JAPAN INTERNATIONAL COOPERATION AGENCY

THE KINGDOM OF THAILAND

BANGKOK METROPOLITAN AQUATIC ENVIRONMENT

THE STUDY FOR THE MASTER PLAN ON
SEWAGE SLUDGE TREATMENT PROJECT AND
THE PROJECT FOR SEWERAGE WORKS IN BANGKOK
IN
THE KINGDOM OF THAILAND

FINAL REPORT

VOL. IV DATA BOOK

OCTOBER 1989

NIPPON KOEI CO., LTD.

JAPAN INTERNATIONAL COOPERATION AGENCY

THE KINGDOM OF THAILAND
BANGKOK METROPOLITAN ADMINISTRATION

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

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FINAL REPORT

DATA BOOK

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A. EXISTING, ONGOING AND PLANNED MAJOR BMA WASTEWATER SCHEMES

Scheme Name and Area Si Phraya (1st Scheme)

Catchment Area 2.7 km^2

Population

- *Population and forecast population of area*
  Designed for 120,000 in 2009
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 104,690 in 2017 (Wastewater User Charge Study, 1998) Assume fully serviced by scheme
- *Population density*
  388 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity: 30,000 m^3/d
  Currently 20,000 m^3/d
- *Peak flow in foul sewers*
  Not known
- *Max fully treated flow*
  20,000 m^3/s (limited by current pumping capacity)

Influent quality

Average BOD: 61 mg/l (October 1995 - April 1999), max.
Monthly average: 89 mg/l. Full records are included in Table M1 in Data Book M

Night soil

None received

Effluent quality

Average BOD: 5 mg/l (October 1995 - April 1999), max.
Monthly average: 9 mg/l Full records are included in Table M1 in Data Book M.

Sludge produced

- *Volume produced*
  1.6 m^3/d average over 19 months (October 1995 - September 1996 and March - September 1998), currently reported to be 1.8 m^3/d
- *Dry solids produced*
  0.11 t/d (October 1996 - September 1997), currently calculated to be 0.3 t/d.
  1.0 t/d assumed in future
- *Percentage of dry solids*
  6 % (October 1996 - September 1997), currently reported to be 15%
- *Per capita dry solids*
  2 g/c/d (calculated from 120,000 population)

- *Stabilisation in plant*
  None

Sewers

- *Type of system*
  Interceptor system on combined sewers
- *Length of foul sewers*
  2.3 km
- *Sewer sizes*
  600 – 1,200 mm dia.
- *No of interceptors*
  14
- *No of manholes*
  36
- *No of pumping stations*
  1
- *Capacity of pumping station*
  Not known

Wastewater Treatment Plant

- *Process*
  Contact stabilisation activated sludge
- *Process units*
  Coarse and fine screens, Flow balancing and pumping, Aerated grit separators, Mixed liquor contact aeration tanks, Rectangular scraped clarifiers, Return activated sludge stabilisation aeration tanks, Chlorination, Polymer dosing and sludge floculation tanks, Sludge gravity thickeners, Sludge storage tanks, Polymer dosing and sludge belt presses, Sludge cake to skips, Rapid gravity sand filter for effluent used for road washing only.
- *Site area*
  0.30 ha
- *Housing*
  Fully housed

Implementation

- *Completion*
  1994
- *Current status*
  Operational

Scheme Name and Area Ratanakosin (2nd Scheme)

Catchment Area 4.1 km^2

Population

- *Population and forecast population of area*
  Designed for 160,000 in 2011
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 93,675 in 2017 (Wastewater User Charge Study, 1998)
- *Population density*
  228 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity: 40,000 m^3/d
- *Peak flow in foul sewers*
  5 x DWF = 200,000 m^3/d
- *Max fully treated flow*
  2.5 x DWF = 100,000 m^3/d

Influent quality
Not known

Night soil
None will be received

Effluent quality
Not known

Sludge to be produced

- *Volume produced*
  40 m^3/d from Design Report
- *Dry solids produced*
  8 t/d from Design Report
- *Percentage of dry solids*
  20 % design requirement
- *Per capita dry solids*
  70 g/c/d calculated
- *Stabilisation in plant*
  None

Sewers

- *Type of system*
  Interceptor Sewerage on existing Combined Drainage

- *Length of foul sewers*
  Not known
- *Sewer sizes*
  300 – 1,500 mm dia.
- *No of interceptors*
  4
- *No of manholes*
  Not known
- *No of pumping stations*
  Only at WWTP
- *Capacity of pumping stations*
  5 x DWF to preliminary treatment

Wastewater Treatment Plant

- *Process*
  2 stage activated sludge
- *Process units*
  Coarse and fine screens, aerated grit channels, 2 circular path 1st stage aeration tanks with diffused air, 4 horizontal flow intermediate clarifiers, 2 circular path 2nd stage aeration tanks with diffused air, 4 horizontal flow final clarifiers, post aeration, sludge gravity thickeners, sludge belt presses.
- *Site area*
  0.64 ha
- *Housing*
  Plant on 3 operational floors with full air management and odour control.

Implementation

- *Contract start*
  1993
- *Current status (November 1998)*
  80 % complete but contract halted
- *Planned completion*
  1999

Scheme Name and Area **Din Daeng - BMA Stage 1 (3rd Scheme)**

Catchment Area 37.8 km^2

Population

- *Population and forecast population of area*
  697,875 in 1990, 1,080,175 in 2015. Designed for 1,080,000 in 2011
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 1,169,930 in 2017 (Wastewater User Charge Study, 1998) Assume will be 92 % serviced in 2017
- *Population density*
  310 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity: 341,289 m^3/d for Stage 1 and 2, and 463,104 for Stage 3
- *Peak flow in foul sewers and preliminary treatment*
  5 x DWF: 1,706,400 m^3/d for Stage 1 and 2, and 2,315,520 m^3/d for Stage 2.
- *Max fully treated flow*
  1.5 x DWF = 511,920 m^3/d for Stage 1, 2.5 x DWF for Stage 2 = 833,200 m^3/d and for Stage 3 = 1,157,760 m^3/d.

Influent quality

Assumed for Stage 1: BOD 150 mg/l, SS 150 mg/l, N 30 mg/l, P 8 mg/1
Assumed for Stage 2: BOD 200 mg/l, SS 200 mg/l, N 35 mg/l, P 10 mg/1

Night soil

None will be received

Effluent quality

Design limit for average quality: BOD 20 mg/l, SS 30 mg/l, N (total) 10 mg/l, NH_3(N) 5 mg/l, P 2 mg/l, DO 5 mg/l

Sludge to be produced

- *Volume produced*
  Stage 1: 250 m^3/d, Stage 2: 362 m^3/d (NOSS Design Report - differs from Agricultural Use of Sludge Study: AIT,1998)
- *Dry solids produced*
  Stage 1: 34.1 t/d before lime addition, Stage 2: 51.2 t/d before lime addition (differs from Agricultural Use of Sludge Study)
- *Percentage of dry solids*
  20 % design requirement

- *Per capita dry solids*
  49 g/c/d calculated for Stage 1 and 47 g/c/d for Stage 2 from above - this does not include lime addition (differs from Agricultural Use of Sludge Study: AIT,1998)
- *Stabilisation in plant*
  Partial lime stabilisation

Sewers

- *Type of system*
  Interceptor sewer system collecting from existing combined sewers
- *Length of foul sewers*
  66.4 km
- *Sewer sizes*
  200 – 3,200 mm dia.
- *No of interceptors*
  439
- *No of manholes*
  980
- *No of pumping stations*
  6
- *Capacity of pumping stations*
  Up to 350,000 m^3/d

Wastewater Treatment Plant

- *Process*
  Activated sludge with nitrification and de-nitrification
- *Process units*
  Inlet pumping station, Bar screens, Aerated grit chambers, Aeration tanks with anoxic zones and diffused air system, Circular scraped clarifiers with chemical dosing for P removal, Sludge gravity thickeners, Sludge belt presses, Lime mills and Sludge cake dosing.
- *Site area*
  2.72 ha
- *Housing*
  Fully housed plant with operational plant on 2 floors. Air management and odour control for preliminary treatment only.

Implementation

- *Contract start*
  1993
- *Current status (November 1998)*
  86 % complete but contract suspended
- *Completion*
  Not known

Scheme Name and Area **Yannawa - BMA Stage 2 (4th Scheme)**

Catchment Area 28.5 km^2

Population

- *Population and forecast population of area*
  560,000 in 1992, 900,000 in 2020. Designed in 2 phases for these populations
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 540,275 in 2017 (Wastewater User Charge Study, 1998) Assume will be fully serviced in 2017
- *Population density*
  190 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity: 200,000 m^3/d for Phase 1 and 2, and 360,000 for Phase 3
- *Peak flow in foul sewers and preliminary treatment*
  5 x DWF: 1,000,000 m^3/d for Phase 1 and 2, and 1,800,000 m^3/d for Phase 2.
- *Max fully treated flow*
  1.5 x DWF = 300,000 m^3/d for Phase 1, 2.5 x DWF for Phase 2 = 500,000 m^3/d and for Phase 3 = 900,000 m^3/d for Stage 3.

Influent quality

Assumed for Phase 1: BOD 150 mg/l, SS 150 mg/l, N 30 mg/l, P 8 mg/l
Assumed for Phase 2: BOD 200 mg/l, SS 200 mg/l, N 35 mg/l, P 10 mg/l

Night soil

- *Volume delivered*
  1,000 m^3/d
- *Quality*
  Assume COD 35,000 mg/l, BOD 4,000 mg/l, TS 25,000 mg/l, TDS 6,000 mg/l, SS 19,000 mg/l, P 310 mg/l, pH 7.2, Alkalinity ($CaCO_3$) 1,800 mg/l, Grease 440 mg/l.

Effluent quality

Design limit for average quality: BOD 20 mg/l, SS 30 mg/l, N (total) 10 mg/l, NH_3(N) 5 mg/l, P 2 mg/l, DO 5 mg/l

Sludge to be produced

- *Volume produced*
  Wastewater sludge at 20 % dry solids = 215 m^3/d in Phase 1 & 2, and 442 m^3/d in Phase 3 calculated from solids quantities excluding lime addition. Lime is proposed to be added at 5 kg/kg ds which is considered excessive.

- *Dry solids produced*
  24.0 t/d from wastewater + 19.0 t/d from night soil = 43.0 t/d in Phase 1 and 2, 31.6 t/d from wastewater + 19.0 t/d from night soil = 50.6 t/d in Phase 3 from Design Report excluding lime addition.
- *Percentage of dry solids*
  20 % design requirement
- *Per capita dry solids*
  53 g/c/d calculated for Phase 1 and 2 and 43ghd for Phase 3 from above - this does not include lime addition (differs slightly from Agricultural Use of Sludge Study: AIT',1998)
- *Stabilisation in plant*
  Lime stabilisation of wastewater sludge only.

Sewers

- *Type of system*
  Interceptor sewer system collecting from existing combined sewers
- *Length of foul sewers*
  53 km
- *Sewer sizes*
  150 – 2,250 mm dia
- *No of interceptors*
  429
- *No of manholes*
  589
- *No of pumping stations*
  3
- *Capacity of pumping stations*
  106 – 1,513 l/s

Wastewater Treatment Plant

- *Process*
  Sequential batch reactor activated sludge (CASS)
- *Process units*
  Inlet pumping station, Dynamic grit separators, Fine bar screens with compactors, Pumps to reactor basins with provision for chemical dosing for P removal, Reactor basins, Collection and cascade outfall, Sludge gravity thickeners, Sludge belt presses with polymer pre-conditioning, alum and lime dosing.
- *Site area*
  3.2 ha
- *Housing*
  Fully housed plant on 4 operating floors

Implementation

- *Contract start*
  1995
- *Current status (November 1998)*
  Design and construction 79 % complete
- *Completion*
  1999

Scheme Name and Area Nong Khaem - BMA Stage 3 (Part of 5th Scheme)

Catchment Area 42.9 km^2

Population

- *Population and forecast population of area*
  178,000 in 1992, 450,000 in 2020. Designed in 2 stages for these populations
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 362,685 in 2017 (Wastewater User Charge Study, 1998) Assume will be 49 % serviced in 2017 assuming Stage 2 does not proceed
- *Population density*
  85 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity:157,000 m^3/d for Stage 1 Phase 1 and 2, not specified for Stage 2
- *Peak flow in foul sewers and preliminary treatment*
  5 x DWF: 785,000 m^3/d for Stage 1, not specified for Stage 2
- *Max fully treated flow*
  1.5 x DWF = 236,000 m^3/d for Phase 1, 2.5 x DWF for Phase 2 = 393,000 m^3/d for Stage 1, not specified for Stage 2

Influent quality

Assumed for Phase 1: BOD 150 mg/l, SS 150 mg/l, N 30 mg/l, P 8 mg/l
Assumed for Phase 2: BOD 200 mg/l, SS 200 mg/l, N 35 mg/l, P 10 mg/l

Night soil

No new provision for night soil deliveries. Existing plant to remain

Effluent quality

Design limit for average quality: BOD 20 mg/l, SS 30 mg/l, N (total) 10 mg/l, NH_3(N) 5 mg/l, P 2 mg/l, DO 5 mg/l

Sludge to be produced

- *Volume produced*
  73.0 m^3/d (Agricultural Use of Sludge Study: AIT,1998) for Stage 2
- *Dry solids produced*
  14.5 t/d (Agricultural Use of Sludge Study: AIT,1998) for Stage 1
- *Percentage of dry solids*
  20 % design requirement
- *Per capita dry solids*
  32 g/c/d (Agricultural Use of Sludge Study: AIT,1998)

- *Stabilisation in plant*
  Digestion plant for sludges from Nong Khaem, Ratburana and Yannawa

Sewers

- *Type of system*
  Interceptor sewer system collecting from existing combined sewers
- *Length of foul sewers*
  42.1 km
- *Sewer sizes*
  300 – 2,300 mm dia.
- *No of interceptors*
  208
- *No of manholes*
  356
- *No of pumping stations*
  8
- *Capacity of pumping stations*
  Up to 785,000 m^3/d

Wastewater Treatment Plant

- *Process*
  Activated sludge (vertical loop reactor)
- *Process units - wastewater treatment*
  Coarse and fine screens, Vortex grit separators, Vertical Loop Reactor aeration tanks with both diffused air and surface aeration, Horizontal flow clarifers with ferric chloride addition for phosphate removal, Diffused air flotation sludge thickeners.
- *Process units - central sludge treatment*
  Sludge cake rapid mix and slurry preparation tanks, Mesophilic anaerobic sludge digesters with membrane gas holders, Sludge belt presses.
- *Site area*
  8.32 ha
- *Housing*
  Open plant

Implementation

- *Contract start*
  1996
- *Current status (November 1998)*
  Design and construction 20 % complete
- *Completion*
  2001

Scheme Name and Area **Ratburana - BMA Stage 3 (Part of 5th Scheme)**

Catchment Area 42.3 km^2

Population

- *Population and forecast population of area*
  177,000 in 1992, 375,000 in 2020. Designed in 2 stages for these populations
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 435,195 in 2017 (Wastewater User Charge Study, 1998) Assume will be 42 % serviced in 2017 assuming Stage 2 does not proceed or 86 % if it does.
- *Population density*
  103 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity: 65,000 m^3/d for Stage 1 Phase 1 and 2, 130,000 m^3/d for Stage 2
- *Peak flow in foul sewers and preliminary treatment*
  5 x DWF: 650,000 m^3/d for Stage 1and 2
- *Max fully treated flow*
  1.5 x DWF = 98,000 m^3/d for Phase 1, 2.5 x DWF for Phase 2 = 163,000 m^3/d for Stage 1, 325,000 m^3/d for Stage 2

Influent quality

Assumed for Phase 1: BOD 150 mg/l, SS 150 mg/l, N 30 mg/l, P 8 mg/l
Assumed for Phase 2: BOD 200 mg/l, SS 200 mg/l, N 35 mg/l, P 10 mg/l

Night soil

- *Volume delivered*
  400 m^3/d
- *Quality*
  Assume COD 35,000 mg/l, BOD 4,000 mg/l, TS 25,000 mg/l, TDS 6,000 mg/l, SS 19,000 mg/l, P 310 mg/l, pH 7.2, Alkalinity ($CaCO_3$) 1,800 mg/l, Grease 440 mg/l.

Effluent quality

Design limit for average quality: BOD 20 mg/l, SS 30 mg/l, N (total) 10 mg/l, NH_3(N) 5 mg/l, P 2 mg/l, DO 5 mg/l

Sludge to be produced

- *Volume produced*
  55.0 m^3/d (Agricultural Use of Sludge Study: AIT,1998) for Stage 1.
- *Dry solids produced*
  11.0 t/d (Agricultural Use of Sludge Study: AIT,1998) for Stage 1

- *Percentage of dry solids*
  20 % design requirement
- *per capita dry solids*
  45 g/c/d (Agricultural Use of Sludge Study: AIT,1998)
- *Stabilisation in plant*
  None proposed

Sewers

- *Type of system*
  Interceptor sewer system collecting from existing combined sewers
- *Length of foul sewers*
  21.7 km
- *Sewer sizes*
  300 – 2,300 mm dia.
- *No of interceptors*
  164
- *No of manholes*
  162
- *No of pumping stations*
  5
- *Capacity of pumping stations*
  Up to 325,000 m^3/d (5 x DWF)

Wastewater Treatment Plant

- *Process*
  Activated sludge (vertical loop reactor)
- *Process units*
  Coarse and fine screens, Vortex grit separators, Vertical Loop Reactor aeration tanks with both diffused air and surface aeration, Horizontal flow clarifers with ferric chloride addition for phosphate removal, Diffused air flotation sludge thickeners, Sludge belt presses, Lime addition to sludge cake.
- *Site area*
  1.41 ha
- *Housing*
  Housed plant, but with odour control for preliminary treatment units

Implementation

- *Contract start*
  1996
- *Current status (November 1998)*
  Design and construction 20 %
- *Completion*
  2001

Scheme Name and Area Chatuchak - BMA Stage 4 (6th Scheme)
Note the extent of this scheme is being reviewed in July 1999 in view of budget constraints.

Catchment Area 33.4 km^2

Population

- *Population and forecast population of area*
  430,000 in BMA plan (432,000 in Agricultural Use of Sludge Study: AIT,1998)
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 320,401 in 2017 (Wastewater User Charge Study, 1998) Assume mostly serviced by scheme
- *Population density*
  96 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity: 150,000 m^3/d (115,200 m^3/d in 2000, 127,900 m^3/d in 2010 and 150,000 m^3/d in 2020)
- *Peak flow in foul sewers and preliminary treatment*
  5 xDWF: 750,000 m^3/d
- *Max fully treated flow*
  1.5 x DWF = 225,000 m^3/d for Phase 1, 2.5 x DWF = 375,000 m^3/d for Phase 2

Influent quality

Assumed for Phase 1: BOD 150 mg/l, SS 150 mg/l, N 30 mg/l, P 8 mg/l
Assumed for Phase 2: BOD 200 mg/l, SS 200 mg/l, N 35 mg/l, P 10 mg/l

Night soil

None to be delivered

Effluent quality

Design limit for average quality: BOD 20 mg/l, SS 30 mg/l, N (total) 10 mg/l, NH_3(N) 5 mg/l, P 2 mg/l, DO 5 mg/l

Sludge to be produced

- *Volume produced*
  67.0 m^3/d (Agricultural Use of Sludge Study: AIT,1998) for Stage 1.
- *Dry solids produced*
  13.4 t/d (Agricultural Use of Sludge Study: AIT,1998) for Stage 1
- *Percentage of dry solids*
  20 % design requirement

- *Per capita dry solids*
  31 g/c/d assumed and used to derive quantities (Agricultural Use of Sludge - Study: AIT,1998)
- *Stabilisation in plant*
  None proposed

Sewers

- *Type of system*
  Interceptor sewer system collecting from existing combined sewers
- *Length of foul sewers*
  31 km
- *Sewer sizes*
  400 – 2,250 mm dia.
- *No of interceptors*
  300
- *No of manholes*
  Not known
- *No of pumping stations*
  3
- *Capacity of pumping stations*
  150,000 – 900,000 m^3/d (6 x DWF)

Wastewater Treatment Plant

- *Process – wastewater treatment*
  Bid documents requires screening, grit removal, storm flow separation, biological and/or chemical treatment
- *Process – sludge treatment*
  Anaerobic digestion has now been selected from options in bid document.
- *Site area*
  1.12 ha
- *Housing*
  Fully housed

Implementation

- *Contract start*
  1999
- *Current status (November 1998)*
  Tenders submitted and contract being negotiated
- *Completion*
  2003

Scheme Name and Area — Khlong Toey (7th Scheme)
Note scheme not committed - information from SAPROF Study for OECF,1998

Catchment Area — 57.15 km^2

Population

- *Population and forecast population of area*
  694,000 in 2017. Previously 847,000
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 813,590 in 2017 (Wastewater User Charge Study, 1998) Assume mostly serviced by scheme
- *Population density*
  142 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity: 261,000 m^3/d. Previously 320,000 m^3/d.
- *Peak flow in foul sewers and preliminary treatment*
  5 x DWF: 1,035,000 m^3/d
- *Max fully treated flow*
  1.5 x DWF = 391,500 m^3/d

Influent quality

Assumed for Phase 1: BOD 150 mg/l, SS 150 mg/l, N 30 mg/l, P 8 mg/1
Assumed for Phase 2: BOD 200 mg/l, SS 200 mg/l, N 35 mg/l, P 10 mg/1

Night soil

None to be delivered

Effluent quality

Design limit for average quality: BOD 20 mg/l, SS 30 mg/l, N (total) 10 mg/l, NH_3(N) 5 mg/l, P 2 mg/l, DO 5 mg/l

Sludge to be produced

- *Volume produced*
  170 m^3/d
- *Dry solids produced*
  33.93 t/d based on 1 kg/kg BOD
- *Percentage of dry solids*
  20 % design requirement
- *Per capita dry solids*
  49 g/c/d
- *Stabilisation in plant*
  None proposed

Sewers

- *Type of system*
  Interceptor sewer system collecting from existing combined sewers
- *Length of foul sewers*
  92 km
- *Sewer sizes*
  150 – 2,800 mm

Wastewater Treatment Plant

- *Process*
  Nitrifying activated sludge plant
- *Process units*
  Coarse screen, Grit separation, Storm flow separation, Activated sludge aeration tank with mixed liquor re-circulation, Rectangular scraped clarifiers, Final aeration, Centrifugal sludge thickeners, Dewatering centrifuges.
- *Site area*
  3.2 ha
- *Housing*
  Fully housed

Implementation

Feasibility Study being arranged in 1999

Scheme Name and Area **Thonburi** (8th Scheme)
Note scheme not committed - information from SAPROF Study for OECF, 1998

Catchment Area 51.2 km^2

Population

- *Population and forecast population of area*
  1,381,000 in 2017. Previously 1,531,000
- *Serviced population and forecast serviced population of area*
  Total population of area forecast as 1,160,415 in 2017 (Wastewater User Charge Study, 1998) Assume mostly serviced by scheme
- *Population density*
  227 per ha in 2017

Flow

- *Dry weather flow*
  Design capacity: 518,000 m^3/d. Previously 575,000 m^3/d.
- *Peak flow in foul sewers and preliminary treatment*
  5 x DWF: 2,590,000 m^3/d
- *Max fully treated flow*
  1.5 x DWF = 778,000 m^3/d

Influent quality

Assumed for Phase 1: BOD 150 mg/l, SS 150 mg/l, N 30 mg/l, P 8 mg/1
Assumed for Phase 2: BOD 200 mg/l, SS 200 mg/l, N 35 mg/l, P 10 mg/1

Night soil

None to be delivered

Effluent quality

Design limit for average quality: BOD 20 mg/l, SS 30 mg/l, N (total) 10 mg/l, NH_3(N) 5 mg/l, P 2 mg/l, DO 5/mg/l

Sludge to be produced

- *Volume produced*
  338 m^3/d
- *Dry solids produced*
  67.34 t/d based on 1 kg/kg BOD
- *Percentage of dry solids*
  20 % design requirement
- *Per capita dry solids*
  49 g/c/d
- *Stabilisation in plant*
  None proposed

Sewers

- *Type of system*
  Interceptor sewer system collecting from existing combined sewers
- *Length of foul sewers*
  97 km
- *Sewer sizes*
  150 – 3,800 mm

Wastewater Treatment Plant

- *Process*
  Nitrifying activated sludge plant
- *Process units*
  Coarse screen, Grit separation, Storm flow separation, Activated sludge aeration tank with mixed liquor re-circulation, Rectangular scraped clarifiers, Final aeration, Centrifugal sludge thickeners, Dewatering centrifuges.
- *Site area*
  4.8 ha
- *Housing*
  Fully housed

Implementation

No committed programme

B. SOLID WASTE LANDFILL SITES

SOLID WASTE LANDFILL SITES

Site Name and Location	Lat Krebang
Management	Privately managed under 5 year contract commenced 1994
Capacity	
Total	about 6 million t
Daily quantity accepted	3,500 t/d
Remaining capacity (January 1999)	About 3 months
When expected to be full	1999
Plans when full	Contractor preparing new site in Samuk Prakarn
Site Area	35 ha
Site Access	Poor unpaved track
Waste Delivery	Contractor collects from On-Nut Transfer Station
Costs	*Contractor paid Baht 149 per tonne*
Environmental Control	
Cover	No regular soil cover, most of waste exposed during inspection. 300mm soil cover planned.
Base lining	300 mm clay seal
Leachate management	Leachate collection and treatment in aerated lagoons but aerators not operating during inspection
Gas management	None
Odour control	Spray masking but notfunctioning during inspection
Site management	Poor and environmentally unsatisfactory
Complaints from neighbours	Reported complaints
Waste segregation	Segregation during waste collection but also scavengers on landfill site
Night soil or wastewater sludges accepted	No

Site Name and Location	Kamphangsaen
Management	Privately managed under contract commenced 1989
Capacity	
Total	40 million t
Daily quantity accepted	4,000 t/d
Remaining capacity (January 1999)	38 million t, sufficient for more than 30 years
When expected to be full	after 2020
Site Area	160 ha
Site Access	Good paved track
Waste Delivery	Contractor collects from Nong Khaem and Tharaeng Transfer Stations
Costs	Contractor paid Baht 173 per tonne from Nong Khaem and Baht 214 per tonne from Tharaeng
Environmental Control	
Cover	regular soil cover
Base lining	20 m clay seal
Leachate management	Leachate collection and treatment in aerated lagoons
Gas management	None
Odour control	None
Site management	Good
Complaints from neighbours	No neighbours
Waste segregation	None at site
Night soil or wastewater sludges accepted	No

C. BMA COMMUNITY WASTEWATER TREATMENT PLANTS AND KHLONG WATER IMPROVEMENT LAGOONS INSPECTED BY THE STUDY TEAM

Name and Function

Huay Kwuang Wastewater Treatment Plant

Serves 38 local residential apartment blocks with a predominantly separate sewerage system and WWTP

Management

BMA

Plant constructed in 1975 for NHA, transferred to BMA in 1990.

Location

Huay Kwuang

Operating Units

Coarse bar screen,
Lift pumps
Bar screens
Grit channels
Primary settlement tanks
Conventional activated sludge plant
Secondary settlement tanks
Return sludge lift pumps
Chlorination plant (not used)
Sludge storage and sludge consolidation tanks
Sludge digestion
Sludge belt press

Condition and Development Plans

Clean and orderly plant with pleasant landscaping closely surrounded by apartment housing blocks. No treatment plant covering and odours evident. Bio-gas not utilised for heating, but gas mixing in digester. Excess gas is released periodically from digester without flare.

Incoming Flow and Quality

See performance records in Table M2 Data Book M.

Effluent Flow, Quality and Utilisation

See performance records in M2 Data Book M.

Some effluent used for watering the treatment plant site but most discharged to khlong.

Sludge Production

4 m^3/d sludge cake at 14 % ds trucked for use in Sirikit Park in city.

Operation Staff

5 technical staff and 10 workers.

Other Information

BOD measured once per week, COD and SS three times per week

Name and Function

Klong Chan Community Treatment Plant

This is a septic tank/extended aeration process plant serving the local housing area. The plant only treats the overflow from the single septic tank.

Management

BMA

Location

Lat Phrao

Operating Units

Bar screen, Influent pump chamber, Aeration tanks, Secondary sedimentation tanks, Chlorination contact tank (not used), sludge sand beds.

Plant Condition and Development Plans

The aeration tanks suffer foaming problems. The plant is well kept although equipment is old.

Incoming Flow and Quality

Septic tank effluent inflow approx. 2,000m^3/d but WWTP design capacity is 6,500 m^3/d.

BOD 280 mg/l, COD 450 mg/l, SS 50 mg/l, pH 7

Effluent Quality

BOD 25 mg/l, COD 46 mg/l, SS 17 mg/l, pH 7

National Standard is 20:30 BOD:SS.

Final effluent discharged to Khlong Chan.

Sludge Disposal

There is no regular removal of sludge cake from the sand bed.

Other Information

BOD , SS and pH analysed by BMA once a week.

Name and Function

Rama Indra Community Treatment Plant

This is a septic tank/extended aeration process unit serving the local housing area. The plant only treats the overflow from the single septic tank.

Management

BMA

Location

North-East Bangkok

Operating Units

Bar screen, Pump chamber, Aeration tank with three floating aerators, Secondary sedimentation tanks, Chlorination contact tank (not used), Sludge sand beds.

Plant Condition and Development Plans

Plant is well kept but with ageing equipment.

Incoming Flow and Quality

Septic tank inflow approx. 400m^3/d but WWTP design capacity is 800 m^3/d.
BOD 170 mg/l, SS 57 mg/l, pH 7

Effluent Quality

BOD 17 mg/l, COD mg/l, SS 24 mg/l, pH = 7
National Standard is 20:30 BOD:SS.
Final effluent discharged to canal.

Sludge Disposal

No regular removal of sludge cake is from the sand beds.

Other Information

BOD , SS and pH analysed by BMA once a week.

Name and Function

Tung Song Houng WTP No 1

This is an aeration/polishing pond system serving the local population accepting the overflow from the septic tanks.

Management

BMA

Location

Don Muang

Operating Units

Inlet pumping chamber, Bar screen, Aeration pond with 5 surface aerators, Polishing pond. The polishing pond contains fish.

Plant Condition and Development Plans

This old plant is well kept. Mechanical equipment is generally old, although recently the aeration system has been replaced. There is a problem with algal growth in ponds which is raked out manually.

Incoming Flow and Quality

Actual flow 1,500m^3/d, but WWTP designed for 3,000 m^3/d

BOD 109 mg/l, COD 119 mg/l, SS 55 mg/l, pH 7.3

Effluent Quality

BOD 20 mg/l, COD 47 mg/l, SS 25 mg/l, pH 7.6

National Standard is 20:30 BOD:SS.

Final effluent discharged to Klong Bang Pood.

Sludge Disposal

No sludge is removed from the ponds.

Operation Staff

1 technical scientist and several labourers.

Other Information

Samples are analysed for BOD , COD, SS and pH by BMA site laboratory about twice a month.

Name and Function

Tung Song Houng WTP No 2

This is a conventional activated sludge plant serving the local population accepting overflow from septic tanks.

Management

BMA

Location

Don Muang

Operating Units

Inlet to balancing tank via bar screen, Aeration tank, Secondary settlement tank, Chlorination tank. Sludge drying bed. The sludge digestion tank is being used as a highrate aerobic system before secondary settlement.

Plant Condition and Development Plans

This plant has mechanical equipment which is generally old and much of the steel work is rusty and needs replacing.

Incoming Flow and Quality

Current inflow is 474m^3/d but WWTP is designed for 700 m^3/d.

BOD 164 mg/l, COD 289 mg/l, SS 132 mg/l, pH 7.2

Effluent Quality

BOD 53 mg/l, COD 84 mg/l, SS 28 mg/l, pH = 7.5

National Standard is 20:30 BOD:SS..

Final effluent discharged to the Khlong.

Sludge Production and Quality

Sludge is removed from the bottom of the secondary settlement tank on to sand beds from where it is used as compost within the WWTP site.

Other Information

Samples are analysed for BOD , COD, SS and pH by the BMA site laboratory about once/twice a month.

Name / Function

Makkasan Pond

This is an aerated lagoon plant to improve Khlong Sam Sen water quality but there are also drain inlets.

Location & *Address*

Makkasan, Din Daeng

Operating Units

Aeration Pond with 3 – 12 day retention
Sedimentation Pond
14 ha site

Incoming Flow

30,000 – 140,000 m^3/d, quality not known

Effluent Disposal

Final effluent discharged to the Klong Sam Sen.

Sludge Disposal

No sludge is wasted from the sedimentation pond.

Name / Function

Rama IX Pond

This is an aerated lagoon plant to improve Khlong Lat Phrao.

Location & *Address*

Lat Phrao

Operating Units

Aeration Pond

Sedimentation Pond

8 ha site

Incoming Flow and Quality

30,000 – 60,000 m^3/d

BOD 15 mg/l., COD 30 mg/l., SS 100 mg/l.

Effluent Quality

BOD 10 mg/l., COD 21 mg/l., SS 56 mg/l.

Final effluent discharged to the Khlong Lat Phrao

Sludge Disposal

No sludge is wasted from the sedimentation pond.

D. PRIVATE WASTEWATER TREATMENT PLANTS INSPECTED BY THE STUDY TEAM

Name and Function

Klang (Central) Hospital WWTP

Plant built in 1979 for a 200-bed hospital. Developed in 1985/1987 for 400 beds.

Location

Pom Prap Sattru Pra

Operating Units

Grit chamber with bar screen, Equalisation tank, Aeration tank, Secondary sedimentation tank, Chlorination contact tank.

Plant Condition

Plant operates adequately though mechanical equipment is old. The aeration system has been recently been replaced.

Incoming Flow and Quality

Inflow about $200m^3/d$.

BOD 246 mg/l, COD 266 mg/l, pH 6.5

Effluent Quality and Disposal

BOD 8.5 mg/l, COD 76 mg/l, SS 40 mg/l, pH 6.5

National Standard is BOD:SS 20:30.

Final effluent discharged to klong.

Sludge Disposal

Small amount of waste sludge used as liquid fertiliser.

Management Arrangement

Managed by BMA hospital staff on a part time basis.

Other Information

Samples analysed about twice a week.

Name and Function

Vajira Hospital WWTP

Plant built in 1983 for 500 bed hospital.

Location

Dusit

Operating Units

Bar screen and scum separator, Aeration tank, Secondary sedimentation tanks, Chlorination contact tank with fish in final chamber. Sludge belt-press with polymer addition.

Plant Condition and Development Plans

The plant is well maintained though mechanical equipment is old.

Incoming Flow and Quality

Inflow about 2,000m^3/d

BOD 90 mg/l, COD 150 mg/l, SS 65 mg/l, pH 7

Effluent, Quality and Disposal

BOD 17 mg/l, COD 30 mg/l, SS 24 mg/l, pH 7

National Standard is BOD:SS 20:30.

Final effluent discharged to khlong.

Sludge Disposal

Sludge cake is used as compost on the site grounds.

Management Arrangement

Managed by BMA hospital staff part time by 4 labourers and 1 technician.

Other Information

Samples analysed by BMA site laboratory about once a week.

Name and Function

CP Tower WWTP

This is an extended activated sludge/aerobic system constructed in 1990 serving this 30-floor commercial building. Wastewaters are from offices, shops and restaurants. There are approx 2,000 staff and the WWTP has a design capacity for 6,000 p.e.

Location

Bang Rak

Operating Units

Equalisation tank and pre-aeration tank
Contact aeration tank
Sedimentation tank
Chlorine contact tank
Effluent sump
Sludge sump
The design was by Unoimax Int of Bangkok.

Plant Condition

This plant is in good condition and located within the basement of the CP Tower.

Incoming Flow and Quality

Design inflow 480m^3/d at 200 mg BOD/l.

Effluent, Quality and Disposal

National Standard is BOD:SS 20:30.
Final effluent discharged to drain.

Sludge Disposal

12 m^3 of sludge is removed by vacuum road tanker once a year.

Management Arrangement

Managed by CP staff of which 5 to 6 staff are responsible for water and wastewater operations.

Name and Function

River Garden Apartment WWTP

This is a septic tank/anaerobic filter unit system constructed in 1990 for this 17-floor condominium of 46 apartments housing about 100 people.

Location

Bang Rak

Operating Units

Septic tanks
Two-stage anaerobic units
Sedimentation tank
Chlorine contact tank
This plant was designed by ASC Consultant.

Plant Condition and Development Plans

The plant is in good condition located within the basement.

Incoming Flow and Quality

Not known

Effluent, Quality and Disposal

National Standard is BOD:SS 20:30.
Final effluent discharged to drain.

Sludge Disposal

Sludge is removed by vacuum road tanker once a year.

Name and Function

Narai Hotel WWTP

This plant was constructed in 1995 to serve the 15-floor hotel of 471 rooms, kitchen and restaurant with 500 staff.

Location

Bang Rak

Operating Units

Screening chamber
Sludge re-aeration tank
Contact aeration tank
Sedimentation tank
Disinfection contact tank
Sludge storage tank
Sludge press (not used)

Plant Condition

This plant is new and in good condition.

Incoming Flow and Quality

Design inflow is 700m^3/d at 200 mg BOD/l.

Effluent Quality and Disposal

National Standard is 20:30, BOD:SS.
Effluent BOD 14 mg/l, COD 54 mg/l, SS 15 mg/l, pH 7.78, Grease/oils 0.1 – 20.
Final effluent discharged to drain.

Sludge Disposal

No sludge is wasted from the sedimentation tank

Management Arrangement

Managed by hotel staff by 4 to 5 technical operators.

Other Information

Analysis by private laboratory about once/twice a month.
Chlorine is dosed only in the high season, usually November to May.

Name and Function

Singha Beer WWTP, Boon Rawd Brewery Co.

This is an Upward Flow Anaerobic Sludge Blanket (UASB) and Activated Sludge (AS) system constructed in 1994/95. The plant is an upgrade of an Anoxic/AS plant which was originally constructed in 1980.

The flows enters the equalisation tank from the various production lines.

Location

Dusit

Operating Units

Screening basket
Equalisation tank,
Anaerobic UASB reactor
Aeration tank
Sedimentation tank
Thickener tank
Sludge plate press.

Plant Condition

This plant is new and all equipment is in good condition.

Incoming Flow and Quality

Design inflow is 6,000m^3/d.

BOD 1600 mg/l, COD 2000 mg/l, SS 600 mg/l, TDS 3000 mg/l, N 50 mg/l, P 5 mg/l.

Effluent Quality and Disposal

BOD 15 mg/l, SS 25 mg/l, TDS 1250 mg/l, N <5 mg/l, P 5 mg/l.

Final effluent discharged to drain leading to Chao Phraya river.

Sludge Disposal

12 m^3/week of sludge is taken for use on the Singha sugar cane fields.

Management Arrangement

Managed by Singha staff WWTP manager, one laboratory assistant and 15 operators.

Other Information

Aeration tank has a spray masking odour control system.

E. FORECASTS OF FUTURE POPULATION IN PROPOSED SCHEME AREAS

Table E.1 Forecasts of Future Population in Planned and Proposed Wastewater Scheme Areas (1/3)

Category 1 (Planned Areas)

Catchment Name	District	Dist Area (km^2)	Dist Area (%)	Catch Area (km^2)	1998		2000		2010		2020	
					Density (no/ha)	Population (x1000)	Density (no/ha)	Population (x1000)	Density (no/ha)	Population (x1000)	Density (no/ha)	Population (x1000)
Khlong Toey West	Khlong Toey	12.27	100	12.27	166	204	168	206	179	220	190	233
	Vadhana	13.28	100	13.28	93	124	96	127	112	149	130	173
	Total			25.55	128	328	130	333	144	369	159	406
Khlong Toey East	Phra Khannong	13.6	75	10.20	102	104	108	110	137	140	176	180
	Suan Laung	23.68	40	9.47	66	63	70	66	94	89	128	121
	Bang Na	20.28	70	14.20	69	98	72	102	88	125	107	152
	Total			33.87	78	265	82	278	105	354	134	453
Thonburi North	Bang Phlat	11.36	100	11.36	150	170	154	175	170	193	190	216
	Total			11.36	150	170	154	175	170	193	190	216
Thonburi Central	Bang Noi	11.94	95	11.34	178	202	179	203	184	209	190	216
	Bangkok Yai	6.18	100	6.18	241	149	246	152	271	167	298	184
	Total			17.52	200	351	203	355	215	376	228	400
Thonburi South	Thonburi	8.63	100	8.63	335	289	336	290	340	293	344	297
	Khlong San	6.05	100	6.05	295	178	296	179	304	184	313	189
	Cham Thong	26.25	35	9.19	70	64	71	65	78	72	86	79
	Total			23.87	222	531	224	534	230	549	237	565
Nong Bon	Bang Na	20.28	25	5.07	69	35	72	37	88	45	107	54
	Phra Kannong	13.6	25	3.40	102	35	108	37	137	47	176	60
	Prawet	45.88	60	27.53	30	83	31	85	33	91	36	99
	Suan Luang	23.68	40	9.47	66	63	70	66	94	89	128	121
	Total			45.47	48	216	49	225	60	272	73	334
	Adjusted total	Ratio	1.21	55.00	58	261	59	272	73	329	88	404

Table E.1 Forecasts of Future Population in Planned and Proposed Wastewater Scheme Areas (2/3)

Category 2 (Proposed Areas)

Catchment Name	District	Dist Area (km^2)	Dist Area (%)	Catch Area (km^2)	1998		2000		2010		2020	
					Density (no/ha)	Population (x1000)	Density (no/ha)	Population (x1000)	Density (no/ha)	Population (X1000)	Density (no/ha)	Population (x1000)
Bang Sue	Dusit	10.67	20	2.13	202	43	203	43	205	44	206	44
	Bang Sue	11.55	90	10.40	222	231	227	236	253	263	280	291
	Chatuchak	32.91	20	6.58	72	47	73	48	79	52	85	56
	Total			19.11	168	321	171	327	188	359	205	391
Huay Kwuang	Huay Kwuang	15.3	100	15.30	100	153	107	164	149	228	207	317
	Total			15.30	100	153	107	164	149	228	207	317
Wang Thong Lang	Bang Kapi	29.7	40	11.88	70	83	74	88	96	114	125	149
	Suan Luang	23.68	10	2.37	66	16	70	17	94	22	128	30
	Wang T. L.	19.21	100	19.21	74	142	79	152	105	202	140	269
	Total			33.46	72	241	77	257	101	338	134	448
	adjusted total	Ratio	1.07	36.00	77	257	82	274	108	361	143	478
Bung Kum	Bang Kum	25	90	22.50	71	160	77	173	110	248	158	356
	Kha Yao	28.72	60	17.23	33	57	35	60	52	90	76	131
	Lat Phrao	30.48	25	7.62	62	47	65	50	82	62	104	79
	Total			47.35	56	264	60	283	84	400	120	566
	adjusted total	Ratio	0.90	43.00	51.0	239.0	54.0	256.0	76.0	362.0	108.0	512.0

Table E.1 Forecasts of Future Population in Planned and Proposed Wastewater Scheme Areas (3/3)

Category 3 (Proposed Areas)

Catchment Name	District	Dist Area (km^2)	Dist Area (%)	Catch Area (km^2)	1998		2000		2010		2020	
					Density (no/ha)	Population (x1000)	Density (no/ha)	Population (x1000)	Density (no/ha)	Population (x1000)	Density (no/ha)	Population (x1000)
Don Muang	Don Muang	34.56										
	Airport	-9.1		25.50	75	191	79	201	100	254	126	321
	Sai Mai			4.20	55	23	59	25	77	32	102	43
	Total			29.70	72	214	76	226	96	286	123	264
Sai Mai	Sai Mai			34.80	55	191	59	205	77	268	102	354
	Bang Khen			16.40	56	92	59	97	80	131	108	177
	Total			51.20	55	283	59	302	78	399	104	531
Lak Si	Lak Si		100	25.00	62	156	66	166	89	223	120	300
	Total			25.00	62	156	66	166	89	223	120	300
Bang Khen	Bang Khen			16.60	56	93	59	98	80	133	108	180
	Sai Mai			5.70	55	31	59	34	77	44	102	58
	Total			22.30	56	124	59	132	79	177	107	238
Lat Phrao[1)]				26.30	62	163	65	171	82	216	104	274
	Total			26.30	62	163	65	171	82	216	104	274
Eastern Corridor	Saphan Sung			12.10	32	25	35	42	50	61	74	90
	Bang Kapi			7.20	70	50	74	53	96	69	125	90
	Khanna Yao			7.50	33	25	35	26	52	39	76	57
	Bung Kum			2.10	71	15	77	16	110	23	158	33
	Minburi			16.00	16	25	18	29	28	45	42	67
	Total			44.90	31	140	37	166	53	237	75	337
Nong Jok[3)]	Nong Jok			26.10	25	67	27	71	36	94	48	125
	Total			26.10	25	67	27	71	36	94	48	125
Lat Krabang[2)]	Lat Krabang			16.50	34	56	38	63	63	104	104	172
	Total			16.50	34	56	38	63	63	104	104	172
City South West	Chom Thong			15.20	70	106	71	108	78	119	86	131
	Bang Khun Tien			15.30	35	53	37	56	50	77	68	104
	Bang Bon			9.90	37	37	40	40	54	54	74	74
	Pasi Chareon			5.30	105	56	109	58	133	70	162	86
	Bang Khae			1.90	51	10	53	10	64	12	76	14
	Total			47.60	55	262	57	272	70	332	86	409

Note:
1): Assume that Lat Phrao densities apply to other districts in area
2): Assume 80 % of population in this part of district
3): Assume 50 % of population in this part of district

F. RELEVANT WATER QUALITY STANDARDS

2. Effluent

A. Industrial Effluent Standards (PCD/MOSTE)

Items	Unit	Standard values
1. pH	-	5.5 – 9.0
2. Total Dissolved Solids (TDS)	mg/l	- not more than 3,000 mg/l depending on receiving water or type of industry unde consideration of PCC but not exceed 5,000 mg/l not more than 5,000 mg/l exceed TDS of receiving water having salinity of more than 2,000 mg/l or TDS of sea if discharge to sea
3. Suspended Solids (SS)	mg/l	- not more than 50 mg/l depending on receiving water or type of industry or type of wastewater treatment system under consideration of PCC but not exceed 150 mg/l
4. Temperature	°C	not more than 40
5. Colour and Odor	-	not objectionable
6. Sulfide (as H_2S)	mg/l	not more than 1.0
7. Cyanide (as HCN)	mg/l	not more than 0.2
8. Heavy Metals		
- Zinc	"	not more than 5.0
- Chromium (Hexavalent)	"	not more than 0.25
- Chromium (Trivalent)	"	not more than 0.75
- Arsenic	"	not more than 0.25
- Copper	"	not more than 2.0
- Mercury	"	not more than 0.005
- Cadmium	"	not more than 0.03
- Barium	"	not more than 1.0
- Selenium	"	not more than 0.02
- Lead	"	not more than 0.2
- Nickel	"	not more than 1.0
- Manganese	"	not more than 5.0
9. Fat, Oil and Grease (FOG)	"	not more than 5 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 15 mg/l
10.Formaldehyde	"	not more than 1.0
11.Phenol	"	not more than 1.0
12.Free Chlorine	"	not more than 1.0
13.Pesticides	"	not detectable

Items	Unit	Standard values
14.Biochemical Oxygen Demand (BOD)	"	not more than 20 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 60 mg/l
15.Total Kjeldahl Nitrogen (TKN)	"	not more than 100 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 200 mg/l
16.Chemical Oxygen Demand (COD)	"	not more than 120 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 400 mg/l

Remarks :

1. PCC = Pollution Control Committee
2. The standards were summarized from the Notification of the Ministry of Science, Technology and Environment, No.3, B.E. 2539 (1996) issued under the Enhancement and Conservation of the National Environmental Quality Act B.E. 2535 (1992). The Notification was published in the Royal Government Gazette, Vol. 113, Part 13 D, Dated February 13, B.E. 2539 (1996).
3. Notification of the Ministry of Science, Technology and Environment, No.4, B.E. 2539 (1996) issued under the Enhancement and Conservation of the National Environmental Quality Act. B.E. 2535 (1992) and published in the Royal Government Gazette, Vol. 113, Part 13 D, dated February 13, B.E. 2539 (1996) specifies that pollution sources that the above standards are to be applied are factories group II and III issued under the Factory Act B.E. 2535 (1992) and every kind of industrial estates.

4 Notification of the Pollution Control Committee, No. 3, B.E. 2539 (1996) dated August 20 B.E. 2539 (1996) has issued types of factories (category of factories issued under the Factory Act B.E. 2535 (1992) that are allowed to discharge effluent having different standards from the Minister Notification No.3 above as follows:

4.1 BOD up to 60 mg/l

1) animal furnishing factories (category 4 (1))
2) starch factories (category 9 (2))
3) food from starch factories (category 10)
4) animal food factories (category 15)
5) textile factories (category 22)
6) tanning factories (category 29)
7) pulp and paper factories (category 38)
8) chemical factories (category 42)
9) pharmaceutical factories (category 46)

10) frozen food factories (category 92)

4.2 COD up to 400 mg/l

1) food furnishing factories (category 13 (2))
2) animal food factories (category 15 (1))
3) textile factories (category 22)
4) tanning factories (category 29)
5) pulp and paper factories (category 38)

4.3 TKN

1) 100 mg/l – effective after 1 year from the date published in the Royal Government Gazette of the Ministerial Notification No. 4
2) 200 mg/l – effective after 2 year from the date published in the Royal Government Gazette of the Ministerial Notification No. 4 for the following factories :
   - food furnishing factories (category 13 (2))
   - animal food factories (category 15 (1))

C. Building Effluent Standards

1) Standard Values

Parameter	Unit	Range or Maximum Permitted Value For These Categories				
		A	B	C	D	E
1. pH	-	5-9	5-9	5-9	5-9	5-9
2. BOD	mg/l	20	30	40	50	200
3. Solids						
3.1 SS	mg/l	30	40	50	50	60
3.2 Settleable S.	mg/l	0.5	0.5	0.5	0.5	-
3.3 TDS	mg/l	500	500	500	500	-
4. Sulfide	mg/l	1.0	1.0	3.0	4.0	-
5. Total Kjeldahl Nitrogen (TKN)	mg/l	35	35	40	40	-
6. Fat, Oil and Grease (FOG)	mg/l	20	20	20	20	100

* These values are in addition to the TDS of the water used.

Source : Notification of the Ministry of Science, Technology and Environment issued under the Enhancement and conservation of the National Environmental Quality Act. B.E. 2535, published in the Royal Government Gazette, Vol. 111 special part 9, dated February 4, B.E. 2537 (1994).

2) Type and Sizes of Buildings Subject to Effluent Control

Building Type	Size	Level of Standard	Remarks
1. Condominium	Less than 100 units 100 but not more than 500 500 units or more	C B A**	
2. Hotels	Less than 60 rooms 60 but not more than 200 200 rooms or more	C B A**	
3. Dormitories	From 10 to not greater than 50 rooms From 50 to 250 rooms 250 rooms or more	D C B	
4. Massage parlors (or equivalent)	From 1,000 m^2 to not greater than 5,000 m^2 5,000 m^2 or more	C B	
5. Hospitals	From 10 to not greater than 30 beds 30 beds or more	B A**	
6. Schools, Colleges, Universities or Institutes	From 5,000 m^2 to not greater than 25,000 m^2 25,000 m^2 or more	B A**	
7. Government offices, Stage enterprises, International agencies, Banks, and Office Buildings	From 5,000 m^2 to not greater than 10,000 m^2 10,000 m^2 to not greater than 55,000 m^2 55,000 m^2 or more	C B A**	Working Area only (excluding central service area)
8. Department stores	From 5,000 m^2 to not greater than 25,000 m^2 25,000 m^2 or more	B A**	
9. Fresh food markets	From 500 m^2 to not greater than 1,000 m^2 From 1,000 m^2 to not greater than 1,500 m^2 From 1,500 m^2 to not greater than 2,500 m^2 2,500 m^2 or more	D C B A**	
10. Restaurants and food shops or food centers	Less than 100 m^2 From 100 m^2 to not greater than 250 m^2 From 250 m^2 to not greater than 500 m^2 From 500 m^2 to not greater than 2,500 m^2 2,500 m^2 or more	E D C B A**	Dining area

* Level of Standard refers to the 6 parameters listed in standard Value-Building Effluent Standards.

** This type and size of building will be controlled by the Pollution Control Officer, as specified in Section 69 of the Act.

D. Housing Estate Standards

1) Standard Values

Parameter	Unit	Range of Maximum Permitted Values for These Categories	
		A 100 units but not more than 500	B more than 500 units
1. pH	-	5.5-9.0	5.5-9.0
2. BOD	mg/l	30	20
3. Solids			
Suspended Solids (SS	-	40	30
Settleable Solids	ml	0.5	0.5
TDS	mg/l	500	500
4. Sulfide	"	1.0	1.0
5. Total kjeldahl Nitrogen (TKN)	"	35	35
6. Fat, Oil and Grease (FOG)	"	20	20

Source : Notification of the Ministry of Science, Technology and Environment No. 5.6 B.E. 2539 (1996) issued under the Enhancement and Conservation of National Environmental Quality Act, B.E. 2535 (1992), published in the Royal Government Gazette, Vol. 113, Special Part 9, dated March 27, B.E. 2539 (1996).

2) Methods for Examination

Parameter	Method
1. pH Value	pH Meter
2. BOD	Azide Modification at 20 ° celceus, 5 days
3. Suspended Solids	Glass Fibre Filter Disc
4. TDS	Dry Evaporation 103-105 ° celceus, 1 hour
5. Settleable Solids	Imhoff cone 1,000 cm^3, 1 hour
6. Sulfide	Titrate
7. Total Kjeldahl Nitrogen	Kjeldahl
8. Fat, Oil and Grease	Sovent Extraction by Weight

Remark : Based on : Standard Methods for Examination of Water and Wastewater Recommended by APHA, AWWA and WEF of America

4. Surface Water

A. face Water Quality Standards ; Classification and Objectives.

Parameter	Unit	Statistic	Standard Value for Class***				
			1	2	3	4	5
1. Color, Odor and Taste	-	-	N	n	n	n	-
2. Temperature	℃	-	N	n'	n'	n'	-
3. pH Value	-	-	N	5-9	5-9	5-9	-
4. Dissolved Oxygen	mg/l	P20	N	6	4	2	-
5. BOD (5 day, 20 ℃)	mg/l	P80	n	1.5	2.0	4.0	-
6. Coliform Bacteria							
- Total Coliform	MPN/100 ml	P80	n	5,000	20,000	-	-
- Fecal Coliform	MPN/100 ml	P80	n	1,000	4,000	-	-
7. NO_3-N	mg/l	Max. allowance	n	5.0	5.0	5.0	-
8. NH_3-N	"	"	n	0.5	0.5	0.5	-
9. Phenols	"	"	n	0.005	0.005	0.005	-
10. Cu	"	"	n	0.1	0.1	0.1	-
11. Ni	"	"	n	0.1	0.1	0.1	-
12. Mn	"	"	n	1.0	1.0	1.0	-
13. Zn	"	"	n	1.0	1.0	1.0	-
14. Cd	"	"	n	0.005*	0.005*	0.005*	-
	"	"		0.05**	0.05**	0.05**	
15. Cr hexavalent	"	"	n	0.05	0.05	0.05	-
16. Pb	"	"	n	0.05	0.05	0.05	-
17. Total Hg	"	"	n	0.002	0.002	0.002	-
18. As	"	"	n	0.01	0.01	0.01	-
19. CN	"	"	n	0.005	0.005	0.005	-
20. Radioactivity							
- Gross alpha	Becqurel/l	"	n	0.1	0.1	0.1	-
- Gross beta	"	"	n	1.0	1.0	1.0	-
21. Organochlorine Pesticides (total)	mg/l	"	n	0.05	0.05	0.05	-
22. DDT	µg/l	"	n	1.0	1.0	1.0	-
23. α BHC	"	"	n	0.02	0.02	0.02	-
24. Dieldrin	"	"	n	0.1	0.1	0.1	-
25. Aldrin	"	"	n	0.1	0.1	0.1	-
26. Heptachlor & Heptachlor epoxide	"	"	n	0.2	0.2	0.2	-
27. Endrin	"	"	n	none	none	none	-

Note : P = Percentile value
n = naturally
n' = naturally but changing not more than 3°C
* = when water hardness not more than 100 mg/l as $CaCO_3$
** = when water hardness more than 100 mg/l as $CaCO_3$
*** = Water Classification

Classifications	Objectives/Condition & Benificial Usages
Class 1	Extra clean fresh surface water resources used for : (1) conservation not necessary pass through water treatment processes require only ordinary process for pathogenic destruction (2) ecosystem conservation where basic organisms can breed naturally
Class 2	Very clean fresh surface water resources used for : (1) consumption which requires ordinary water treatment processes before use (2) aquatic organism of conservation (3) fisheries (4) recreation
Class 3	Medium clean fresh surface water resources used for : (1) consumption, but passing through an ordinary treatment process before using (2) agriculture
Class 4	Fairly clean fresh surface water resources used for : (1) consumption, but requires special water treatment process beforeusing (2) industry
Class 5	The resources which are not classification in class 1-4 and used for Navigation

Parameter	Methods for Examination of Surface Water Quality
1. Water Temperature	Thermometer
2. pH Value	Electrometric pH Meter
3. Dissolved Oxygen	Azide Modification
4. BOD	Azide Modification at 20 °C, 5 days
5. Total Coliform Bacteria and Fecal Colifrom Bacteria	Multiple Tube Fermentation Technique
6. NO_3-N	Cadmium Reduction
7. NH_3-N	Distillation Nesslerization
8. Phenol	Distillation, 4-Amino antipyrene
9. As	Atomic Absorption-Gaseous Hydride
10. CN	Pyridine-Barbituric Acid
11. Cu, Ni, Mn, Zn, Cd, Cr hexavalent and Pb	Atomic Absorption-Direct Aspiration
12. Total Hg	Atomic Absorption-Cold Vapor Technique
13. Radioactivity	Low Background Proportional Counter
14. Total Organochlorine pesticides, DDT, α-BHC, Dieldrin, Aldrin, Endrin, Heptachlor and Heptachlor epoxide	Gas-Chromatography

Remark : Based on Standard Methods for Examination of Water and Wastewater Recommended by APHA AWWA and WEF of America

Source : Notification of the National Environmental Board, No. 8, B.E. 2537 issued under the Enhancement and Conservation of National Environmental Quality Act, B.E. 2535, published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E. 2537 (1994).

B. Chao Phraya River Water Quality Standards (Figure 1).

Control Areas (km. from River Mouth)	Water Quality Standards (Same as Standards of Water Classification)
7 - 62	Class 4
62 - 142	Class 3
142 - 379	Class 2

G. ANALYSIS OF KHLONG WATER QUALITY SURVEYS

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (1/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Khlong Toey West	1993	91	6	43	40
		92	0		
		98	0		
		101	7	26	
		271	4	32	
		303	4	52	
		351	1	54	
		373	0		
		501	3	33	
		611	0		
		612	0		
		651	0		
	1994	91	3	23	31
		92	0		
		98	0		
		101	3	25	
		271	3	22	
		303	4	28	
		351	0		
		373	0		
		501	2	59	
		611	0		
		612	0		
		651	0		
	1996	91	5	24	27
		92	0		
		98	0		
		101	5	27	
		271	4	24	
		303	6	39	
		351	2	24	
		373	0		
		501	5	22	
		611	0		
		612	0		
		651	0		
	1977	91	9	16	20
		92	9	14	
		98	0		
		101	6	20	
		271	8	13	
		303	9	33	
		351	9	26	
		373	0		
		501	0		
		611	0		
		612	0		
		651	0		
	Average over whole period				30

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (2/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Khlong Toey East	1993	271	4	32	38
		272	0		
		281	3	44	
		282	0		
		365	0		
		481	0		
	1994	271	3	22	32
		272	0		
		281	1	42	
		282	0		
		365	0		
		481	0		
	1996	271	4	24	27
		272	0		
		281	5	30	
		282	0		
		365	0		
		481	0		
	1997	271	8	13	15
		272	8	13	
		281	1	16	
		282	5	21	
		365	3	7	
		481	1	20	
	Average over whole period				28

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (3/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Thonburi North	1993	369	0		
		491	0		
		521	0		
		527	0		
		531	0		
		551	0		
		561	0		
		591	0		
	1994	369	0		
		491	0		
		521	0		
		527	0		
		531	0		
		551	0		
		561	0		
		591	0		
	1996	369	0		
		491	0		
		521	0		
		527	0		
		531	0		
		551	0		
		561	0		
		591	0		
	1997	369	0		32
		491	2	29	
		521	2	35	
		527	0		
		531	2	40	
		551	2	28	
		561	2	27	
		591	0		
	Average for whole period				32

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (4/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Thonburi Central	1993	251	5	19	19
		252	0		
		261	3	18	
		262	0		
		332	0		
		333	0		
		391	0		
		394	0		
	1994	251	3	25	26
		252	0		
		261	3	26	
		262	0		
		332	0		
		333	0		
		391	0		
		394	0		
	1996	251	4	14	16
		252	0		
		261	4	17	
		262	0		
		332	0		
		333	0		
		391	0		
		394	0		
	1997	251	7	10	12
		252	10	11	
		261	5	7	
		262	10	9	
		332	6	30	
		333	0		
		391	5	10	
		394	5	7	
	Average over whole period				18

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (5/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Thonburi South	1993	132	0		42
		151	2	57	
		152	0		
		161	3	56	
		191	3	56	
		201	3	34	
		202	0		
		211	1	19	
		231	0		
		291	0		
		341	2	29	
		342	0		
		631	0		
		641	0		
		642	0		
	1994	132	0		31
		151	2	60	
		152	0		
		161	2	39	
		191	2	21	
		201	2	17	
		202	0		
		211	0		
		231	0		
		291	0		
		341	1	16	
		342	0		
		631	0		
		641	0		
		642	0		

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (6/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Thonburi South (Continued)	1996	132	0		31
		151	3	35	
		152	0		
		161	3	52	
		191	3	33	
		201	3	18	
		202	0		
		211	3	16	
		231	0		
		291	0		
		341	3	32	
		342	0		
		631	0		
		641	0		
		642	0		
	1997	132	7	29	18
		151	8	42	
		152	3	23	
		161	7	21	
		191	4	18	
		201	4	9	
		202	7	13	
		211	10	11	
		231	5	9	
		291	3	24	
		341	3	8	
		342	6	10	
		631	0		
		641	0		
		642	0		
	Average over whole period				31

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (7/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Nong Bon	1993	273	4	28	28
		461	0		
	1994	273	3	19	19
		461	0		
	1996	273	3	15	15
		461	0	0	
	1997	273	2	9	10
		461	8	10	
	Average over whole period				18
Bang Sue	1993	113	4	43	28
		114	4	30	
		121	4	23	
		381	0		
		511	6	24	
		512	5	18	
		523	0		
		571	0		
		572	0		
	1994	113	5	22	21
		114	5	18	
		121	5	30	
		381	0		
		511	5	22	
		512	5	15	
		523	0		
		571	0		
		572	0		
	1996	113	6	29	21
		114	6	22	
		121	5	26	
		381	0		
		511	6	13	
		512	6	14	
		523	0		
		571	0		
		572	0		
	1997	113	5	19	12
		114	5	12	
		121	7	14	
		381	4	4	
		511	9	10	
		512	9	12	
		523	0		
		571	0		
		572	0		
	Average over whole period				20

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (8/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Huay Kwuang	1993	85	4	40	40
		91	6	43	
		92	0		
		98	0		
		123	3	39	
		171	4	57	
		181	0		
		182	4	27	
		501	3	33	
	1994	85	5	25	26
		91	3	23	
		92	5	23	
		98	0		
		123	3	30	
		171	5	33	
		181	0		
		182	5	22	
		501	2	27	
	1996	85	5	29	28
		91	5	24	
		92	0		
		98	0		
		123	5	33	
		171	5	42	
		181	0		
		182	5	19	
		501	5	22	
	1997	85	6	40	23
		91	9	16	
		92	9	14	
		98	0		
		123	3	18	
		171	6	47	
		181	1	11	
		182	6	13	
		501	0		
	Average over whole period				29

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (9/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Wang Thong Lang	1993	33	0		27
		94	5	27	
		181	0		
		182	4	27	
	1994	33	0		21
		94	5	19	
		181	0		
		182	5	22	
	1996	33	0		18
		94	5	16	
		181	0		
		182	5	19	
	1997	33	0		12
		94	10	13	
		181	1	11	
		182	6	13	
	Average over whole period				20
Bung Kum	No data				
Don Muang	No data				
Lak Si	1993	514	6	26	
	1994	514	5	20	
	1996	514	6	38	
	1997	514	9	13	
	Average over whole period				24
Bang Khen	1993	183	0		
		581	0		
		582	0		
	1994	183	0		
		581	0		
		582	0		
	1996	183	0		
		581	0		
		582	0		
	1997	183	4	11	
		581	0		
		582	0		
	Average over whole period				11

Table G.1 Analysis of Khlong Survey Annual Data from DDS, BMA (10/10)

Proposed Service Area	Year	Sample Location Ref	No. of Samples	Average BOD (mg/l)	Average BOD of all Samples (mg/l)
Sai Mai	No data				
Lad Phrao	No data				
Nong Jok	No data				
Eastern Corridor	1993	90	0		26
		92	0		
		95	5	26	
	1994	90	0		20
		92	0		
		95	5	20	
	1996	90	0		17
		92	0		
		95	5	17	
	1997	90	0		16
		92	10	14	
		95	10	17	
	Average over whole period				20
City South West	1993	211	1	19	20
		221	4	26	
		431	0		
		432	2	16	
	1994	211	0		24
		221	3	23	
		431	0		
		432	4	24	
	1996	211	3	16	16
		221	4	17	
		431	0		
		432	5	14	
	1997	211	10	11	12
		221	10	14	
		431	4	9	
		432	4	13	
	Average over whole period				18
Lad Krebang	No data				

H. UNIT COSTS

Table II.1 Labour Wages (Basic Wage Rate)

Exchange Rate,36.0 Baht/US$

No.	Description	Unit	Daily Wage Rate	
			L/C (Baht)	F/C (Equiv.US$)
1	Foreman			
	Foreman	MD	600	16.67
	Mechanic	MD	400	11.11
	Electrician	MD	400	11.11
2	Operator and driver			
	Heavy equipment operator	MD	350	9.72
	Assistant operator	MD	225	6.25
	Dump truck driver	MD	300	8.33
	Cargo truck driver	MD	300	8.33
3	Civil worker			
	Rigger	MD	200	5.56
	Welder	MD	200	5.56
	Steel worker	MD	200	5.56
	Reinforcement worker	MD	175	4.86
	Pipe fitter	MD	200	5.56
	Plumber	MD	225	6.25
	Carpenter	MD	200	5.56
	Mason	MD	225	6.25
	Concrete worker	MD	200	5.56
	Plaster	MD	225	6.25
	Pavement worker	MD	175	4.86
	Painter	MD	200	5.56
4	Labour			
	Skilled labour	MD	300	8.33
	Common labour	MD	175	4.86

Table II.2 Unit Prices of Construction Materials (1/4)

Exchange Rate US$1.00 = 36.0 Baht

(As of October, 1998)

No.	Commodity	Unit	Site Delivery Price (Baht)	Allocation of Unit Price			
				Allocation Ratio		Allocated Unit Price	
				F/C (%)	L/C (%)	F/C (US$)	L/C (Baht)
1	Cement and admixture						
	Ordinary portland cement,(50kg)	t	2,150	0	100	0	2,150
	Water reducing Agent	Litre	14	80	20	0.3	2.8
	Air entraining Agent	Litre	30	80	20	0.7	6
2	Aggregate and ste						
	Sand	m^3	300	0	100	0	300
	Gravel	m^3	800	0	100	0	800
	Cobble and rubble stone	t	250	0	100	0	250
	Crushed stone						
	Split stone, (10 mm to 20 mm)	m^2	250	0	100	0	250
	Split stone, (25 mm to 40 mm)	m^2	250	0	100	0	250
	Purchased aggregate						
	Concrete aggregate (Fine)	m^3	400	0	100	0	400
	Concrete aggregate (Coarse)	m^3	400	0	100	0	400
3	Steel materials						
	Reinforcement bar (Round)	t	15,000	0	100	0	15,000
	Reinforcement bar (Deformed)	t	14,000	0	100	0	14,000
	Steel plate	t	20,000	80	20	444	4,000
	Steel shee pile, U-II (48 kg/m)	t	20,000	80	20	444	4,000
	Steel shee pile, U-III (60 kg/m)	t	20,000	80	20	444	4,000
	Steel shee pile, U-IV (76.1 kg/m)	t	20,000	80	20	444	4,000
	Galvanized pipe (w/socket), D-50 mm	Lin.m	820	0	100	0	820
	Galvanized pipe (w/socket), D-75 mm	Lin.m	1,500	0	100	0	1,500
	Galvanized pipe (w/socket), D-100 mm	Lin.m	2,500	0	100	0	2,500
	Annealed iron wire	kg	30	0	100	0	30
	Nail	kg	20	0	100	0	20
	Angle	t	15,000 to 19,000	80	20	333 to 422	3,000 to 3,800
	Galvanized wire	kg	35	0	100	0	35
	Checkered plate	t	18,000 to 20,000	80	20	400 to 444	3,600 to 4,000
	H-shape steel	t	20,000 to 24,000	80	20	444 to 533	4,000 to 4,800
	Channel steel	t	14,000 to 20,000	80	20	311 to 444	2,800 to 4,000
	Steel pipe, (25 mm) L = 6m	No.	420	0	100	0	420
	Steel pipe, (40 mm) L = 6m	No.	580	0	100	0	580
	Steel pipe, (50 mm) L = 6m	No.	740	0	100	0	740
	Steel pipe, (65 mm) L = 6m	No.	980	0	100	0	980
	Steel pipe, (80 mm) L = 6m	No.	1,250	0	100	0	1,250
	Steel pipe, (100 mm) L = 6m	No.	1,850	0	100	0	1,850
	Steel casing pipe, 50*50*3 L = 6m	No.	650	0	100	0	650
4	Timber materials						
	Plank, 10 inch (Yang Wood)	Cu.ft	310	0	100	0	310
	Square, 1 inch *3 inch	Lin.m	42	0	100	0	42
	Plywood waterproof, 10mm *1.2m *2.4m	Sheet	800	0	100	0	800
	Plywood waterproof, 15mm *1.2m *2.4m	Sheet	1,200	0	100	0	1,200
	Timber pile, D-150 mm. L=3m	No.	350	0	100	0	350
	Timber log, L=4m	No.	360	0	100	0	360

Table H.2 Unit Prices of Construction Materials (2/4)

Exchange Rate US$1.00 = 36.0 Baht

(As of October, 1998)

No.	Commodity	Unit	Site Delivery Price (Baht)	Allocation of Unit Price			
				Allocation Ratio		Allocated Unit Price	
				F/C (%)	I/C (%)	F/C (US$)	I/C (Baht)
5	Concrete produce						
	Mortar	m^3	1,875	0	100	0	1,875
	Ready mixed concrete, type A, 415 kg/cm^2	m^3	2,380	0	100	0	2,380
	Ready mixed concrete, type B, 300 kg/cm^2	m^3	2,270	0	100	0	2,270
	Ready mixed concrete, type C, 240 kg/cm^2	m^3	2,160	0	100	0	2,160
	Ready mixed concrete, type D, 210 kg/cm^2	m^3	2,110	0	100	0	2,110
	Ready mixed concrete, type E, 180 kg/cm^2	m^3	2,060	0	100	0	2,060
	Ready mixed concrete, type F, 150 kg/cm^2	m^3	2,100	0	100	0	2,100
	Hume pipe, class 2, type B, D300 *1.0m	No.	295	0	100	0	295
	Hume pipe, class 2, type B, D400 *1.0m	No.	350	0	100	0	350
	Hume pipe, class 2, type B, D500 *1.0m	No.	410	0	100	0	410
	Hume pipe, class 2, type B, D600 *1.0m	No.	530	0	100	0	530
	Hume pipe, class 2, type B, D800 *1.0m	No.	910	0	100	0	910
	Hume pipe, class 2, type B, D1,000 *1.0m	No.	1,500	0	100	0	1,500
	Hume pipe, class 2, type B, D1,200 *1.0m	No.	1,960	0	100	0	1,960
	Hume pipe, class 2, type C, D1,500 *1.0m	No.	3,200	0	100	0	3,200
	Hume pipe, class 2, type C, D1,750 *1.0m	No.	6,400	0	100	0	6,400
	Hume pipe, class 2, type C, D2,000 *1.0m	No.	16,300	0	100	0	16,300
	Hume pipe, class 2, type C, D2,500 *1.0m	No.	21,500	0	100	0	21,500
	Pipe fitting, class 1, type T, 200 * 150 *600	No.	2,700	0	100	0	2,700
	Pipe fitting, class 1, type T, 250 * 150 *600	No.	4,500	0	100	0	4,500
	Pipe fitting, class 1, type T, 300 * 150 *600	No.	7,200	0	100	0	7,200
	Pipe fitting, class 1, type T, 350 * 150 *600	No.	8,300	0	100	0	8,300
	Pipe fitting, class 1, type T, 400 * 150 *800	No.	9,500	0	100	0	9,500
	Pipe fitting, class 1, type T, 450 * 150 *800	No.	10,600	0	100	0	10,600
	Pipe fitting, class 1, type T, 250 * 200 *600	No.	4,900	0	100	0	4,900
	Pipe fitting, class 1, type T, 300 * 200 *600	No.	7,900	0	100	0	7,900
	Pipe fitting, class 1, type T, 350 * 200 *600	No.	8,900	0	100	0	8,900
	Pipe fitting, class 1, type T, 400 * 200 *800	No.	10,500	0	100	0	10,500
	Pipe fitting, class 1, type T, 450 * 200 *800	No.	11,000	0	100	0	11,000
	Pipe fitting, class 1, type Y, 200 * 150 *600	No.	4,700	0	100	0	4,700
	Pipe fitting, class 1, type Y, 250 * 150 *600	No.	7,900	0	100	0	7,900
	Pipe fitting, class 1, type Y, 300 * 150 *600	No.	9,500	0	100	0	9,500
	Pipe fitting, class 1, type Y, 350 * 150 *600	No.	13,200	0	100	0	13,200
	Pipe fitting, class 1, type Y, 400 * 150 *800	No.	15,000	0	100	0	15,000
	Pipe fitting, class 1, type Y, 450 * 150 *800	No.	17,000	0	100	0	17,000
	Pipe fitting class 1, type Y, 250 * 200 *600	No.	8,400	0	100	0	8,400
	Pipe fitting class 1, type Y, 300 * 200 *600	No.	10,100	0	100	0	10,100
	Pipe fitting class 1, type Y, 350 * 200 *600	No.	14,000	0	100	0	14,000
	Pipe fitting class 1, type Y, 400 * 200 *800	No.	16,200	0	100	0	16,200
	Pipe fitting class 1, type Y, 450 * 200 *800	No.	18,200	0	100	0	18,200
	Pipe fitting , class 1, Bend , 30 , 150	No.	1,800	0	100	0	1,800
	Pipe fitting , class 1, Bend , 30 , 200	No.	2,500	0	100	0	2,500
	Pipe fitting , class 1, Bend , 45 , 150	No.	2,100	0	100	0	2,100
	Pipe fitting , class 1, Bend , 45 , 200	No.	2,800	0	100	0	2,800
	Pipe fitting , class 1, Short, D150 *200 mm	No.	1,300	0	100	0	1,300
	Pipe fitting , class 1, Short, D200 *200 mm	No.	1,700	0	100	0	1,700
	Centrifugal RC pile, D300 *60t *8m	No.	2,296	0	100	0	2,296
	Centrifugal RC pile, D300 *60t *12m	No.	3,444	0	100	0	3,444
	Centrifugal RC pile, D350 *65t *10m	No.	3,680	0	100	0	3,680
	Centrifugal RC pile, D350 *65t *14m	No.	5,152	0	100	0	5,152
	Centrifugal RC pile, D400 *70t *10m	No.	4,580	0	100	0	4,580
	Centrifugal RC pile, D400 *70t *15m	No.	6,870	0	100	0	6,870
	Centrifugal RC pile, D500 *80t *10m	No.	6,920	0	100	0	6,920
	Centrifugal RC pile, D500 *80t *15m	No.	10,380	0	100	0	10,380
	Centrifugal RC pile, D600 *90t *10m	No.	9,380	0	100	0	9,380
	Centrifugal RC pile, D600 *90t *15m	No.	14,070	0	100	0	14,070

Table II.2 Unit Prices of Construction Materials (3/4)

Exchange Rate US$1.00 = 36.0 Baht

(As of October, 1998)

No.	Commodity	Unit	Site Delivery Price (Baht)	Allocation of Unit Price			
				Allocation Ratio		Allocated Unit Price	
				F/C (%)	L/C (%)	F/C (US$)	L/C (Baht)
6	PVC materials						
	PVC pipe, (Class 8.5), D=25 mm	No.	85	0	100	0	85
	PVC pipe, (Class 8.5), D=55 mm	No.	180	0	100	0	180
	PVC pipe, (Class 8.5), D=80 mm	No.	350	0	100	0	350
	PVC pipe, (Class 8.5), D=100 mm	No.	410	0	100	0	410
	PVC pipe, (Class 8.5), D=125 mm	No.	620	0	100	0	620
	PVC pipe, (Class 8.5), D=150 mm	No.	880	0	100	0	880
	PVC pipe, (Class 8.5), D=200 mm	No.	1,390	0	100	0	1,390
	PVC pipe, (Class 8.5), D=250 mm	No.	2,010	0	100	0	2,010
	PVC pipe,(Class 8.5), D=300 mm	No.	2,850	0	100	0	2,850
	PVC pipe, (Class 8.5), D=400 mm	No.	5,250	0	100	0	5,250
	PVC Waterstop, W-200 mm	Lin.m	211	0	100	0	211
	PVC Waterstop, W-300 mm	Lin.m	460	0	100	0	460
7	Fuel						
	Diesel	Litre	11.54	80	20	0.3	2.3
	Gasoline	Litre	13.05	80	20	0.3	2.6
	Kerosine	Litre	12.01	80	20	0.3	2.4
	Lubricant	Litre	40.00	80	20	0.9	8.0
	Electricity	kWh	3.00	0	100	0	3.0
8	Gas						
	Oxegen gas ($6m^3$)	Cylinder	80	0	100	0	80
	Acetylene gas (5.5 kg)	Cylinder	350	0	100	0	350
9	Road and bridge materials						
	Road handrail	Lin.m	900	0	100	0	900
	Bitumen, 80/100	t	4,600	80	20	102	920
	Bitumen, MC30	t	7,250	80	20	161	1,450
	Asphalt emulsion	kg	5.45	80	20	0.1	1.1
	Guard rail	Lin.m	5,000	0	100	0	5,000
	Guard post, & 4 inc *1.2m	No.	1,000	0	100	0	1,000
	I-steel grider	kg	18 to 22	80	20	0.4 to 0.5	3.6 to 4.4
	High tension bolt	kg	33	80	20	0.7	6.6
	Paint, (primer)	Gallon	380	80	20	8.4	76
	Paint, (finish)	Gallon	700	80	20	15.6	140
	Anchor cap, 19mm *600mm	Lin.m	35	0	100	0	35
	Welded iron net	m^2	150	0	100	0	150
	Rubber Joint filler, -10 mm *3 feet *6 feet	m^2	1,100	0	100	0	1,100
	Welding wire	kg	50	0	100	0	50
	Adhesive agent	kg	260	80	20	5.8	52
10	Form materials						
	Form tie, 9mm *210 mm	No.	14.00	0	100	0	14.0
	Washer	No.	5.80	0	100	0	5.8
	Cone, (Steel)	No.	6.00	0	100	0	6.0
	Crip	No.	5.00	0	100	0	5.0
	Separator, 8-10 mm *20 mm	No.	50	0	100	0	50
	Metal form, 300 * 150	No.	325	0	100	0	325
	Metal form, 200 * 150	No.	280	0	100	0	280
	Metal form, 150 * 150	No.	225	0	100	0	225
	Metal form, 100 * 150	No.	180	0	100	0	180

Table H.2 Unit Prices of Construction Materials (4/4)

Exchange Rate US$1.00 = 36.0 Baht

(As of October, 1998)

No.	Commodity	Unit	Site Delivery Price (Baht)	Allocation of Unit Price			
				Allocation Ratio		Allocated Unit Price	
				F/C (%)	L/C (%)	F/C (US$)	L/C (Baht)
11	Other materials						
	Bentonite	kg	7.0	0	100	0	7.0
	Palm fibre, 7 inch	m^2	90	0	100	0	90
	Sand bag	Pc.	3.5	0	100	0	3.5
	Welding rod, 20kg	Pack	900	0	100	0	900
	Plastic mat, 30 mm * 1.5 m	m^2	2,800	0	100	0	2,800
	Electrode for mild steel	Pack	300	0	100	0	300
	Electric cable, 2*2.5 VAE	Lin.m	9.7	0	100	0	9.7
	Electric cable, 2*1.5 VAE	Lin.m	6.1	0	100	0	6.1
	Chisel for hand	Pc.	200	80	20	4.4	40

Table II.3 Investigated Unit Cost

No	Description	Formula
1	Collector System for WWTP	
	Shield Slurry Type	$y = 0.0006 x^2 - 1.5555 x + 5,778$
	Earth Pressure Balancing Pipe Jack	$y = 0.6936 x + 1,357.1$
	Slurry Shield Pipe Jacking	$y = 0.6743 x + 1,372.3$
	Microtunneling	$y = 0.7000 x + 1,356.7$
2	Construction Unit Cost for Collector System (Japanese)	
	Shield Slurry Type	$y = \{(7.54 \times 10^{-6})x^2 - (5.35 \times 10^{-3})x + 57.48\} \times (113.2/90.1) \times (10^4/125)$
	Pipe Jacking Method	$y = (0.027x) \times (113.2/90.1) \times (10^4/125)$
3	Transportation Cost of Sludge Cake by Dump Truck	
	For 10 ton class	$y = 3.2807x + 38.405$
	For 6 ton class	$y = 5.3415x + 28.020$
	For 4 ton class	$y = 8.2026x + 41.813$
4	Transportation Cost of Ash and Compost by Dump Truck	
	For 10 ton class	$y = 2.6279x + 30.584$
	For 6 ton class	$y = 4.2898x + 22.088$
	For 4 ton class	$y = 6.5657x + 32.723$
5	Transportation Cost of Sludge Cake by Self-propelled Barge, 180m^3 class	
	For 10 km	90 Baht/m^3
	For 50 km	203 Baht/m^3
	For 100 km	341 Baht/m^3
	For 200 km	627 Baht/m^3
6	Transportation Cost of Chaff by 10 ton class Dump Truck	
	For 2.5 km	237 Baht/m^3
	For 5.0 km	301 Baht/m^3
	For 7.5 km	326 Baht/m^3
	For 10 km	358 Baht/m^3
	For 20 km	512 Baht/m^3
7	Transportation Cost of Night Soil by 9kl Vacuum Car	
		$y = 4.0101x + 35.073$
8	Transportation Cost of Reclaimed Wastewater Reuse by 12 m^3 Water Tanker	
		$y = 1.648x + 19.052$
9	Excavation Cost of Common	79 Baht/m^3

Table II.4 Overall Construction Cost for Sewerage System

Thousand US$

No.	Work Item	Capacity	Construction Cost
1.	Collector System	DWF m^3/d	
	Thonburi South	180,800	103,931
	Tonburi Central	157,900	90,804
	Tonburi North	77,900	44,791
	Khlong Toey West	165,000	95,270
	Khlong Toey East	185,400	106,588
	Bang Sue	126,100	72,524
	Huay Kwuang	124,300	71,429
	Wang Thong Lang	141,100	81,115
	Bung Kum	147,800	84,856
	Sub-total	1,306,300	751,308
2.	Wastewater Treatment Plant	DWF m^3/d	Cost
	Thonburi South	180,800	76,840
	Tonburi Central	157,900	67,108
	Tonburi North	77,900	33,108
	Khlong Toey West	165,000	70,125
	Khlong Toey East	185,400	78,795
	Bang Sue	126,100	53,593
	Huay Kwuang	124,300	52,828
	Wang Thong Lang	141,100	59,968
	Bung Kum	147,800	62,815
	Sub-total	1,306,300	555,180
3.	Reclaimed Wastewater Reuse Facilities	m^3/d	Cost
	Tanks and Water Supply System	15,450	4,712
	Sub-total		4,712
	Total		1,311,200

Table II.5 Overall Construction Cost for Option No. L2

Estimation Condition

- Digesting with Gas Generating, Odor Removal, Dewatering and Leachet Treatment
- Simple Landfill

Thousand US$

No.	Work Item	Capacity	Construction Cost
1.	Nong Khaem Sludge Treatment Center	t DS/d	
	1) Digesting Plant, 4,000 m^3 @4 tanks	52.8 t DS/d	7,945
	2) Gas Generating Equipment, 440 kW @4	1,760 kW	10,400
	3) Odor Removal Apparatus	L.S.	2,380
	4) Dewatering Equipment	52.8 t DS/d	10,870
	5) Leachet Treatment Plant	1,000 m^3/d	1,670
	Sub-total		33,265
2.	Simple Landfill	m^3	Cost
	Landfill Yard	1,500,000	4,500
	Sub-total		4,500
	Total		37,765

Table II.6 Overall Construction Cost for Option No. A2

Estimation Condition

- Composting
- Order Removal

Thousand US$

No.	Work Item	Capacity	Construction Cost
1.	Compost Factory	t DS/d	
	North Factory	98.5	24,800
	East Factory	83.0	17,700
	West Factory	68.7	16,000
	Total	250.2	58,500

Table H.7 Transportation Cost of Materials by Dump Truck

Dump Truck	Distance (km)	Solid Sludge Cake		Ash		Compost	
		Baht/m^3	Baht/t	Baht/m^3	Baht/t	Baht/m^3	Baht/t
4 tons ($2\ m^3$)	2.5	75	65	60	100	60	92
	5.0	95	82	75	125	75	115
	7.5	104	90	83	138	83	128
	10.0	115	99	90	150	90	138
	12.5	145	125	115	192	115	177
	15.0	165	142	130	217	130	200
	20.0	190	164	150	250	150	231
	25.0	230	198	185	308	185	285
	30.0	285	246	230	383	230	354
	40.0	380	328	305	508	305	469
	50.0	460	397	365	608	365	562
6 tons ($4\ m^3$)	2.5	50	43	40	67	40	62
	5.0	63	54	50	83	50	77
	7.5	69	59	55	92	55	85
	10.0	75	65	60	100	60	92
	12.5	95	82	75	125	75	115
	15.0	108	93	86	143	86	132
	20.0	125	108	100	167	100	154
	25.0	150	129	120	200	120	185
	30.0	185	159	150	250	150	231
	40.0	250	216	200	333	200	307
	50.0	300	259	240	400	240	369
10 tons ($7\ m^3$)	2.5	46	40	37	62	37	57
	5.0	59	51	47	78	47	72
	7.5	64	55	51	85	51	78
	10.0	70	60	56	93	56	86
	12.5	78	67	62	103	62	95
	15.0	88	76	70	117	70	108
	20.0	100	86	80	133	80	123
	25.0	116	100	93	155	93	143
	30.0	140	121	112	187	112	172
	40.0	175	151	140	233	140	215
	50.0	200	172	160	267	160	246

Table H.8 Transportation Cost of Various Materials

Hauling Distance	Sludge Cake	Night Soil	Reclaimed Water	Chaff
	Self-Propelled Barge	Vacuum Car	Water Tanker	Dump Truck
	180 m^3	9 m^3	12 m^3	10 t
km	Baht/m^3	Baht/m^3	Baht/m^3	Baht/t
2.5		50	23	237
5.0		63	29	301
7.5		68	32	326
10.0	90	75	35	358
12.5		84	39	397
15.0		94	44	448
20.0	119	108	50	512
25.0		126	58	
30.0	146	151	70	
40.0	173	188	88	
50.0	203	251	100	
60.0	229			
70.0	256			
80.0	287			
90.0	314			
100.0	341			
125.0	411			
150.0	478			
175.0	547			
200.0	627			
250.0	753			

Table II.9 Transportation Unit Cost of Sludge Cake from WWTP to Disposal Site

Wastewater Treatment Plant	Tharaeng		Nong Khaem		On-Nut	
	Distance (km)	Unit Cost (Baht/m^3)	Distance (km)	Unit Cost (Baht/m^3)	Distance (km)	Unit Cost (Baht/m^3)
Si Phraya	37	160	30	137		
Ratanakosin	36	157	26	124		
BKK Central	30	137	32	143		
Yannawa	35	153	33	147		
Nong Khaem	52	209	-	-		
Ratburana	53	212	34	150		
Huay Kwuang(Existing)	28	130	34	150		
Chatuchak	28	130	18	97	24	117
Khlong Toey West	22	111	27	127	13	81
Khlong Toey East	27	127	32	143	16	91
Thonburi North	28	130	21	107	27	127
Thonburi Central	31	140	21	107	30	137
Thonburi South	32	143	20	104	29	134
Bang Sue	21	107	28	130	32	143
Huay Kwuang	19	101	22	111	18	97
Wang Thong Lang	13	81	36	157	16	91
Bung Kum	6	58	44	183	15	88

Note: Transportation unit costs of the Sludge Cake are computed by the following formula;

$y = 3.2807 x + 38.405$

where;

x is Transportation distance by km to the disposal site

y is Transportation cost in Baht

Table H.10 Construction Cost of Simple Landfill

On the basis of;

Excavation Volume; 1,500,000 m^3

Excavation Depth: 10 m

Mean Excavation Area; 150,000 m^2 (400 m x 400 m)

No.	Work Item	Unit	Quantity	Unit Cost	Amount
				US$	x 10^3 US$
1	Access Road, Macadam, We = 7.5 m	m	1,500	110	165
2	Excavation, Common, L = 500 m	m^3	1,500,000	2.2	3,300
3	Miscellaneous, 5% of above	L.S.			175
	Sub-total				3,640
7	Overhead and Others, 25% of above	L.S.			910
	Total				4,550

Construction Unit Cost

4,550,000 US$ ÷1,500,000 m^3 = 3.0 US$/$m^3$

Table II.11 Annual Operation and Maintenance Cost of Landfill Yard (Well-equipped)

1) • Swampdozer 13 ton, 2 units for Spreading and Compaction Work of Dumping Solid Cake

• Rental Charge of Swampdozer

5,980 yen/hr. x 0.50 — 2,990 yen/hr.

• Operator's Cost

Operator	350 B/d ÷ 5 hr./d = 70 B/hr.	
Assistant	225 B/d ÷ 5 hr./d = 45 B/hr.	380 yen/hr.
Sub total	115 B/hr x 3.333 yen/B	

• POL

127 PS x 0.138 ℓ/PS x 11.54 B/ℓ x 1.20 x 3.333 yen/B — 810 yen/hr.

Total — 4,180 yen/hr.

4,180 yen/hr. ÷ 3.333 yen/B = 1,254 B/hr. — Say 1,300 B/hr.

Annual O&M Cost

1,300 B/hr. x 900 hr./year x 2 units x 1.07 — 2,500,000 Baht

2) • Drainage Pumping Unit (One unit is standby)

• Electricity Charge

7.5 KW x 3.0 B/KW x 365 d/year = 8,213 B

• Operator's Cost

200 B/d x 2 men x 30 d/month x 12 month/year = 144,000 B

Sub-Total	152,213 x 1.30	Say 200,000 Baht

3) • Annual Total O&M Cost

• Well-equipped — 2,700,000 Baht

Say 75,000 US$

• Simple (without Drainage) — 2,500,000 Baht

Say 70,000 US$

Table H.12 Cost Estimate of Collector System, Thonburi South Scheme, 180,800 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	1,000	0.9	2,050	1,845	Earth Pressure Balancing Pipe Jacking
2	1,000	1.3	2,050	2,665	Earth Pressure Balancing Pipe Jacking
3	1,400	0.3	2,330	699	Earth Pressure Balancing Pipe Jacking
4	1,200	1.5	2,190	3,285	Earth Pressure Balancing Pipe Jacking
5	2,000	1.4	2,740	3,836	Earth Pressure Balancing Pipe Jacking
6	1,000	1.5	2,050	3,075	Earth Pressure Balancing Pipe Jacking
7	2,200	0.6	2,880	1,728	Earth Pressure Balancing Pipe Jacking
8	1,000	2.1	2,050	4,305	Earth Pressure Balancing Pipe Jacking
9	1,400	1.1	2,330	2,563	Earth Pressure Balancing Pipe Jacking
10	2,400	0.5	3,020	1,510	Earth Pressure Balancing Pipe Jacking
11	800	1.2	1,910	2,292	Slurry Shield Pipe Jacking
12	1,000	0.6	2,050	1,230	Earth Pressure Balancing Pipe Jacking
13	1,600	0.7	2,470	1,729	Earth Pressure Balancing Pipe Jacking
14					
15					
16					
Sub-Total		**13.7**		**30,762**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	700 to 150	212,700	344	73,169	Microtunneling for 150,200 and 250
Sub-Total				**73,169**	Slurry Shield Pipe Jacking for 300, 400, 500, 600 and 700

Total Construction Cost **103,931** (x1,000 US$)

Table H.13 Cost Estimate of Collector System, Thonburi Central Scheme, 157,900 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	800	1.9	1,910	3,629	Slurry Shield Pipe Jacking
2	600	1.5	1,780	2,670	Slurry Shield Pipe Jacking
3	600	1.4	1,780	2,492	Slurry Shield Pipe Jacking
4	1,400	2.6	2,330	6,058	Earth Pressure Balancing Pipe Jacking
5	1,200	2.8	2,190	6,132	Earth Pressure Balancing Pipe Jacking
6	2,000	2.0	2,740	5,480	Earth Pressure Balancing Pipe Jacking
7	1,000	3.1	2,050	6,355	Earth Pressure Balancing Pipe Jacking
8	2,200	1.8	2,880	5,184	Earth Pressure Balancing Pipe Jacking
9	800	2.9	1,910	5,539	Slurry Shield Pipe Jacking
10	2,400	2.9	3,020	8,758	Earth Pressure Balancing Pipe Jacking
Sub-Total		**22.9**		**52,297**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	500 to 150	155,900	247	38,507	Microtunneling for 150,200 and 250
Sub-Total				**38,507**	Slurry Shield Pipe Jacking for 300, 400 and 500

Total Construction Cost **90,804** (x1,000 US$)

Table H.14 Cost Estimate of Collector System, Thonburi North Scheme, 77,900 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	1,000	2.2	2,050	4,510	Earth Pressure Balancing Pipe Jacking
2	1,400	1.5	2,330	3,495	Earth Pressure Balancing Pipe Jacking
3	800	2.6	1,910	4,966	Slurry Shield Pipe Jacking
4	500	0.9	1,710	1,539	Slurry Shield Pipe Jacking
5	1,600	1.9	2,470	4,693	Earth Pressure Balancing Pipe Jacking
6	800	1.4	1,910	2,674	Slurry Shield Pipe Jacking
7	800	1.0	1,910	1,910	Slurry Shield Pipe Jacking
8	2,000	1.2	2,740	3,288	Earth Pressure Balancing Pipe Jacking
9	800	1.2	1,910	2,292	Slurry Shield Pipe Jacking
Sub-Total		**13.9**		**29,367**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	400 to 150	77,900	198	15,424	Microtunneling for 150,200 and 250
Sub-Total				**15,424**	Slurry Shield Pipe Jacking for 300 and 400

Total Construction Cost **44,791** (x1,000 US$)

Table H.15 Cost Estimate of Collector System, Khlong Toey West Scheme, 165,000 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	800	1.6	1,910	3,056	Slurry Shield Pipe Jacking
2	800	1.6	1,910	3,056	Slurry Shield Pipe Jacking
3	1,400	2.7	2,330	6,291	Earth Pressure Balancing Pipe Jacking
4	1,000	2.6	2,050	5,330	Earth Pressure Balancing Pipe Jacking
5	1,800	2.2	2,610	5,742	Earth Pressure Balancing Pipe Jacking
6	1,000	2.7	2,050	5,535	Earth Pressure Balancing Pipe Jacking
7	1,400	2.0	2,330	4,660	Earth Pressure Balancing Pipe Jacking
8	600	0.8	1,780	1,424	Slurry Shield Pipe Jacking
9	2,200	1.6	2,880	4,608	Earth Pressure Balancing Pipe Jacking
10	600	1.8	1,780	3,204	Slurry Shield Pipe Jacking
11	600	0.9	1,780	1,602	Slurry Shield Pipe Jacking
12	1,400	3.0	2,330	6,990	Earth Pressure Balancing Pipe Jacking
13	2,600	0.9	3,160	2,844	Earth Pressure Balancing Pipe Jacking
Sub-Total		**24.4**		**54,342**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	500 to 150	165,700	247	40,928	Microtunneling for 150,200 and 250
Sub-Total				**40,928**	Slurry Shield Pipe Jacking for 300, 400 and 500

Total Construction Cost **95,270** (x1,000 US$)

Table H.16 Cost Estimate of Collector System, Khlong Toey East Scheme, 185,400 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	800	1.9	1,910	3,629	Slurry Shield Pipe Jacking
2	800	1.8	1,910	3,438	Slurry Shield Pipe Jacking
3	1,200	1.3	2,190	2,847	Earth Pressure Balancing Pipe Jacking
4	600	1.9	1,780	3,382	Slurry Shield Pipe Jacking
5	1,400	3.1	2,330	7,223	Earth Pressure Balancing Pipe Jacking
6	1,000	2.1	2,050	4,305	Earth Pressure Balancing Pipe Jacking
7	1,800	1.8	2,610	4,698	Earth Pressure Balancing Pipe Jacking
8	1,000	2.9	2,050	5,945	Earth Pressure Balancing Pipe Jacking
9	2,200	1.4	2,880	4,032	Earth Pressure Balancing Pipe Jacking
10	800	2.2	1,910	4,202	Slurry Shield Pipe Jacking
11	1,000	3.4	2,050	6,970	Earth Pressure Balancing Pipe Jacking
12	1,200	2.0	2,190	4,380	Earth Pressure Balancing Pipe Jacking
13	2,200	1.1	2,880	3,168	Earth Pressure Balancing Pipe Jacking
14	1,000	2.3	2,050	4,715	Earth Pressure Balancing Pipe Jacking
15	600	1.8	1,780	3,204	Slurry Shield Pipe Jacking
16	1,200	1.0	2,190	2,190	Earth Pressure Balancing Pipe Jacking
Sub-Total		**32.0**		**68,328**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	500 to 150	154,900	247	38,260	Microtunneling for 150,200 and 250
Sub-Total				**38,260**	Slurry Shield Pipe Jacking for 300, 400 and 500

Total Construction Cost **106,588** (x1,000 US$)

Table H.17 Cost Estimate of Collector System, Bang Sue Scheme, 126,100 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	1,200	1.1	2,190	2,409	Earth Pressure Balancing Pipe Jacking
2	800	0.7	1,910	1,337	Slurry Shield Pipe Jacking
3	1,400	0.8	2,330	1,864	Earth Pressure Balancing Pipe Jacking
4	1,000	2.0	2,050	4,100	Earth Pressure Balancing Pipe Jacking
5	1,200	0.9	2,190	1,971	Earth Pressure Balancing Pipe Jacking
6	2,000	1.9	2,740	5,206	Earth Pressure Balancing Pipe Jacking
7	1,000	1.7	2,050	3,485	Earth Pressure Balancing Pipe Jacking
8	1,200	2.0	2,190	4,380	Earth Pressure Balancing Pipe Jacking
9	800	0.9	1,910	1,719	Slurry Shield Pipe Jacking
10	1,400	0.5	2,330	1,165	Earth Pressure Balancing Pipe Jacking
11	2,400	0.5	3,020	1,510	Earth Pressure Balancing Pipe Jacking
Sub-Total		**13.0**		**29,146**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	700 to 150	126,100	344	43,378	Microtunneling for 150,200 and 250
Sub-Total				**43,378**	Slurry Shield Pipe Jacking for 300, 400, 600 and 700

Total Construction Cost **72,524** (x1,000 US$)

Table H.18 Cost Estimate of Collector System, Huay Kwuang Scheme, 124,300 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	1,200	3.1	2,190	6,789	Earth Pressure Balancing Pipe Jacking
2	800	0.7	1,910	1,337	Slurry Shield Pipe Jacking
3	1,400	0.4	2,330	932	Earth Pressure Balancing Pipe Jacking
4	800	2.2	1,910	4,202	Slurry Shield Pipe Jacking
5	800	1.0	1,910	1,910	Slurry Shield Pipe Jacking
6	1,800	1.1	2,610	2,871	Earth Pressure Balancing Pipe Jacking
7	1,000	2.8	2,050	5,740	Earth Pressure Balancing Pipe Jacking
8	800	1.4	1,910	2,674	Slurry Shield Pipe Jacking
9	1,400	0.1	2,330	233	Earth Pressure Balancing Pipe Jacking
10	2,200	0.7	2,880	2,016	Earth Pressure Balancing Pipe Jacking
Sub-Total		**13.5**		**28,704**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	700 to 150	124,200	344	42,725	Microtunneling for 150,200 and 250
Sub-Total				**42,725**	Slurry Shield Pipe Jacking for 300, 400, 500, 600 and 700

Total Construction Cost **71,429** (x1,000 US$)

Table H.19 Cost Estimate of Collector System, Wang Thong Lang, 141,100 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	800	2.3	1,910	4,393	Slurry Shield Pipe Jacking
2	800	1.9	1,910	3,629	Slurry Shield Pipe Jacking
3	1,200	0.2	2,190	438	Earth Pressure Balancing Pipe Jacking
4	600	1.0	1,780	1,780	Slurry Shield Pipe Jacking
5	600	1.3	1,780	2,314	Slurry Shield Pipe Jacking
6	1,400	1.5	2,330	3,495	Earth Pressure Balancing Pipe Jacking
7	800	1.7	1,910	3,247	Slurry Shield Pipe Jacking
8	1,600	1.2	2,470	2,964	Earth Pressure Balancing Pipe Jacking
9	600	1.1	1,780	1,958	Slurry Shield Pipe Jacking
10	2,000	2.8	2,740	7,672	Earth Pressure Balancing Pipe Jacking
11	800	1.2	1,910	2,292	Slurry Shield Pipe Jacking
12	800	1.3	1,910	2,483	Slurry Shield Pipe Jacking
13	1,400	1.1	2,330	2,563	Earth Pressure Balancing Pipe Jacking
14	800	1.7	1,910	3,247	Slurry Shield Pipe Jacking
15	1,600	0.8	2,470	1,976	Earth Pressure Balancing Pipe Jacking
16	2,400	0.6	3,020	1,812	Earth Pressure Balancing Pipe Jacking
Sub-Total		**21.7**		**46,263**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	500 to 150	141,100	247	34,852	Microtunneling for 150,200 and 250
Sub-Total				**34,852**	Slurry Shield Pipe Jacking for 300, 400 and 500

Total Construction Cost **81,115** (x1,000 US$)

Table H.20 Cost Estimate of Collector System, Bung Kum Scheme, 147,800 m^3/day

Pipe Reference No.	Collector Pipe Size		Construction Cost		Construction Method
	Diameter	Length	Unit	Amount	
	(mm)	(km)	US $/m	x1,000 US $	
1	1,000	1.7	1,910	3,247	Earth Pressure Balancing Pipe Jacking
2	1,000	1.2	1,910	2,292	Earth Pressure Balancing Pipe Jacking
3	1,600	1.4	2,330	3,262	Earth Pressure Balancing Pipe Jacking
4	1,800	3.1	2,050	6,355	Earth Pressure Balancing Pipe Jacking
5	800	1.6	2,610	4,176	Slurry Shield Pipe Jacking
6	1,000	1.7	2,050	3,485	Earth Pressure Balancing Pipe Jacking
7	800	1.8	2,330	4,194	Slurry Shield Pipe Jacking
8	1,400	1.5	1,780	2,670	Earth Pressure Balancing Pipe Jacking
9	2,200	1.0	2,880	2,880	Earth Pressure Balancing Pipe Jacking
10	800	2.1	1,780	3,738	Slurry Shield Pipe Jacking
11	600	1.2	1,780	2,136	Slurry Shield Pipe Jacking
12	1,200	1.0	2,330	2,330	Earth Pressure Balancing Pipe Jacking
13	1,400	2.4	3,160	7,584	Earth Pressure Balancing Pipe Jacking
Sub-Total		**21.7**		**48,349**	

Pipe Ref. No.	Diameter mm	DWF m^3/d	Unit US$/$m^3$/d	Amount x1,000 US $	Construction Method
-	500 to 150	147,800	247	36,507	Microtunneling for 150,200 and 250
Sub-Total				**36,507**	Slurry Shield Pipe Jacking for 300, 400 and 500

Total Construction Cost **84,856** (x1,000 US$)

Table H.21 Cost Estimate for Integrated Anaerobic Digesting and Composting Plants

No.	Dry Solid	Digesting		Generating		Odor Removal		Dewatering (by Belt Press)		Leachet		Sub-Total	Composting		Total
	Capacity	Cap.	Cost	Cap.	Cost	Cap.	Cost	Cap.	Cost	Cap.	Cost	Cost	Cap.	Cost	Cost
	t DS/d	m^3/d	x 10^3 US$	kW	x 10^3 US$	m^3/min	x 10^3 US$	t DS/d	x 10^3 US$	m^3/d	x 10^3 US$	x 10^3 US$	t DS/d	x 10^3 US$	x 10^3 US$
1	10.0	200	1.490	440	1.950	L.S	447	7.0	2.038	190	313	6.238	7.0	1.745	7.983
2	80.0	1.600	4.700	3.520	12.500	L.S	3.500	56.0	6.000	1.520	2.500	29.200	56.0	9.500	38.700
3	160.0	3.200	7.500	7.040	18.500	L.S	7.000	112.0	9.500	3.040	5.000	47.500	112.0	16.500	64.000

Table H.22 Breakdown of Cost Estimate for Integrated Anaerobic Digesting and Composting Plant (Dry Solid Capacity = 10 t DS/d)

No.	Work Item	Digesting	Generating	Odor Removal	Dewatering (by Belt Press)	Leachet	Sub-Total	Composting	Total
1	Planning Condition	Ds = 10 t/d Qd = 200 m^3/d	Output; 440kW Q'ty; 1 Unit		Ds = 7 t/d Cake Q'ty; 35 m^3/d	Cake Moisture; 80 % Dry Solid; 20 % Ow = 160 m^3/d		Ds = 7.0 t/d Padding Fermentor	
2	Construction Cost								
	Civil and Architecture	625,000	300,000	94,000	842,000	141,000		835,000 (1)	
	Machinery	565,000	1,650,000	277,000	788,000	110,000		620,000 (2)	
	Electric	300,000		76,000	408,000	62,000		290,000	
	Sub-Total	**1,490,000**	**1,950,000**	**447,000**	**2,038,000**	**313,000**	**6,238,000**	**1,745,000**	**7,983,000**
3	Annual O&M Cost								
	Chemical	0	0	0	207,000	1,250		0	
	Fuel	0	0	0	0	0		77,000	
	Electric Charge	4,300	0	50,800	15,000	2,500		76,000	
	Maintenance	14,000	42,000	4,200	19,000	1,050		24,000	
	Personnel	10,500	10,500	0	12,000	0		26,000	
	Sub-Total	**28,800**	**52,500**	**55,000**	**253,000**	**4,800**	**394,100**	**203,000**	**597,100**

Note: (1) Composter
(2) Dryer

Table H.23 Breakdown of Cost Estimate for Integrated Anaerobic Digesting and Composting Plant (Dry Solid Capacity = 80 t DS/d)

No.	Work Item	Digesting	Generating	Odor Removal	Dewatering (by Belt Press)	Leachet	Sub-Total	Composting	Total
1	Planning Condition	Ds = 80 t/d Qd = 1,600 m^3/d	Output; 3,540kW Q'ty; 1 Unit		Ds = 56 t/d Cake Q'ty; 280 m^3/d	Cake Moisture; 80 % Dry Solid; 20 % Qw = 1,280 m^3/d		Ds = 56.0 t/d Padding Fermentor	
2	Construction Cost								
	Civil and Architecture	2,130,000	1,900,000	750,000	3,900,000	1,125,000		4,215,000	
	Machinery	1,720,000	10,600,000	2,150,000	1,400,000	875,000		3,700,000	
	Electric	850,000		600,000	700,000	500,000		1,585,000	
	Sub-Total	**4,700,000**	**12,500,000**	**3,500,000**	**6,000,000**	**2,500,000**	**29,200,000**	**9,500,000**	**38,700,000**
3	Annual O&M Cost								
	Chemical	0	0	0	163,000	7,100		0	
	Fuel	0	0	0	0	0		658,000	
	Electric Charge	35,000	0	406,000	119,000	16,300		496,000	
	Maintenance	41,000	268,000	34,000	34,000	6,600		100,000	
	Personnel	10,500	67,000	0	55,000	0		146,000	
	Sub-Total	**86,500**	**335,000**	**440,000**	**371,000**	**30,000**	**1,262,500**	**1,400,000**	**2,662,500**

Table H.24 Breakdown of Cost Estimate for Integrated Anaerobic Digesting and Composting Plant (Dry Solid Capacity = 160 t DS/d)

No.	Work Item	Digesting	Generating	Odor Removal	Dewatering (by Belt Press)	Leachet	Sub-Total	Composting	Total
1	Planning Condition	Ds = 160 t/d Qd = 3,200 m^3/d	Output; 7,040kW Q'ty; 1 Unit		Ds = 112 t/d	Cake Moisture; 80 % Dry Solid; 20 % Qw = 2,560 m^3/d		Ds = 112.0 t/d Padding Fermentor	
2	Construction Cost								
	Civil and Architectur	3,400,000	2,800,000	1,500,000	6,200,000	2,250,000		7,300,000	
	Machinery	2,700,000	15,700,000	4,300,000	2,200,000	1,750,000		6,450,000	
	Electric	1,400,000		1,200,000	1,100,000	1,000,000		2,750,000	
	Sub-Total	**7,500,000**	**18,500,000**	**7,000,000**	**9,500,000**	**5,000,000**	**47,500,000**	**16,500,000**	**64,000,000**
3	Annual O&M Cost								
	Chemical	0	0	0	242,000	10,500		0	
	Fuel	0	0	0	0	0		1,236,000	
	Electric Charge	57,000	0	738,000	176,000	24,500		931,000	
	Maintenance	66,000	400,000	62,000	50,000	10,000		189,000	
	Personnel	17,000	100,000	0	82,000	0		274,000	
	Sub-Total	**140,000**	**500,000**	**800,000**	**550,000**	**45,000**	**2,035,000**	**2,630,000**	**4,665,000**