APPENDIX A

Table A-1 : Population Numbers in the SLC by Sex, District and Area

District / Area	Number of people		
	Total	Male	Female
Muang Phatthalung	124,010	59,744	64,266
Municipal area	42,169	20,239	21,930
Non-municipal area	81,841	39,505	42,336
Kong Ra	32,718	16,126	16,592
Municipal area	0	0	0
Non-municipal area	32,718	16,126	16,592
Khao Chaison	44,047	21,568	22,479
Municipal area	3,285	1,543	1,742
Non-municipal area	40,762	20,025	20,737
Tamot	26,036	12,852	13,184
Municipal area	9,504	4,680	4,824
Non-municipal area	16,532	8,172	8,360
Khuan Khanun	82,609	39,913	42,696
Municipal area	5,762	2,685	3,077
Non-municipal area	76,847	37,228	39,619
Pak Phyun	49,803	24,507	25,296
Municipal area	4,424	2,136	2,288
Non-municipal area	45,379	22,371	23,008
Si Banpot	15,901	7,988	7,913
Municipal area	0	0	0
Non-municipal area	15,901	7,988	7,913
Pa Bon	41,415	20,444	20,971
Municipal area	3,556	1,760	1,796
Non-municipal area	37,859	18,684	19,175
Bang Kaeo	24,651	12,096	12,555
Municipal area	3,875	1,830	2,045
Non-municipal area	20,776	10,266	10,510
Pa Phayom	31,024	15,346	15,678
Municipal area	0	0	0
Non-municipal area	31,024	15,346	15,678
Si Nakharin	24,025	12,084	11,941
Municipal area	0	0	0
Non-municipal area	24,025	12,084	11,941
Total	496,239	242,668	253,571
Municipal area	72,575	34,873	37,702
Non-municipal area	423,664	207,795	215,869

District / Area	Number of people		
	Total	Males	Females
Muang Songkhla	162,508	79,818	82,690
Municipal Area	84,116	40,565	43,551
Non-Municipal Area	78,392	39,253	39,139
Sathing Phra	52,744	25,478	27,266
Municipal Area	3,545	1,709	1,836
Non-Municipal Area	49,199	23,769	25,430
Ranot	78,245	38,353	39,892
Municipal Area	19,147	9,270	9,877
Non-Municipal Area	59,098	29,083	30,015
Krasaesin	18,375	8,893	9,482
Municipal Area	0	0	0
Non-Municipal Area	18,375	8,893	9,482
Rattaphum	65,419	32,140	33,279
Municipal Area	7,983	3,849	4,134
Non-Municipal Area	57,436	28,291	29,145
Sadao	102,127	50,783	51,344
Municipal Area	44,755	22,057	22,698
Non-Municipal Area	57,372	28,726	28,646
Hat Yai	321,926	152,461	169,465
Municipal Area	185,557	85,591	99,966
Non-Municipal Area	136,369	66,870	69,499
Na Mom	20,396	9,859	10,537
Municipal Area	0	0	0
Non-Municipal Area	20,396	9,859	10,537
Khuan Niang	34,049	16,576	17,473
Municipal Area	4,404	2,092	2,312
Non-Municipal Area	29,645	14,484	15,161
Bang Klam	26,114	12,947	13,167
Municipal Area	0	0	0
Non-Municipal Area	26,114	12,947	13,167
Singha Nakhon	79,318	38,847	40,471
Municipal Area	35,555	17,624	17,931
Non-Municipal Area	43,763	21,223	22,540
Khlong Hoi Khong	22,888	11,570	11,318
Municipal Area	0	0	0
Non-Municipal Area	22,888	11,570	11,318
Total	984,109	477,725	506,384
Municipal Area	385,062	182,757	202,305
Non-Municipal Area	599,047	294,968	304,079

Source: NSO, 2002.

APPENDIX B

Interview Form: Consumption of Chemical Fertilizer

No.							
Name of respondent							
Location							

Date……..…… Month…….……. Year.....

1. Status of respondent ?
   - ❒ Shop owner
   - ❒ Spouse
   - ❒ Child
   - ❒ Shop owner's relative
   - ❒ Salesperson
   - ❒ Other (please specify) ……

2. Type of fertilizers sold ?
   - ❒ Chemical fertilizer
   - ❒ Compost / Organic fertilizer
   - ❒ Other (please, specify).....

3. How do you obtain chemical fertilizer ?
   - ❒ Self-produced
   - ❒ Imported from other areas

   Please specify source (s) of chemical fertilizer imports.

   1.....

   2.....

   3……..

4. Where did you distribute chemical fertilizer to the agriculturists ?

❒ In Songkhla province (not including Chana, Saba Yoi, Na Thawee, and The Pa districts).

❒ In Phatthalung province only.

❒ Other (please specify).....

5. How much chemical fertilizer do you sell of the following grades (only quantities distributed in Phatthalung and Songkhla provinces with the exception Chana, Saba Yoi, Na Thawee, and The Pa districts) ?

Grade	Quantity (kg / month)	Type of plant using this grade
❒ 15 - 15 - 15		
❒ 16 - 16 - 16		
❒ 13 - 13 - 21		
❒ 8 - 24 - 24		
❒ - -		
❒ - -		

6. Do you encounter any problems as a result of selling chemical fertilizers ?

……

……

……...

7. Please give any comment / suggestions relating to the sale of chemical fertilizer.

…….

……

……...

……

APPENDIX C

Chemical Fertilizer Consumption as established from Interviews

Table C-1 : Chemical Fertilizer Consumption as established from Interviews

Distributor (shop)	Fertilizer grades and quantity sold (t/y)				
	8-24-24	13-13-21	15-15-15	16-16-16	Total
1. Boonsom 8 Nakhon Nai Rd., Muang, Songkhla	70	100	150	50	370
2. Muang Kaset 376-80 Triburee Rd., Muang, Songkhla	60	95	140	30	325
3. Songkhla Kankaset 46/14-15 Tri-Ngam Rd., Muang, Songkhla	65	90	120	35	310
4. J.J. Southern 528 Kanjanawanich Rd., Hat-Yai , Songkhla	200	380	600	170	1,350
5. Thainamchemi Kaset Ltd., Part. 19 Moo 2 Pa-Sawang 7, Hat-Yai, Songkhla	100	180	200	80	560
6. Thai Kaset 102 Montree 2 Rd., Hat-Yai, Songkhla	70	100	150	60	380
7. Trang Kaset 1 Chaiyakul Utid Rd., Hat-Yai, Songkhla	70	100	120	50	340
8. Prasit Panich 62-63 Pratan Utid Rd., Hat-Yai, Songkhla	60	80	110	50	300
9. Aupakorn Kaset 43-5 Niwas Rd., Muang, Phatthalung	240	250	400	140	1,030
Total	935	1,375	1,990	665	4,965

Source: Interview, 2002.

APPENDIX D

Calculation of Inflows of P and Cd from Phosphate Fertilizer

1. Chemical fertilizer requirements for each type of commercial crop have been recommended by the Songkhla Provincial Agricultural Office (Srisai, 2002):

$$CF_{AO} = (A \times AR_{AO}) / 10^3 \quad \text{(App. D-1)}$$

Where CF_{AO} is the fertilizer requirement recommended by the Agriculture Office.

A is the area for commercial crop cultivation.

AR_{AO} is the application rate as recommended by the Agriculture Office.

Commercial crop	A (rai)	AR_{AO} (kg/rai/y)	CF_{AO} (t/y)
Paddy field	1,174,875	40	46,995
Rubber	2,144,375	25	53,609
Field crop & Orchard	200,187	50	10,009
Total	3,519,437	115	110,614

2. Agriculturists would apply chemical fertilizer at half the rate recommended by the government agencies:

$$CF_{act} = CF_{AO} \times 0.5 \quad \text{(App. D-2)}$$

Where CF_{act} is the actual fertilizer consumption as applied by agriculturists.

Commercial crop	CFact (t/y)
Paddy field	23,497
Rubber	26,805
Field crop & Orchard	5,005
Total	55,307

3. P applied through the use of chemical fertilizer is calculated as:

$$PCF_{iw} = (CF_{iw} \times P_{cf}) / 100 \quad \text{(App. D-3)}$$

Where PCF_{iw} is P contents in chemical fertilizer consumption calculated using interview data.

CF_{iw} is chemical fertilizer consumption (calculated using interview data).

P_{cf} is P contents in chemical fertilizer (obtained from research data).

Fertilizer grade ($N\text{-}P_2O_5\text{-}K_2O$)	CF_{iw} (t/y)	P_{cf} (%)	PCF_{iw} (t/y)
8-24-24	935	9.8	92
13-13-21	1,375	6.4	88
15-15-15	1,990	6.8	135
16-16-16	665	7.3	49
Total	4,965		364

4. Quantity of other grades of chemical fertilizer applied by agriculturists:

$$CF_{otg} = CF_{act} - CF_{iw} \quad \text{(App. D- 4)}$$

Where CF_{otg} is quantity of other grades of chemical fertilizers applied.

CF_{act} (t/y)	CF_{iw} (t/y)	CF_{otg} (t/y)
55,307	4,965	50,342

5. Maximum P contents is calculated to represent the worst case situation for consumption of other grades of chemical fertilizer:

$$MPCF_{otg} = (CF_{otg} \times MP_{cf}) / 100 \quad \text{(App. D-5)}$$

Where $MPCF_{otg}$ is maximum P content used in calculation of consumption of other grades of chemical fertilizer.

MP_{cf} is maximum P contents in chemical fertilizer (obtained from research data).

CF_{otg} (t/y)	MP_{cf} (%)	$MPCF_{otg}$ (t/y)
50,342	9.8	4,934

6. Total P content in actual chemical fertilizer applied by agriculturists:

$$\sum P_{cf} = PCF_{iw} + MPCF_{otg} \quad \text{(App. D-6)}$$

Where $\sum P_{cf}$ is the total P contents of actual chemical fertilizer applied.

PCF_{iw} (t/y)	$MPCF_{otg}$ (t/y)	$\sum P_{cf}$ (t/y)
364	4,934	5,297

7. Inflow of P in actual chemical fertilizer applied is calculated:

$$FP_{cf\,[g/cap/y]} = (\sum P_{cf} \times 10^6) / 1.5 \times 10^6 \quad \text{(App. D-7)}$$

$$FP_{cf\,[kg/km2\ of\ agri.\ soil/y]} = (\sum P_{cf} \times 10^3) / 5{,}691.4 \quad \text{(App. D-8)}$$

$$FP_{cf\,[kg/km2\ of\ total\ SLC/y]} = (\sum P_{cf} \times 10^3) / 7{,}534 \quad \text{(App. D-9)}$$

FP_{cf} (g/cap/y)	FP_{cf} (kg/km^2 of agri. soil/y)	FP_{cf} (kg/km^2 of total SLC/y)
3,513	931	703

8. P_2O_5 contents in chemical fertilizer (obtained using interview data):

$$PO_{cf} = (CF_{iw} \times P_2O_5) / 100 \quad \text{(App. D-10)}$$

Where PO_{cf} is P_2O_5 content in chemical fertilizer.

Fertilizer grades (N-P_2O_5-K_2O)	CF_{iw} (kg/y)	P_2O_5 (%)	PO_{cf} (kg/y)
8-24-24	935,000	24	224,400
13-13-21	1,375,000	13	178,750
15-15-15	1,990,000	15	298,500
16-16-16	665,000	16	106,400
Total	4,965,000		808,050

9. Cd contents in P_2O_5 fertilizer obtained using interview data:

$$CdPF_{iw} = (PO_{cf} \times Cd_{cf}) / 10^9 \quad \text{(App. D-11)}$$

Where $CdPF_{iw}$ is Cd content in P_2O_5 fertilizer (obtained using interview data).

Cd_{cf} is Cd content in P_2O_5 fertilizer (obtained from research data).

Fertilizer grades ($N\text{-}P_2O_5\text{-}K_2O$)	PO_{cf} (kg/y)	Cd_{cf} (mg Cd/kg P_2O_5)	$CdPF_{iw}$ (t/y)
8-24-24	224,400	1.4	0.00031
13-13-21	178,750	1.4	0.00025
15-15-15	298,500	30.1	0.00898
16-16-16	106,400	1.4	0.00015
Total	808,050		0.0097

10. Maximum of P_2O_5 content is use to calculate quantities in other grades of chemical fertilizer applied (worst case situation):

$$MPO_{otg} = (CF_{otg} \times MP_{cf}) / 100 \quad \text{(App. D- 12)}$$

Where MPO_{otg} is maximum of P_2O_5 content used in calculation for other grades of chemical fertilizer applied.

MP_{cf} is maximum of P_2O_5 contents of chemical fertilizer (obtained from research data).

CF_{otg} (kg/y)	MP_{cf} (%)	MPO_{otg} (kg/y)
50,341,880	24	12,082,051

11. Maximum Cd content for other grades of P_2O_5 fertilizer applied:

$$MCdPO_{otg} = (MPO_{otg} \times MCd_{po}) / 10^9 \quad \text{(App. D-13)}$$

Where $MCdPO_{otg}$ is maximum Cd content for other grades of P_2O_5 fertilizer applied.

MCd_{po} is maximum Cd contents of P_2O_5 fertilizer (obtained from research data).

MPO_{otg} (kg/y)	MCd_{po} (mg/kg P_2O_5)	$MCdPO_{otg}$ (t/y)
12,082,051	30.1	0.36

12. Total Cd content of actual P_2O_5 fertilizer applied by agriculturists:

$$\sum Cd_{po} = CdPF_{iw} + MCdC_{otg} \quad \text{(App. D-14)}$$

Where $\sum Cd_{po}$ is total Cd content of actual P_2O_5 fertilizer applied by agriculturists.

$CdPF_{iw}$ (t/y)	$MCdPO_{otg}$ (t/y)	$\sum Cd_{po}$ (t/y)
0.0097	0.36	0.37

13. Inflow of Cd of actual P_2O_5 fertilizer as applied by agriculturists is calculated:

$$FCd_{po\ [g/cap/y]} = (\sum Cd_{po} \times 10^6) / 1.5 \times 10^6 \quad \text{(App. D-15)}$$

$$FCd_{po\ [g/km2\ of\ agri.\ soil/y]} = (\sum Cd_{po} \times 10^6) / 5{,}691.4 \quad \text{(App. D-16)}$$

$$FCd_{po\ [g/km2\ of\ total\ SLC/y]} = (\sum Cd_{po} \times 10^6) / 7{,}534 \quad \text{(App. D-17)}$$

FCd_{po} (g/cap/y)	FCd_{po} (g/km^2 of agri. soil/y)	FCd_{po} (g/km^2 of total SLC/y)
0.249	66	50

APPENDIX E

Numbers of Swine Farmed in the SLC

Table E-5 : Numbers of Swine Farmed in the SLC

Basin	Province	District	Swine (head)
1. Klong Pa Phayom	Phatthalung	Pa Phayom	4,757
		Khuan Khanun	30,346
		Si Banpot	5,697
		Total	40,800
2. Klong Na Tom	Phatthalung	Muang	12,484
		Khao Chaison	437
		Kong Ra	1,902
		Si Nakharin	6,602
		Total	21,425
3. Klong Ta Kead	Phatthalung	Khao Chaison	8,722
		Tamot	2,380
		Kong Ra	21
		Pa Bon	299
		Bang Kaeo	2,793
		Total	14,215
4. Klong Pa Bon	Phatthalung	Pak Phyun	883
		Pa Bon	13,550
		Bang Kaeo	475
		Total	14,908
5. Klong Phru Por	Phatthalung	Pak Phyun	5,834
		Pa Bon	5,366
	Songkhla	Khuan Niang	1,098
		Rattaphum	9,455
		Total	21,753
6. Klong Rattaphum	Songkhla	Khuan Niang	818
		Rattaphum	15,084
		Total	15,902
7. Klong U-Tapao	Songkhla	Muang	1,714
		Hat-Yai	33,301
		Sadao	9,511
		Khlong Hoi Kong	695
		Bang Klam	12,109
		Na Mom	396
		Khuan Niang	141
		Total	57,867
8. Sathing Phra peninsular	Songkhla	Singha Nakhon	3,672
		Sathing Pra	21,318
		Krasaesin	7,706
		Ranot	6,811
		Total	39,507
9. Songkhla Lake	Songkhla	Muang	13
		Total	13

Source: LDO, 2002 and REO 12, 2002.

APPENDIX F

Calculation of Inflows of P and Cd from Animal Feed

1. Total consumption of feedstuff for SLC swine:

$$\sum_{FT} = (NS \times QF \times T) / 10^6 \qquad \text{(App. F-1)}$$

Where $\sum FT$ is total consumption of feedstuff for SLC swine.

NS is the number of swine in the SLC.

QF is the quantity of feedstuff consumed per head of swine in the SLC.

T is the time period for swine breeding from birth until slaughter.

NS (head/y)	QF_{avg} (g/head/day)	T (days)	$\sum_{FT}$ (t/y)
226,390	1,543	120	41,918

2. P content in total feedstuff consumed by SLC swine:

$$\sum P_{ft} = (NS \times PC_{avg} \times T) / 10^6 \qquad \text{(App. F-2)}$$

Where $\sum P_{ft}$ is total P content in feedstuff consumed by swine in the SLC.

PC_{avg} is average of P content in feedstuff consumed by SLC swine (obtained from research data).

NS (head/y)	PC_{avg} (g/head/day)	T (days)	$\sum P_{ft}$ (t/y)
226,390	7.36	120	200

3. Inflow of P in feedstuff consumed by SLC swine is calculated:

$FP_{ft\ [g/cap/y]} = (\sum P_{ft} \times 10^6) / 1.5 \times 10^6$ (App. F-3)

$FP_{ft\ [kg/km2\ of\ agri.\ soil\ /y]} = (\sum P_{ft} \times 10^3) / 5{,}691.4$ (App. F-4)

$FP_{ft\ [kg/km2\ of\ total\ SLC/y]} = (\sum P_{ft} \times 10^3) / 7{,}534$ (App. F-5)

FP_{ft} (g/cap/y)	FP_{ft} (kg/km^2 of agri. soil/y)	FP_{ft} (kg/km^2 of total SLC/y)
133	35	27

4. Cd contamination in feedstuff consumed by SLC swine:

$\sum Cd_{ft} = (\sum_{FT} \times Cd_{ft}) / 10^6$ (App. F-6)

Where $\sum Cd_{ft}$ is total Cd contamination in feedstuff consumed by SLC swine.

Cd_{ft} is Cd content in feedstuff consumed by SLC swine (obtained from research data).

$\sum_{FT}$ (t/y)	Cd_{ft} (ppm)	$\sum Cd_{ft}$ (t/y)
41,918	0.32	0.013

5. Inflow of Cd in feedstuff consumed by SLC swine is calculated:

$FCd_{ft\ [g/cap/y]} = (\sum Cd_{ft} \times 1{,}000{,}000) / 1{,}500{,}000$ (App. F-7)

$FCd_{ft\ [g/km2\ of\ agri.\ soil/y]} = (\sum Cd_{ft} \times 1{,}000{,}000) / 5{,}691.4$ (App. F-8)

$FCd_{ft\ [g/km2\ of\ total\ SLC/y]} = (\sum Cd_{ft} \times 1{,}000{,}000) / 7{,}534$ (App. F-9)

FCd_{ft} (g/cap/y)	FCd_{ft} (g/km^2 of agri. soil/y)	FCd_{ft} (g/km^2 of total SLC/y)
0.009	2.4	1.8

APPENDIX G

Calculate of Inflows of P and Cd from Swine Manure

7.1 Total P content in manure from SLC swine:

$$\sum P_{sm} = (\sum P_{ft} \times P_{sm}) / 100 \qquad \text{(App. G-1)}$$

Where $\sum P_{sm}$ is total P content in SLC swine manure derived from feed intakes.

P_{sm} is P content in swine manure as a result of feed consumption (obtained from research data).

$\sum P_{ft}$ (t/y)	P_{sm} (%)	$\sum P_{sm}$ (t/y)
200	80	160

7.2 Inflow of P in SLC swine manure derived from feeds intake is calculated:

$$FP_{sm\ [g/cap/y]} = (\sum P_{sm} \times 10^6) / 1.5 \times 10^6 \qquad \text{(App. G-2)}$$

$$FP_{sm\ [kg/km2\ of\ agri.\ soil/y]} = (\sum P_{sm} \times 10^3) / 5{,}691.4 \qquad \text{(App. G-3)}$$

$$FP_{sm\ [kg/km2\ of\ total\ SLC/y]} = (\sum P_{sm} \times 10^3) / 7{,}534 \qquad \text{(App. G-4)}$$

FP_{sm} (g/cap/y)	FP_{sm} (kg/km^2 of agri. soil/y)	FP_{sm} (kg/km^2 of total SLC/y)
107	28	21

7.3 Total quantity of manure from SLC swine resulting from consumption:

$$\sum SM = (\sum FT \times Q_{sm}) / 100 \qquad \text{(App. G-5)}$$

Where $\sum SM$ is total quantity of manure from SLC swine resulting from feeds intake.

Q_{sm} is quantity of manure from swine resulting from feeds intake.

$\sum_{FT}$ (t/y)	Q_{sm} (%)	$\sum$ SM (t/y)
41,918	80	33,534

7.4 Total Cd content in swine manure resulting from consumption of feedstuff:

$$\sum Cd_{sm} = (\sum SM \times Cd_{sm}) / 10^6 \quad \text{(App. G-6)}$$

Where $\sum Cd_{sm}$ is total Cd content in swine manure resulting from consumption of feedstuff.

Cd_{sm} is Cd content in swine manure (obtained from research data).

$\sum$ SM (t/y)	Cd_{sm} (ppm)	$\sum Cd_{sm}$ (t/y)
33,534	0.32	0.011

7.5 Inflow of Cd in SLC swine manure is calculated:

$$FCd_{sm\ [g/cap/y]} = (\sum Cd_{sm} \times 10^6) / 1.5 \times 10^6 \quad \text{(App. G-7)}$$

$$FCd_{sm\ [g/km2\ of\ agri.\ soil/y]} = (\sum Cd_{sm} \times 10^6) / 5{,}691.4 \quad \text{(App. G-8)}$$

$$FCd_{sm\ [g/km2\ of\ total\ SLC/y]} = (\sum Cd_{sm} \times 10^6) / 7{,}534 \quad \text{(App. G-9)}$$

FCd_{sm} (g/cap/y)	FCd_{sm} (g/km^2 of agri. soil/y)	FCd_{sm} (g/km^2 of total SLC/y)
0.007	1.8	1.4

APPENDIX H

Calculation of Inflows of P and Cd in SLC Agricultural Soil from Precipitation

1. Total P quantity in SLC agricultural soil as a result of precipitation:

$$\sum P_{pp} = (A \times PP_{avg} \times PC_{pp}) / 10^3 \quad \text{(App. H-1)}$$

Where $\sum P_{pp}$ is total P quantity in SLC agricultural soil as a result of precipitation.

PP_{avg} is an average precipitation in the SLC.

PC_{pp} is P concentration in SLC precipitation (obtained from research data).

A (km^2)	PP_{avg} (mm/y)	PC_{pp} (mg/L)	$\sum P_{pp}$ (t/y)
5,691.4	1,880	0.03	321

2. Inflow of P in SLC agricultural soil as a result of precipitation is calculated :

$$FP_{pp\ [g/cap/y]} = (\sum P_{pp} \times 10^6) / 1.5 \times 10^6 \quad \text{(App. H-2)}$$

$$FP_{pp\ [kg/km2\ of\ total\ SLC/y]} = (\sum P_{pp} \times 10^3) / 7{,}534 \quad \text{(App. H-3)}$$

FP_{pp} (g/cap/y)	FP_{pp} (kg/km^2 of total SLC/y)
214	43

3. Total Cd quantity in SLC agricultural soil as a result of precipitation:

$$\sum Cd_{pp} = (A \times PP_{avg} \times CdC_{pp}) / 10^6 \quad \text{(App. H-4)}$$

Where $\sum Cd_{pp}$ is total Cd quantity in SLC agricultural soil as a result of precipitation.

PP_{avg} is an average precipitation in the SLC.

CdC_{pp} is Cd concentration in SLC precipitation (obtained from research data).

A (km^2)	PP_{avg} (mm/y)	CdC_{pp} (µg/L)	$\sum Cd_{pp}$ (t/y)
5,691.4	1,880	0.01	0.11

4. Inflow of Cd in SLC agricultural soil as a result of precipitation is calculated :

$FCd_{pp\ [g/cap/y]} = (\sum Cd_{pp} \times 10^6) / 1.5 \times 10^6$ (App. H-5)

$FCd_{pp\ [kg/km2\ of\ total\ SLC/y]} = (\sum Cd_{pp} \times 10^6) / 7{,}534$ (App. H-6)

FCd_{pp} (g/cap/y)	FCd_{pp} (g/km^2 of total SLC/y)
0.07	14.2

APPENDIX I

Soil Type in SLC

Table I –1 : Soil type in SLC

Soil types	Coverage	Characteristic	Agricultural suitability
1. Humid clays	20 %	Poor drainage, low P and K levels	Moderate suitable for rice production and few field crops
2. Hydromorphic alluvial soils	15%	Poor drainage and flooding some contain acid sulphate and saline salts	Mainly inland wetlands and coastal plains of recent deposits of beach soil, better drained are for rice and dry season crop.
3. Podsoil	16%	Low fertility due to low base saturation and cation exchange capacity	Mainly used for rubber plantation
4. Slope complex soil	17%	Well-drained with poor fertility and high erosion hazard	Moderate suitable for rubber plantation
5. Lithosols / Podsoil association	7%	Low fertility	-
6. Humic clay podsoil association	21%	Poor drained, low K and P, low fertility.	Moderate suitable for rice production and few field crops
7. Miscellaneous	4%	-	-

Source: EmSong, 1999b.

APPENDIX J

Calculation of Accumulations of P and Cd in SLC Agricultural Soil

1. Total P content in the upper soil layer of SLC agricultural soil:

$$\sum P_{as} = (A \times 10^6 \times S_{depth} \times S_{density} \times PC_{as}) / 10^9 \quad \text{(App. J-1)}$$

Where $\sum P_{as}$ is total P content in the upper layer of agricultural soil.

PC_{as} is P contents in the agricultural soil (obtained from research data).

S_{depth} is soil depth.

$S_{density}$ is soil density.

A (km^2)	S_{depth} (m)	$S_{density}$ (kg/m^3)	PC_{as} (mg/kg)	$\sum P_{as}$ (t)
5,691.4	0.2	2,300	95	248,714

2. Accumulation of P in the upper soil layer of SLC agricultural soil is calculated:

$$FP_{as\ [g/cap/y]} = (\sum P_{as} \times 10^6) / 1.5 \times 10^6 \quad \text{(App. J-2)}$$

$$FP_{as\ [kg/km2\ of\ agri.\ soil/y]} = (\sum P_{as} \times 10^3) / 5{,}691.4 \quad \text{(App. J-3)}$$

$$FP_{as\ [kg/km2\ of\ total\ SLC/y]} = (\sum P_{as} \times 10^3) / 7{,}534 \quad \text{(App. J-4)}$$

FP_{as} (g/cap/y)	FP_{as} (kg/km^2 of agri. soil/y)	FP_{as} (kg/km^2 of total SLC/y)
165,810	43,700	33,012

3. Total Cd content in the upper soil layer of SLC agricultural soil:

$$\sum Cd_{as} = (A \times 10^6 \times S_{depth} \times S_{density} \times CdC_{as}) / 10^9 \quad \text{(App. J-5)}$$

Where $\sum Cd_{as}$ is total Cd content in the upper soil layer of agricultural soil.

Cd_{as} is Cd contents in the agricultural soil (obtained from research data).

A (km^2)	S_{depth} (m)	$S_{density}$ (kg/m^3)	CdC_{as} (mg/kg)	$\sum Cd_{as}$ (t)
5,691	0.2	2,300	0.024	63

4. Accumulation of Cd in the upper soil layer of SLC agricultural soil is calculated:

$$FCd_{as\ [g/cap/y]} = (\sum Cd_{as} \times 10^6) / 1.5 \times 10^6 \quad \text{(App. J-6)}$$

$$FCd_{as\ [g/km2\ of\ agri.\ soil/y]} = (\sum Cd_{as} \times 10^6) / 5{,}691.4 \quad \text{(App. J-7)}$$

$$FCd_{as\ [g/km2\ of\ total\ SLC/y]} = (\sum Cd_{as} \times 10^6) / 7{,}534 \quad \text{(App. J-8)}$$

FCd_{as} (g/cap/y)	FCd_{as} (g/km^2 of agri. soil/y)	FCd_{as} (g/km^2 of total SLC/y)
42	11,040	8,340

APPENDIX K

Calculation of Outflow of P resulting from Soil Inputs for Plant Cultivation

1. Total P emission resulting from soil inputs for plant cultivation:

$$\sum P_{pc} = (\sum P_{cf} + \sum P_{sm} + \sum P_{pp}) \times P_{pc} / 100 \quad \text{(App. K-1)}$$

Where $\sum P_{pc}$ is total P emission from soil inputs to plant cultivation.

P_{pc} is P content from soil inputs taken up by plants (obtained from research data).

$\sum P_{cf}$ (t/y)	$\sum P_{sm}$ (t/y)	$\sum P_{pp}$ (t/y)	P_{pc} (%)	$\sum P_{pc}$ (t/y)
5,297	160	321	10	578

2. Outflow of P from soil inputs for plant cultivation is calculated:

$$FP_{pc\ [g/cap/y]} = (\sum P_{pc} \times 10^6) / 1.5 \times 10^6 \quad \text{(App. K-2)}$$

$$FP_{pc\ [kg/km2\ of\ agri.\ soil/y]} = (\sum P_{pc} \times 10^3) / 5{,}691.4 \quad \text{(App. K-3)}$$

$$FP_{pc\ [kg/km2\ of\ total\ SLC/y]} = (\sum P_{pc} \times 10^3) / 7{,}534 \quad \text{(App. K-4)}$$

FP_{pc} (g/cap/y)	FP_{pc} (kg/km^2 of agri. soil/y)	FP_{pc} (kg/km^2 of total SLC/y)
385	102	77

APPENDIX L

Calculation of Outflows of P and Cd from SLC Surface Water Runoff

1. P concentration inputs to SLC surface water runoff:

$MP_{sr} = (Q_{sr} \times MPC_{sr})$ (App. L-1)

Where MP_{sr} is maximum P concentration in input to SLC surface water runoff.

Q_{sr} is quantity of SLC surface water runoff.

MPC_{sr} is maximum P concentration in SLC surface water runoff (obtained from research data).

Q_{sr} ($1x10^6$ m^3/y)	MPC_{sr} (mg/L)	MP_{sr} (t/y)
4,896	0.3	1,469

2. Outflow of P input to SLC surface water runoff is calculated:

$FMP_{sr\ [g/cap/y]} = (MP_{sr} \times 10^6) / 1.5 \times 10^6$ (App. L-2)

$FMP_{sr\ [kg/km2\ of\ agri.\ soil/y]} = (MP_{sr} \times 10^3) / 5,691.4$ (App. L-3)

$FMP_{sr\ [kg/km2\ of\ total\ SLC/y]} = (MP_{sr} \times 10^3) / 7,534$ (App. L-4)

FMP_{sr} (g/cap/y)	FMP_{sr} (kg/km^2 of agri. soil/y)	FMP_{sr} (kg/km^2 of total SLC/y)
1,306	344	260

3. Cd concentration in input to SLC surface water runoff:

$MCd_{sr} = (Q_{sr} \times MCdC_{sr})$ (App. L-5)

Where MCd_{sr} is maximum Cd concentration in inputs to SLC surface water runoff

$MCdC_{sr}$ is maximum Cd concentrations in SLC surface water runoff (obtained from research data).

Q_{sr} ($1x10^6$ m^3/y)	$MCdC_{sr}$ (mg/L)	MCd_{sr} (t/y)
4,896	0.0005	2.45

4. Outflow of Cd input to SLC surface water runoff is calculated:

$FMCd_{sr\ [g/cap/y]} = (MCd_{sr} \times 10^6) / 1.5 \times 10^6$ (App. L-6)

$FMCd_{sr\ [g/km2\ of\ agri.\ soil/y]} = (MCd_{sr} \times 10^6) / 5,691.4$ (App. L-7)

$FMCd_{sr\ [g/km2\ of\ total\ SLC/y]} = (MCd_{sr} \times 10^6) / 7,534$ (App. L-8)

$FMCd_{sr}$ (g/cap/y)	$FMCd_{sr}$ (g/km^2 of agri. soil/y)	$FMCd_{sr}$ (g/km^2 of total SLC/y)
1.6	430	325

APPENDIX M

Table M-1 : Quantity of Municipal Solid Waste Generated in the SLC

Province	District	Area	Waste generated (kg/cap/day)
Songkhla	Hat Yai	TM. Ban Phru	0.84
	sadao	TM. Sadao	0.82
	Hat Yai	NM. Hat Yai	1.59
	Muang	NM. Songkhla	1.13
	Ranot	TM. Ranot	0.96
	Khuan Niang	TM. Khuan Niang	0.83
	Sadao	TM. Phang La	0.96
	Hat Yai	TM. Pa Tong	0.74
	Rattaphum	TM. Kam Phaeng Petch	0.44
	Sathing Phra	TM. Sathing Phra	1.32
	Rattaphum	TM. Na Sithong	1.75
	Sadao	TM. Prik	1.39
	Sadao	TM. Pa Dang Besa	0.8
	Ranot	TM. Bo Tru	0.36
	Singha Nakhon	TM. Singha Nakhon	0.09
	Muang	SAO. Khao Rupchang	0.60
	Muang	SAO. Tung Wang	0.60
	Muang	SAO. Pa Wong	0.60
	Singha Nakhon	SAO. Muang Ngam	0.60
	Bang Klam	SAO. Tha Chang	0.60
	Rattaphum	SAO. Kam Phaeng Petch	0.60
	Rattaphum	SAO. Khao Phra	0.60
	Rattaphum	SAO. Khu Ha Tai	0.60
	Rattaphum	SAO. Tha Chamuang	0.60
	Sadao	SAO. Samnak Taeo	0.60
	Hat Yai	SAO. Klong Hae	0.60
	Hat Yai	SAO. Khuan Lung	0.60
	Hat Yai	SAO. Kho Hong	0.60
	Hat Yai	SAO. Thung Tam Sao	0.60
	Hat Yai	SAO. Nam Noi	0.60
Total			23.02
Average			0.77

APPENDIX M

Table M-1: Quantity of Municipal Solid Waste Generated in the SLC (Continue)

Province	District	Area	Waste generated (kg/cap/day)
Phatthalung	Muang	TM. Phatthalung	0.58
	Pak Phyun	TM. Pak Phyun	0.33
	Bang Kaeo	TM. Tha Maduer	0.73
	Khao Chaison	TM. Khao Chaison	0.54
	Khuan Khanun	TM. Khuan Khanun	0.52
	Khuan Khanun	TM. Makok Nuer	0.14
	Tamot	TM. Mae Kri	0.14
	Tamot	TM. Tamot	0.84
	Pa Bon	TM. Pa Bon	0.55
	Muang	SAO. Khuan Maprao	0.6
	Kong Ra	SAO. Khlong Chaleum	0.6
	Khao Chaison	SAO. Khao Chaison	0.6
	Khao Chaison	SAO. Harn Pho	0.6
Total			6.77
Average			0.52

Source: REO 12, 2002b.

Note:

TM. = Tombon Municipality

NM. = Nakhon Municipality

SAO. = Sub-District Administration Organization

APPENDIX N

Calculation of Inflow and Stock of P for MSW in SLC Landfills

1. Total P content in MSW (Municipal Solid Waste):

$$\sum P_{MSW} = (Q_{MSW} \times 365 \times PC_{MSW}) / 100 \quad \text{(App. N-1)}$$

Where $\sum P_{MSW}$ is total P content in MSW.

Q_{MSW} is quantity of MSW (wet weight of waste).

PC_{MSW} is P content in MSW (obtained from research data).

SK_{NM} is Songkhla Nakhon Municipality, covering an area of 200 rai (0.32 km^2) which has been in operation since 1999 (REO 12, 2002b).

HY_{NM} is Hat-Yai Nakhon Municipality, covering an area of 135 rai (0.22 km^2) which has been in operation for 20 years and is now nearly full (REO 12, 2002b).

BP_{NM} is Ban-Phru Muang Municipality, covering an area of 100 rai (0.16 km^2) which has been in operation since 1999 (Ban-Phru Muang Municipality, 2002).

SD_{NM} is Sadao Tombon Municipality, covering an area of 96 rai (0.15 km^2) which has been in operation since 1995 (Sadao Muang Municipality, 2002).

PT_{NM} is Phatthalung Muang Municipality, covering an area of 95 rai (0.15 km^2) and has been in operation since 2000 (REO 12, 2002b).

Landfills (site)	Q_{MSW} (t/d)	PC_{MSW} (%)	$\sum P_{MSW}$ (t/y)
SK_{NM}	85	0.1	31
HY_{NM}	230	0.1	84
BP_{MM}	30	0.1	11
SD_{TM}	20	0.1	7
PT_{MM}	30	0.1	11
Total	395		144

2. Inflow of P in MSW is calculated:

$FP_{MSW\ [g/cap/y]} = (\sum P_{MSW} \times 10^6) / 1.5 \times 10^6$ (App. N-2)

$FP_{MSW\ [kg/km2\ of\ agri.\ soil/y]} = (\sum P_{MSW} \times 10^3) / 5{,}691.4$ (App. N-3)

$FP_{MSW\ [kg/km2\ of\ total\ SLC/y]} = (\sum P_{MSW} \times 10^3) / 7{,}534$ (App. N-4)

FP_{MSW} (g/cap/y)	FP_{MSW} (kg/km^2 of agri. soil/y)	FP_{MSW} (kg/km^2 of total SLC/y)
96	25	19

3. Stocks of MSW in SLC landfills as recorded by governmental bodies are calculated:

$\sum MSW_{lf} = (OPT \times Q_{MSW} \times 365\ days)$ (App. N-5)

Where $\sum MSW_{lf}$ is total MSW stock in SLC landfills.

Landfills (site)	Operation (y)	Q_{MSW} (t/d)	$\sum MSW_{lf}$ (t)
SK_{NM}	5	85	155,125
HY_{NM}	20	230	1,679,000
BP_{MM}	5	30	54,750
SD_{TM}	8	20	58,400
PT_{MM}	3	30	32,850
Total	41	395	1,980,125

4. Total P quantity stored as in SLC landfills:

$\sum P_{lf} = (\sum MSW_{lf} \times PC_{MSW}) / 100$ (App. N-5)

$\sum MSW_{lf}$ (t)	PC_{MSW} (%)	$\sum P_{lf}$ (t)
1,980,125	0.1	1,980

5. Accumulation of P stock in SLC landfills is calculated:

$FP_{lf\ [g/cap/y]} = (\sum P_{lf} \times 10^6) / 1.5 \times 10^6$ (App. N-6)

$FP_{lf\ [kg/km2\ of\ agri.\ soil/y]} = (\sum P_{lf} \times 10^3) / 5{,}691.4$ (App. N-7)

$FP_{lf\ [kg/km2\ of\ total\ SLC/y]} = (\sum P_{lf} \times 10^3) / 7{,}534$ (App. N-8)

FP_{lf} (g/cap)	FP_{lf} (kg/km^2 of agri. soil)	FP_{lf} (kg/km^2 of total SLC)
1,320	348	263

APPENDIX O

Calculation of Inflows and Outflows of P and Cd Concentration in WWTPs

1. Total P quantity in raw domestic wastewater draining to WWTP:

$$\sum P_{WTP,\,inf} = (DWW_{avg} \times PC_{WTP,\,inf} \times 365 \text{ days}) / 10^6 \qquad \text{(App. O-1)}$$

Where $\sum P_{WTP,\,inf}$ is total quantity of P in domestic wastewater draining to WWTPs.

$PC_{WTP,\,inf}$ is P concentration in domestic wastewater draining to WWTPs.

DWW_{avg} is an average quantity of domestic wastewater.

DWW_{avg} (m^3/d)	$PC_{WTP,\,inf}$ (mg/L)								$\sum P_{WTP,\,inf}$ (t/y)
	10/09/02	11/10/02	14/11/02	12/12/02	10/01/03	07/02/03	10/03/03	Avg.	
58,000	0.6	0.7	2.4	2.7	1.5	1.1	1.8	1.54	32.66

2. Inflow of P in domestic wastewater draining to WWTPs is calculated:

$$FP_{WTP,inf\,[g/cap/y]} = (\sum P_{WTP,inf} \times 10^6) / 1.5 \times 10^6 \qquad \text{(App. O-2)}$$

$$FP_{WTP,inf\,[kg/km2\ of\ agri.\ soil/y]} = (\sum P_{WTP,inf} \times 10^3) / 5{,}691.4 \qquad \text{(App. O-3)}$$

$$FP_{WTP,inf\,[kg/km2\ of\ total\ SLC/y]} = (\sum P_{WTP,inf} \times 10^3) / 7{,}534 \qquad \text{(App. O-4)}$$

$FP_{WTP,\,inf}$ (g/cap/y)	$FP_{WTP,\,inf}$ (kg/km^2 of agri. soil/y)	$FP_{WTP,\,inf}$ (kg/km^2 of total SLC/y)
22	6	4

3. Total Cd quantity in raw domestic wastewater draining to WWTPs:

$$\sum Cd_{WTP,\,inf} = (DWW_{avg} \times CdC_{WTP,\,inf} \times 365 \text{ days}) / 10^6 \qquad \text{(App. O-5)}$$

Where $\sum Cd_{WTP,\,inf}$ is total Cd quantity in domestic wastewater draining to WWTPs.

$CdC_{WTP,\,inf}$ is Cd concentration in domestic wastewater draining to WWTPs.

DWW_{avg} (m^3/day)	$CdC_{WTP, inf}$ (mg/L)							$\sum Cd_{WTP, inf}$ (t/y)
	2002							
	Jan.	Feb.	March	Apr.	May	June	Avg.	
58,000	0.003	0.0006	0.0010	ND	ND	ND	0.006	0.127

Note: (ND = <0.0005 mg/L).

4. Inflow of Cd in domestic wastewater draining to WWTPs is calculated:

$$FCd_{WTP, inf\,[g/cap/y]} = (\sum Cd_{WTP, inf} \times 10^6) / 1.5 \times 10^6 \quad \text{(App. O-6)}$$

$$FCd_{WTP, inf\,[g/km2\ of\ agri.\ soil/y]} = (\sum Cd_{WTP, inf} \times 10^6) / 5{,}691.4 \quad \text{(App. O-7)}$$

$$FCd_{WTP, inf\,[g/km2\ of\ total\ SLC/y]} = (\sum Cd_{WTP, inf} \times 10^6) / 7{,}534 \quad \text{(App. O-8)}$$

$FCd_{WTP, inf}$ (g/cap/y)	$FCd_{WTP, inf}$ (g/km^2 of agri. soil/y)	$FCd_{WTP, inf}$ (g/km^2 of total SLC/y)
0.09	22	17

5. Total quantity of P in domestic wastewater after treatment:

$$\sum P_{WTP,\ efl} = (DWW_{avg} \times PC_{WTP, efl} \times 365\ days) / 10^6 \quad \text{(App. O-9)}$$

Where $\sum P_{WTP, efl}$ is total P concentration of wastewater after treatment.

$PC_{WTP, efl}$ is quantity of P from wastewater after treatment.

DWW_{avg} (m^3/day)	$PC_{WTP, efl}$ (mg/L)								$\sum P_{WTP,\ efl}$ (t/y)
	10/09/02	11/10/02	14/11/02	12/12/02	10/01/03	07/02/03	10/03/03	Avg.	
58,000	0.9	0.5	0.5	2.0	0.2	0.8	0.4	0.76	16.03

6. Outflow of P in domestic wastewater after treatment is calculated:

$FP_{WTP, efl\ [g/cap/y]} = (\sum P_{WTP, efl} \times 10^6) / 1.5 \times 10^6$ (App. O-10)

$FP_{WTP, efl\ [g/km2\ of\ agri.\ soil/y]} = (\sum P_{WTP, efl} \times 10^6) / 5{,}691.4$ (App. O-11)

$FP_{WTP, efl\ [g/km2\ of\ total\ SLC/y]} = (\sum P_{WTP, efl} \times 10^6) / 7{,}534$ (App. O-12)

$FP_{WTP, efl}$ (g/cap/y)	$FP_{WTP, efl}$ (kg/km^2 of agri. soil/y)	$FP_{WTP, efl}$ (kg/km^2 of total SLC/y)
11	3	2

7. Total quantity of Cd in domestic wastewater after treatment:

$\sum Cd_{WWTP, efl} = (DWW_{avg} \times CdC_{WTP, efl} \times 365\ days) / 10^6$ (App. O-13)

Where $\sum Cd_{WWTP, efl}$ is total quantity of Cd from wastewater after treatment.

$CdC_{WWTP, efl}$ is P concentrations from wastewater after treatment.

DWW_{avg} (m^3/day)	$CdC_{WTP, efl}$ (mg/L)							$\sum Cd_{WWTP, efl}$ (t/y)
	2002							
	Jan.	Feb.	March	Apr.	May	June	Avg.	
58,000	0.0009	0.0007	0.0006	ND	ND	ND	0.003	0.06

8. Outflow of Cd in domestic wastewater after treatment is calculated:

$FCd_{WTP, efl\ [g/cap/y]} = (\sum Cd_{WTP, efl} \times 10^6) / 1.5 \times 10^6$ (App. O-14)

$FCd_{WTP, efl\ [g/km2\ of\ agri.\ soil/y]} = (\sum Cd_{WTP, efl} \times 10^6) / 5{,}691.4$ (App. O-15)

$FCd_{WTP, efl\ [g/km2\ of\ total\ SLC/y]} = (\sum Cd_{WTP, efl} \times 10^6) / 7{,}534$ (App. O-16)

$FCd_{WTP, efl}$ (g/cap/y)	$FCd_{WTP, efl}$ (g/km^2 of agri. soil/y)	$FCd_{WTP, efl}$ (g/km^2 of total SLC/y)
0.04	11	8