]: Transport of dewatered sludge to North Plant (quantity: 167 t Wet/d in 2020)
			[A-2B]: Transport of dewatered sludge to East Plant (quantity: 218 t Wet/d in 2020)	[A-2E]: Transport of dewatered sludge to East Plant (quantity: 109 t Wet/d in 2020)
			[A-2C]: Transport of dewatered sludge to West Plant (quantity: 389 t Wet/d in 2020)	[A-2F]: Transport of dewatered sludge to West Plant (quantity: 195 t Wet/d in 2020)
		WWTPs, NSTPs, Community WWTPs→ Kampansaen landfill site	None	[A-2G]: Transport of dewatered sludge to Kampangsaen (quantity: 495 t Wet/d in 2020)
A-3	Composting	Northern Area	[A-3A]: North Plant (Capacity: 400 t Wet/d in 2020)	[A-3D]: North Plant (Capacity: 200 t Wet/d in 2020)
		Eastern Area	[A-3B]: East Plant (Capacity: 240 t Wet/d in 2020)	[A-3E]: East Plant (Capacity: 120 t Wet/d in 2020)
		Western Area	[A-3C]: West Plant (Capacity: 400 t Wet/d in 2020)	[A-3F]: West Plant (Capacity: 200 t Wet/d in 2020)
A-4	Selling of sludge compost	From 3 composting plants	[A-4A]: Product 941 t Wet/d in 2020	[A-4B]: Product 471 t Wet/d in 2020

Note: The numbers marked by [ ] stand for the item number to specify a certain facility or work in this system.

7.6 Recommendations

(1) Management of Sewage Inflow

Considering either the landfill disposal or the useful use of sewage sludge, the quality of sewage inflow must be observed and controlled. In agricultural use of sludge, adequate standards of sludge fertilizer should be first established beforehand. To observe such standards, the quality of sludge to be originated from respective sources should be judged in the course of the planning stage and also the operation stage of sewerage, as shown in Figure 7.6.1.



THE STUDY FOR MASTER PLAN ON SEWAGE SLUDGE TREATMENT / DISPOSAL AND RECLAIMED WASTEWATER REUSE IN BANGKOK	Figure 7.6.1 SELECTION PROCEDURE FOR AGRICULTURAL USE OF SLUDGE
JAPAN INTERNATIONAL COOPERATION AGENCY	

Meanwhile, to assess actual status of toxic substance intrusion precisely and address such hindrances, inflow and sludge must be monitored on a regular basis.

(2) Promotion of Environmental-Friendly Landfill

The following should be prepared to promote environmental-friendly landfill disposal:

- To enact the regulations which specify the quality of landfill sludge, so as to prevent hazardous substances in sludge like heavy metals, organic chlorides, etc. from being discharged into the environment,
- To establish the standards in which proper landfill practice dedicated to sludge become prevalent to promote safe and hygienic disposal.

(3) Promotive Organizations and Dissemination for Compost Marketing

Much of the efforts must be made based on the cooperation between concerned sectors, especially agricultural sector, to promote compost marketing, namely:

- Establishment of Organization of Production and Distribution System
  BMA should be prepared for the establishment of organization suitable for the local conditions to produce competitive products and to market them securely. Proper storage facilities and functions are required to cope with the seasonal fluctuation of the demand, also.
- Training of Farmers
  To promote proper utilization of sludge fertilizer, adequate guidance should be formulated. And, the training of farmers and agriculture experts is needed.
- Dissemination Activities
  To promote the agricultural use of sludge fertilizer, massive activities for dissemination of not only bodies concerned with agriculture but also public are essential. These activities should cover education to promote awareness and social acceptance for sludge fertilizer.

(4) Study on Sludge Generation from WWTPs

The precise projection of sludge quantity generated in WWTPs is a key pre-requisite in sludge treatment/disposal planning. In this Study, a number of parameters for operation conditions and biological characteristics were assumed to estimate the sludge generation quantity. To make more precise estimation by setting suitable parameters, a continuous monitoring and assessment through actual operation of WWTPs should be carried out.

(5) Reassessment of Generated Sludge Quantity and Construction Schedule

A step-wise construction schedule of sludge treatment/disposal facilities is proposed in this Study based on the projected sludge quantity in the future. However, actual sludge quantity generated yearly in the future will vary directly depending on the implementation of sewerage development. Therefore, the reassessment of the sludge quantity by year and the construction schedule of facilities is needed in the course of the implementation stage.

CHAPTER 8 PRELIMINARY COST ESTIMATION AND FINANCIAL/ ECONOMIC EVALUATION

8.1 Preliminary Cost Estimation

(1) Basic Conditions for the Cost Estimation

In order to make a preliminary financial evaluation, construction and O&M costs for the overall systems including WWTPs, sludge treatment/disposal, reclaimed water reuse, and NSTPs were roughly estimated by utilizing the relevant data of existing and ongoing projects in Thailand, as well as similar projects in the region or Japan if no such projects are available in Thailand.

(2) Unit Cost Estimation

All unit costs, prices, and values estimated or assumed are summarized in Table 8.1.1.

(3) Cost Estimation of Representative Options

As discussed in the earlier section, Options A2, L1, L2 and L4 were selected to make a comparative cost analysis for sludge treatment/disposal. The unit cost for sludge treatment/disposal after dewatering in WWTPs is -2,969, 8,539, 2,156, and 1,399 Baht/t DS for Option A2, L1, L2, and L4, 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.

8.2 Financial and Economic Evaluation

(1) Financial Evaluation of Relevant Existing Plants

The Si Phraya WWTP is the only plant currently in operation. The recent operating data shows a clear learning curve of O&M cost. Sludge cake production is relatively small, ranging from 27 to 54 t/month and is transferred by truck to be used for flower nurseries in public parks, which shows fast growth of nursery flower. The average sludge content in wastewater is 66.06 g/m^3 (based on records from April to August 1998) which is quite low.

Table 8.1.1 List of Unit Costs

	US$ Basis		Baht Basis	
Wastewater Treatment Plant				
Exchange rate	(B/US$)	36		
Construction cost	(US$/m³/d)	1,000	(B/m³/d)	36,000
Annual O&M cost	(US$/m³/d)	15	(B/m³/d)	540
WW treatment charge	(US$/m³)	0.139	(B/m³)	5.00
Wastewater Sludge				
Compost-DS ratio (Non-digested, 1:0.5)	(t compost/t DS)	5.0		
Plant construction (20 year depreciation)				
Incineration (ash type)	(US$/t/day)	21	(B/t/day)	767
Digestion	(US$/t DS)	41	(B/t DS)	1,464
Compost	(US$/t DS)	29	(B/t DS)	1,035
Production/treatment/O&M cost				
Incineration (ash type)	(US$/t/day)	21	(B/t/day)	758.7
Digestion	(US$/t DS)	34.8	(B/t DS)	1,254
Compost	(US$/t DS)	83.3	(B/t DS)	3,000
Unit revenue from digestion	(US$/t DS)	55.0	(B/t DS)	1,980
Distance from WWTP to STC	(km)	25.0		
Distance from STC to Landfill	(km)	15.0		
Distance from Compost Factory to Market	(km)	10.0		
Distance from WWTP to Compost Factory	(km)	100.0		
Landfill (controlled type)	(US$/t)	7.30	(B/t)	263
Weight reduction by incineration: cake/ash		12.5		
Bulking materials density		0.2		
Bulking materials cost	(US$/t)	2	(B/t)	75
Compost sales price	(US$/t)	42	(B/t)	1,500
Wastewater Reclaimed Water				
Watering public parks and gardens and plants along road (everyday)	(m³/100ha)	30		
Road sprinkling (once a week)	(m³/100ha)	10		
Cost of additional facility installation	(US$/unit)	88,972	(B/unit)	3,203,000
O&M for additional facility	(US$/m³)	0.025	(B/m³)	0.89
Reclaimed water sales price	(US$/m³)	0.139	(B/m3)	5.00
Reclaimed water production cost	(US$/m³)	0.067	(B/m³)	2.40
Transportation cost (6 ton truck)				
Hauling distance 2 km	(US$/m³)	1.075	(B/m³)	38.70
Hauling distance 4 km	(US$/m³)	1.372	(B/m³)	49.39
Hauling distance 6 km	(US$/m³)	1.669	(B/m³)	60.07
Hauling distance 8 km	(US$/m³)	1.965	(B/m³)	70.75
Hauling distance 10 km	(US$/m³)	2.262	(B/m³)	81.44
Night Soil Treatment Plant				
Plant construction	(US$/m³/d)	9,722	(B/m³/d)	350,000
O&M	(US$/m³/d)	2,600	(B/m³/d)	93,600
Charge cost/bill	(US$/bill/month)	0.078	(B/bill/month)	2.8
No. of people/house	(People/house)	5		
Charge rate	(US$/m³)	1.389	(B/m³)	50
Transportation of collection (20km)	(US$/m³)	3.000	(B/m³)	108

Table 8.1.2 Local Cost Based Comparison Among Sludge Treatment Options

Option No.		Agricultural use A2	Landfill disposal L2	Landfill disposal L1	Landfill disposal L4
Option Name		compost without Digestion	Dewatered sludge after Digestion	Ash after Digestion	Dewatered sludge without digestion
Cost					
Dewater at on-site					
Dry solid capacity	(t DS/d)	10	10	10	10
Construction	(US$)	2,038,000	2,038,000	2,038,000	2,038,000
O&M	(US$/y)	253,000	253,000	253,000	253,000
Unit cost	**(US$/t DS)**	**97**	**97**	**97**	**97**
Transport					
Unit cost	**(US$/t DS)**	**5.09**	**1.67**	**1.67**	**0.00**
Incineration					
Unit cost of construct.	(US$/t DS)			106.54	
Unit cost for O&M	(US$/t DS)			105.38	
Unit cost	**(US$/t DS)**			**211.92**	
Digestion					
Dry solid capacity	(t DS/d)		160	160	
Construction unit cost	(US$/t DS)		41	41	
O&M unit cost	(US$/t DS)		35	35	
Unit cost	**(US$/t DS)**	**0**	**76**	**76**	**0**
Composting					
Dry solid capacity	(t DS/d)	112			
Construction unit cost	(US$/t DS)	29			
O&M unit cost	(US$/t DS)	83			
Production					
Bulking materials	(t/d)	280			
Bulking materials cost	(US$/d)	583			
Transportation	(US$/t)	0.79			
Production unit cost	(US$/t DS)	7.18			
Unit cost	**(US$/t DS)**	**119**			
Unit cost(excl. construction)	*(US$/t DS)*	*91*			
Compost production	(t/t DS)	5			
Transport					
Unit cost	**(US$/t DS)**	**0.99**	**1.22**	**0.16**	**2.36**
Landfill					
Unit cost	**(US$/t DS)**		**36.50**	**2.92**	**36.50**
Total cost	**(US$/t DS)**	**223**	**212**	**389**	**136**
Revenue					
Sales income of compost	**(US$/t DS)**	**208**	**0**	**0**	**0**
Cost recover by generation	**(US$/t DS)**		**55.00**	**55.00**	**0.00**
Total revenue	**(US$/t DS)**	**208**	**55**	**55**	**0**
Treatment cost including Dewater(=Cost-Revenue)					
Overall dry sludge treatment cost	**(US$/t DS)**	**15**	**157**	**334**	**136**
	(B/t DS)	**531**	**5,657**	**12,039**	**4,899**
Balance after WWTP (Excluding dewater)	**(US$/t DS)**	**-82**	**60**	**237**	**39**
	(B/t DS)	**-2,969**	**2,156**	**8,539**	**1,399**
Balance after composting (=Revenue-Cost) (Amount of profit)	**(US$/t DS)**	**87.56**			
	(B/t DS)	**3,152**			

(2) Financial Analysis of Each Treatment System

The financial analysis includes (1) wastewater treatment systems, (2) sludge treatment systems, (3) reclaimed wastewater reuse systems, and (4) night soil treatment system. The wastewater treatment system has a breakeven point at the WW charge rate of 4.06 Baht/m^3. The nightsoil treatment system can breakeven at the charge rate of 353 Baht/m^3, which is 7 times higher than the present rate. The overall treatment system is largely affected by WW charge rate, not much by other factors. The overall system has a breakeven point at the WW charge rate of 4.04 Baht/m^3, as shown in Table 8.2.1. 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, as shown in Table 8.2.2.

(3) Pre-Feasibility Study of the Overall Sludge Treatment System for the Thee Representative Scenarios

The objective of this pre-FS is to examine possibilities of privatization for the overall sludge treatment system. 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 38.0 % 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 the roles of sludge digestion should belong to the BMA. FIRR (Financial Internal Rate of Return) on investment is calculated at 10.92 %. The sensitivity analysis indicates that a 10 % change of the compost price causes around a 3.4 % change in FIRR and a 10 % change of the compost plant construction cost affects approximately a 1.6 % change in FIRR, as shown in Table 8.2.3.

In 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. The results are summarized in Table 8.2.4.

In order to introduce the sludge compost successfully, the public sector has to clear out various other factors in advance, which were not discussed in the Study, i.e. 1) monitoring of sludge quality for safety, 2) educating people not to discharge toxic staff into sewerage system, 3) research on how to apply the sludge compost to what kinds of agricultural products, 4) research on appropriate and

Table 8.2.1 Breakeven Cost Analysis

	Set Value (B/m³)	Accumulated Surplus up to 2020 (Mil. B)
WWTP System		
WW treatment charge rate		
Original rate +40%	7.00	37,229.48
Original rate +20%	6.00	24,555.37
Original rate	5.00	11,881.25
Original rate -20%	4.00	-792.86
Original rate -40%	3.00	-13,466.98
Estimated Breakeven rate	**4.06**	**0.00**
NSTP System		
NS charge rate	(B/m³)	(Mil. B)
Original rate +1000%	500.00	607.94
Original rate +600%	300.00	-220.61
Original rate	50.00	-1,256.29
Estimated Breakeven rate	**353.00**	**0.00**
Compost sales price	(B/t)	(Mil. B)
Original rate +100%	3,000.00	216.91
Original rate +50%	2,250.00	-519.69
Original rate	1,500.00	-1,256.29
Estimated Breakeven rate	**2,780.00**	**0.00**
Overall System		
WW treatment charge rate	(B/m³)	(Mil. B)
Original rate	5.00	12,182.68
Original rate -20%	4.00	-491.43
Original rate -40%	3.00	-13,165.54
Estimated Breakeven rate	**4.04**	**0.00**

Table 8.2.2 Total Initial Investment Cost for 3 Scenarios

(Unit: Mil. US$)

Item	Scenario 1	Scenario 2	Scenario 3
WWTP	1,928.3	1,928.3	1,928.3
WW Sludge			
Digestion	33.9	25.4	33.9
Compost Factory	43.6	43.6	21.8
Incineration	0.0	17.1	0.0
Dumping site	16.3	13.2	32.2
Reclaimed WW Reuse	4.7	4.7	4.7
NSTP	1.8	1.8	1.8
Total	2,028.6	2,034.2	2,022.7

Table 8.2.3 Sensitivity Analysis of Sludge Treatment for Scenario 1

(FIRR in %)

		Unit cost for compost plant construction (US$/t DS/d))				
		-20%	-10%	**Original**	+10%	+20%
Compost sales price (B/t)		167.857	188.839	**209.821**	230.804	251.786
+20%	1.800	22.72%	19.76%	**17.38%**	15.43%	13.78%
+10%	1.650	18.71%	16.21%	**14.17%**	12.48%	11.04%
Original	**1.500**	**14.75%**	**12.65%**	**10.92%**	**9.47%**	**8.23%**
-10%	1.350	10.75%	9.01%	**7.56%**	6.34%	5.29%
-20%	1.200	6.55%	5.14%	**3.96%**	2.96%	2.10%

Table 8.2.4 Summary of Pre-Feasibility Study for 3 Scenarios

		Scenario 1		Scenario 2		Scenario 3	
		Sludge in 2020		Sludge in 2020		Sludge in 2020	
		(t DS/d)	(%)	(t DS/d)	(%)	(t DS/d)	(%)
Assumption							
No-use							
Option L2 (Landfill after digestion)		114.2	37.8%	85.6	28.3%	114.2	37.8%
Option L1 (Landfill after incineration)		0.0	0.0%	28.5	9.4%	0.0	0.0%
Option L4 (Landfill w/o digestion)		0.0	0.0%	0.0	0.0%	94.0	31.1%
Use							
Option A2 (Compost)		188.0	62.2%	188.0	62.2%	94.0	31.1%
Total		302.2	100.0%	302.2	100.0%	302.2	100.0%
Accumulated cost up to 2020	(Mil. US$)	162.58		185.72		115.67	
Accumulated revenue up to 2020	(Mil. US$)	215.16		223.71		119.88	
Accumulated balance up to 2020	(Mil. US$)	52.58		37.99		4.22	
FIRR	(%)	10.92%		7.22%		1.94%	
Net present value at 5% discount rate	(Mil. US$)	17.54		6.88		-4.21	
Net present value at 10% discount rate	(Mil. US$)	1.83		-5.58		-7.62	

efficient manufacturing process of the sludge compost, 5) promotion of the sludge compost to farmers and 6) training of farmers for use of the sludge compost.

Since these costs, as well as capital cost, are not included in this financial analysis, the sludge compost business can not be viable without sufficient level of cooperation from the private sector, even in case of Scenario 1.

(4) Economic Evaluation of Overall Wastewater and Night Soil Treatment System

The proposed overall wastewater and night soil treatment system is economically viable and acceptable since the proposed system would have major intangible economic benefits stemming from various aspects of social, economic, agricultural and industrial viewpoints.

CHAPTER 9 ORGANIZATION AND INSTITUTIONAL PLAN

9.1 Legislation and its Enforcement

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; this should begin soon. In addition, to improve the present poor enforcement of the law, urgent remedial action on several fronts (including increased and visible top management commitment, training in the law and its application, delegation of increased powers to district level environment and sanitation staff, and programs to increase public awareness) is recommended.

9.2 Overall Organization of the Water and Sewage Sectors

Basic objectives for the development of the water and sewage sector are suggested, which should lead into a national policy (currently non-existent) for the longer term development and management of the water and sewage sectors. This should emphasize devolution to local government of the management of their own services in line with the Constitution. 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. It is suggested that this issue should be properly reviewed at a high level.

9.3 Central Wastewater Treatment Plants (Central WWTPs)

Community WWTPs should continue with their present reporting arrangements. Managers of the larger Central WWTPs should, as these come on stream, report to the Director of the Water Quality Management Division of DDS. When the Director's workload becomes excessive, then alternative arrangements would be needed. The Central WWTPs should be organized in four divisions, with routine services (e.g. maintenance, analytical laboratory, procurement, accounts) supplied on site, and only infrequently needed or more technical support being provided centrally.

9.4 Sludge and Night Soil Collection, Treatment and Disposal

The management of sludge from Central WWTPs and NSTPs to final destination will require the execution of a number of key activities including: the marketing of sludge products and farmer education and training, establishing quality standards, and the management of sludge movement and processing to final disposal site. One way of handling these is to establish a 'Sludge Management Agency (SMA)' under the Department of Drainage and Sewerage or the Department of Public Cleansing. The agency would need to be set up and funded by BMA in the first instance partly to develop a market for priced sludge products. Private participation could come later.

9.5 Wastewater User Charge

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 the 'Polluter Pays' principle and would encourage polluters to reduce pollution loads. This Study proposes the application of a user charge based on volume of water consumption and BOD load and a separate fee for commercial users.

9.6 Privatization

The potential for further private sector participation has been assessed and an extension into specific target areas is recommended, for example: in Central WWTPs, either service contracts for non-core activities or a management contract for operation and maintenance; in the creation of new facilities for sludge composting; for the SMA after start-up and initial operation by BMA; and in district offices (on a pilot basis) for night soil collection and sewer cleaning

9.7 Training Facilities and Needs

Existing education and training facilities appear adequate and no major requirements for training were reported, except in the case of district offices. Here a full assessment of training needs is required, particularly in environmental matters. Because of their responsibilities for service delivery, public contact, and law enforcement, district staff should be at least as well trained and developed as those in BMA 1 and 2.

CHAPTER 10 IMPLEMENTATION PLAN

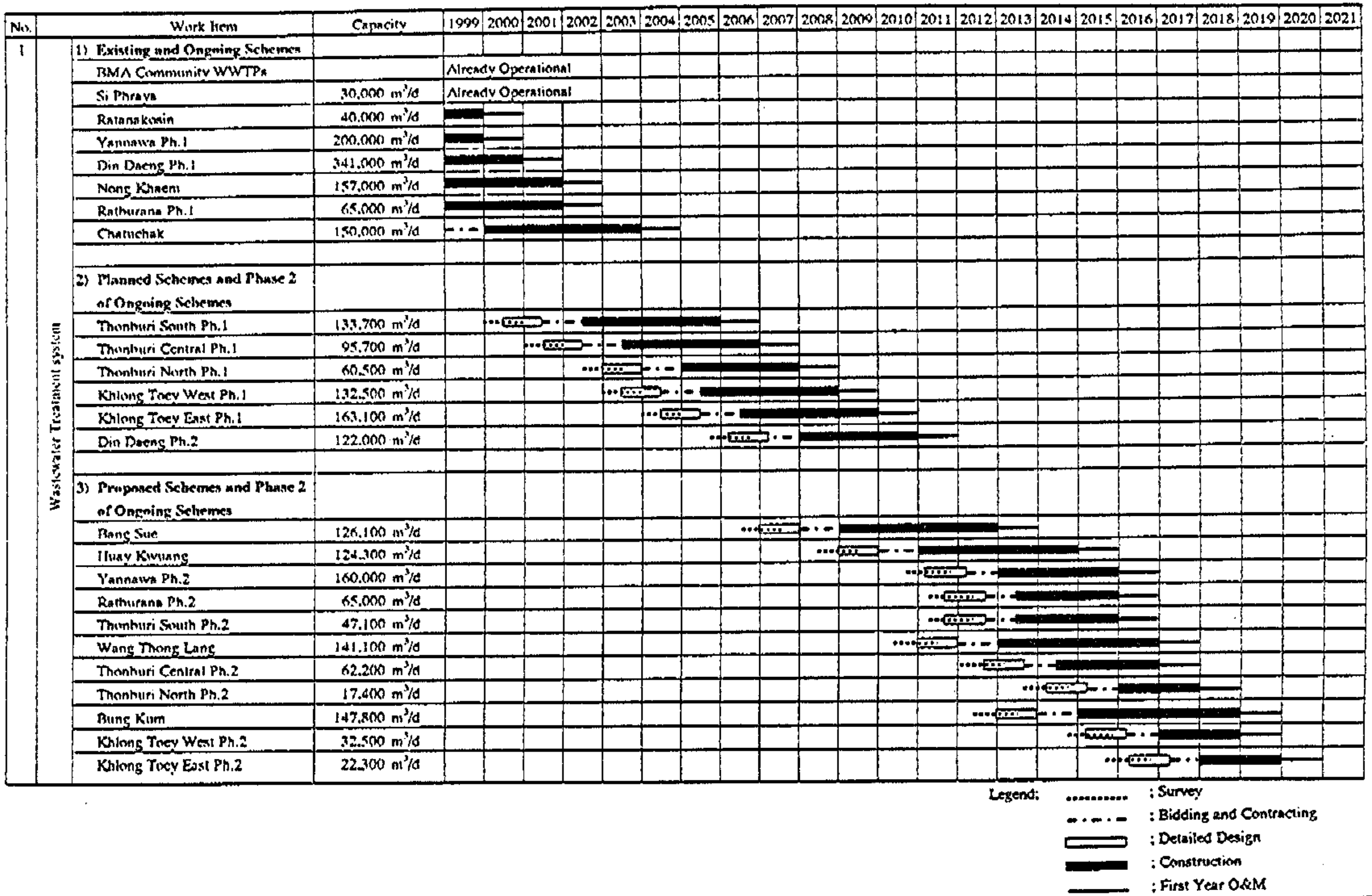
10.1 Project Procurement

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.

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.

10.2 Implementation Schedule

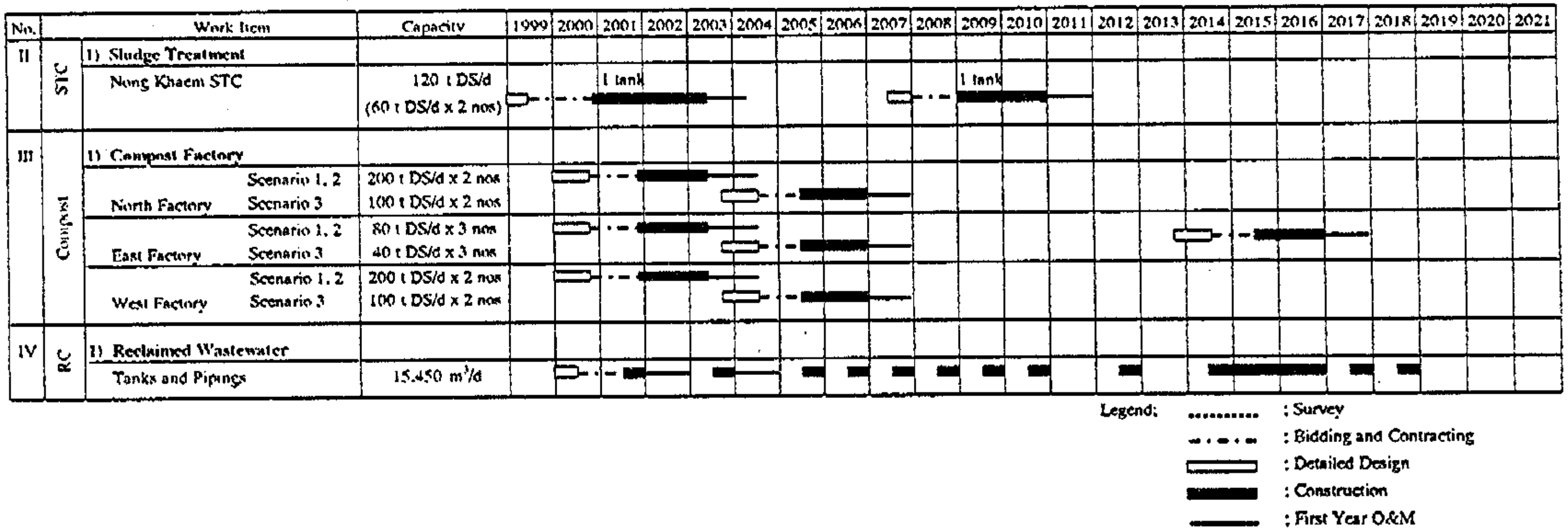
A proposed implementation schedule for the Master Plan is shown in Figure 10.2.1. This indicates the development of wastewater collection and treatment schemes, the sludge treatment center at Nong Khaem, three new composting plants, facilities for reclaimed wastewater use, and the development of a new sanitary landfill for sludge cake disposal. Many of the components of the Master Plan are proposed to be developed in phases to allow for increasing demands for these services over the Master Plan period and incremental investment.



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

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 10.2.1
IMPLEMENTATION SCHEDULE (1/2)



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

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 10.2.1
IMPLEMENTATION SCHEDULE (2/2)

CHAPTER 11 INITIAL ENVIRONMENTAL EXAMINATION

11.1 General

(1) Objectives of IEE

An Initial Environmental Examination (IEE) was conducted as part of the Study. The objectives of the IEE for the Project are as follows:

i) To identify potential impacts of the proposed Project
ii) To evaluate potential impacts of the proposed Project through JICA Environmental Guideline
iii) To indicate the scope of EIA to be conducted in due course

(2) Environmental Impact Assessment in Thailand

The basic policy and concepts of Environmental Impact Assessment in Thailand are described in the Enhancement and Conservation of National Environmental Quality Act. Wastewater collection, WWTP projects, STC projects, and sludge disposal are not included, therefore an environmental report is not required for submission to the Ministry of Science and Technology and Environment (MOSTE). The BMA has started five wastewater projects in Bangkok but is not required to submit an environmental report to MOSTE for any of them

(3) JICA Guidelines on Environmental Assessments

While appraising a project, JICA confirms that the necessary mitigation measures will be taken during project planning with regard to environmental issues in accordance with either the local environmental law or JICA Environmental Guidelines. The confirmation is carried out on the basis of materials provided by the recipient country. Since Thailand does not have any regulation of IEE and EIA for wastewater and sludge management, JICA guidelines will be followed in order to conduct Environmental Assessment of this Project.

11.2 Scope of IEE

The wastewater sludge disposal is principally branched in the line of existence of high level toxic heavy metals, and a number of alternative options are proposed. From the final disposal point of view, it is possible to combine the options shown into two main streams for sludge disposal, that is, landfill and agricultural use.

For IEE, it would be sufficient to examine the environmental evaluation considering the final disposal options for sludge disposal. This can be justified because, in different options for similar final disposal option, the differences are the unit processes involved and degree of treatment.

The two stream-lined options to be subjected to IEE are as follows:

Option	A :	High-risk sludge	-------------	Landfill
	B :	Low-risk sludge	-------------	Agricultural Use

11.3 Screening

In order to identify the potential impacts, a checklist method was applied for screening for the IEE. The checklist includes 23 environmental items defined by JICA Environmental Guideline. The result of the screening is shown in Table 11.3.1 and 11.3.2.

11.4 Evaluation of Potential Impacts

The potential impacts caused by the project are evaluated on ten environmental issues, which are raised after screening in Section 11.3. The results of the evaluation are summarized in the environmental checklist shown in Table 11.4.1.

11.5 Scope of EIA

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:

i) Public Health Condition
ii) Ground Water Pollution
iii) Flora and Fauna
iv) Landscape
v) Water Pollution
vi) Soil Contamination

Table 11.3.1 Format for Screening (Option A)

No.	Environmental Item	Description	Evaluation
Social Environment			
1.	Resettlement	Resettlement due to land occupancy (transfer of the rights of residence and land ownership)	[Y] (N) [?]
2.	Economic Activities	Loss of production base and change of economic structure	[Y] (N) [?]
3.	Traffic and Public Facilities	Impacts on schools, hospitals, and present traffic conditions, such as traffic jams and accidents	(Y) [N] [?]
4.	Split of Communities	Separation of regional communities by hindrance of regional traffic	[Y] (N) [?]
5.	Cultural Property	Loss or decrease of the value of cultural assets, such as temples, shrines and archaeological assets	[Y] (N) [?]
6.	Water Rights and Rights of Common	Obstruction of fishing rights, water rights, and rights of common	[Y] (N) [?]
7.	Public Health Condition	Worsening of health and sanitary condition due to the generation of garbage and pathogenic insects	[Y] (N) [?]
8.	Waste	Generation of construction waste, surplus soils, sludge, and domestic waste	(Y) [N] [?]
9.	Hazards (Risk)	Increase in risk of cave-ins, ground failure and accidents	[Y] (N) [?]
Natural Environment			
10.	Topography and Geology	Change of valuable topography and geology due to excavation and earthfill	[Y] (N) [?]
11.	Soil Erosion	Topsoil erosion by rainfall after land reclamation and deforestation	[Y] (N) [?]
12.	Groundwater	Exhaustion of groundwater caused by over-draft, and water pollution by leachate	(Y) [N] [?]
13.	Hydrological Situation	Changes of river discharge and riverbed condition due to filling work and drainage inflow	[Y] (N) [?]
14.	Coastal Zone	Coastal erosion and change of coastal vegetation due to change of littoral drift and reclamation	[Y] (N) [?]
15.	Fauna and Flora	Obstruction of breeding and extinction of species due to the changes of habitat conditions	[Y] (N) [?]
16.	Meteorology	Change of micro-climate, such as temperature, wind, etc., due to large-scale reclamation and construction	[Y] (N) [?]
17.	Landscape	Change of topography and vegetation due to reclamation. Deterioration of aesthetic harmony by structures	[Y] (N) [?]
Pollution			
18.	Air Pollution	Pollution caused by exhaust gas or toxic gas from vehicles and factories	[Y] (N) [?]
19.	Water Pollution	River and groundwater pollution caused by inflow of drainage and sludge from water treatment facilities	[Y] [N] (?)
20.	Soil Contamination	Contamination caused by discharge or diffusion of waste water drainage or toxic materials	[Y] [N] (?)
21.	Noise and Vibration	Noise and vibration generated by vehicles and operation of water treatment plants	(Y) [N] [?]
22.	Land Subsidence	Land deformation and land subsidence caused by the lowering of water table	[Y] (N) [?]
23.	Offensive Odor	Generation offensive odor and exhausted gas	(Y) [N] [?]
Overall Evaluation: Either IEE or EIA is necessary for the Project Implementation?			(Y) [N]

Table 11.3.2 Format for Screening (Option B)

No.	Environmental Item	Description	Evaluation
Social Environment			
1.	Resettlement	Resettlement due to land occupancy (transfer of the rights of residence and land ownership)	[Y] (N) [?]
2.	Economic Activities	Loss of production base and change of economic structure	[Y] (N) [?]
3.	Traffic and Public Facilities	Impacts on schools, hospitals, and present traffic conditions, such as traffic jams and accidents	(Y) [N] [?]
4.	Split of Communities	Separation of regional communities by hindrance of regional traffic	[Y] (N) [?]
5.	Cultural Property	Loss or decrease of the value of cultural assets, such as temples, shrines and archaeological assets	[Y] (N) [?]
6.	Water Rights and Rights of Common	Obstruction of fishing rights, water rights, and rights of common	[Y] (N) [?]
7.	Public Health Condition	Worsening of health and sanitary condition due to the generation of garbage and pathogenic insects	[Y] [N] (?)
8.	Waste	Generation of construction waste, surplus soils, sludge, and domestic waste	(Y) [N] [?]
9.	Hazards (Risk)	Increase in risk of cave-ins, ground failure and accidents	[Y] (N) [?]
Natural Environment			
10.	Topography and Geology	Change of valuable topography and geology due to excavation and earthfill	[Y] (N) [?]
11.	Soil Erosion	Topsoil erosion by rainfall after land reclamation and deforestation	[Y] (N) [?]
12.	Groundwater	Exhaustion of groundwater caused by over-draft, and water pollution by leachate	[Y] [N] (?)
13.	Hydrological Situation	Changes of river discharge and riverbed condition due to filling work and drainage inflow	[Y] (N) [?]
14.	Coastal Zone	Coastal erosion and change of coastal vegetation due to change of littoral drift and reclamation	[Y] (N) [?]
15.	Fauna and Flora	Obstruction of breeding and extinction of species due to the changes of habitat conditions	[Y] [N] (?)
16.	Meteorology	Change of micro-climate, such as temperature, wind, etc., due to large-scale reclamation and construction	[Y] (N) [?]
17.	Landscape	Change of topography and vegetation due to reclamation. Deterioration of aesthetic harmony by structures	[Y] [N] (?)
Pollution			
18.	Air Pollution	Pollution caused by exhaust gas or toxic gas from vehicles and factories	[Y] (N) [?]
19.	Water Pollution	River and groundwater pollution caused by inflow of drainage and sludge from water treatment facilities	[Y] [N] (?)
20.	Soil Contamination	Contamination caused by discharge or diffusion of waste water drainage or toxic materials	[Y] (N) [?]
21.	Noise and Vibration	Noise and vibration generated by vehicles and operation of water treatment plants	(Y) [N] [?]
22.	Land Subsidence	Land deformation and land subsidence caused by the lowering of water table	[Y] (N) [?]
23.	Offensive Odor	Generation offensive odor and exhausted gas	[Y] [N] (?)
Overall Evaluation: Either IEE or EIA is necessary for the Project Implementation?			(Y) [N]

Table 11.4.1 Environmental Issues Raised by IEE

Option 1	Option 2
Social Environment	Social Environment
1) Traffic and Public Facilities	1) Traffic and Public Facilities
2) Waste	2) Public Health Condition
	3) Waste
Natural Environment	Natural Environment
1) Ground Water	1) Ground Water
	2) Fauna & Flora
	3) Landscape
Pollution	Pollution
1) Water Pollution	1) Water Pollution
2) Soil Contamination	2) Noise and Vibration
3) Noise and Vibration	3) Offensive Odor
4) Offensive Odor	

However, EIA should be carried out in conventional pattern covering all other relevant aspects. If STC construction differ from the anticipated program of the Study, IEE and EIA have to be carried out. If a "simple landfill site" is to be constructed far from the existing solid waste landfill site, IEE and EIA have to be carried out properly. A summary of IEE is given in Table 11.4.2. Out of the options shown by the symbols, M and X which show "major issues" and "not clear", respectively, should be considered as Environmental Impact Assessment (EIA) items to be implemented in the later stage.

Table 11.4.2 Summary of IEE

Environmental Item	Option A	Option B	Problem	Countermeasure
1. Traffic and Public Facilities	S	S	Traffic will increase	Route and time of transport have to pre-planned.
2. Public Health Condition	N	X	In case of land application, a health risk is prevailing	Proper reuse plan in to be developed, final disposal should be monitored carefully.
3. Waste	S	S	Generation of waste	No problem it final disposal conducted properly and regulatory.
4. Ground Water	M	S	Leachate can pollute ground water resources	Sanitary landfill with leachate treatment is recommended. If not possible, ground water use should be restricted.
5. Fauna & Flora	N	X	Trace toxic can change flora & fauna	Controlled land application should be adopted.
6. Landscape	N	X	Use of comport may change crop pattern	Controlled land application should be adopted.
7. Water Pollution	X	S	Groundwater pollution can lead to wide-spread water pollution	Sanitary landfill is recommended.
8. Soil Contamination	X	N	May cause pollution by trace toxic substances	Sanitary landfill and controlled land application is required.
9. Noise and Vibration	S	S	Will generate during transportation	Route and time of transport have to be pre-planned.
10. Offensive Odor	S	S	May cause some odor during transport and disposal	Closed truck should be used for transport, agricultural area should be chosen carefully.

Note:
M: Major, S: Small, N: None, X: Not clear

CHAPTER 12 RECOMMENDATIONS

This Master Plan Study differs from many in forecasting future sludge quantities and treatment and disposal needs in that it included extensive surveys to determine wastewater quality and quantity and sludge characteristics, and used these to develop proposals for sludge treatment and disposal systems for the target year. However, the Study period and resources restricted the extent of the survey and the extent to which the plans and programs could be developed. Further, only the Si Phraya wastewater treatment plant is operational and from which plant performance records are available, although another fifteen treatment plants are now being developed and proposed in the Master Plan. As a result, extensive assumptions were necessary to estimate future sludge quantities and it is recommended that sludge production forecasts be re-assessed when these new sewage treatment plants become operational and can provide new data. In particular, the BOD Reduction Factor accounting for the loss of BOD in the drainage system described in Chapter 6 should be re-evaluated.

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 following are recommendations which address many of these problems and constraints.

12.1 Improvements to the Wastewater Collection System

Current wastewater projects in BMA will provide interceptors on the existing combined sewer pipes to convey wastewater to treatment plants downstream. However, these networks are primarily provided to remove storm water to the khlongs for flood control and in many respects are unsuitable for wastewater transfer. In the city of Bangkok, the flat and low-lying terrain and small topographic gradient hinders natural drainage, and this, together with poor catchment definition and the general condition of the pipe network gives concern as to whether the new interceptor sewers will be effective. The heavy congestion and high density development in much of the city would make it very difficult and expensive to install new separate sewers. There is therefore no choice other than the continued use of the combined drainage system and this must predominate in future plans. Further, due to the topography, the pipe network frequently becomes surcharged constraining the free flow of wastewater and this is likely to remain a problem even after the new interceptor sewers are connected. The following are major problems concerning the present pipe reticulation system.

1) Catchment boundaries are not clearly established and the arrangement is often inappropriate for wastewater transfer. In particular the catchment area of each branch pipe is not specific, flow directions in the sewers are variable and uncertain, and there is no basis for establishing wastewater flows.
2) The sewer pipes do not generally have hydraulically appropriate gradients. The direction of flow is sometimes variable and much of the network contains stagnant wastewater and backflows from the khlongs often occur.
3) Due to their age and condition, the pipes allow groundwater intrusion sometimes resulting in unexpectedly large flows. This, together with backflows from the khlongs downstream results in weak wastewaters in the pipe network.
4) The drainage system includes U-shaped side drains, closed conduits and open channels, many of which are unsuitable for conveying wastewater.
5) Many properties discharge wastewaters directly to the khlongs which will limit the proportion of wastewater collected in the new interceptor sewers.

Taking these matters into account, the following improvements are required to ensure that the combined drainage interceptor sewer systems will be properly effective.

1) A comprehensive survey of the existing pipe reticulation system is needed.
2) A register of each pipeline is required recording its structural and operating condition.
3) A full review of the catchment arrangements is needed.
4) Hydraulic analysis of the existing pipe networks is needed.
5) Damaged pipelines and other works need to be repaired or replaced.
6) Sewer maintenance needs to be improved to ensure that the pipes are free of blockages.
7) A program to ensure that all properties are connected to the pipe network must be established.
8) Hydraulic modeling should be undertaken for the design of drainage improvements taking into account both storm water and wastewater requirements.
9) The new interceptor sewer designs should be re-evaluated taking these matters into account. This should include a re-assessment of the necessary Peak Flow capacity requirements.

It is recommended that a pilot project be undertaken in the Si Phraya wastewater service area to address these matters which may serve as a demonstration project.

12.2 Sludge Treatment and Disposal

Three alternatives for sludge treatment and disposal are proposed in this Master Plan described in Chapter 7. In the implementation of the Plan, BMA will need to introduce a number of control measures in which careful judgement will be necessary to balance the practicalities of implementation and operation, environmental needs and financial constraints. The following recommendations and activities should be taken into consideration.

1) Heavy metal contamination in the sludge could only be predicted as a risk assessment in this Master Plan. This should be re-evaluated for each wastewater treatment plant sludge when the new plants are commissioned and following adequate monitoring of the sludge properties. Monitoring sludge properties should continue on a regular basis and the method of treatment and disposal route for each sludge kept continuously under review. Management arrangements must be sufficiently flexible to provide for these changes in requirements.
2) Heavy metal contamination may also occur in solid wastes and these should be similarly monitored and controlled. New regulations to limit hazardous materials in each disposal option need to be developed. The regulations concerning the discharge of heavy metals to the sewers need to be better enforced in future which should reduce the proportion of heavy metal contaminated sludge and consequently the constraints on disposal.
3) Comprehensive monitoring of sludge quality is essential before sludges are used for agriculture. BMA should seek the cooperation and assistance of universities and other research institutions to develop the necessary monitoring programs. Monitoring programs must continue during implementation and be developed as new requirements are identified.
4) Sludges uncontaminated with heavy metals are recommended for agricultural use in this Master Plan. Two options are proposed, using either 100 % or 50 % of the uncontaminated sludge depending on the market demand. In developing agricultural use of sludge, BMA must produce attractive sludge products at a price to compete with already available organic fertilizers, find and develop new markets, and enlighten and educate farmers and traders in the agricultural sector.

12.3 Reclaimed Wastewater Reuse

Treated wastewater reuse is practiced to a limited extent in the private sector in the central part of Bangkok for miscellaneous use in buildings and garden watering in hotels, hospitals and offices, and by district offices in the vicinity of Si Phraya Wastewater Treatment Plant. By the target year of 2020, this Master Plan proposes that sixteen wastewater treatment plants will be in operation in the central part of BMA making available huge quantities of treated wastewater. However, it will not be possible to utilize this to a large extent since it will generally be more expensive than readily available potable water after taking additional treatment needs and transport into account.

For extensive reuse of treated wastewater, a large new pipe network would need to be established, but this is not a realistic option in the midst of the congested city center. Treated wastewater reuse will, therefore, remain limited to miscellaneous building and garden purposes in the private sector. Nevertheless BMA should consider developing this market opportunity selling treated wastewater to the private sector organizations.

In view of the large volumes of treated wastewater soon to be available, its use for khlong water improvement is an attractive option which should be developed. However, this should be considered together with BMA current projects for khlong water improvement and for flood control management. Further study is necessary in this area taking all aspects of khlong management into account.

12.4 Organizations and Institutions

Cooperation and coordination between DDS and DPC is essential for the development and implementation of the proposals for sludge treatment and disposal in this Master Plan. The new sewerage, wastewater and sludge treatment, and sludge disposal systems are currently controlled by DDS, whereas night soil treatment and disposal is to be controlled by DPC as at present. In Chapter 9, two options are proposed, unifying the organizations and maintaining the independent activities of each. The establishment of new organization arrangements should be further studied by BMA to address the new activities identified in this Master Plan.

The Master Plan proposes that the management for the agricultural use of composted sludge be undertaken by the private sector in due course. However, the establishment of this new market, the operation of compost factories, and the distribution and sale of compost requires further study in conjunction with both BMA and the agriculture sector organizations.