2.3 Carvão Remedial Alternatives

(a) Alternative descriptions

55. *Alternative 1*: The feature of this alternative is active treatment. A lime neutralization treatment plant capable of treating 25 m^3/min of mine discharge would be constructed near the mine portal. The design of the treatment plant would be patterned process known as the High Density Sludge (HDS) process.

56. *Alternative 2*: The feature of this alternative is passive wet land treatment. The drainage from the Mina Santana portal would be treated using anaerobic and aerobic wetlands to reduce acid and metal loadings.

57. *Alternative 3*: The feature of this alternative is passive treatment with open limestone drains. The limestone drain consists of a trapezoidal channel filled with limestone rip-rap. When acid water contacts the limestone, some of the calcium carbonate dissolves, adding alkalinity and neutralizing some of the acidity in the water. The total length of the open limestone drain would be approximately 450m due to land availability restriction. The width of the drain would vary depending on the gradient in order to maintain a fairly constant velocity of 2 m/sec.

(b) Rio Carvão alternative evaluations

58. Evaluations of the Rio Carvão remedial alternatives are presented. As stated previously, remedial actions that address only the flow from the mine portal are not expected to achieve significant reductions in acidity and metals concentrations at the downstream monitoring point PU-2. A large sources of acid and metal loadings are present both upstream and down stream of monitoring point CS-5. These sources contribute significantly greater acid and metal loads than the minewater from the Mina Santana portal. Without addressing these additional sources, remediation of the mine portal will have little mitigating effect on downstream water quality.

59. *Effectiveness Evaluation*: The evaluation of Rio Carvão remedial alternatives with respect to their anticipated effectiveness is summarized below:

- *Alternative 1*: The HDS lime neutralization treatment plant prescribed under this alternative would be highly effective in treating the minewater discharge. Treatment is expected to result in nearly 100 percent removal of acidity, aluminum, iron, and manganese at monitoring point CS-4. Other metals concentrations would be reduced to below their detection limits. After treatment with hydrated lime, the water at CS-4 is expected to have a net excess alkalinity of 150 to 200 mg/L. Therefore, the discharge of this water into the Rio Carvão would have beneficial effects, including raising the pH of the water and precipitating some of the metals downstream of the confluence of the unnamed tributary and the Rio Carvão. However, the acidity, aluminum, iron, and manganese concentrations immediately downstream of the confluence would only be reduced by an estimated 40 to 50 percent;

- *Alternative 2*: Passive wetland treatment systems are an innovative approach to reducing acidity and metals loadings in mine water. Wetlands are expected to be effective in removing the contaminants of concern provided they are properly designed. However, the land area available for wetland construction at the Rio Carvão FS site is too small for the design of properly sized wetlands. Wetland treatment systems sized to treat the 20 cubic meter per minute flow from the mine would cover an estimated 70 hectares, whereas only 2 to 3 hectares of land are available for construction. The largest wetlands that could be constructed given the available land area would be ineffective in treating the portal discharge because the wetlands would be hydraulically and chemically overloaded. Because the wetland treatment systems would be overloaded, only slight reductions in acidity and metals concentrations could be observed at monitoring point CS-4. Reductions would probably be less than 10 percent; and

- *Alternative 3*: Although open limestone drains are an innovative passive approach to remedying acid mine drainage, they have proven effective in treating acid streams and rivers in the eastern US. However, as with passive wetland treatment systems described above, the length of the open limestone drain illustrated in Figure IV-3-11 does not provide sufficient contact time to achieve highly effective treatment. Design criteria developed for open limestone drains in the U.S. cannot be met given large volumetric flow rate and the physical constraints of the Rio Carvão site. It is estimated that approximately 25 percent of the acid and metals could be removed at CS-4 by the open limestone drain. At this level of removal, the acidity, aluminum, iron, and manganese concentrations immediately downstream of the confluence of the unnamed tributary and the Rio Carvão would only be reduced by an estimated 10 to 15 percent.

60. ***Implementability Evaluation***: The evaluation of Rio Carvão remedial alternatives with respect to their anticipated implementability is summarized below:

- *Alternative 1*: The implementability of the active treatment system prescribed under Alternative 1 is questionable. The equipment and physical structures are all readily implementable. The treatment plant, equipment pad and shelters, and the sludge storage impoundment are all readily constructible; and operators with the skills needed to operate the plant could certainly be found locally or nationally. However, the large quantity of hydrated lime needed to operate the plant and the huge volume of sludge produced over the life of the plant makes this alternative impractical to implement;

- *Alternative 2*: The Alternative 2 is not implementable at the Rio Carvão site. As stated in the previous section, the land area needed for constructing a wetland treatment system large enough to achieve effective treatment is not available at the Rio Carvão site. A small wetland capable of fitting within the available land area would be practically ineffective in treating the flow from the mine. Hence, there is no feasible way of implementing Alternative 2, given the severity of the site constraints; and

- *Alternative 3*: The Alternative 3 would be readily implementable. A large volume of limestone would have to be imported from off site, but all other construction materials would be locally available. The open limestone drains are readily constructible using conventional, readily available earth-moving equipment. The resulting treatment system would be completely passive and would require no operator attention for the estimated 10 year life of the drain. After the limestone is dissolved, the drain would have to be replaced with new limestone brought to the site. Although the available land area is not optimal for construction of a properly sized limestone drain, the system illustrated in Figure IV-3-11 would still be effective in adding alkalinity to the Rio Carvão water and achieving some small reductions in the acidity and metals.

61. *Investment Costs*: Investment costs were estimated in Section II-D of Main Text in detail. Water quality simulation for the FS sites are presented in Section II-B of Main Text in detail. Together with those results, cost estimates are summarized below.

TABLE C-II-3

CARVÃO REMEDIAL COST AND EFFECTIVENESS

	Loads Reduction Rate (%)	pH [a]	Cost (R$ million)
Alternative 1	100	4.6	6.1 + 0.7/year [b]
Alternative 2	--	--	(11.0)
Alternative 3	10	4.0	0.3

a/ Estimated at the monitoring point (CS04) right before joining the Rio Carvão (Current pH = less than 4).
b/ Annual operating cost.

62. In the most effective alternative (Alternative 1), metals and acidity concentrations are expected to be reduced by nearly 100 percent. In spite of the greatest reductions, it would not meet the existing Brazilian surface water quality norms. Because a large sources of acid and metal loadings are discharged from an active coke plant upstream of the monitoring point (CS04) in the unnamed stream. The larger sources of those loadings should be mitigated first. This also indicates that water quality should be evaluated on the Rio Urussanga basin as a whole in the overall remediation study, taking into consideration the effects of other upstream and downstream tributary influxes. Alternative 2 requires 70 hectares for wetland construction, whereas only less than 2 to 3 hectares are available in the FS site. Alternative 2 would not be physically feasible. In the overall remediation program, Alternative 3 would be only a practical mitigation alternative.

2.4 Capivari Remedial Alternative

(a) Alternative Descriptions

63. *Alternative 1*: The features of this alternative are source containment, impoundment closure and passive treatment. A ground water cut-off wall would be constructed to completely surround the reactive waste piles and impoundment. The purpose of the cut-off wall would be to contain contaminated groundwater within the site boundaries and prevent further subsurface migration of acid and metal contaminants into and out of the site. The impoundment would have to be emptied prior to filling. The remedial actions are as follows:

i.) Construction of a groundwater cut-off wall;
ii.) Filling the impoundment with inert material;
iii.) Covering of reactive wastes and impoundment with a wet cover system; and
iv.) Construction of passive wetland systems.

64. *Alternative 2*: The features of this alternative are surface water diversion, source containment, impoundment closure and passive treatment. A difference is that a surface water diversion structure is being replaced with the groundwater cut-off wall in Alternative 1. Water in the Rio Dos Pregos would be diverted around the site in a concrete open channel for the reduction of the surface water inflow into the Capivari pond that occurs through seepage or surface flows at the northern end of the pond. Diverting the river would also prevent the river water from becoming contaminated by seepage from the pond as it flows around the east side of the pond. The remedial actions are as follows:

i.) Clean water diversion;
ii.) Filling the impoundment with inert material;
iii.) Covering of reactive wastes and impoundment with a wet cover system; and
iv.) Construction of passive wetland systems.

65. *Alternative 3*: The features of this alternative are source containment and impoundment closure. Differences between Alternative 2 and 3 are the elimination of the surface water diversion structure and passive wetland treatment systems from Alternative 2. Also, the reactive wastes and closed impoundment would be capped with a dry soil cover, rather than a wet cover system in Alternatives 1 and 2. The remedial actions are as follows:

i.) Filling the impoundment with inert material; and
ii.) Covering of reactive wastes and impoundment with dry soil cover systems.

(b) Capivari alternative evaluations

66. *Effectiveness Evaluation*: The evaluation of the Capivari remedial alternatives with respect to their effectiveness in reducing acid and metal loadings in site surface water and groundwater is presented below:

- *Alternative 1*: Implementation of Alternative 1 is expected to significantly reduce acid and metal loadings to the Rio Dos Pregos and to groundwater downgradient of the site. Load reduction of up to 95 percent could be achieved by the combination of actions prescribed under this alternative. At this estimated level of load reduction, acid and metal concentrations at monitoring point PT-14 would meet the water quality goals for the JICA team FS sites. Draining, filling, and capping the impoundment is expected to be highly effective in reducing the acidic, metal-laden seepage into groundwater and surface water. Capping the coal reject piles would also effectively reduce the load amount. Because site groundwater hydrology has not been characterized, the possible effectiveness of the groundwater cut-off wall remains uncertain;

- *Alternative 2*: Elimination of the groundwater cut-off wall and installation of the clean water diversion are the only difference between the Alternative 1and Alternative 2. The effect of eliminating the cut-off wall is difficult to gauge because little information on groundwater hydrology and subsurface water quality is available at the Capivari FS site. Diverting the clean water from the Rio Dos Pregos around the northeast side of the Capivari impoundment is expected to prevent contamination of the major flow component from the site, thereby effectively reducing the acid and metal loading. Diversion of the Rio Dos Pregos is also expected to reduce inflows and seepage into the impoundment. Based on this evaluation, the overall reduction in acid and metal loading to surface water is expected to range between 90 and 98 percent. At this level of load reduction, the acidity and metals concentrations at monitoring point PT-14 would not meet site water quality goals at the low end but would meet the goals at the high end of the estimated load reductions. The effectiveness with respect to reducing groundwater loadings is uncertain; and

- *Alternative 3*: Covering the reactive wastes and impoundment with a dry soil cover system, as prescribed under Alternative 3, is expected to significantly reduce the effectiveness of the remediation. In addition, the elimination of the passive wetland treatment systems and the clean water diversion would further reduce the overall effectiveness of the Alternative 3. Loading estimates indicate the overall reduction in acid and metal loading to the Rio Dos Pregos would probably be less than 50 percent under this alternative. Given this estimated reduction in effectiveness, the metals concentrations at Monitoring Point PT-14 are expected to exceed water quality goals for the JICA FS sites.

67. ***Implementability Evaluation***: With the exception of constructing the groundwater cut-off wall (Alternative 1), the Capivari alternatives are expected to be readily implementable. The proposed cover systems and passive wetland treatment systems can be constructed using conventional earthmoving techniques. However, specialized technical expertise and oversight would be needed to ensure the proper design and construction of the prescribed passive wetland treatment systems. Construction and operation of the lime neutralization system is expected to be readily implementable, although some specialized pieces of equipment may need to be obtained.

68. Construction of the groundwater cut-off wall under Alternative 1 would be difficult due to its anticipated depth of up to 30 meters. Specialized drilling or excavating equipment would be needed to construct the wall, and the availability of the needed equipment is uncertain. Also, the volume of materials needed to construct the wall is potentially very large. For example, to completely encircle the site with a concrete cut-off wall 30 meters deep and 1 meter wide would require an estimated 130,000 cubic meters of concrete. The local availability of concrete in large quantities, such as this, is not certain. Constructing the wall using alternative techniques, such as deep soil mixing, may be precluded due to the unavailability of the specialized equipment needed.

69. Materials necessary to construct the wet cover system of the Capivari Alternative 1 are available locally. However, filling the existing Capivari impoundment would require an estimated 1.2 million cubic meters of borrow material. Excavating and transporting this amount of material is expected to take several years to complete. Also, reclaiming the borrow area for such a large volume of material would be difficult and costly due to the size of the excavation. On the other hand, filling the impoundment with bottom ash would result in positive environmental benefits.

70. ***Investment Costs***: Investment costs were estimated in Section II-D of Main Text in detail. Water quality simulation for the FS sites are presented in Section II-B of Main Text in detail. Together with those results, cost estimates are summarized below.

TABLE C-II-4

CAPIVARI REMEDIAL COST AND EFFECTIVENESS

	Loads Reduction Rate (%)	pH [a]	Cost (R$ million)
Alternative 1	up to 95	5.3	56.7
Alternative 2	90 - 98	5.0 - 5.7	18.5
Alternative 3	less than 50	less than 4.5	14.5

a/ Estimated at the monitoring point of PT-14, downstream of the FS site boundary (Current pH = 3.7).

71. In Alternative 1, the construction cost of the cut-off wall would be almost prohibitive. Alternative 2 would be the most practical and effective remedial alternative with the reduction of metals and acidity concentrations by 90 to 98 percent. In spite of the greatest reductions, it would not meet the existing Brazilian surface water quality norms.

3. Conclusions of the FS Site Study

72. The major conclusions of the FS site study are as follows:

- ⇨ The area is so polluted that the most economical covering system, i.e., dry soil cover system, would have little effect in mitigating ARD. Both heavy metal concentrations and pH levels would remain practically unchanged based on model simulation results;

- ⇨ Using more effective technologies, i.e., wet cover or capillary system and passive wetland treatment would not either restore water quality to the level required by existing Brazilian norms for surface water quality within the FS sites themselves. However, the significant reduction in the acidity level and metal concentrations resulting from these methods allows natural healing forces originating from growing water plants and increased bacteria activity to further neutralize the water. Overall remediation for washery reject dumps should be based on the combination of wet cover system and passive wetlands;

- ⇨ The active treatment would achieve load reductions by nearly 100 percent. However, in the case of the Carvao FS site, which is being surrounded by discharges from larger sources of acidity and metal concentrations, the installation of an active neutralization plant would not be an effective solution. The larger pollution source areas should be mitigated first;

- ⇨ Water quality should be evaluated based on the individual river basins as a whole in the overall remediation study, taking into consideration the effects of other upstream and downstream tributary influxes; and

- ⇨ Although overburden waste is treated as acidity free material, re-grading and covering with grass seeded clay (dry cover) would be required for effective land use.

D CIVIL ENGINEERING AND COST ESTIMATES

1. FS Sites Remedial Cost Estimates

1.1 Basic Guidelines

1. Designing and cost estimates were carried out based on the following guidelines:

i.) Design criteria are based on Brazilian local practices such as recommendations by *ZETA-IESA* together with Japanese standards for roads and earth moving by the Ministry of Construction of Japan;

ii.) Construction method is principally based on local practices;

iii.) Prices are based on quotations provided by local construction companies in Santa Catarina, such as *SETEP Topografia e Construções*, and double checked with the standard costs issued by the *Departemento de Estradas de Rodagem de Santa Catarina*;

iv.) Earth volumes to be moved are calculated by a computer using 1:1,000 scale maps made by the JICA Team except for those of the Capivari and Carvão FS sites;

v.) Channel sections are principally determined from flow volumes which are calculated by the "Rational Formula", using an average rainfall intensity presented in Secitin II-E, Hydrology, of this Main Text; and

vi.) Extensive river rehabilitation is not included in the remedial work, but revetment for riverside protection is included.

2. Specific guidelines for the FS sites are as follows:

Fiorita FS site:

i.) Overburden waste is treated as acidity free material and two simple alternatives for its reclamation are considered, i.e. a.) re-grading and covering with a 30 cm grass seeded clay layer (single layer dry cover) and b.) leaving it as it is;

ii.) A channel would be constructed between Pond H and Pond I as illustrated in Figure III-7 of Summary Report, for prevention of surface soil erosion due to storm water runoff;

iii.) Road construction would be done only for existing road rehabilitation purposes;

iv.) Box culverts with a similar dimension to the current cross-section of the Rio Fiorita would be placed at the two crossing points of the road; and

v.) Flow boxes would be placed at confluence points and the areas of steep hydraulic gradient.

Capivari FS site:

i.) The cost estimate for groundwater cutoff wall construction is based on a concrete structure. However, there is no appropriate acid proof construction material among available conventional materials that would protect against a pH 3 environment. Although rubber, plastic or ceramics can work, costs would be prohibitive;

ii.) Material for lake filling would be soil or earth extracted from wetland construction, of which volume is equivalent to that of lake filling;

iii.) A cross section of the concrete channels for clean water diversion is based on that of current ditches.

1.2 Design Criteria

3. Design criteria are as follows:

i.) Leveling: A slope gradient of overburden waste would be re-graded at 1V : 2H. Surface would be covered with a 30 cm grass seeded clay as shown in Figure D-1. A flat zone of 4 m in width would be placed at the foot of overburden waste along the pond;

ii.) Road rehabilitation: The road would be 4 m wide without pavement. Side gutters would be placed on both sides of the road as shown in Figure D-2. Overburden waste would be used for road subgrade material and black reject for surface material, which should be completely compacted;

iii.) Revetment construction: Revetment would be mason- or concrete-made for prevention of riverside erosion and insulation of black rejects from water as shown in Figure D-3. A cross section was based on a 10 year average rainfall intensity and would vary from location to location as shown in Table D-1; and

iv.) Channel construction: Channels, as shown in Figures D-4 through D-8, would be placed where water runs through black reject disposal areas to protect the river from this pollution source material. Cross sections were based on the 10 year average rainfall intensity and would vary from location to location as shown in Table D-2.

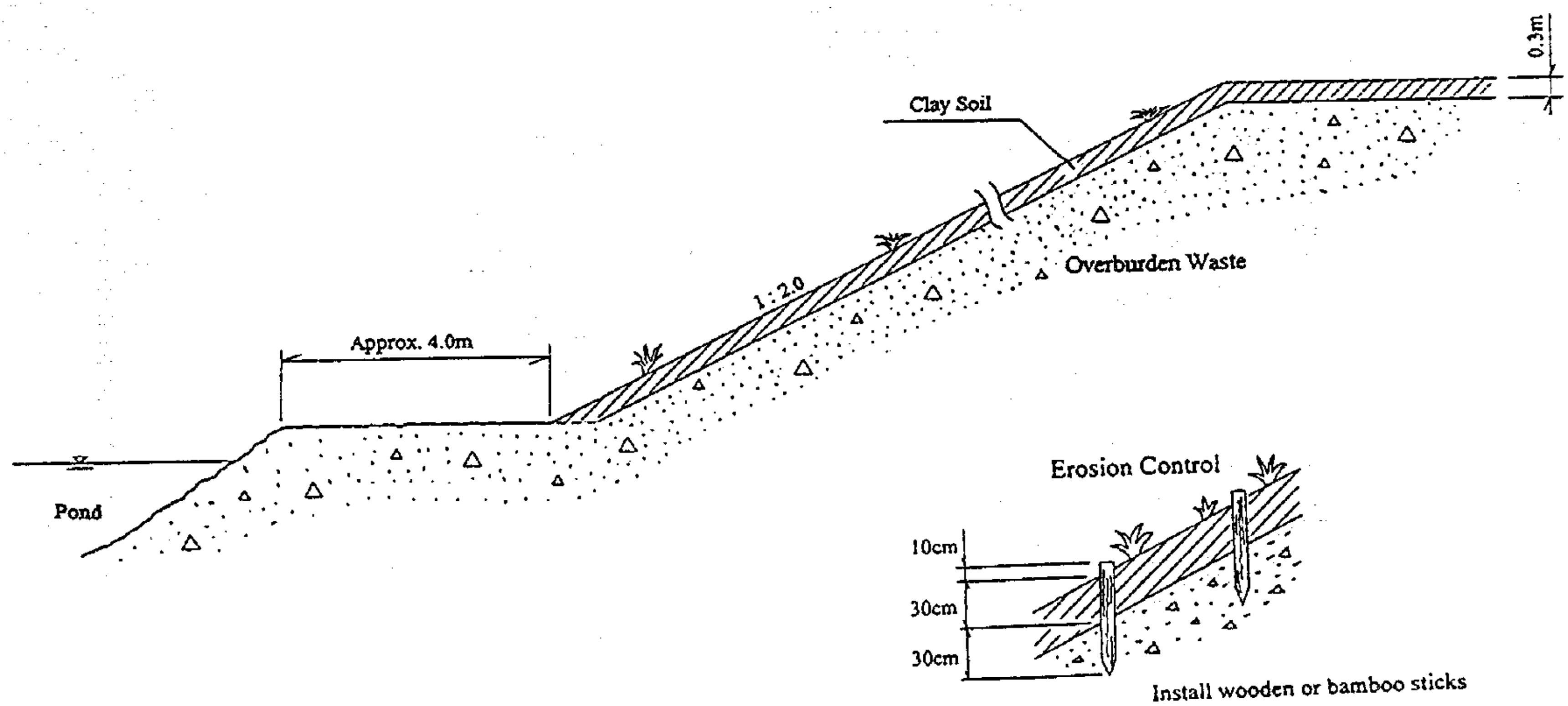
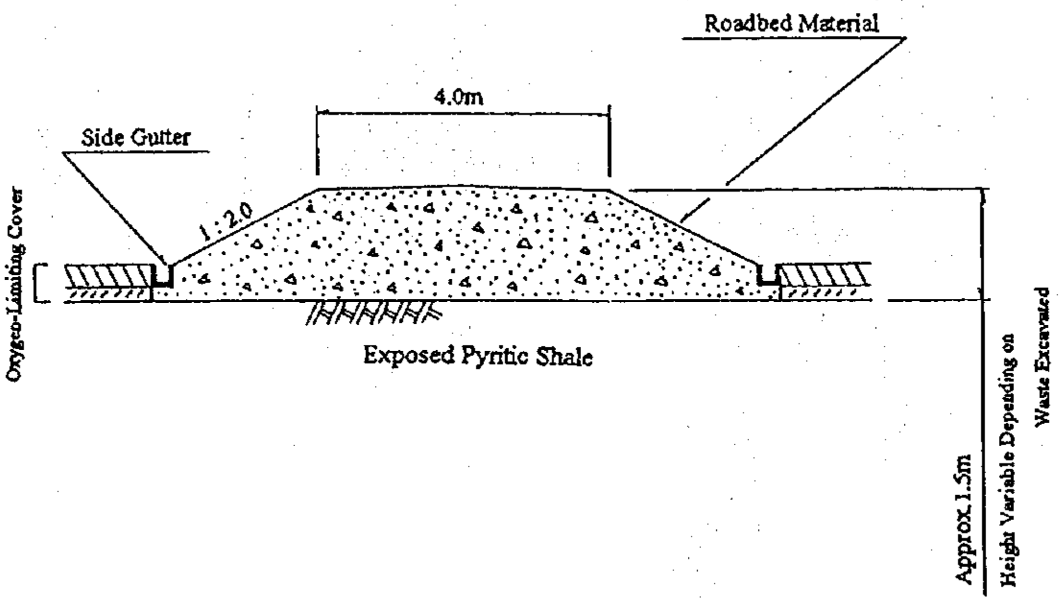


FIGURE D-1 DESIGN CRITERIA FOR LEVELING OF OVERBURDEN WASTE AREA



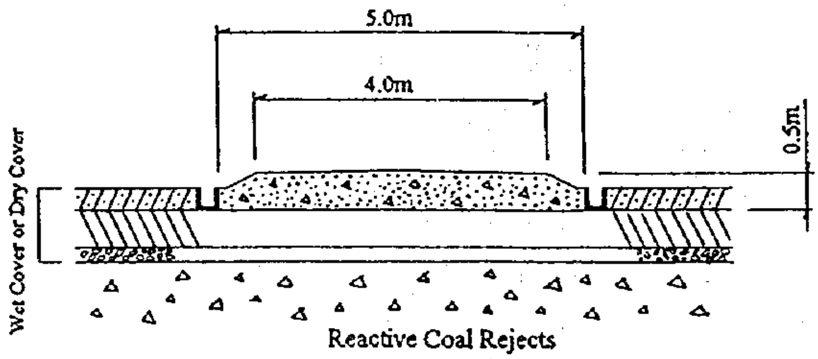


FIGURE D-2

DESIGN CRITERIA FOR ROAD REHABILITATION

TABLE D-1

REVETMENT FORMS

Concrete Channel Revetment for Rio Fiorita

Case	(1)	(2)	(3)
Width : W(m)	5.0	6.0	8.0
Height : H(m)	2.5	2.0	1.5
Length : L(m)	500	100	250

Masonry Revetment for Rio Fiorita

Case	(1)	(2)	(3)
Width : W(m)	6.0	7.0	8.0
Height : H(m)	4.0	3.5	3.0
Length : L(m)	420	—	—

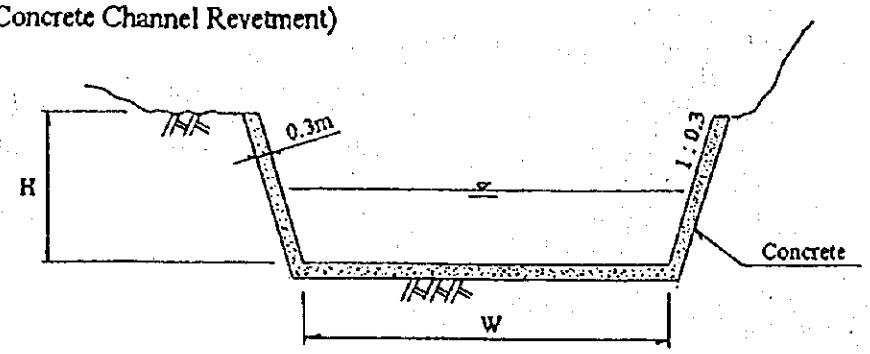
Masonry Revetment for Rio Rocinha

Case	(1)	(2)	(3)
Width : W(m)	10.0	13.0	17.0
Height : H(m)	5.0	4.0	3.0
Length : L(m)	—	280	750

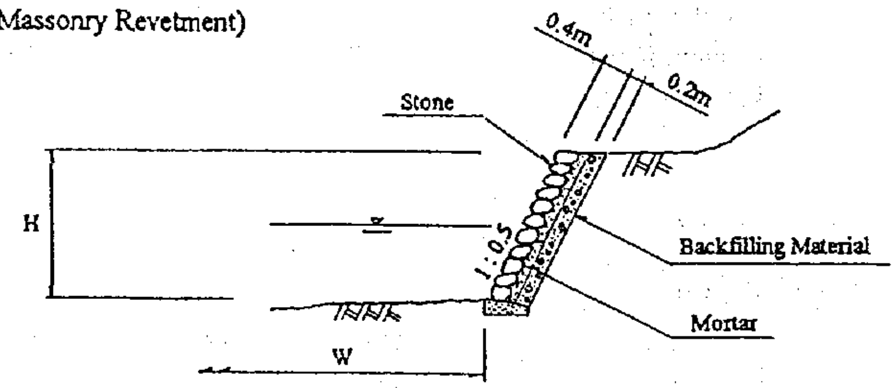
Concrete Revetment for Rio Rocinha

Case	(1)	(2)	(3)
Width : W(m)	8.0	10.0	13.0
Height : H(m)	6.0	5.0	4.0
Length : L(m)	—	200	200

(Concrete Channel Revetment)



(Massonry Revetment)



(Concrete Revetment)

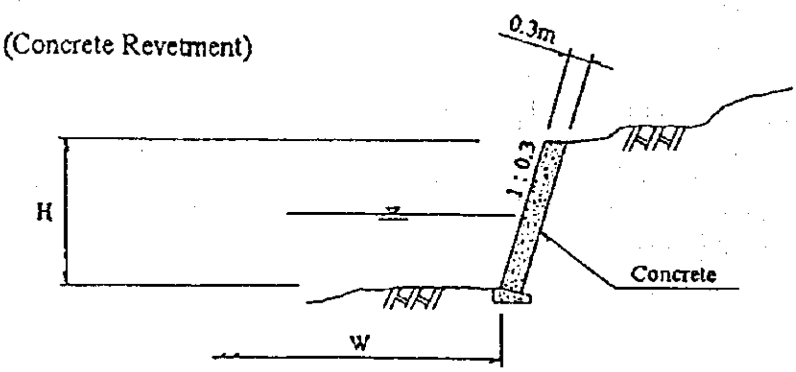


FIGURE D-3

DESIGN CRITERIA FOR REVETMENT

TABLE D-2

CHANNEL FORMS

Open Channel for Rio Fiorita

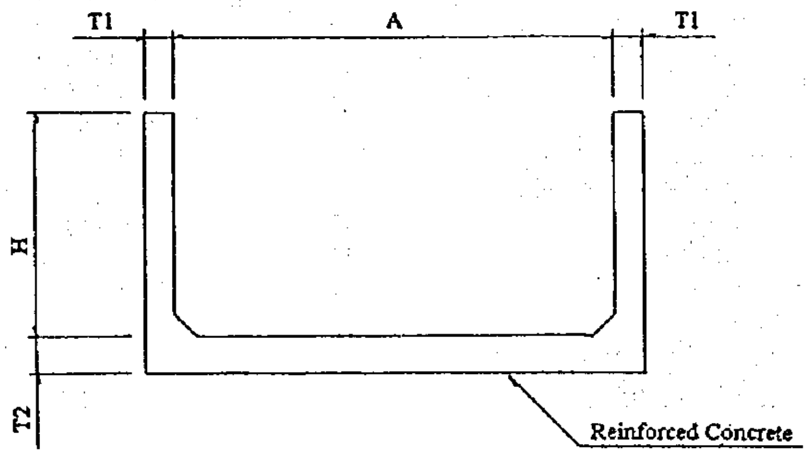
Location	Catchment Area (ha)	Section Form Width×Heigh (mm)	Length (m)
Channel ①	17	1400× 700	400
Channel ②	34	1500× 750	40
Channel ③	7	1000× 500	450
Channel ④	58	2000×1000	750
Channel ⑤	61	2000×1000	780
Open Channel for Rio Rocinha			
Channel ①	85	2000×1000	250
Channel ②	24	1400× 700	200
Channel ③	260	4000×2000	350
Open Channel for Capivari			
Channel ①		3000×2000	1,400
Open Channel for Side Gutter			
Rio Fiorita		300×300	10,000
Rio Rocinha		300×300	6,000

Box Culvert for Rio Fiorita

Location	Type	Section Form Width×Heigh (mm)	Length (m)
Channel ③	A	1000× 500	8
Channel ④	A	2000×1000	46
Main Stream	B	2500×2500	16
Tributary	A	2000×1000	8
Box Culvert for Rio Rocinha			
Channel ①	A	2000×1000	8
Channel ②	A	1400× 700	8
Box Culvert for Capivari			
Channel ①	B	1500×2000	16

Flow Box for Rio Fiorita

Location	Type	Section Form Width×Heigh (mm)	Quantity (set)
Channel ①-④	A	2500×1500	1
Channel ④	B	2500×1500	1
Flow Box for Rio Rocinha			
Channel ①	B	2500×1500	2
Channel ②	B	1900×1200	1



Rio Fiorita

		A (mm)	H (mm)	T1 (mm)	T2 (mm)
	Channel①	1,400	700	70	90
	Channel②	1,500	750	80	90
	Channel③	1,000	500	70	90
	Channel④	2,000	1,000	95	115
	Channel⑤	2,000	1,000	95	115

Rio Rocinha

		A (mm)	H (mm)	T1 (mm)	T2 (mm)
	Channel①	2,000	1,000	95	115
	Channel②	1,400	700	70	90
	Channel③	4,000	2,000	210	250

Capivari

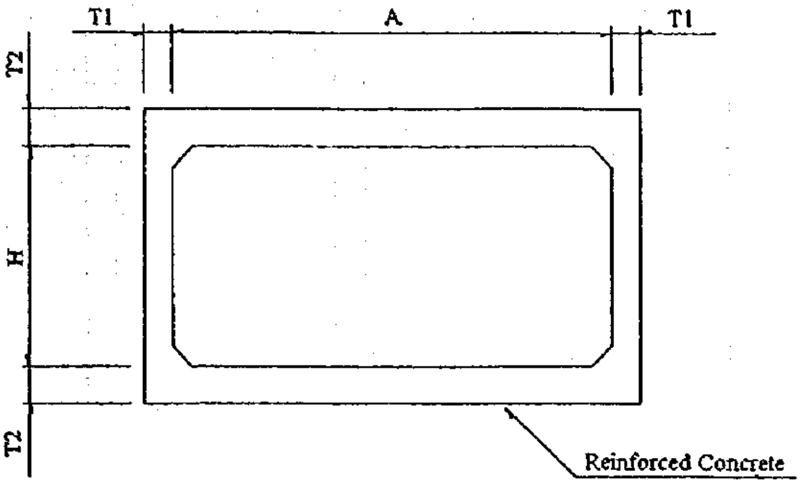
		A (mm)	H (mm)	T1 (mm)	T2 (mm)
	Channel①	3,000	2,000	210	240

Side Gutter

		A (mm)	H (mm)	T1 (mm)	T2 (mm)
		300	300	50	60

FIGURE D-4

DESIGN CRITERIA FOR OPEN CHANNEL

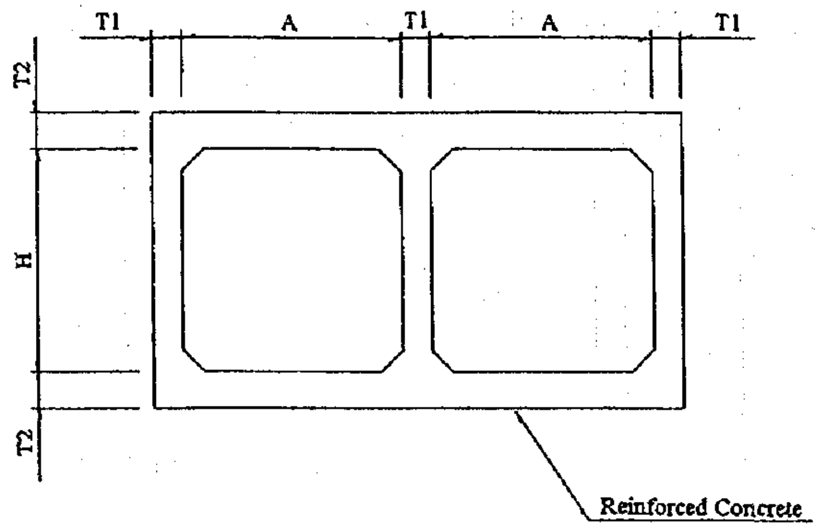


Rio Fiorita		A (mm)	H (mm)	T1 (mm)	T2 (mm)
	Channel③	1,000	500	130	130
	Channel④	2,000	1,000	140	180
	Tributary	2,000	1,000	140	180

Rio Rocinha		A (mm)	H (mm)	T1 (mm)	T2 (mm)
	Channel①	2,000	1,000	140	180
	Channel②	1,400	700	130	150

FIGURE D-5

DESIGN CRITERIA FOR BOX CULVERT (TYPE A)

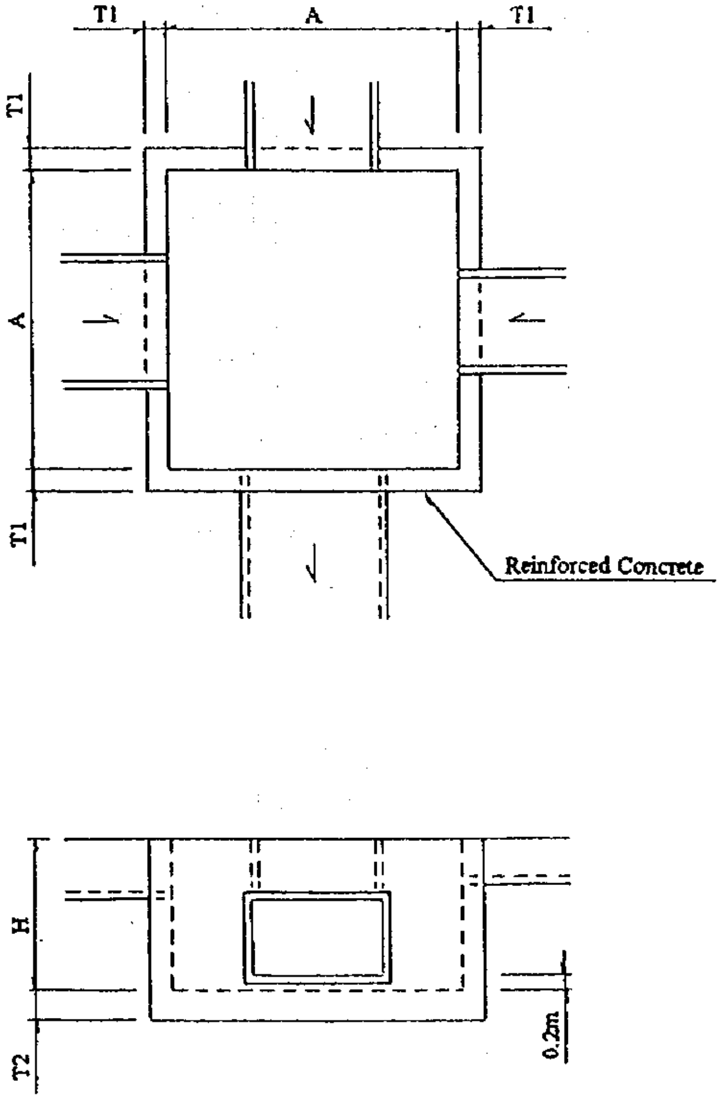


		A (mm)	H (mm)	T1 (mm)	T2 (mm)
Rio Fiorita	Main Stream	2,500	2,500	220	220

		A (mm)	H (mm)	T1 (mm)	T2 (mm)
Capivari	Channel①	1,500	2,000	150	170

FIGURE D-6

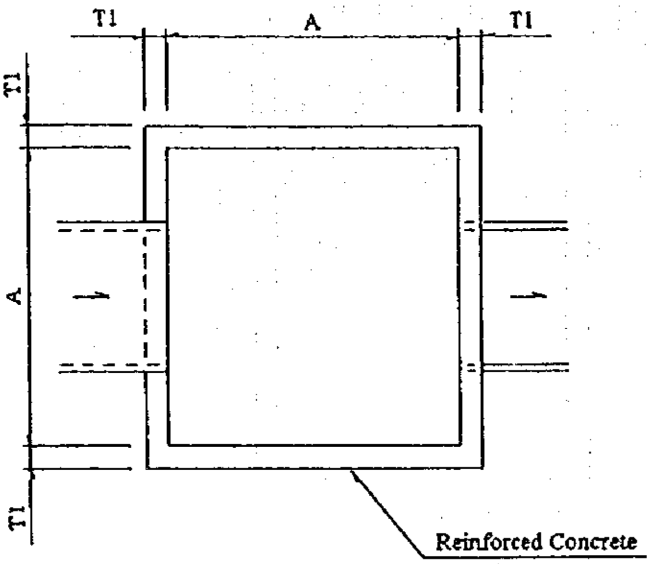
DESIGN CRITERIA FOR BOX CULVERT (TYPE B)

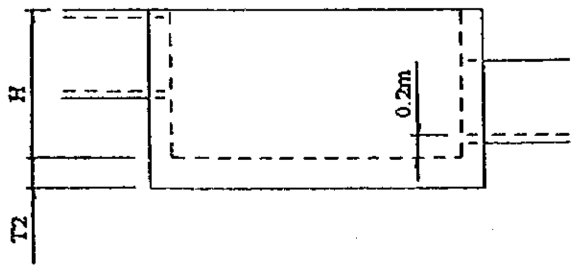


		A (mm)	H (mm)	T1 (mm)	T2 (mm)
Rio Fiorita					
	Channel①-④	2,500	1,500	135	190

FIGURE D-7

DESIGN CRITERIA FOR FLOW BOX (TYPE A)





Rio Fiorita

		A (mm)	H (mm)	T1 (mm)	T2 (mm)
	Channel④	2,500	1,500	135	190

Rio Rocinha

		A (mm)	H (mm)	T1 (mm)	T2 (mm)
	Channel①	2,500	1,500	135	190
	Channel②	1,900	1,200	110	150

FIGURE D-8

DESIGN CRITERIA FOR FLOW BOX (TYPE B)

1.3 FS Site Remedial Cost Estimates

4. Based on requirements for acid water treatment and the above-mentioned criteria, work and material required for the remedial actions are quantified for each FS site, including those for its alternatives.

5. Since there is no market for low grade clay (covering material) in the region, the clay price was estimated by costs calculation, i.e., excavation costs, transportation costs and royalty (R$ 0.6 per ton times 1.05, i.e., tonnage royalty plus 5% sales royalty). Since gravel (material for a 10 cm capillary break) is currently very expensive in the region (R$ 17 per ton plus transportation cost), it was assumed that gravel would be supplied by crushing overburden waste. The price of gravel was also estimated by cost calculation, i.e., excavation, crushing and transportation costs (R$ 12 per ton including transportation). These are summarized in Tables D-3 and D-4.

6. The summary of investment costs estimated for all the alternatives is presented below. Details are presented in Table D-5 through D-19.

SUMMARY OF INVESTMENT COSTS

FS Site	Alternative	Costs (R$x1000)	Descriptions
Fiorita	Alternative 1	11,367	Table D- 5
	Alternative 2	9,990	Table D- 6
	Alternative 3	8,127	Table D- 7
	Alternative 4	6,319	Table D- 8
	Alternative 5	4,560	Table D- 9
	Alternative 6	2,705	Table D-10
Rocinha	Alternative 1	6,174	Table D-11
	Alternative 2	4,492	Table D-12
	Alternative 3	2,942	Table D-13
Carvão	Alternative 1	7,433	Table D-14
	Alternative 2	10,473	Table D-15
	Alternative 3	120	Table D-16
Capivari	Alternative 1	57,243	Table D-17
	Alternative 2	14,355	Table D-18
	Alternative 3	13,752	Table D-19

TABLE D-3

CLAY PRICE ESTIMATE

Clay Cost

Clay Haul Distance 3.5 Km

Equipment:	Quantity	Capacity (m3/hr)	Utilization (%)	Hourly Cost (R$/hr)
Crawler Dozer	1	256	78.52	75.88
Wheel Loader CAT 966	1	201	100.00	54.28
Rear dump truck	10	220	91.36	212.23
			(A) Sub total	342.39

Worker	Quantity	Salary Base		Hourly Cost
Common Labor	0.20	7.50		1.50
Operator	12	7.50		90.00
Servant	1	2.25		2.25
			(B) Sub total	93.75

(C) Product of Team	201.00	m3/hr
(D) Unit Cost (D)=((A)+(B))/(C)	2.17	R$/m3
(E) Overhead Charge (37.8%)	0.82	R$/m3
(F) Total of Direct Costs	2.99	R$/m3
(F) Revegetation Costs (4% of Direct costs)	0.12	R$/m3

Clay Royalty	R$/ton	R$/m3
Royalty	0.60	0.89
Sales Royalty	0.03	0.04
	(E) Sub total	0.93

Total Unit Cost	4.04	R$/M3

TABLE D-4

GRAVEL PRICE ESTIMATE

Gravel Cost

Equipment:	Quantity	Capacity (m3/H)	Utilization (%)	Hourly Cost (R$/hr)
Crawler Dozer	1	256	66.74	78.31
Wheel Loader CAT 966	2	402	42.50	87.38
Jaw Crusher	1	171	100.00	88.52
Corn Crusher	1	114	100.00	64.71
Vibratory Screen	4	228	50.00	42.70
Belt Conveyoy	8	348	100.00	139.21
Rear dump truck	4	88	90.91	93.25
			(A) Sub total	594.08

Worker	Quantity	Salary Base (R$/hr)		Hourly Cost (R$/hr)
Common Labor	1.00	7.50		7.50
Operator	8	7.50		60.00
Pointer	2	4.00		8.00
Servant	5	2.25		11.25
			(B) Sub total	86.75

(C) Product of Team	80.00	m3/hr
(D) Unit Cost (D)=((A)+(B))/(C)	8.51	R$/m3
(E) Overhead Charge (37.78%)	3.22	R$/m3
Total Unit Cost	11.73	R$/m3

TABLE D-5

INVESTMENT COST ESTIMATE FOR THE FIORITA FS SITE: ALTERNATIVE 1

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				469	5% of 2 through 11
2	**Reactive Waste Excavation and Disposal**					
	Excavate, Load, Haul, and Dump Reactive Wastes	m3	766,000	1.61	1,232	
3	**Place Reactive Waste to the Ponds**					
	Access Road Construct through the Ponds	m				
	Place Reactive Waste to the Ponds	m3	360,000	0.44	158	
4	**Construct On-Site Repository**					Repository site is 400m x 165m x 8m
4.1	Furnish Underdrain System	m	400	105.75	42	Place lime stone in Underdrain
4.2	Place and Compact Clay layer	m3	41,820	0.74	31	
4.3	Wet Cover					
	Grading Clay and Gravel	m3	34,850	0.37	13	
	Clay Compaction	m3	41,820	0.74	31	
4.4	Material					
	Clay	m3	104,550	4.04	422	Excavate, haul, and place
	Gravel	m3	6,970	11.73	82	On site excavate, crush, and place
5	**Regrading Overburden Waste**	m3	5,178,300	0.37	1,926	Total area is 160ha
6	**Road Construction**					
6.1	Road Construction	m	5,000	12.60	63	Total road distance is 5000m
6.2	Side Gutter	m	10,000	23.90	239	Furnish side gutter both sides the road
7	**Covering**					
7.1	Clay Laying for Overburden Waste Area	m3	460,620	0.37	171	Total area is 153.4 ha
7.2	Reactive Waste Area (Oxygen Cover)					Total area is 25.63ha
	Grading Clay and Organic Matter	m3	76,890	0.37	29	
	Organic Matter Compaction	m3	51,260	0.74	38	
7.3	Material					
	Clay	m3	537,510	4.04	2,169	Excavate, haul, and place
	Organic Matter	m3	51,260	2.78	142	Purchase, haul, and place
8	**Install River Channel Erosion Control Structure**					Concrete channel revetment, Masonry
	Revetment	m	850	743.53	632	revetment and Concrete Revetment
9	**Install Crean Water Diversion Channels**					
9.1	Open Channel	m	2,420	121.91	295	
9.2	Box culvert	m	78	611.92	48	
9.3	Flow Box	Lump sum	2	1,720.00	3	
10	**Install Wetland Treatment System**					
0.1	Excavate Wetland Pond Area	m3	46,400	1.19	55	
0.2	Construct Concrete Outlet Structure	Lump sum	4	31,347.50	125	
0.3	Rip-lap Channel	m3	540	53.83	29	
0.4	Place Limestone and Organic Materials	m3	46,400	0.44	20	
	Limestone	m3	23,200	33.10	768	Purchase, haul, and place
	Organic Material	m3	23,200	2.78	64	Purchase, haul, and place
0.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	3,000	0.44	1	
	Cobble	m3	3,000	6.33	19	
0.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	29,600	0.44	13	
11	**Revegetation**	m2	1,605,100	0.32	511	Total area is 160ha
12	**Engineering and Construction Inspection**				492	5% of 1 through 11
13	**Contingencies**				1,033	10% of total capital cost
	Total				11,367	

TABLE D-6

INVESTMENT COST ESTIMATE FOR THE FIORITA FS SITE: ALTERNATIVE 2

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				412	5% of 2 through 9
2	**Reactive Waste Excavation and Disposal** Excavate, Load, Haul, and Dump Reactive Wastes	m3	139,000	1.61	224	Reactive wastes only located in stream channels or water courses would be excavated
3	**Regrading Overburden Waste**	m3	51,783,000	0.37	1,926	
4	**Road Construction**					
4.1	Road Construction	m	5,000	3.02	15	Total road distance is 5000m
4.2	Side Gutter	m	10,000	23.89	239	Furnish side gutter both sides the road
5	**Covering**					
5.1	Clay Laying for Overburden Waste Area	m3	481,530	0.37	179	Total area is 160ha
5.2	Reactive Waste Area (Wet Cover)					Total area is 21.0 ha
	Grading Clay and Gravel	m3	105,050	0.37	39	
	Compaction Clay	m3	105,050	0.74	77	
5.3	Material					
	Clay	m3	670,620	4.04	2,706	Excavate, haul, and place
	Gravel	m3	21,010	11.73	246	On site excavate, crush, and place
6	**Install River Channel Erosion Control Structure** Revetment	m	850	744.44	633	Concrete channel revetment, Masonry revetment and Concrete Revetment
7	**Install Crean Water Diversion Channels**					
7.1	Open Channel	m	2420	121.91	295	
7.2	Box culvert	m	78	611.92	48	
7.3	Flow Box	Lump sum	2	1,720.00	3	
8	**Install Wetland Treatment System**					
8.1	Excavate Wetland Pond Area	m3	46,400	1.19	55	
8.2	Construct Concrete Outlet Structure	Lump sum	4	31,482.19	126	
8.3	Rip-rap Channel	m3	540	53.83	29	
8.4	Place Limestone and Organic Materials	m3	46,400	0.44	20	
	Limestone	m3	23,200	33.10	768	Purchase, haul, and place
	Organic Material	m3	23,200	2.78	64	Purchase, haul, and place
8.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	3,000	0.44	1	
	Cobble	m3	3,000	6.33	19	
8.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	29,600	0.44	13	Use of native overburden
9	**Revegetation**	m2	1,605,100	0.32	511	Total area is 160ha
10	**Engineering and Construction Inspection**				432	5% of 1 through 9
11	**Contingencies**				908	10% of total capital cost
	Total				9,990	

TABLE D-7

INVESTMENT COST ESTIMATE FOR THE FIORITA FS SITE: ALTERNATIVE 3

No.	Item	Unit	Quantity	Unit cost ($US)	Total cost (1,000$US)	
1	**Mobilization, Demobilization and Site Preparation**				335	5% of 2 through 7
2	**Reactive Waste Excavation and Disposal**	m3	139,000	1.61	224	Reactive wastes only located in stream channels or water courses would be excavated
	Excavate, Load, Haul, and Dump Reactive Wastes					
3	**Regrading Overburden Waste**	m3	5,178,300	0.37	1,926	
4	**Road Construction**					
4.1	Road Construction	m	5,000	3.02	15	Total road distance is 5000m
4.2	Side Gutter	m	10,000	23.89	239	Furnish side gutter both sides the road
5	**Covering**					
5.1	Clay Laying for Overburden Waste Area	m3	481,530	0.37	179	Total area is 160ha
5.2	Reactive Waste Area (Dry Cover II)					Total area is 21.0 ha
	Grading Clay	m3	126,060	0.37	47	
5.3	Material					
	Clay	m3	607,590	4.04	2,452	Excavate, haul, and place
6	**Install Wetland Treatment System**					
6.1	Excavate Wetland Pond Area	m3	46,400	1.19	55	
6.2	Construct Concrete Outlet Structure	Lump sum	4	31,482.39	126	
6.3	Rip-lap Channel	m3	540	53.83	29	
6.4	Place Limestone and Organic Materials	m3	46,400	0.44	20	
	Limestone	m3	23,200	33.10	768	Purchase, haul, and place
	Organic Material	m3	23,200	2.78	64	Purchase, haul, and place
6.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	3,000	0.44	1	
	Cobble	m3	3,000	6.33	19	
6.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	29,600	0.44	13	Use of native overburden
7	**Revegetation**	m2	1,605,100	0.32	511	Total area is 160ha
8	**Engineering and Construction Inspection**				351	5% of 1 through 7
9	**Contingencies**				737	10% of total capital cost
	Total				8,111	

TABLE D-8

INVESTMENT COST ESTIMATE FOR THE FIORITA FS SITE: ALTERNATIVE 4

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				261	5% of 2 through 11
2	**Reactive Waste Excavation and Disposal**					
	Excavate, Load, Haul, and Dump Reactive Wastes	m3	766,000	1.61	1,232	
3	**Place Reactive Waste to the Ponds**					
	Access Road Construct through the Ponds	m	3,500	1.73	6	
	Place Reactive Waste to the Ponds	m3	360,000	0.44	158	
4	**Construct On-Site Repository**					Repositoy site is 400m x 165m x 8m
4.1	Furnish Underdrain System	m	400	105.75	42	Place lime stone in Underdrain
4.2	Place and Compact Clay layer	m3	41,820	0.74	31	
4.3	Wet Cover					
	Grading Clay and Gravel	m3	34,850	0.37	13	
	Clay Compaction	m3	41,820	0.74	31	
4.4	Material					
	Clay	m3	104,550	4.04	422	Excavate, haul, and place
	Gravel	m3	6,970	11.73	82	On site exacavate, crush, and place
5	**Regrading Overburden Waste**	m3	582,557	0.37	217	Total area is 160ha
6	**Road Construction**					
6.1	Road Construction	m	5,000	12.60	63	Total road distance is 5000m
6.2	Side Gutter	m	10,000	23.90	239	Furnish side gutter both sides the road
7	**Covering**					
7.1	Reactive Waste Area (Oxygen Cover)					Total area is 25 63ha
7.2	Grading Clay and Organic Matter	m3	76,890	0.37	29	
	Organic Matter Compaction	m3	51,260	0.74	38	
7.3	Material					
	Clay	m3	76,890	4.04	310	Excavate, haul, and place
	Organic Matter	m3	51,260	2.78	142	Purchase, haul, and place
	Install River Channel Erosion Control Structure					Concrete channel revetment, Masonry
8	Revetment	m	850	743.53	632	revetment and Concrete Revetment
	Install Crean Water Diversion Channels					
9	Open Channel	m	2,420	121.91	295	
9.1	Box culvert	m	78	611.92	48	
9.2	Flow Box	Lump sum	2	1,720.00	3	
	Install Wetland Treatment System					
10	Excavate Wetland Pond Area	m3	46,400	1.19	55	
0.1	Construct Concrete Outlet Structure	Lump sum	4	31,347.50	125	
0.2	Rip-lap Channel	m3	540	53.83	29	
0.3	Place Limestone and Organic Materials	m3	46,400	0.44	20	
	Limestone	m3	23,200	33.10	768	Purchase, haul, and place
	Organic Material	m3	23,200	2.78	64	Purchase, haul, and place
0.4	Construct Aerobic Rock Filter					
	Place Cobble	m3	3,000	0.44	1	
	Cobble	m3	3,000	6.33	19	
0.5	Construct Reacration Bar					
	Place Reacration Bar Materials	m3	29,600	0.44	13	Use of native overburden
11	**Revegetation**	m2	256,300	0.32	82	Total area is 25 6 ha
12	**Engineering and Construction Inspection**				274	5% of 1 through 11
13	**Contingencies**				574	10% of total capital cost
	Total				6,319	

TABLE D-9

INVESTMENT COST ESTIMATE FOR THE FIORITA FS SITE: ALTERNATIVE 5

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				188	5% of 2 through 8
2	**Reactive Waste Excavation and Disposal**	m3	139,000	1.61	224	Reactive wastes only located in stream channels or water courses would be excavated
	Excavate, Load, Haul, and Dump Reactive Wastes					
3	**Road Construction**					
3.1	Road Construction	m	5,000	3.02	15	Total road distance is 5000m
3.2	Side Gutter	m	10,000	23.89	239	Furnish side gutter both sides the road
4	**Covering**					
4.1	Reactive Waste Area (Wet Cover)					Total area is 21.0 ha
	Grading Clay and Gravel	m3	105,050	0.37	39	
	Compaction Clay	m3	105,050	0.74	77	
4.2	Material					
	Clay	m3	189,090	4.04	763	Excavate, haul, and place
	Gravel	m3	21,010	11.73	246	On site excavate, crush, and place
5	**Install River Channel Erosion Control Structure**					Concrete channel revetment, Masonry revetment and Concrete Revetment
	Revetment	m	850	744.44	633	
6	**Install Crean Water Diversion Channels**					
6.1	Open Channel	m	2420	121.91	295	
6.2	Box culvert	m	78	611.92	48	
6.3	Flow Box	Lump sum	2	1,720.00	3	
7	**Install Wetland Treatment System**					
7.1	Excavate Wetland Pond Area	m3	46,400	1.19	55	
7.2	Construct Concrete Outlet Structure	Lump sum	4	31,482.19	126	
7.3	Rip-lap Channel	m3	540	53.83	29	
7.4	Place Limestone and Organic Materials	m3	46,400	0.44	20	
	Limestone	m3	23,200	33.10	768	Purchase, haul, and place
	Organic Material	m3	23,200	2.78	64	Purchase, haul, and place
7.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	3,000	0.44	1	
	Cobble	m3	3,000	6.33	19	
7.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	29,600	0.44	13	Use of native overburden
8	**Revegetation**	m2	256,300	0.32	82	Total area is 25.6 ha
9	**Engineering and Construction Inspection**				197	5% of 1 through 8
10	**Contingencies**				415	10% of total capital cost
	Total				4,560	

TABLE D-10

INVESTMENT COST ESTIMATE FOR THE FIORITA FS SITE: ALTERNATIVE 6

No.	Item	Unit	Quantity	Unit cost ($US)	Total cost (1,000$US)	
1	**Mobilization, Demobilization and Site Preparation**				112	5% of 2 through 6
2	**Reactive Waste Excavation and Disposal** Excavate, Load, Haul, and Dump Reactive Wastes	m3	139,000	1.61	224	Reactive wastes only located in stream channels or water courses would be excavated
3	**Road Construction**					
3.1	Road Construction	m	5,000	3.02	15	Total road distance is 5000m
3.2	Side Gutter	m	10,000	23.89	239	Furnish side gutter both sides the road
4	**Covering**					
4.1	Reactive Waste Area (Dry Cover II)					Total area is 21.0 ha
4.2	Grading Clay	m3	126,060	0.37	47	
4.3	Material					
	Clay	m3	126,060	4.04	509	Excavate, haul, and place
5	**Install Wetland Treatment System**					
5.1	Excavate Wetland Pond Area	m3	46,400	1.19	55	
5.2	Construct Concrete Outlet Structure	Lump sum	4	31,482.19	126	
5.3	Rip-lap Channel	m3	540	53.83	29	
5.4	Place Limestone and Organic Materials	m3	46,400	0.44	20	
	Limestone	m3	23,200	33.10	768	Purchase, haul, and place
	Organic Material	m3	23,200	2.78	64	Purchase, haul, and place
5.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	3,000	0.44	1	
	Cobble	m3	3,000	6.33	19	
5.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	29,600	0.44	13	Use of native overburden
6	**Revegetation**	m2	256,300	0.32	82	Total area is 160ha
7	**Engineering and Construction Inspection**				116	5% of 1 through 6
8	**Contingencies**				244	10% of total capital cost
	Total				2,681	

TABLE D-11

INVESTMENT COST ESTIMATE FOR THE ROCINHA FS SITE: ALTERNATIVE 1

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				255	5% of 2 through 9
2	**Backfilling for Pond**	m3	20,000	0.37	7	
3	**Regrading Reactive Reject**	m3	459,600	0.37	171	
4	**Road Construction**					
4.1	Road Construction	m	3,000	3.02	9	Total road distance is 3,000m
4.2	Side Gutter	m	6,000		143	Furnish side gutter both sides the road
5	**Install Wet Cover Systems over Reactive Wastes**					
5.1	Clay Compaction	m3	225,200	0.74	166	Total area is 45 ha
	Clay, Gravel Laying	m3	225,200	0.37	84	
5.2	Material					
	Clay	m3	405,360	4.04	1,636	Excavate, haul, and place
	Gravel	m3	45,040	11.73	528	
	Limestone	m3	6,452	33.10	214	Purchase, haul, and place
6	**Install River Channel Erosion Control Structures**					
	Revetment	m	1,030	487.89	503	Concrete channel revetment, Masonry revetment and Concrete Revetment
7	**Install Clean Water Diversion Channels**					
7.1	Open channel	m	800	321.95	258	
7.2	Box Culvert	Lump sum	6		4	
7.3	Flow Box	Lump sum	2		4	
8	**Install Wetland Treatment System**					
8.1	Excavate Wetland Pond Area	m3	88,500	1.19	106	
8.2	Concrete Control Structure	Lump sum	4	31,482	125.93	
8.3	Rip-rap Channel	m3	360	53.83	19	
8.4	Place Limestone and Organic Materials	m3	51,000	0.44	22	
	Limestone	m3	25,500	33.10	844	Purchase, haul, and place
	Organic Material	m3	25,500	2.78	71	Purchase, haul, and place
8.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	3,000	0.44	1	
	Cobble	m3	3,000	6.33	19	
8.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	29,600	0.44	13	
9	**Revegetation**	m2	450,400	0.32	143	Total area is 45ha
10	**Engineering and Construction Inspection**				267	5% of 1 through 11
11	**Contingencies**				561	10% of total capital cost
	Total				6,174	

TABLE D-12

INVESTMENT COST ESTIMATE FOR THE ROCINHA FS SITE: ALTERNATIVE 2

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	Mobilization, Demobilization and Site Preparation				185	5% of 2 through 9
2	Backfilling for Pond	m3	20,000	0.37	7	
3	Regrading Reactive Reject	m3	459,600	0.37	171	
4	Road Construction					
4.1	Road Construction	m	3,000	3.02	9	Total road distance is 3,000m
4.2	Side Gutter	m	6,000	23.89	143	Furnish side gutter both sides the road
5	Install Dry Cover I Systems over Reactive Wastes					
5.1	Clay Compaction	m3	135,120	0.74	99	Total area is 45 ha
	Clay Laying	m3	135,120	0.37	50	
5.2	Material					
	Clay	m3	270,240	4.04	1,091	Excavate, haul, and place
6	Install River Channel Erosion Control Structures					
	Revetment	m	1,030	487.89	503	Concrete channel revetment, Masonry revetment and Concrete Revetment
7	Install Clean Water Diversion Channels					
7.1	Open channel	m	800	321.95	258	
7.2	Box Culvert	Lump sum	6		4	
7.3	Flow Box	Lump sum	2		4	
8	Install Wetland Treatment System					
8.1	Excavate Wetland Pond Area	m3	88,500	1.19	106	
8.2	Concrete Control Structure	Lump sum	4	31,482	125.93	
8.3	Rip-lap Channel	m3	360	53.83	19	
8.4	Place Limestone and Organic Materials	m3	51,000	0.44	22	
	Limestone	m3	25,500	33.10	844	Purchase, haul, and place
	Organic Material	m3	25,500	2.78	71	Purchase, haul, and place
8.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	3,000	0.44	1	
	Cobble	m3	3,000	6.33	19	
8.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	29,600	0.44	13	
9	Revegetation	m2	450,400	0.32	143	Total area is 45ha
10	Engineering and Construction Inspection				194	5% of 1 through 9
11	Contingencies				408	10% of total capital cost
	Total				4,492	

TABLE D-13

INVESTMENT COST ESTIMATE FOR THE ROCINHA FS SITE: ALTERNATIVE 3

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				121	5% of 2 through 7
2	**Regrading Reactive Reject**	m3	459,600	0.37	171	
3	**Road Construction**					
3.1	Road Construction	m	3,000	3.02	9	Total road distance is 3,000m
3.2	Side Gutter	m	6,000	23.89	143	Furnish side gutter both sides the road
4	**Install Dry Cover II Systems over Reactive Wastes**					
4.1	Clay Laying	m3	270,240	0.37	101	
4.2	Material					
	Clay	m3	270,240	4.04	1,091	
5	**Install River Channel Erosion Control Structures**					
	Revetment	m	1,030	487.89	503	Concrete channel revetment, Masonry revetment and Concrete Revetment
6	**Install Clean Water Diversion Channels**					
6.1	Open channel	m	800	321.95	258	
6.2	Box Culvert	Lump sum	6		4	
6.3	Flow Box	Lump sum	2		4	
7	**Revegetation**	m2	450,400	0.32	143	Total area is 45ha
8	**Engineering and Construction Inspection**				127	5% of 1 through 7
9	**Contingencies**				267	10% of total capital cost
	Total				2,942	

TABLE D-14

INVESTMENT COST ESTIMATE FOR THE CARVÃO FS SITE: ALTERNATIVE 1

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				306	5% of 2
2	**Acid Water Neutralization Plant**				6,129	
2.1	Mechanical Construction					
	Tanks	set	1		1,107	
	Pumps	set	1		512	
	Miscellaneous	set	1		1,609	
2.2	Civil Construction	Lump sum	1		1,603	
3	**Engineering and Construction Inspection**				322	5% of 1 through 2
4	**Contingencies**				676	10% of total capital cost
	Total				7,433	

Annual Operating and Maintenance Costs
for
Active Treatment

Item	Unit	Quantity	Unit cost ($US)	Total cost (1,000$US)
Annual O&M Costs				
Lime Regent	tons	5,475	70	383
Other Regents	Lump sum		45,000	45
Electric Energy	Lump sum		75,000	75
Operator Labor	Lump sum		52,800	53
Replacement Parts	Lump sum		120,000	120
Miscellaneous Unlisted Items	Lump sum		67,605	68
Total				744

TABLE D-15

INVESTMENT COST ESTIMATE FOR THE CARVÃO FS SITE: ALTERNATIVE 2

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				432	5% of 2 through 4
2	**Install Wetland Treatment System**					
2.1	Excavating for Wet land	m3	1,641,127	1.19	1,957	
2.2	Concrete Control Structure	Lump sum	4	70,834.93	283	
2.3	Rip-lap Channel	m3	9,375	53.83	505	
2.4	Place Limestone and Organic Materials	m3	491,413	0.44	216	
	Limestone	m3	137,313	33.10	4,545	
	Organic Material	m3	354,100	2.78	984	
2.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	10,000	1.19	12	
	Cobble	m3	10,000	6.33	63	
4	**Revegetation**	m2	224,727	0.32	71	
5	**Engineering and Construction Inspection**				453	5% of 1 through 4
6	**Contingencies**				952	10% of total capital cost
	Total				10,473	

TABLE D-16

INVESTMENT COST ESTIMATE FOR THE CARVÃO FS SITE: ALTERNATIVE 3

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				5	5% of 2 through 2
2	**Limestone Drains**					
2.1	Excavating for Channel	m3	2,700	1.61	4	
2.2	Furnish and Install Geotextile	m2	5,400	0.75	4	
2.3	Limestone Laying	m3	2,700	0.44	1	
2.4	Limestone	m3	2,700	33.10	89	
3	**Engineering and Construction Inspection**				5	5% of 1 through 2
4	**Contingencies**				11	10% of total capital cost
5	**Total**				120	

TABLE D-17

INVESTMENT COST ESTIMATE FOR THE CAPIVARI FS SITE: ALTERNATIVE 1

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				2,113	5% of 2 through 7
2	**Grand Water Cut-off Wall Co**	Lump sum	1	30,350,760.00	30,351	
3	**Backfilling Capivari Lake**	m3	1,890,000	0.37	703	
4	**Regrading Reactive Reject**	m3	800,000	0.37	298	
5	**Install Wet Cover Systems over Reactive Wastes**					Total area is 80 ha
5.1	Clay Soil Compaction	m3	400,000	0.74	294	
5.2	Clay, Gravel Laying	m3	400,000	0.37	149	
	Material					
	Clay	m3	720,000	4.04	2,905	
	Gravel	m3	80,000	11.73	939	
6	**Install Wetland Treatment System**					
6.1	Excavate Wetland Pond Area	m3	1,890,000	1.61	3,039	
6.2	Concrete Control Structure	Lump sum	4	23,611.64	94	
6.3	Rip lap Channel	m3	270	53.83	15	
6.4	Place Limestone and Organic Ma	m3	150,000	0.44	66	
	Limestone	m3	75,000	33.10	2,483	
	Organic Material	m3	75,000	2.78	208	
6.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	22,500	0.44	10	
	Cobble	m3	22,500	6.33	143	
6.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	111,000	0.44	49	
7	**Revegetation**	m2	1,600,000	0.32	509	Total area is 160 ha
8	**Engineering and Construction Inspection**				2,218	5% of 1 through 7
9	**Contingencies**				4,658	10% of total capital cost
	Total				51,243	

TABLE D-18

INVESTMENT COST ESTIMATE FOR THE CAPIVARI FS SITE: ALTERNATIVE 2

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	**Mobilization, Demobilization and Site Preparation**				592	5% of 2 through 7
2	**Backfilling Capivari Lake**	m3	1,890,000	0.37	703	
3	**Regrading Reactive Reject**	m3	800,000	0.37	298	
4	**Install Wet Cover Systems over Reactive Wastes**					Total area is 80 ha
4.1	Clay Soil Compaction	m3	400,000	0.74	294	
4.2	Clay, Gravel Laying Material	m3	400,000	0.37	149	
	Clay	m3	720,000	4.04	2,905	
	Gravel	m3	80,000	11.73	939	
5	**Install Clean Water Diversion Channels**					
5.1	Excavating for Channel	m	1,400	9.65	14	
5.2	Open Channel	m	1,400	495.37	694	
5.3	Box Culvert	m	16	801.61	13	
6	**Install Wetland Treatment System**					
6.1	Excavate Wetland Pond Area	m3	1,890,000	1.19	2,253	
6.2	Concrete Control Structure	Lump sum	3	31,482.19	94	
6.3	Rip lap Channel	m3	270	53.83	15	
6.4	Place Limestone and Organic Materials	m3	150,000	0.44	66	
	Limestone	m3	75,000	33.10	2,483	
	Organic Material	m3	75,000	2.78	208	
6.5	Construct Aerobic Rock Filter					
	Place Cobble	m3	22,500	0.44	10	
	Cobble	m3	22,500	6.33	143	
6.6	Construct Reaeration Bar					
	Place Reaeration Bar Materials	m3	111,000	0.44	49	
7	**Revegetation**	m2	1,600,000	0.32	509	Total area is 160 ha
8	**Engineering and Construction Inspection**				621	5% of 1 through 7
9	**Contingencies**				1,305	10% of total capital cost
	Total				14,355	

TABLE D-19

INVESTMENT COST ESTIMATE FOR THE CAPIVARI FS SITE: ALTERNATIVE 3

No.	Item	Unit	Quantity	Unit cost (R$)	Total cost (1,000R$)	
1	Mobilization, Demobilization and Site Preparation (5% of 2 through 9)				567	5% of 2 through 5
2	**Backfilling Capivari Lake**	m3	1,890,000	0.37	703	
	Backfill Material - Granite	m3	1,890,000	4.04	7,627	
3	**Regrading Reactive Reject**	m3	800,000	0.37	298	Total area is 80 ha
4	**Install Dry Cover I Systems over Reactive Wastes**					
4.1	Clay Soil Compaction	m3	240,000	0.74	177	
	Clay Laying	m3	240,000	0.37	89	
4.2	Material					
	Clay	m3	480,000	4.04	1,937	
5	**Revegetation**	m2	1,600,000	0.32	509	Total area is 160 ha
6	**Engineering and Construction Inspection**				595	5% of 1 through 5
7	**Contingencies**				1,250	10% of total capital cost
	Total				13,752	

2. Overall Remedial Cost Estimates

2.1 Approach to Overall Remediation

7. Since this is only a pre-feasibility study, individual pollution sources as well as overburden waste dumps in the overall remediation study areas have not been fully identified. Therefore, the only possibility is to extrapolate the findings of the FS sites study. However, since there are no identical sites with Carvão (underground mine water) and Capivari (a large lake filled with washery reject) in the region, their findings have not been used for the overall cost estimates.

8. **Overburden Waste Dumps:** Overall remedial actions for overburden waste dumps are based on the Fiorita study. However, washery reject treatment was eliminated from overburden remedial actions, since rejects are rarely found in the other overburden waste areas. The amount of re-grading work for waste dumps depends on their topographical types. They were classified into three types with different coefficients for re-grading: (i) saw (dragline waste dump), coefficient = 1.00; (ii) heap (stacked waste dump), coefficient = 0.75; and (iii) flat (flatly spread waste dump), coefficient = 0.20. Each type was categorized further into two, i. e., river flow or no river in the waste areas. Deference between the two in remedial actions is with or without river bank protection work (revetment), respectively. The remedial actions are as follows:

i.) Overburden waste re-grading;
ii.) Road construction;
iii.) Dry covering;
iv.) Re-vegetation; and
v.) River revetment, if a river exists in the dump area.

9. **Washery Reject Dumps:** Overall remedial actions for washery reject dumps are based on the Rocinha study. The area has two topographical types of washery reject and their re-grading or leveling costs are also different: (i) a slope area and (ii) a flat area. Overall reject dumps were therefore classified into two types. Each type was categorized further into two, i. e., river flow or no river in the waste areas. Since a wet cover system is relatively expensive, another category was added, which is a reject dump not directly connected with rivers and ground water reserves. In that later category, dry cover was used, because little risk and similar results are expected, totaling 425 ha as illustrated in Figure A-2 of Section II. A of this Main Text. The remedial actions are as follows:

(A) Wet cover and wetland
i.) Re-grading;
ii.) Road construction;
iii.) Wet covering;
iv.) Channel construction;
v.) Wetland construction;
vi.) Re-vegetation; and

vii.) River revetment, if the river exists in the dump area.

(B) Dry cover
(This is identical with the overburden remedial actions without river flow.)
i.) Overburden waste re-grading;
ii.) Road construction;
iii.) Dry covering; and
iv.) Re-vegetation.

2.2 Overall Remedial Cost Estimates

10. Unite costs (R$x 1000/ha) for varying waste dumps according to the above definitions are summarized in Table D-20 below.

TABLE D-20

ESTIMATED OVERALL REMEDIAL UNIT COSTS (R$1,000/ha)

Waste Type	Topo-Type	River	Unit Costs
	Saw	River Flow	29.14
	Saw	No River	25.76
Overburden (White Waste)	Heap	River Flow	26.57
	Heap	No River	23.18
	Flat	River Flow	20.90
	Flat	No River	17.51
	Flat	River Flow	86.3
	Flat	No River	77.7
Washery Reject(Black Shale)	Slope	River Flow	87.9
	Slope	No River	79.3
	(No Groundwater/No River)		18.2

11. Overall remedial costs include those for remediation of abandoned, active and inactive areas. However, it should be noted that remedial costs for the active and inactive areas do not indicate environmental improvement costs for current operations. They are the costs for final rehabilitation to be required at a time of mine closure for the restoration of the area's environment.

12. Estimated overall remedial costs are presented in Table D-21 below. Costs estimated by land status are presented in Table D-22 for wet cover systems and Table D-23 for wet/dry cover systems.

TABLE D-21

OVERALL REMEDIAL COST ESTIMATES

Items	Wet Cover (R$000)	Wet/Dry Cover (R$000)
Labor	22,411	21,198
Parts	10,125	9,654
Tire	553	520
Fuel/Lub	10,430	9,950
Depreciation	6,327	6,027
Cement	4,145	3,878
Mortar	1,842	1,818
Sand	528	493
Cobble	2,129	1,997
Clay	57,209	52,371
Royalty for clay	17,213	15,757
Gravel	18,339	15,198
Limestone	36,974	30,666
Board	2,386	2,182
Timber	259	237
Nail	69	63
Steel bar	5,013	4,415
Fertilizer	3,846	3,854
Seeds	1,006	1,008
Cellulose	2,663	2,668
Emulsion	947	949
Organic matter	2,681	2,256
Mobilization (5%)	11,297	10,252
Engineering (5%)	11,862	10,765
Contingency (10%)	24,909	22,607
Total	**274,003**	**248,673**

TABLE D-22

COST ESTIMATES BY LAND STATUS FOR WET COVER SYSTEMS

Unit: $R x 1000

Municipality	Waste Type	Topo Type	River	Abandoned		Active		Inactive		Total	
				Area (ha)	$Rx1000	Area (ha)	$Rx1000	Area (ha)	$Rx1000	Area (ha)	$Rx1000
Capivari de Baixo	Black Shale	Flat	No river	80.0	7,177					80.0	7,177
	Water	Pond	No river	80.0	7,177					80.0	7,177
		Sub-total		160.0	14,355					160.0	14,335
Criciuma	Black Shale	Flat	No river	87.0	6,761					87.0	6,761
	Black Shale	Flat	River flow	582.2	50,247	163.0	14,068	93.9	8,104	839.1	72,419
	Black Shale	Slope	No river	12.0	951					12.0	951
	Black Shale	Slope	River flow	58.0	5,097					58.0	5,097
	White Waste	Flat	No river	39.0	683					39.0	683
	White Waste	Flat	River flow	29.5	617					29.5	617
		Sub-total		807.7	64,356	163.0	14,068	93.9	8,104	1,064.6	86,528
Forquilhinha	Black Shale	Flat	River flow	165.5	14,284	191.2	16,502			355.7	30,783
	Water	Pond(flatBS)	River flow			28.0	2,417			28.0	2,417
		Sub-total		165.5	14,284	219.2	18,918			384.7	33,202
Icara	Black Shale	Flat	River flow	36.0	3,107	8.8	759			44.8	3,866
Lauro Muller	Black Shale	Flat	No river	11.4	886					11.4	886
	Black Shale	Flat	River flow	42.7	3,685	56.8	4,921			99.5	8,607
	Black Shale	Heap	No river	8.0	634					8.0	634
	Black Shale	Heap	River flow	32.2	2,830					32.2	2,830
	Black Shale	River Bank	River flow			27.8	2,421			27.8	2,421
	Black Shale	Slope	No river			8.0	634			8.0	634
	Black Shale	Slope	River flow					16.8	1,463	16.8	1,463
	Water	Pond	River flow			0.5	44	0.8	70	1.3	113
		Pond(flatBS)	River flow	0.5	43	3.0	259			3.5	302
	White Waste	Flat	No river	8.0	140					8.0	140
	White Waste	Heap	No river	115.1	2,668	8.8	204			123.9	2,872
	White Waste	Heap	River flow	128.5	3,414					128.5	3,414
	White Waste	Saw	No river	5.0	129					5.0	129
	White Waste	Saw	River flow	71.8	2,093	64.4	1,877	18.0	525	154.2	4,494
		Sub-total		423.2	16,522	169.3	10,360	35.6	2,057	628.1	28,939
Sideropolis	Black Shale	Flat	No river	18.0	1,399	191.0	14,843			209.0	16,241
	Black Shale	Flat	River flow	8.5	734					8.5	734
	Water	Pond	River flow	15.0	752					15.0	752
		Pond(flatBS)	River flow			1.0	86			1.0	86
		Pond(saw)	No river	25.0	644					25.0	644
		Pond(saw)	River flow	61.0	1,778					61.0	1,778
	White Waste	Flat	River flow	10.0	209					10.0	209
	White Waste	Saw	No river	113.0	2,911					113.0	2,911
	White Waste	Saw	River flow	628.4	22,762					628.4	22,762
		Sub-total		878.9	31,188	192.0	14,929			1,070.9	46,117
Treviso	Black Shale	Flat	No river			120.8	9,387			120.8	9,387
	Black Shale	Flat	River flow	28.8	2,486					28.8	2,486
	Water	Pond(flatBS)	No river			8.0	622			8.0	622
		Pond(flatBS)	River flow	6.0	518					6.0	518
		Pond(saw)	River flow			2.0	58	6.0	175	8.0	233
	White Waste	Saw	No river	50.0	1,288					50.0	1,288
	White Waste	Saw	River flow	47.0	1,370	108.2	3,153	104.6	3,048	259.8	7,572
		Sub-total		131.8	5,661	239.0	13,221	110.6	3,223	481.4	22,105
Urussanga	Black Shale	Flat	No river	20.8	1,616					20.8	1,616
	Black Shale	Flat	River flow	31.5	2,719	157.2	13,567			188.7	16,286
	Black Shale	Slope	River flow					35.7	3,225	36.7	3,225
	Water	Pond(flatBS)	River flow			4.0	345			4.0	345
		Pond(saw)	No river			1.0	26			1.0	26
		Pond(saw)	River flow	3.5	102					3.5	102
		Pond(slopeBS)	River flow					1.5	132	1.5	132
	White Waste	Flat	River flow	19.0	397					19.0	391
	White Waste	Heap	No river	7.0	162					7.0	162
	White Waste	Saw	No river	322.8	8,315					322.8	8,315
	White Waste	Saw	River flow	284.3	8,286					284.3	8,286
		Sub-total		688.9	21,597	162.2	13,938	38.2	3,357	889.3	38,892
		Grand Total		3,292.0	171,069	1,153.5	86,193	278.3	16,742	4,723.8	274,005

TABLE D-23

COST ESTIMATES BY LAND STATUS FOR WET/DRY COVER SYSTEMS

Unit: $R x 1000

Municipality	Waste Type	Topo Type	River	Abandoned		Active		Inactive		Total	
				Area (ha)	$Rx1000	Area (ha)	$Rx1000	Area (ha)	$Rx1000	Area (ha)	$Rx1000
Capivari de Baixo	Black Shale	Flat	No river	80.0	7,177					80.0	7,177
	Water	Pond	No river	80.0	7,177					80.0	7,177
		Sub-total		160.0	14,355					160.0	14,355
Criciuma	Black Shale	Flat	No river	87.0	1,581					87.0	1,581
	Black Shale	Flat	River flow	582.2	50,247	163.0	14,068	93.9	8,104	839.1	72,419
	Black Shale	Slope	No river	12.0	951					12.0	951
	Black Shale	Slope	River flow	58.0	5,097					58.0	5,097
	White Waste	Flat	No river	39.0	683					39.0	683
	White Waste	Flat	River flow	29.5	617					29.5	617
		Sub-total		807.7	59,176	163.0	14,068	93.9	8,104	1,064.6	81,348
Forquilhinha	Black Shale	Flat	River flow	165.5	14,284	191.2	16,502			356.7	30,765
	Water	Pond(flatBS)	River flow			28.0	2,417			28.0	2,417
		Sub-total		165.5	14,284	219.2	18,918			384.7	33,202
Icara	Black Shale	Flat	River flow	36.0	3,107	8.8	759			44.8	3,866
Lauro Muller	Black Shale	Flat	No river	11.4	207					11.4	207
	Black Shale	Flat	River flow	42.7	3,685	55.8	4,921			99.5	8,607
	Black Shale	Heap	No river	8.0	145					8.0	145
	Black Shale	Heap	River flow	32.2	2,830					32.2	2,830
	Black Shale	River Bank	River flow			27.8	2,421			27.8	2,421
	Black Shale	Slope	No river			8.0	145			8.0	145
	Black Shale	Slope	River flow					16.8	1,463	16.8	1,463
	Water	Pond	River flow			0.5	44	0.8	70	1.3	113
		Pond(flatBS)	River flow	0.5	43	3.0	259			3.5	302
	White Waste	Flat	No river	8.0	140					8.0	140
	White Waste	Heap	No river	115.1	2,668	8.8	204			323.9	2,872
	White Waste	Heap	River flow	128.5	3,414					128.5	3,414
	White Waste	Saw	No river	5.0	129					5.0	129
	White Waste	Saw	River flow	71.8	2,093	64.4	1,877	18.0	525	354.2	4,494
		Sub-total		423.2	15,354	169.3	9,871	35.6	2,057	628.1	27,282
Sideropolis	Black Shale	Flat	No river	18.0	327	191.0	5,852			209.0	6,179
	Black Shale	Flat	River flow	8.5	734					8.5	734
	Water	Pond	River flow	15.0	752					15.0	752
		Pond(flatBS)	River flow			1.0	86			1.0	86
		Pond(saw)	No river	25.0	644					25.0	644
		Pond(saw)	River flow	61.0	1,778					61.0	1,778
	White Waste	Flat	River flow	10.0	209					10.0	209
	White Waste	Saw	No river	113.0	2,911					113.0	2,911
	White Waste	Saw	River flow	628.4	22,762					628.4	22,762
		Sub-total		878.9	30,116	192.0	5,938			1,070.9	36,055
Treviso	Black Shale	Flat	No river			120.8	2,195			120.8	2,195
	Black Shale	Flat	River flow	28.8	2,486					28.8	2,486
	Water	Pond(flatBS)	No river			8.0	622			8.0	622
		Pond(flatBS)	River flow	6.0	518					6.0	518
		Pond(saw)	River flow			2.0	58	6.0	175	8.0	233
	White Waste	Saw	No river	50.0	1,288					50.0	1,288
	White Waste	Saw	River flow	47.0	1,370	108.2	3,153	104.6	3,048	259.8	7,572
		Sub-total		131.8	5,661	239.0	6,028	110.6	3,223	481.4	14,913
Urussanga	Black Shale	Flat	No river	20.8	378					20.8	378
	Black Shale	Flat	River flow	31.5	2,719	157.2	13,567			188.7	16,286
	Black Shale	Slope	River flow					36.7	3,225	36.7	3,225
	Water	Pond(flatBS)	River flow			4.0	345			4.0	345
		Pond(saw)	No river			1.0	26			1.0	26
		Pond(saw)	River flow	3.5	102					3.5	102
		Pond(slopeBS	River flow					1.5	132	1.5	132
	White Waste	Flat	River flow	19.0	397					19.0	397
	White Waste	Heap	No river	7.0	162					7.0	162
	White Waste	Saw	No river	322.8	8,315					322.8	8,315
	White Waste	Saw	River flow	284.3	8,286					284.3	8,286
		Sub-total		688.9	20,358	162.2	13,938	38.2	3,357	889.3	37,653
		Grand Total		3,292.0	162,411	1,153.3	69,521	278.3	16,742	4,723.8	248,673

E HYDROLOGY

1. General

1.1 Introduction

1. In this section, the general hydrological conditions of the concerned area are discussed based on the data obtained to date.

1.2 Precipitation

2. On Table E-1, both average monthly precipitation and evaporation data observed at EPAGRI's meteorological station in Urussanga are summarized. The average yearly total precipitation during the past 19 years is calculated as 1,673 mm (standard deviation is 323 mm). This is almost the same amount as the average in Japan. According to the annual precipitation data, it may be recognized that there are four seasons, including a rainy season from December to February, a dry season from April to September and an additional two changing seasons from rainy to dry or from dry to rainy.

3. On an average, monthly precipitation in these seasons are calculated to be about 210 mm, 100 mm and 140 mm, respectively. The reason why the coefficient of variation of monthly precipitation in the dry season is larger than that in the rainy season must be that rainfall is not stable and large amounts of precipitation can occasionally be produced even during the dry season.

1.3 Evaporation

4. The average monthly evaporation rates are also presented on the same table. According to these evaporation data, the existence of two seasons is recognized; namely, the season of high evaporation from October to March and the low evaporation season from April to September. The threshold value of these two seasons is 90 mm/month of evaporation. The variation coefficient for monthly evaporation is stable and is estimated to range between 0.03 to 0.15 since the evaporation in this area can be strongly influenced by temperature change. Evapo-transpiration values are estimated and are also shown on Table E-1. The correction factor used is the value well known in Japan.

5. The ratio of evapotranspiration to precipitation is estimated as 0.42 on a yearly basis and as 0.19 to 0.60 on a monthly basis. In other words, it may be understood that the runoff coefficient, which is defined as the ratio of surface runoff to precipitation, is about 0.6 on a yearly basis and varies from 0.8 to 0.4 on a monthly basis. The runoff coefficient in winter (May to July) is larger than that in summer (November to January).

TABLE E-1

ANNUAL CHANGE OF PRECIPITATION/EVAPORATION AT URUSSANGA

Source: EPAGRI

Unit: mm/month

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	YEAR	DURATION
Precipitation														1978~1996
Mean	206	212	147	110	117	87	124	100	114	138	135	205	1673	
Standard deviation	106	93	46	46	95	44	93	68	64	66	56	97	323	
C. of Variation	0.51	0.44	0.31	0.42	0.81	0.51	0.75	0.68	0.56	0.48	0.41	0.47	0.19	
Evaporation														1991~1995
Mean	121	102	96	77	58	42	48	63	72	92	116	128	1016	
Standard Deviation	16	14	5	8	3	4	7	2	2	11	8	4	41	
C. of Variation	0.13	0.14	0.05	0.10	0.05	0.10	0.15	0.03	0.03	0.12	0.07	0.03	0.04	
Correction Factor	0.8	0.8	0.7	0.7	0.6	0.5	0.5	0.6	0.6	0.7	0.7	0.8		
Evapo-Transpilation	97	82	67	54	35	21	24	37	43	64	81	102	707	
Evapo Trans./Precipitation	0.47	0.39	0.46	0.49	0.30	0.24	0.19	0.37	0.38	0.46	0.60	0.50	0.42	

1.4 Maximum Daily Precipitation

6. Table E-2 shows the statistical values for the largest monthly precipitation events during the past 19 years observed at the EPAGRI office in Urussanga. The yearly average of largest daily precipitation events is estimated as 94 mm with standard deviation of 41 mm. The monthly average of largest precipitations is calculated as 50 to 60 mm in summer and as 30 to 40 mm in winter. In winter, a large amount of daily precipitation, which may be almost the same as in summer, is suspected to be produced because the variation coefficient in winter is larger in comparison with that of summer.

1.5 Design Rainfall

7. In order to design hydraulic structures such as flow channels, the information regarding the relationship between rainfall duration and rainfall intensity has to be prepared eventually. The following is a trial derivation of the relationship which may be useful for the channel design discussed in other chapters.

8. Derivation of the Relationship between Rainfall Intensity and Rainfall Duration:

i.) Reference: The reference used in this derivation is, as follows:
Alvaro Jose Back, 1995, Documentos No. 154
Secretaria de Estado do Desenvolvimento Rural e da Agricultura
Empresa de Pesquisa Agropecuaria e de Extensao Rural de Santa Catarina

ii) Station: The following four stations were selected for each FS site:

FS Site	Code	Station	Elevation	Latitude/Longitude
Capivari	02848000	Amazem-Capivari	21	28.15/48.59
Rochinha	02849001	Orleans	90	28.21/49.17
Carvao	02849011	Urussanga	48	28.31/49.19
Fiorita	02849012	Ararangua	13	28.53/49.31

iii.) Rainfall amount within rainfall duration defined: Based on the data indicated in the above reference, the rainfall amount within a given duration is estimated, as follows:

Ratio of Rainfall Duration	Ratio of Rainfall*	Ratio of Rainfall Amount in a Given Duration to 24 Hour-Rainfall Amount	Ratio of a Given Duration to One Hour
		alfa	tt
5min/30min	.34	.11	.08
10min/30min	.54	.17	.17
18min/30min	.70	.22	.17
20min/30min	.81	.25	.33
25min/30min	.91	.28	.42
30min/1h	.74	.31	.50
1h/24h	.42	.42	1.0
6h/24h	.72	.72	6.0
8h/24h	.78	.78	8.0
10h/24h	.82	.82	10.0
12h/24h	.85	.85	12.0
24h/24h	-	1.0	24.0

* These values are indicated in the reference shown above.

TABLE E-2

MONTHLY MAXIMUM OF DAILY RAINFALL AT URUSSANGA

Source: EPAGRI

Unit: mm/day

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	YEAR	DURATION
Monthly Maximum														1978~1996
Mean	49	59	41	35	43	38	39	31	34	39	40	52	94	
Standard Deviation	17	47	14	15	30	28	20	18	19	20	18	26	41	
C. of Variation	0.35	0.80	0.34	0.43	0.70	0.74	0.51	0.58	0.56	0.51	0.45	0.50	0.44	

The relationship between alfa and tt shown in the above is formulized as follows.

alfa = log(2.63*tt^.4)

iv.) According to the above reference, the daily rainfall corresponding to the recurrence year is indicated in mm/day as follows.

Code	Station	Recurrence Year						
		5	10	15	20	25	50	100
02848000	Amazem-Capivari	96.6	112.3	121.1	127.3	132.1	146.8	161.4
02849001	Oreleans	129.5	157.7	173.6	184.8	193.4	219.8	246.1
02849011	Urussanga	106.9	126.3	137.2	144.8	150.7	168.8	186.8
02849012	Ararangua	88.5	102.3	110.1	115.6	119.8	132.7	145.6

v.) Based on the above derivation the rainfall amount (RR) corresponding with both given duration and with recurrence year is able to be calculated by the following formula.

RR = RT*alfa = RT*log(2.63*tt^.4)

in which

RR: Rainfall amount corresponding to both given duration and recurrence interval

RT: Daily Rainfall indicated in iv) above

tt: Rainfall Duration given.

Example:

In Rochinha, derive the design rainfall corresponding with both 15 minutes of rainfall duration and a 20 year recurrence interval.

Solution:

In the above equation, take 184.8 for RT and 0.25 for tt, the 33.1 for RR can be calculated. Therefore, the required solution should be 132.4 mm/hr, or 33,4/0.25.

1.6 Surface Water

9. The whole area of the concerned coal field consists of three surface water drainages, including the Ararangua, Tubarao and Urussanga drainage basins. Deterioration of water quality in these river basins has been occurring since the development of coal mining in the region. The water quality within the drainages is not discussed in this chapter. Only the quantitative characteristics are involved in the chapter. Figure E-1 shows the relationship between drainage area and specific discharges observed by CPRM. The specific discharge is observed to be independent of drainage area. The average values of specific discharge are obtained as follows.

Drainage	Average of Specific Discharge		(m3/sec·km2)
Tubarao	0.031 (June 95)	0.010 (Sept 95)	0.032 (Nov 95)
Urussanga	0.009 (Jul 95)	0.018 (Oct 95)	0.004 (Jan 96)
Ararangua	0.015 (Aug 95)	0.006 (Oct 95)	0.114 (Jan 96)

(Source: CPRM)

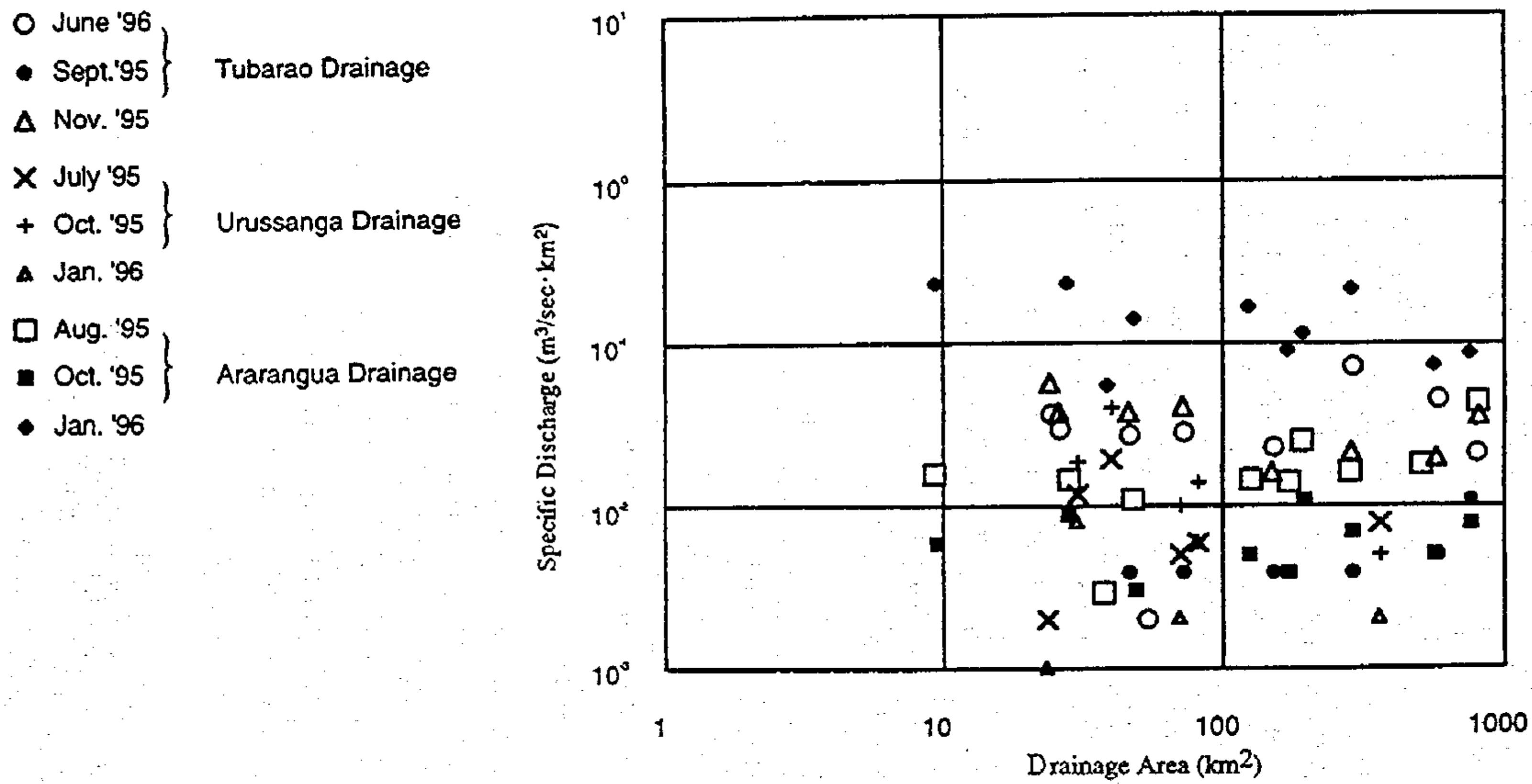


FIGURE E-1

RELATIONSHIP BETWEEN SPECIFIC DISCHARGE AND DRAINAGE AREA

It may be difficult to find any distinctive features based on the above table because few of the observations were done at the same time within each drainage.

1.7 Groundwater

10. The following three kinds of groundwater exist in the concerned study area.

1) Groundwater stored in the fractures of plutonic rocks;
2) Confined groundwater in the sandy sedimentary rocks; and
3) Unconfined groundwater in the alluvium strata.

11. The first type of groundwater is stored in the fractures of plutonic rocks which contributed to form the Sierra Geral Plateau. The water discharged from the mine of Carvao FS site is thought to originate from this kind of groundwater. In general, although it is difficult to find the location of stored area and to estimate the volume of this type of groundwater, a large amount of water can be discharged, as observed to the Carvao FS site, once fracture storage water is encountered. The water stored in the permeable sandy strata in Rio Bonito and/or Palermo Strata is confirmed and is utilized for various human activities. In and around Sideropolis, this type of water is pumped from the depth of 10 to 60 meters. The third type of groundwater is contained in the alluvium deposit, mainly distributed along river channel bottoms. This type of groundwater is closely interrelated to surface water and should be focused on in this study.

2. Site investigation

2.1 Rainfall Investigation

12. **Installation of Rainfall Gauge:** In and around the concerned area, intense thunder storms, Cumulonimbus clouds, are readily generated by the atmospheric disturbances due to the geomorphologic conditions. Although the area covered by this type of storm is usually less than a couple of square kilometers and its duration is less than a few hours, the rainfall intensity is very large and the rain area moves rapidly. It is recognized that the rain produced by thunderstorms must be one of the most important factors to deteriorate the drainage. However, no references describing the characteristic of thunderstorms in the concerned area were found. Because of these reasons, three auto-rain gauges were installed and data collection was begun. Figure E-2 shows the locations of rain gauge stations.

13. **Observation Results:** Figure E-3 shows examples of hourly rainfall patterns observed by the installed raingauges. There are two types of rain in the concerned area; the one is the rain of low intensity and long duration storms such as the rain on June 26 at Carvao, the other is the rain of high intensity and short duration. As shown in the figure, the latter type of rains were observed at all of FS sites. The observation will be continued in order to analyze hydro-meteorological condition of the concerned area.

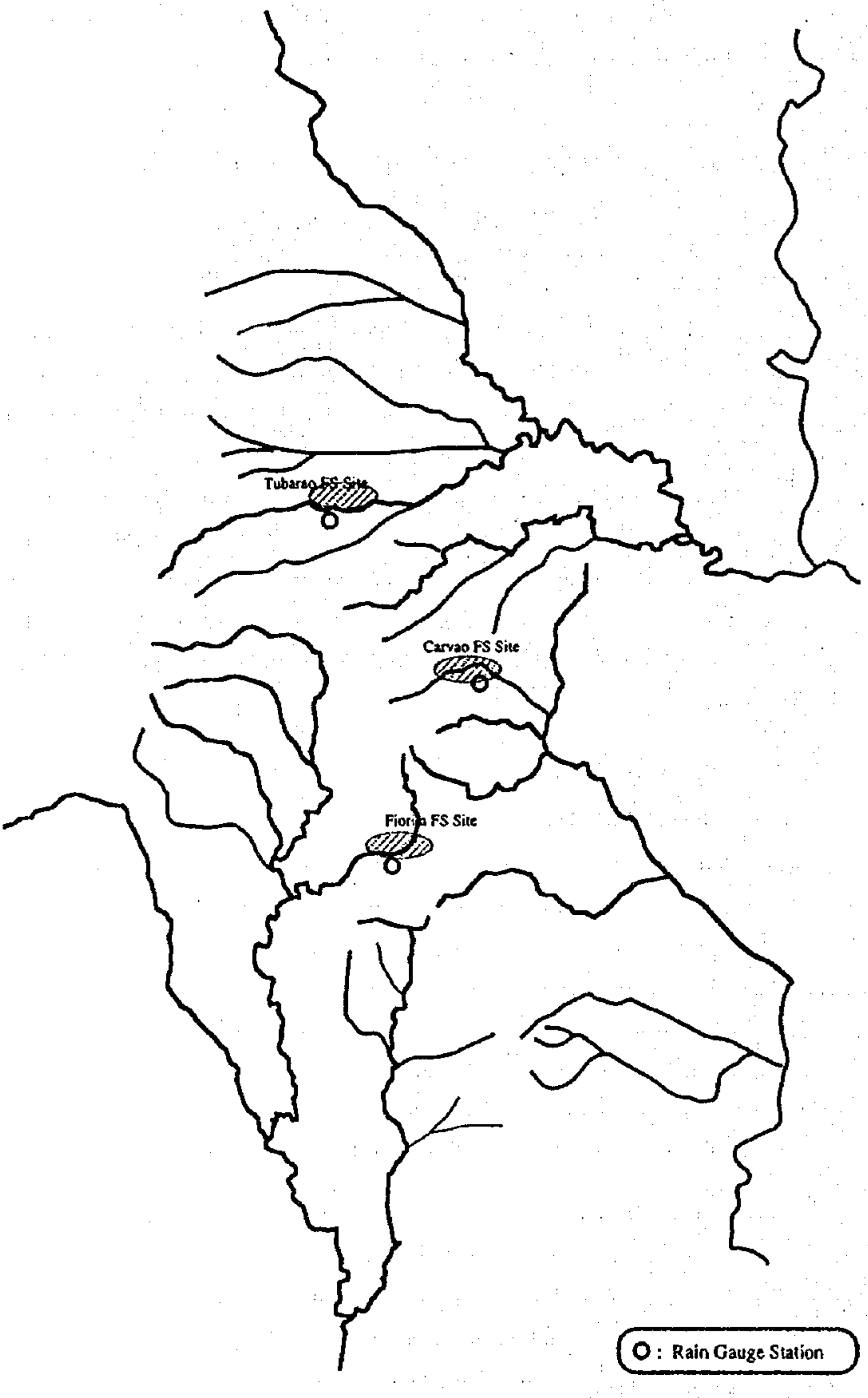


FIGURE E-2 LOCATION OF RAIN GAUGE STATION

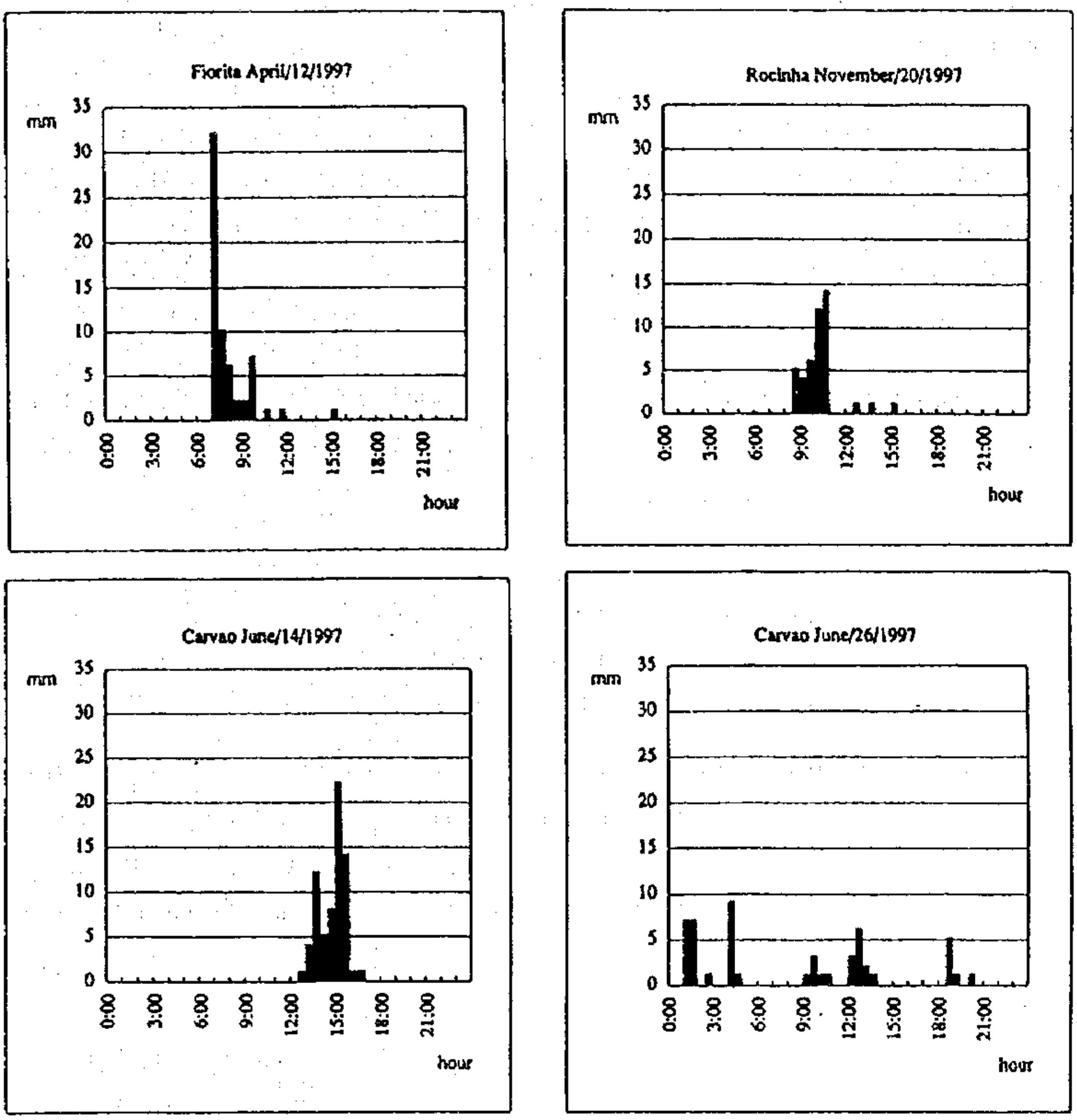


FIGURE E-3 EXAMPLE OF HOURLY RAINFALL PATTERN

2.2 Surface Water Investigation

14. **Cross Sectional Surveying:** At the request of the JICA Team, a local surveying company called Base, completed the work of cross sectional surveying of river channels at 20 locations indicated by the Team.

15. **Surface Flow Observation:** In general, the river discharge is estimated as the product of flow area and flow velocity. The practical observation of flow velocity has been conducted by the Brazilian counterparts using three current meters supplied by JICA. Because of the lack of laborers and of practical difficulties of flow observation, the velocity observations by float were also conducted. The observation was continued until the end of October in 1997.

16. **Auto-Monitoring Station:** Three automonitoring stations were installed to monitor the flow conditions such as stage, electric conductivity and pH. Monitoring equipment consists of Sigma 950 auto monitoring stations. The locations of the stations are as follows.

Drainage	Location Number	Location Name
Ararangua	PA-10	Maracajá
Tubarao	PT-8	Perdas Grande
Urussanga	PU-8	Morro de Fumasa

17. **Observation Results:** Table E-3 shows the observed result, to date. As described in para. 6, the specific discharge in the concerned area is considered not to be subject to area but to be independent. Both the observed discharge values and the specific discharge are indicated on the table. Following are the calculated specific discharge rates. These values can be used to estimate the flow volume at any locations.

		Time			
Drainage		Jan.	Feb.	Mar.(1)	Mar.(2)
Ararangua	Mean	0.124	0.047	0.029	0.015
	Standard Deviation	0.060	0.058	0.074	0.041
Tubarao	Mean	0.060	0.058	0.074	0.041
	Standard Deviation	0.024	0.033	0.088	0.021
Urussanga	Mean	0.060	0.030	0.033	0.037
	Standard Deviation	0.024	0.012	0.019	0.028

Unit: m3/sec·km2

2.3 Groundwater Observation

18. **Installation of Monitoring Wells:** Except that NG-1 was located within the city of Criciuma, all ground water monitoring wells were installed in the four FS sites. The monitoring

TABLE E-3(1/2)

OBSERVATION OF RUNOFF DISCHARGE

Station	Drainage Area (km²)	Observed Runoff Discharge (m³/sec) Jan Disc.	Jan Date	Feb Disc.	Feb Date	Mar Disc.	Mar Date	Mar. Disc.	Mar. Date	Apr.	May	June	July	Aug	Sept	Specific Discharge (m³/sec./km²) Jan	Feb	Mar	Mar	Apr
PA 1	38.71	4.80	17	4.34	18	1.11	7	0.57	11							0.1240	0.0471	0.0287	0.0147	
PA 2	28.45	0.94	17	1.62	18			0.22	11							0.0330	0.0569		0.0077	
PA 3	9.48	3.40	20														0.3586			
PA 4	126.2																			
PA 5	48.33					1.13	4	0.53	11									0.0023	0.0110	
PA 6	291.92																			
PA 7	172.97					2.83	13	2.89	14									0.0164	0.0167	
PA 8	571.02																			
PA 9	196.25																			
PA 10	782.52																			
JA 1	77.96	19.00	31			5.01	13	2.44	18							0.2437		0.0643	0.0313	
JA 2	126.2	11.00	31			3.75	13	3.65	18							0.0872		0.0297	0.0289	
JA 3	209.45					7.56	13	2.88	18									0.0361	0.0138	
JA 4	2.25	0.44	23	0.64	14	0.14	7	0.084	11							0.1956	0.2844	0.0622	0.0373	
JA 5	10.75	0.76	20	0.59	18	0.034	4	0.15	11							0.0707	0.0549	0.0032	0.0140	
JA 6	3.5	0.03	17	0.07	18	-		0.11	10							0.0086	0.0200		0.0314	
JA 7	15.5	1.20	17	0.57	18	0.77	4	0.30	11							0.0774	0.0368	0.0497	0.0194	
JA 8	38.75	0.58	16	3.25	14	1.56	4	1.03	11							0.0150	0.0839	0.0403	0.0266	
JA 9	13	0.19	16	1.15	14	0.54	4	0.47	11							0.0146	0.0885	0.0415	0.0362	
JA 10	54.75	0.76	16	4.61	14	2.19	4	1.41	11							0.0139	0.0842	0.0400	0.0258	
JA 11	18.75	0.51	16	2.00	14	-		-								0.0272	0.1067			
JA 12	79	1.00	16			3.63	14	2.96	18							0.0127		0.0459	0.0375	
PT 1	26.07	2.97	30	1.53	18	7.54	5	0.71	14							0.1139	0.0587	0.2892	0.0272	
PT 2	45.98	3.20	21	4.53	17											0.0696	0.0985			
PT 3	24.63	0.79	21	0.67	17											0.0321	0.0272			
PT 4	70.61			5.51	18	1.55	10	1.66	14								0.0780	0.0220	0.0235	
PT 5	293.53					15.20	12	22.77	19									0.0518	0.0776	
PT 6	579.96					18.20	12	33.55	19									0.0314	0.0578	
PT 7	153.86	21.00	31													0.1365				
PT 8	804.65																			
PT 9	1808.00																			
PT 10																				
PT 14		0.22	24	0.42	19															
PT 16		19.70	24	0.88	19															
JT 1	81.25					3.37	12	2.79	14									0.0415	0.0343	
JT 2	148.75			0.67	13			1.62	14								0.0045		0.0109	
JT 3	241.25					8.40	12	7.93	14									0.0348	0.0329	
JT 4	3.75	0.31	21	0.30	17			0.21	13							0.0827	0.0800		0.0560	
JT 5	13	2.14	29	0.70	17	0.87	6	0.49	13							0.1646	0.0538	0.0669	0.0377	
JT 6	16.5	0.63	21	0.69	17			-								0.0382	0.0418			
JT 7	31.75	6.00	29	3.95	17			2.53	13							0.1890	0.1244		0.0797	

TABLE E-3(2/2)

OBSERVATION OF RUNOFF DISCHARGE

Station	Drainage Area (km²)	Observed Runoff Discharge (m³/sec) Jan		Feb		Mar		Mar.		Apr.	May	June	July	Aug	Sept	Specific Discharge (m³/sec./m²) Jan	Feb	Mar	Mar	Apr
		Disc.	Date	Disc.	Date	Disc.	Date	Disc.	Date											
JT 8	17.25	0.46	21	0.72	17			0.41	13							0.0267	0.0417		0.0238	
JT 9	64			3.26	17	3.34	6	2.70	13								0.0509	0.0522	0.0422	
JT 10	9.75	0.22	21	0.33	18			0.32	13							0.0226	0.0338		0.0328	
PU 1	23.59																	0.0000		
PU 2	30.32																			
PU 3	71.28	4.53	21			3.59	12	4.65	17							0.0636		0.0504	0.0652	
PU 4	40.49																			
PU 5	82.28																			
PU 6	358.21																			
PU 7	123.25			2.61	14												0.0212			
PU 8																				
PU 9	560.21																			
PU 10	7.08	0.284	28	0.27	13	0.047	5	0.048	17							0.0401	0.0381	0.0066	0.0068	
JU 1	53.57	4.20	29			1.05	12	1.60	17							0.0784		0.0196	0.0299	
JU 2	10.75	0.35	21			0.49	10	0.19	13							0.0326		0.0456	0.0177	
JU 3	121.31	10.60	30			5.40	12	8.12	17							0.0874		0.0445	0.0669	

wells at the Capivari site were installed by both the JICA Team and the Counterpart. With regard to other locations rather than Capivari, the work of boring and installing the wells was done by a local company contracted with JICA Team. Table E-4 shows the summary of construction condition for each well. Some of the wells were destroyed by natural flash floods and some by vandalism.

19. **Observation Results:** Table E-5 shows the results of water stage observation. The stages are gradually decreasing under the influence of the change from wet to dry seasons.

2.4 Bed Load and Suspended Solids Observation

20. In this chapter, the suspended solids are first described and, thereafter, the wash load is considered. Although it has been understood, generally, that the sediment load in a river consists of bed load, suspended solids, and the wash load, almost all sediment load may be produced by the wash load in the area where thunderstorms predominate. In these cases, the volume of sediment load can be assumed to be directly proportional to runoff discharge. In Japan, the following formula is well known.

$$QS = (4\times 10\text{-}8 \sim 6\times 10\text{-}6)*Q2$$

in which QS: wash load (m3/sec)
Q : runoff discharge (m3/sec).

21. **Suspended Solids:** During the course of monitoring, the suspended solids have also been observed. Table E-6 shows both the results of the observations and the specific suspended solids (SS). According to the observation at monitoring locations PT-1 and PA-7, located outside of mined areas, the deterioration of the drainages may be judged by whether the SS value exceeds 10 g/sec·km2 which is the typical background load. The following are the calculated averages of SS.

		Month			
Drainage		Jan	Feb	Mar(1)	Mar(2)
	Mean	0.39	20.36	7.35	7.45
Ararangua	Standard Deviation	0.63	19.52	8.67	5.99
	Mean	0.82	12.84	8.65	3.34
Tubarao	Standard Deviation	1.30	5.90	5.63	4.19
	Mean	0.91	11.66	1.88	10.20
Urussanga	Standard Deviation	0.99	7.86	1.43	6.23

Unit: g/sec·km2

22. Almost all of the SS values in February are larger than other months. The cause for this may be related to the rainfall characteristics in February 1997, as follows:

TABLE E-4

SUMMARY OF WELL CONSTRUCTION

Bore Hole No.	Location	Construction Day	Elevation (above MSL)	Well Depth (m)	Water Depth (m)	Geological Condition of Water Bearer Startum
FG-1	Near Santa Barbara Church Rio Florita Village	June 25	120	5	3	Weathering sandstone
FG-2	In shale deposit area between dragline piles	June 28	125	8	6	Fractured sandstone
FG-3	On north bank of Main Fork of Florita Rivera	June 29	130	5	2.8	Coarse reject
CG-1	Capella in Rio Carvao	July 2	170	5	3	Alluvium with pebbles
RG-1	Between Wash Plant and uppermost setting pond	July 10	285	8.8	0	-
RG-2	South of stream/North of road. Upstream of crossing	July 11	255	9.3	7.3	Coarse reject
RG-3	North Rochinha River in the valley bottom	July 16	230	1	0	-
RG-4	Reject pile (see air photo)	July 9	290	7.8	2.8	Weathering sandstone
RG-5	Within a trench of powerline near reject pile	July 9	290	5	0	--x--
RG-6	In coarse refuse besides access road	July 6	310	9.7	3.7	Coarse reject
RG-7	No indication	-	230	-	-	-
RG-8	Public Park in Lauro Muller	July 17	240	5	4	Alluvium
NG-1	In playing field near mining	July 20		6.6	5	Weathering sandstone

TABLE E-5

OBSERVATION OF GROUNDWATER SURFACE IN DEPTH FROM GROUND SURFACE

LOCATION*	JAN	FEB	MAR	MAR	APR	MAY
CG1		2.2(20)	2.12(7)	2.35(14)	2.8( )	2.9(16)
FG1		2.65(25)	3.25(7)	3.3(18)		
FG2		2.09(21)	3.3(7)	3.4(18)		
FG3						
RG1	2.5(22)	2.75(20)	3.0(7)	3.15(14)	3.2( )	3.15(14)
RG2	0.6(22)	5.2(25)	4.9(7)	5.0(14)	5.15( )	5.25(14)
RG4		N/W	N/W	N/W	N/W	N/W
RG6		N/W	N/W	N/W	N/W	N/W
RG8		N/W	N/W	N/W	N/W	N/W
CAG1	0.6(22)	0.5(20)	0.61(10)	0.77(18)	1.2( )	0.85(22)
CAG2		0.6(20)	1.01(10)	0.96(18)	1.6( )	1.25(22)
CAG3		0.25(20)	0.32(10)	0.47(18)	0.43( )	0.35(22)
CAG4		N/W	1.25(10)	N/W		
LBG1	0.48(22)	0.65(20)	1.65(10)	0.87(17)	1.1( )	1.0(19)
DG1						3.2(16)
DG2						1.65( )

*: Ground Elevation (meter in MSL)

TABLE E-6(1/3)

OBSERVATION OF SUSPENDED SOLIDS (ARARANGUA)

Station	Drainage Area (km²) ④	Jan Flowrate Disch ①	Jan Date	Jan SS (g/m³) ②	Jan (g/sec) ③=①x②	Jan Specific SS (g/sec./m²) ⑤=③÷④	Feb Flowrate Disch. ①	Feb Date	Feb SS (g/m³) ②	Feb (g/sec) ③=①x②	Feb Specific SS (g/sec./m²) ⑤=③÷④	Mar Flowrate Disch. ①	Mar Date	Mar SS (g/m³) ②	Mar (g/sec) ③=①x②	Mar Specific SS (g/sec./m²) ⑤=③÷④	Mar Flowrate Disc. ①	Mar Date	Mar SS (g/m³) ②	Mar (g/sec) ③=①x②	Mar Specific SS (g/sec./m²) ⑤=③÷④
PA 1	38.71	4.8	17	<1.0	4.8	0.1240	1.34	18	<0.1	0.134	0.0035	0.57	11	181.0	103.17	2.6652	1.11	7	386.0	428.46	11.0685
PA 2	28.45	0.94	17	<1.0	0.94	0.0330	1.62	18	454.0	735.48	25.8517	0.22	11	156.0	34.32	1.2063		7	434.0		
PA 3																					
PA 4																					
PA 5		3.4	20	93.0	316.2		1.59	18	285.0	453.15		0.53	11	461.0	244.33		1.13	4	85.0	96.05	
PA 6	291.92		29	5.0				25	72.0				11	224.0				4	153.0		
PA 7	172.97		31	<1.00								2.89	14	17.0	49.13	0.2840	2.83	13	212.0	599.96	3.4686
PA 8	571.02		17	6.0				24	158.0				14	31.0				4	198.0		
PA 9	196.25		22	36.0				24	141.0				14	36.0				4	276.0		
PA 10	782.52		22	9.0				24	143.0				14	20.0				4	16.0		
JA 1	77.96	19	31	9.0	171	2.1934			207.0			2.44	18	71.0	173.24	2.2222	5.01	13	324.0	1623.24	20.8214
JA 2	126.2	11	31	12.0	132	1.0460						3.65	18	347.0	1266.55	10.0361	3.76	13	214.0	804.64	6.3759
JA 3	209.45		31	3.0								2.88	18	26.0	74.88	0.3575	7.56	13	165.0	1247.4	5.9556
JA 4	2.25	0.44	23	<1.0	0.44	0.1956	0.64	14	243.0	155.52	69.1200	0.084	11	182.0	15.288	6.7947	0.14	7	476.0	66.64	29.6178
JA 5	10.75	0.76	20	15.0	11.4	1.0605	0.59	18	324.0	191.16	17.7823	0.15	11	476.0	71.4	6.6419	0.034	4	27.0	0.918	0.0854
JA 6	3.5	0.03	17	<1.0	0.03	0.0086	0.07	18	222.0	15.54	4.4400	0.11	10	595.0	65.45	18.7000		4	23.0		
JA 7	15.5	1.2	17	2.0	2.4	0.1548	0.57	18	496.0	282.72	18.2400	0.3	11	491.0	147.3	9.5032	0.77	4	67.0	51.59	3.3284
JA 8	38.75	0.58	16	2.2	1.276	0.0329	3.25	14	424.0	1378	35.5613	1.03	11	482.0	496.46	12.8119	1.56	4	12.0	18.72	0.4831
JA 9	13	0.19	16	1.2	0.228	0.0175	1.15	14	15.0	17.25	1.3269	0.47	11	498.0	234.06	18.0046	0.54	4	50.0	27	2.0769
JA 10	54.75	0.76	16	2.0	1.52	0.0278	4.61	14	264.0	1217.04	22.2290	1.41	11	448.0	631.68	11.5375	2.19	4	39.0	85.41	1.5600
JA 11	18.75	0.51	16	1.0	0.51	0.0272	2	14	85.0	170	9.0667		11	508.0				4	158.0		
JA 12	79	1	16	12.0	12	0.1519						2.96	18	93.0	275.28	3.4846	3.63	14	72.0	261.36	3.3084

TABLE E-6(2/3)

OBSERVATION OF SUSPENDED SOLIDS (URUSSANGA)

Station	Drainage Area	Jan					Feb					Mar					Mar				
		Flowrate		SS		Specific SS	Flowrate		SS		Specific SS	Flowrate		SS		Specific SS	Flowrate		SS		Specific SS
	(km²) ④	Disch ①	Date	(g/m³) ②	(g/sec) ③=①x②	(g/sec./m²) ⑤=③÷④	Disch. ①	Date	(g/m³) ②	(g/sec) ③=①x②	(g/sec./m²) ⑤=③÷④	Disch. ①	Date	(g/m³) ②	(g/sec) ③=①x②	(g/sec./m²) ⑤=③÷④	Disc. ①	Date	(g/m³) ②	(g/sec) ③=①x②	(g/sec./m²) ⑤=③÷④
PU 1																					
PU 2	30.32		30	43.0				13	386.0				13	299.0				5	256.0		
PU 3	71.28	4.53	21	4.8	21.744	0.3051						4.65	17	70.0	325.5	4.5665	3.59	12	245.0	879.55	12.3394
PU 4	40.49		21	<1.0				14	149.0				13	29.0				5	205.0		
PU 5																					
PU 6	358.21		30	14.0				19	46.0				17	66.0				6	470.0		
PU 7	123.25		20	<1.0			2.61	14	24.0	62.64	0.5082		17	96.0				5	145.0		
PU 8																					
PU 9	560.21		31	10.0				25	90.0				17	46.0				5	136.0		
PU 10	7.08	0.284	28	<1.0	0.284	0.0401	0.27	13	434.0	117.18	16.5508	0.048	17	135.0	6.48	0.9153	0.047	5	463.0	21.761	3.0736
JU 1	53.57	4.2	29	22.0	92.4	1.7248						1.6	17	72.0	115.2	2.1505	1.05	12	258.0	270.9	5.0569
JU 2	10.75	0.35	21	<1.0	0.35	0.0326	0.67	13	285.0	190.95	17.7628	0.19	13	40.0	7.6	0.7070	0.49	10	459.0	224.91	20.9219
JU 3	121.31	10.6	30	28.0	296.8	2.4466						8.12	17	16.0	129.92	1.0710	5.4	12	215.0	1161	9.5705

TABLE E-6(3/3)

OBSERVATION OF SUSPENDED SOLIDS (TUBARAO)

Station	Drainage Area	Jan					Feb					Mar					Mar				
		Flowrate		SS		Specific SS	Flowrate		SS		Specific SS	Flowrate		SS		Specific SS	Flowrate		SS		Specific SS
	(km²) ④	Disch ①	Date	(g/m³) ②	(g/sec) ③=①x②	(g/sec./m²) ⑤=③÷④	Disch. ①	Date	(g/m³) ②	(g/sec) ③=①x②	(g/sec./m²) ⑤=③÷④	Disch. ①	Date	(g/m³) ②	(g/sec) ③=①x②	(g/sec./m²) ⑤=③÷④	Disc. ①	Date	(g/m³) ②	(g/sec) ③=①x②	(g/sec./m²) ⑤=③÷④
PT 1	26.07	2.97	30	<1.0	2.97	0.1139	1.53	18	105.0	160.65	6.1623	0.71	14	81.0	57.51	2.2060	7.54	5	25.0	188.5	7.2305
PT 2	45.98	3.2	21	<1.0	3.2	0.0696	4.53	17	110.0	498.3	10.8373		13	123.0				5	74.0		
PT 3	24.63	0.79	21	<1.0	0.79	0.0321	0.67	17	491.0	328.97	13.3565		13	16.0				5	151.0		
PT 4	70.61		30	14.0			5.51	18	138.0	760.38	10.7687	1.66	14	42.0	69.72	0.9874	1.55	10	26.0	40.3	0.5707
PT 5	293.53		31	3.0								22.77	19	175.0	3984.75	13.5753	15.2	12	196.0	2979.2	10.1496
PT 6	579.96		31	10.0								33.55	19	216.0	7246.8	12.4953	18.2	12	156.0	2839.2	4.8955
PT 7	153.86	21	31	13.0	273	1.7743		19	140.0				19	116.0				6	430.0		
PT 8	804.65			<1.0				24	166.0				19	228.0				6	513.0		
PT 9				<1.0				24	232.0				18	68.0				6	262.0		
PT 10				<1.0				24	192.0				18	190.0				6	204.0		
PT 14		0.22	24	5.0	1.1		0.42	19	11.0	4.62			18	169.0				6	506.0		
PT 16		19.7	24	2.0	39.4		0.88	19	145.0	127.6			18	81.0				6	455.0		
JT 1	81.25		31	6.0								2.79	14	47.0	131.13	1.6139	3.37	12	155.0	522.35	6.4289
JT 2	148.75		31	4.0								1.62	14	61.0	98.82	0.6643		12	223.0		0.0000
JT 3	241.25		31	4.0								7.93	14	18.0	142.74	0.5917	8.4	12	155.0	1302	5.3969
JT 4	3.75	0.31	21	<1.0	0.31	0.0827	0.3	17	297.0	89.1	23.7600	0.21	13	28.0	5.88	1.5680		5	133.0		0.0000
JT 5	13	2.14	29	25.0	53.5	4.1154	0.7	17	267.0	186.9	14.3769	0.49	13	59.0	28.91	2.2238	0.87	6	233.0	202.71	15.5931
JT 6	16.5	0.63	21	<1.0	0.63	0.0382	0.69	17	459.0	316.71	19.1945		13	334.0				5	210.0		
JT 7	31.75	6	29	10.0	60	1.8898	3.95	17	81.0	319.95	10.0772	2.53	13	15.0	37.95	1.1953		6	100.0		
JT 8	17.25	0.46	21	2.1	0.966	0.0560	0.72	17	350.0	252	14.6087	0.41	13	53.0	21.73	1.2597		6	240.0		
JT 9	64		30	6.0			3.26	17	20.0	65.2	1.0188	2.7	13	62.0	167.4	2.6156	3.34	6	364.0	1215.76	18.9963
JT 10	9.75	0.22	21	2.0	0.44	0.0451	0.33	18	504.0	166.32	17.0585	0.32	13	73.0	23.36	2.3959		6	275.0		

i.) A large amount of daily rainfall was observed, i.e. more than 30mm/day were observed on February 11, 12 and 15 at the EPAGRI office in Urussanga;

ii.) Monitoring work was conducted on February 13, 14, 17, and 18 during this period of heavy rain; and

iii.) It is understood that sediment loads influenced by the rainfall on Feb. 11 to 15 could be detected at the sampling on Feb 13 to 18.

At the locations of JA-4, JA-8, JA-9, PT-5, JT-5 and JU-2, the larger amounts of sediment load were apt to be detected in comparison with other stations.

23. **Estimation of Wash Load:** Based on the assumption that the wash load can be directly proportional to the square of runoff discharge, the following relationship may represent the envelope of all plots.

Drainage	Formula
Ararangua	Qs = 5500*Qw2
Tubarao	Qs = 2000*Qw2
Urussanga	Qs = 1800*Qw2

in which

Qs : wash load (g/sec)

Qw : runoff discharge (m3/sec)

It may be possible to estimate the wash load for each drainage using the above formulas.

F SOIL AND GEOLOGICAL SURVEY

1. Introduction

1. The main objectives of the soil and geological survey are to:

- Identify supply sources of soil and/or its substitutes which could be used for covering pollution sources and recuperate the polluted land;
- Search for supply sources of limestone and fossil shell, which may be used for acid water neutralization; and
- Understand the regional geological characteristics in order to prevent secondary pollution caused by the exploitation of soil.

2. Geological Map

2. A geological map covering the study area has been compiled at a scale of 1:20,000 from existing documents and interpretation of aerial photographs as well as unpublished information. It is available at the FATMA and DNPM offices in Criciúma. A schematic geological map is presented in Figure F-1. The geology of this area consists of basal granitic rocks, Gondowana sequence and overlaid basalt flow. The Gondowana sequence (Permian in age), which directly overlays the rocks of the Precambrian strata, are divided into two groups and six formations, according to stratigraphy succession by DNPM as shown on Table F-1. Among them, the coal seams are in the Rio Bonito Formation. Lithophacies and lithology are detailed in Table F-2.

TABLE F-1

GENERAL STRATIGRAPHY OF COAL FIELD

Age	Group		Subgroup	Formation
Quaternary				
Cretaceous	Sao Bento			Serra Geral
Jurassic				Botucatu
Permian	late	Passa Dois		Rio do Rasto
				Estrada Nova
				Irati
	middle	Tubarao		Palermo
	early			Rio Bonito
			Itarare	Rio do Sul
Pre Cambrian	(Complex of migmatite, granitic and metamorphic rocks)			

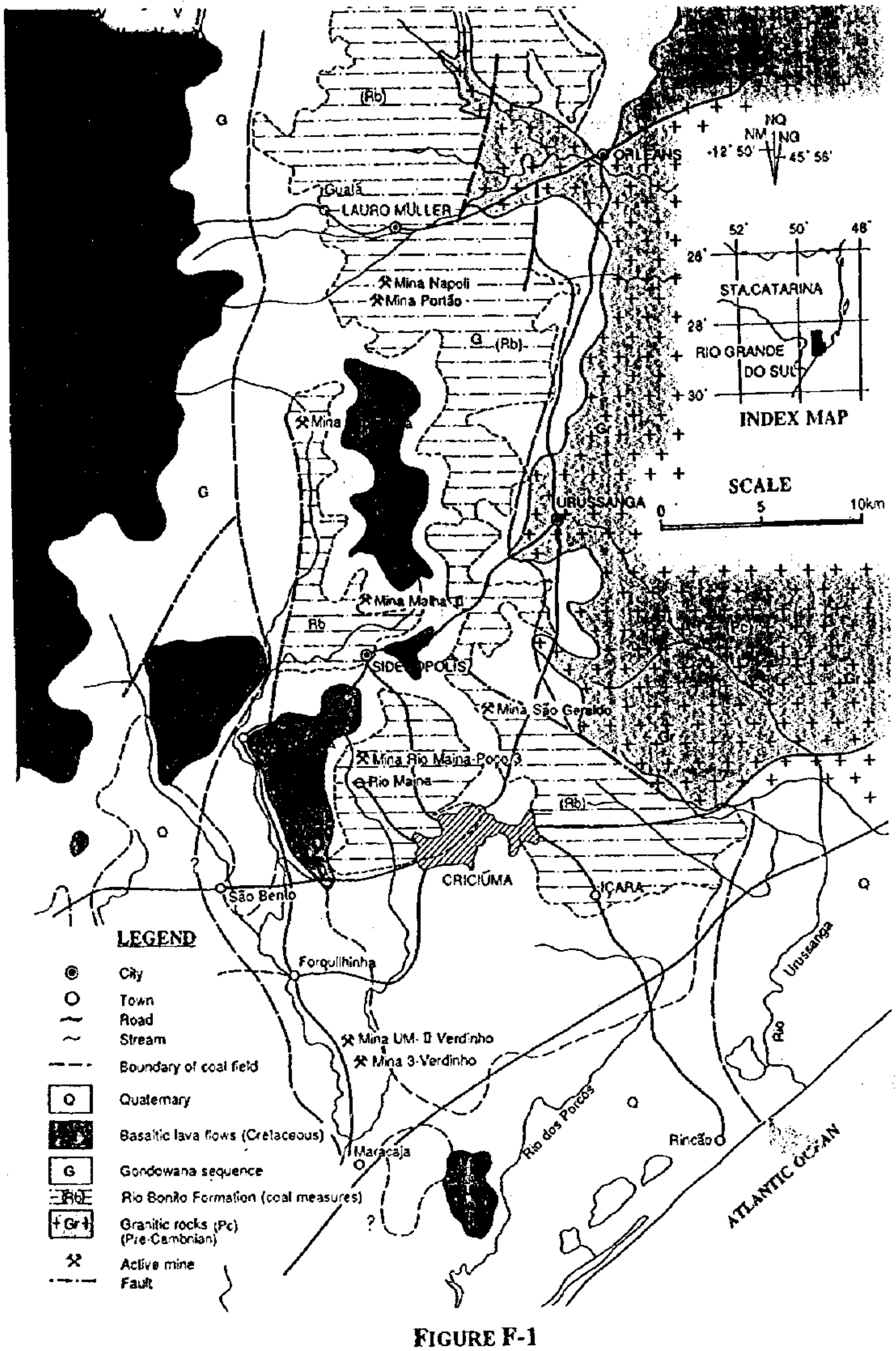
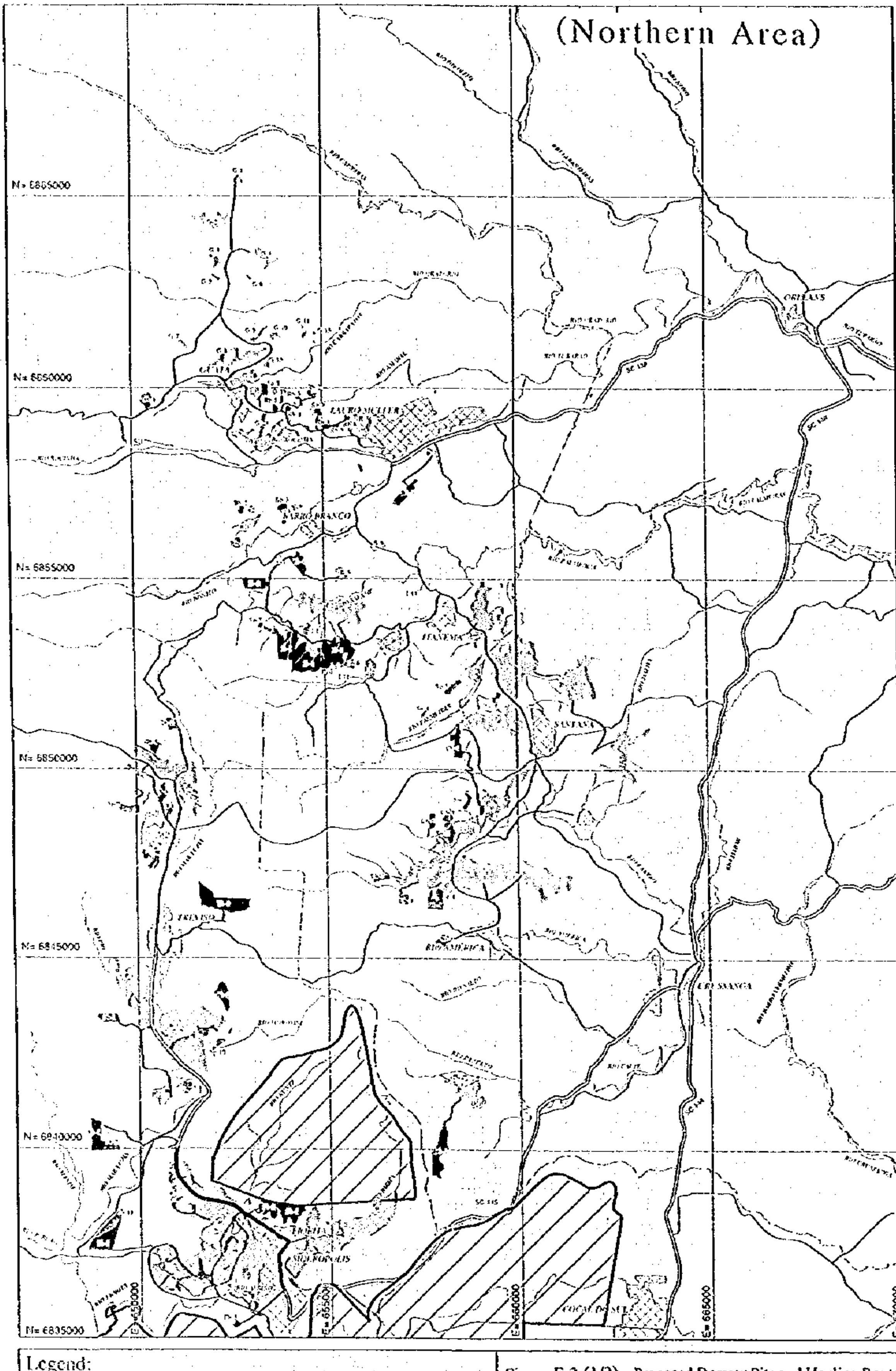


FIGURE F-1

SANTA CATARINA COAL FIELD

Table F-2
Stratigraphy of Santa Catarina Coal Field

Period		Group	Subgroup	Formation	Thickness(m)	Lithology
Quaternary						Alluvial deposit
Cretaceous		Sao Bento		Serra Geral		Basalt flow and diabase dyke
Jurassic				Botucatu	?	Reddish gray feldsperthic medium sandstone
Permian	Upper	Passa Dois		Rio do Rasto	?	Violet dark gray sandstone,siltstone Reddish tabular sandstone
				Estrada Nova	?	Dark gray tabular siltstone with intercalated purple gray fine sandstone
				Irati	30	Dark gray tabular siltstone, contained calcareous nodule. diabase dyke
	Middle	Tubarao		Palermo	80...90	Gray and greenish gray siltstone, Intercalate thin sandstone at basal part
	Lower			Rio Bonito	90	Gray fine and medium sandstone, thin siltstone, Coal
			Itarare	Rio do Sul	ND	Sandstone, siltstone Diamict, varvitos
Pre-cambrian		Complex of metamorphic rocks and migmatite				Migmatite, Granit, Gneiss



Legend:

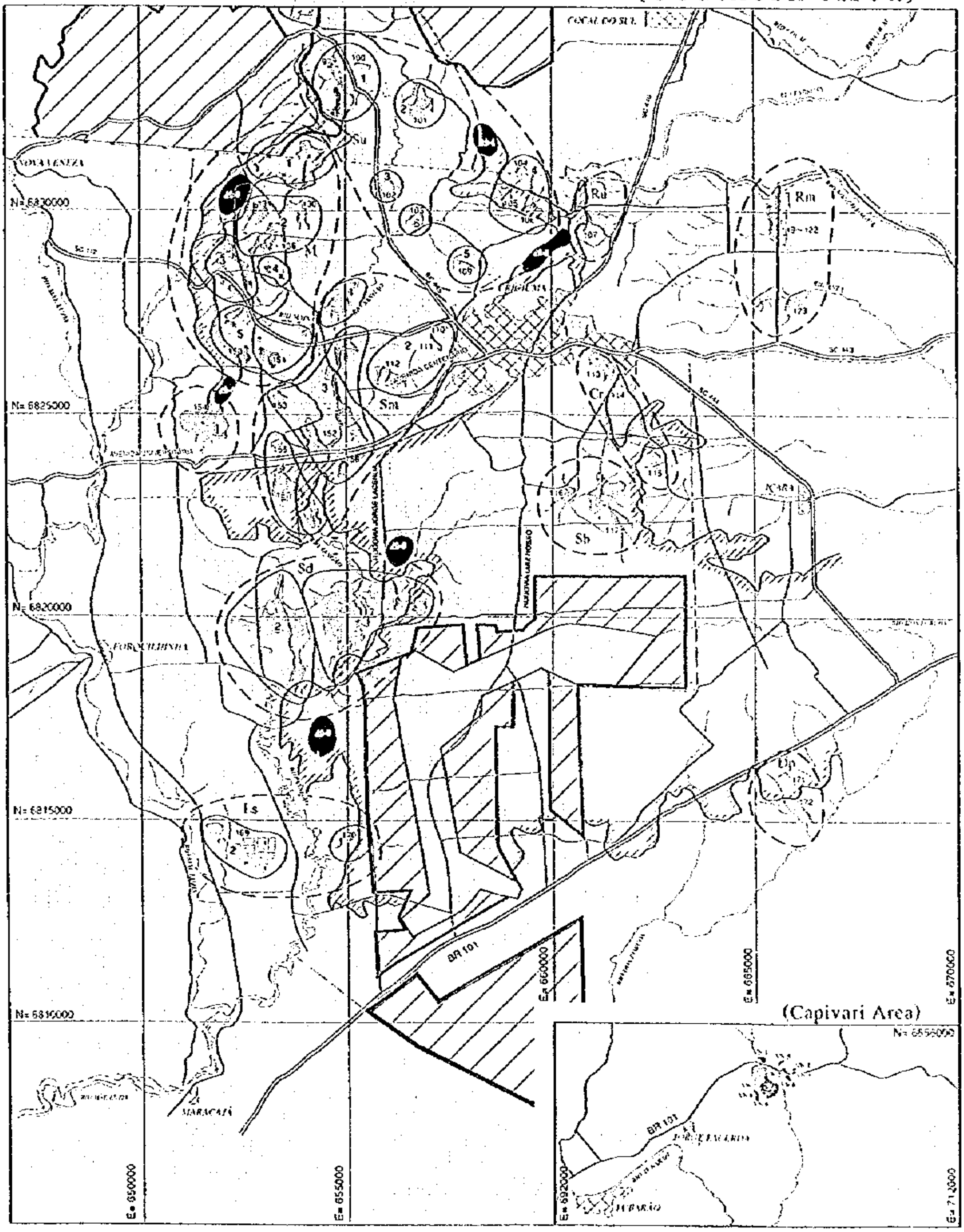
- Black Reject
- Overburden Waste
- Pond.Lake
- Proposed Clay Borrow Pit
- Proposed Soil Borrow Pit
- Hauling Road
- Water Preserved Area

Figure F-2 (1/2) Proposed Borrow Pits and Hauling Route

THE FEASIBILITY STUDY ON RECUPERATION OF MINED OUT AREAS IN SOUTH REGION OF SANTA CATARINA-REPUBLIC OF BRAZIL

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

(Southern Area)



Legend:

	Black Reject		Clay
	Overburden Waste		Grouping
	Pond,Lake		Water Preserved Area
	Proposed Clay Borrow Pit		Environmental Protection Area

Figure F-2 (2/2) Proposed Borrow Pits and Hauling Route

THE FEASIBILITY STUDY ON RECUPERATION OF MINED OUT AREAS IN SOUTH REGION OF SANTA CATARINA-REPUBLIC OF BRAZIL

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

3. The geological map has been used for the following purposes:

- Understand the regional characteristics;
- Determine the distribution of residual soil originated from decomposed rocks of each formation; and
- Select the soil exploitation sites.

3. Soil Survey

4. Soils distributed in the region are classified into the following categories by SNLCS (Servico Nacional de Lavantamento e Conservacao de Solos):

(1) Dark red podozolic soil:
(2) Yellowish red podozoic soil;
(3) Cambisols; and
(4) Gley soil with organic subsoil.

5. The first three are mainly residual sediments originated from the decomposition of rocks in each formation, revealing their original lithological characteristics as illustrated in Table F-2. Their depths or clay contents depend on the lithology of the bed and the existence of structural elements such as faults or shear zones. In general, beds which consist of shale and mud stone are easily weathered into clay. The last category (4) consists of alluvial deposits distributed along the rivers and also in the plains and is used mainly for agriculture. The site survey revealed source areas suitable for remediation materials, i.e. weathered rock and residual sediments, close to the FS sites of Rocinha, Fiorita and Capivari as illustrated in Figures F-2 (1/2) and (2/2) above.

3.1 Required Physical Property of Soil

6. Two types of soil are needed for polluted land remediation: (i) clay or clayey soil for the prevention of water seepage into waste; and (ii) top soil for possible re-vegetation. The required clay characteristics are: (i) **Low permeability** (coefficient of permeability k should be less than 1×10^{-7}cm/sec); and (ii) **High plasticity** against erosion by rain force. On the other hand, for top soil, a high permeability ($k > 1 \times 10^{-4}$cm/sec) is required.

3.2 Soil Exploitation

7. The criteria for site selection are: i.) proximity of the FS site, and ii.) ability to easily acquire the right to exploit the soil. Prior to site survey, appropriate sites were marked on the geological map and then ascertained that they are not part of a protected area regulated by federal and local governments. Another consideration is that exploitation sites be in harmony with agro-forestry development as well as the natural environment.

8. The main protected areas are as follows:

a.	Permanent reservation area:	Area along the rivers Designated hilly areas Steep slope (>45°)
b.	Forest conservation area:	Natural forest
c.	Water preserved area	

3.3 Exploitation for FS Site Remediation

9. After site survey, 18 exploitation sites were selected for the FS site remediation. Most of the proposed exploitation sites are located on the hill tops and covered with eucalyptus and other green vegetation. Soils for the Rocinha and Fiorita FS sites remediation are clayey silt and clay of residual sediments, decomposed from rocks of the Palermo formation and reflecting its original lithologic characteristics. The exploitable clay volumes for the FS site remediation are summarized on Table F-3. Localities and excavation volume are detailed in Table F-4. and Figures F-3 to F-7.

TABLE F-3

EXPLOITABLE CLAY AND TOP SOIL FOR THE FS SITES REMEDIATION

(I) CLAY

FS Site	Numbers of locality	Area(ha)	Volume(m^3)
Rocinha	8	12.64	356,000
Fiorita	3	25.30	576,000
Capivari	7	30.20	604,000
Total	18	68.14	1,536,000

(II) TOP SOIL

FS Site	Numbers of locality	Area(ha)	Volume(m^3)
Rocinha	1	4.40	177,250
Capivari	1	7.40	296,000
Total	2	11.80	473,250

(a) Physical property of soil

10. Clayey soil (4 samples each from Rocinha and Fiorita) and weathered granitic rocks (2 samples from Capivari) were taken and the following were conducted for understanding soil characteristics. Results are summarized in Table F-5.

Soil Tests for Physical Property

	Test	Objectives
(1)	Particle-size analysis (by ASTM D-422)	Classification of soil Estimates of permeability
(2)	Density test	Calculation on general property
(3)	Test for liquid limit and plastic limit (by ASTM D-4318)	Classification of soil by consistency Plasticity
(4)	Permeability test (by ASTM D-2434)	Permeability of soil
(5)	Compaction test by using mechanical rammer (by ASTM D-698)	Degree of soil compaction

TABLE F-4

CLAY AND TOP SOIL LOCALITY (FS SITE)

Proposed Borrow Pits, Excavation Volume and Hauling Distance

Clay and Clacy soil

FS site	Waste No.	Area (ha)	Covering Volume (m3)	Borrow pit No.	Area (ha)	Excavation capacity(m3)	Hauling road (km) (in Borrow area)	Paved	Unpaved	No road	(in waste)	Total distance(km)	Volume(m3) x distance(km)
Recinha	R-2	45.0	225,200	Rb-1	2.30	73,000	0.10	0.50	0.30	0.04	0.40	1.34	97,820
				Rb-2	1.20	62,000	0.10	0.60	1.50	0.05	0.40	2.65	164,300
				Rb-3	0.77	32,000	0.10	0.60	1.00	0.07	0.40	2.17	69,440
				Rb-4	2.36	35,000	0.15	0.83	0.00	0.13	0.40	1.51	52,850
				Rb-5	1.46	26,000	0.10	1.46	0.00	0.16	0.40	2.12	55,120
				Rb-6	1.45	40,000	0.10	1.50	0.00	0.40	0.40	2.40	96,000
				Rb-7	0.90	18,000	0.07	0.54	0.00	0.49	0.40	1.50	27,000
				Rb-8	2.20	70,000	0.15	0.72	0.00	0.02	0.40	1.29	90,300
Subtotal		45.0	225,200		12.64	356,000						Av.1.83	652,830
Florita	F-1	21.0	105,050	Fb-1	21.80	436,000	0.30	0.00	0.00	0.10	1.40	1.80	784,800
				Fb-3	3.50	140,000	0.10	1.50	0.30	0.00	1.40	3.30	462,000
Subtotal		21.0	105,050		25.30	576,000						Av.2.16	1,246,800
Capivari	Cv	80.0	400,000	Vb-1	11.10	222,000	0.25	0.46	0.00	0.12	0.70	1.53	339,660
				Vb-2	5.40	108,000	0.25	1.79	0.04	0.00	0.70	2.78	300,240
				Vb-3	2.40	48,000	0.10	2.48	0.00	0.00	0.70	3.28	157,440
				Vb-4	2.10	42,000	0.10	2.48	0.00	0.00	0.70	3.28	137,760
				Vb-5	3.80	76,000	0.25	1.43	0.35	0.10	0.70	2.83	215,080
				Vb-6	2.60	52,000	0.10	0.00	0.40	0.00	0.35	0.85	44,200
				Vb-7	2.80	56,000	0.10	0.00	0.35	0.00	0.35	0.80	44,800
Subtotal		80.0	400,000		30.20	604,000						Av.2.05	1,239,180
Total		146.0	730,250		68.14	1,536,000							

Top soil

FS site	Waste No.	Area (ha)	Covering Volume (m3)	Borrow pit No.	Area (ha)	Excavation capacity(m3)	Hauling road (km) (in Borrow area)	Paved	Unpaved	No road	(in waste)	Total distance(km)	Volume(m3) x distance(km)
Recinha	R-2	45.0	135,120	So-8	4.40	154,000	0.15	1.60	0.20		0.40	2.35	361,900
Florita	F-1	21.0	607,590	Fb-1*	21.80	872,000	0.30	0.00	0.00	0.10	1.40	1.80	1,569,600
Capivari	Cv	80.0	240,000	Vb-8	7.40	259,000	0.20	2.00	0.15	0.15	0.70	3.20	828,800
Total		146.0	982,710		33.60	1,285,000							

*: Inclued Coarse part

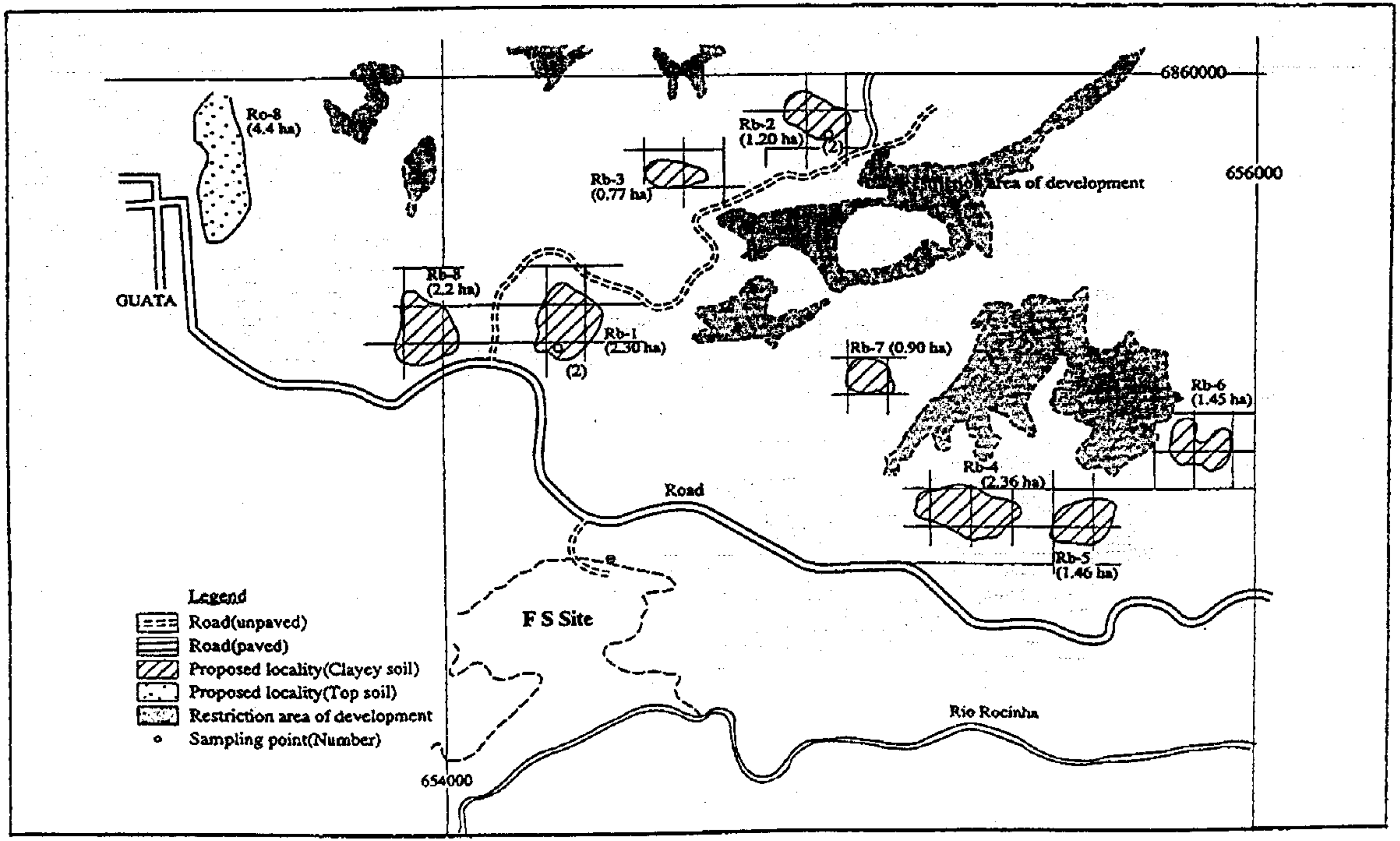


FIGURE F-3 CLAYEY SOIL (RIO ROCINHA)

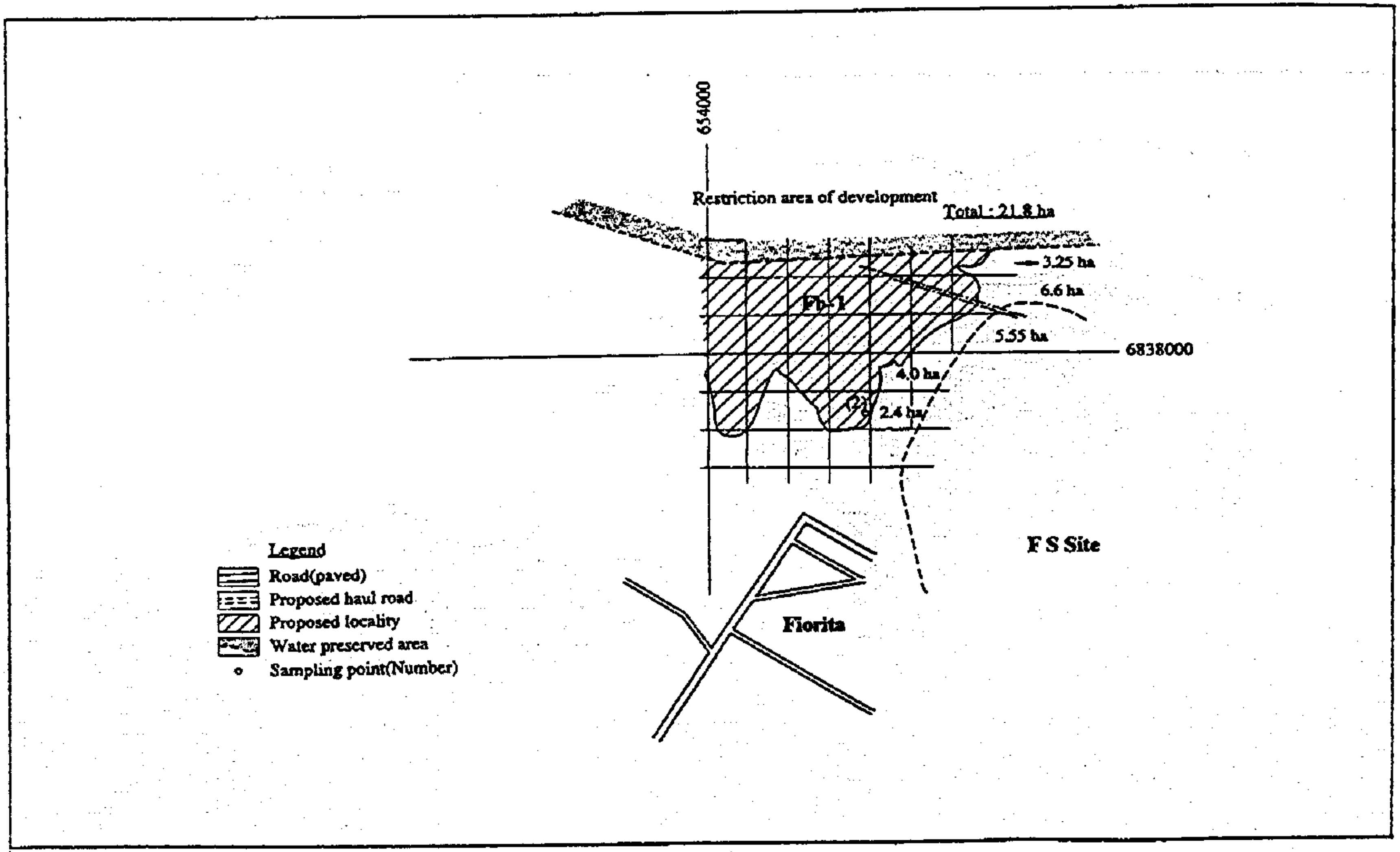


FIGURE F-4 CLAYEY SOIL (RIO FIORITA-1)

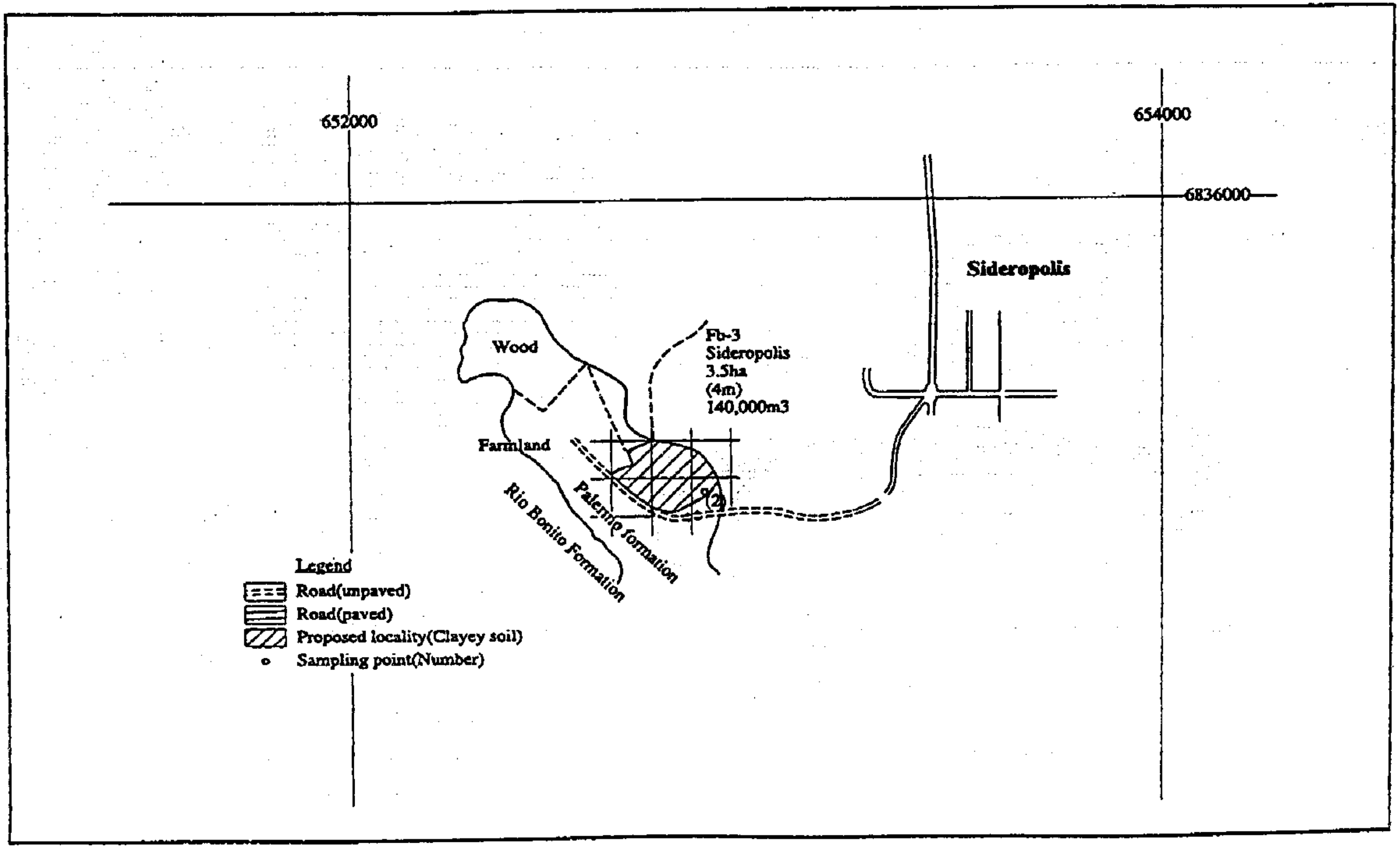


FIGURE F-5 CLAYEY SOIL (RIO FIORITA-2)

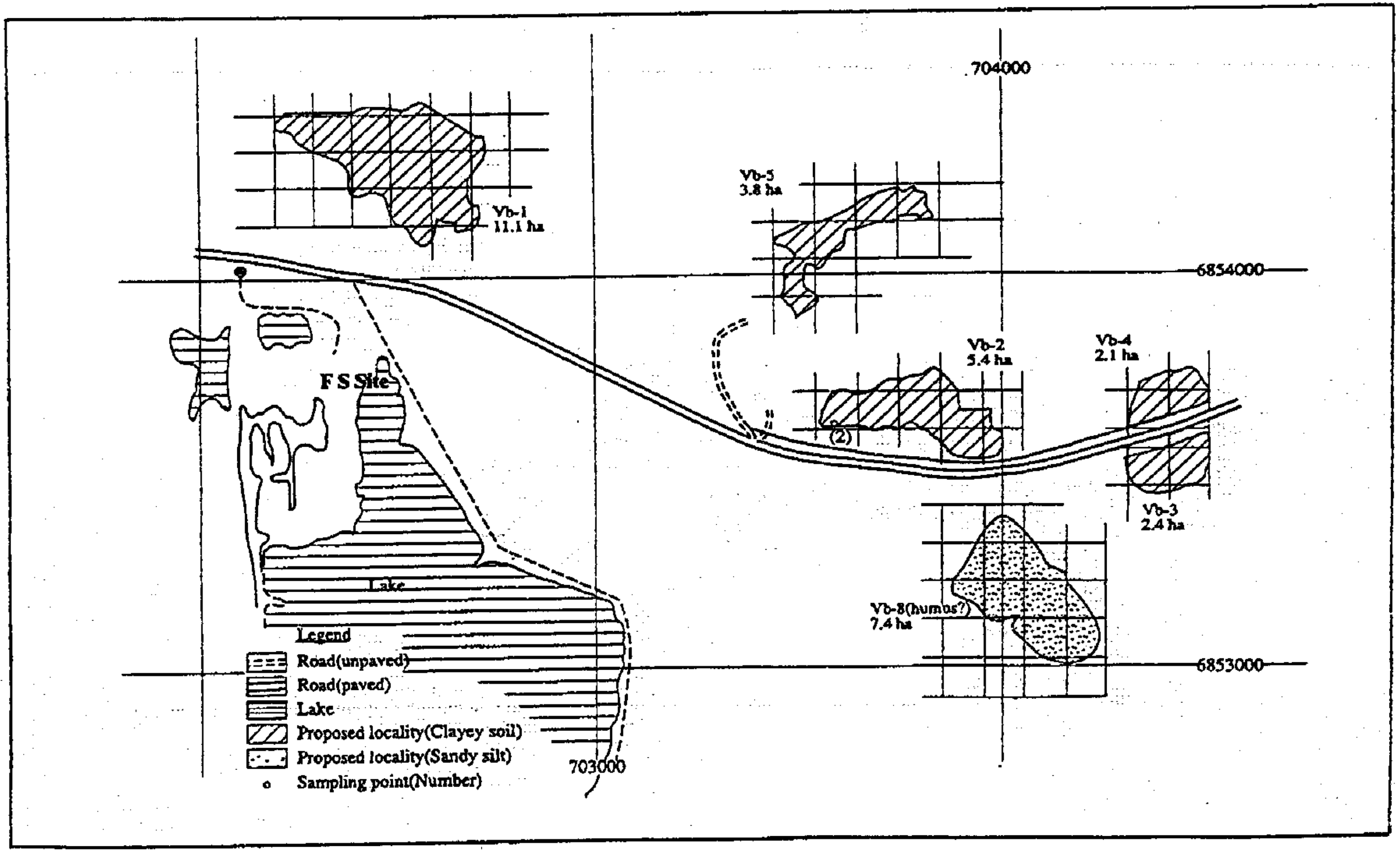


FIGURE F-6 CLAYEY SOIL (CAPIVARI-1)

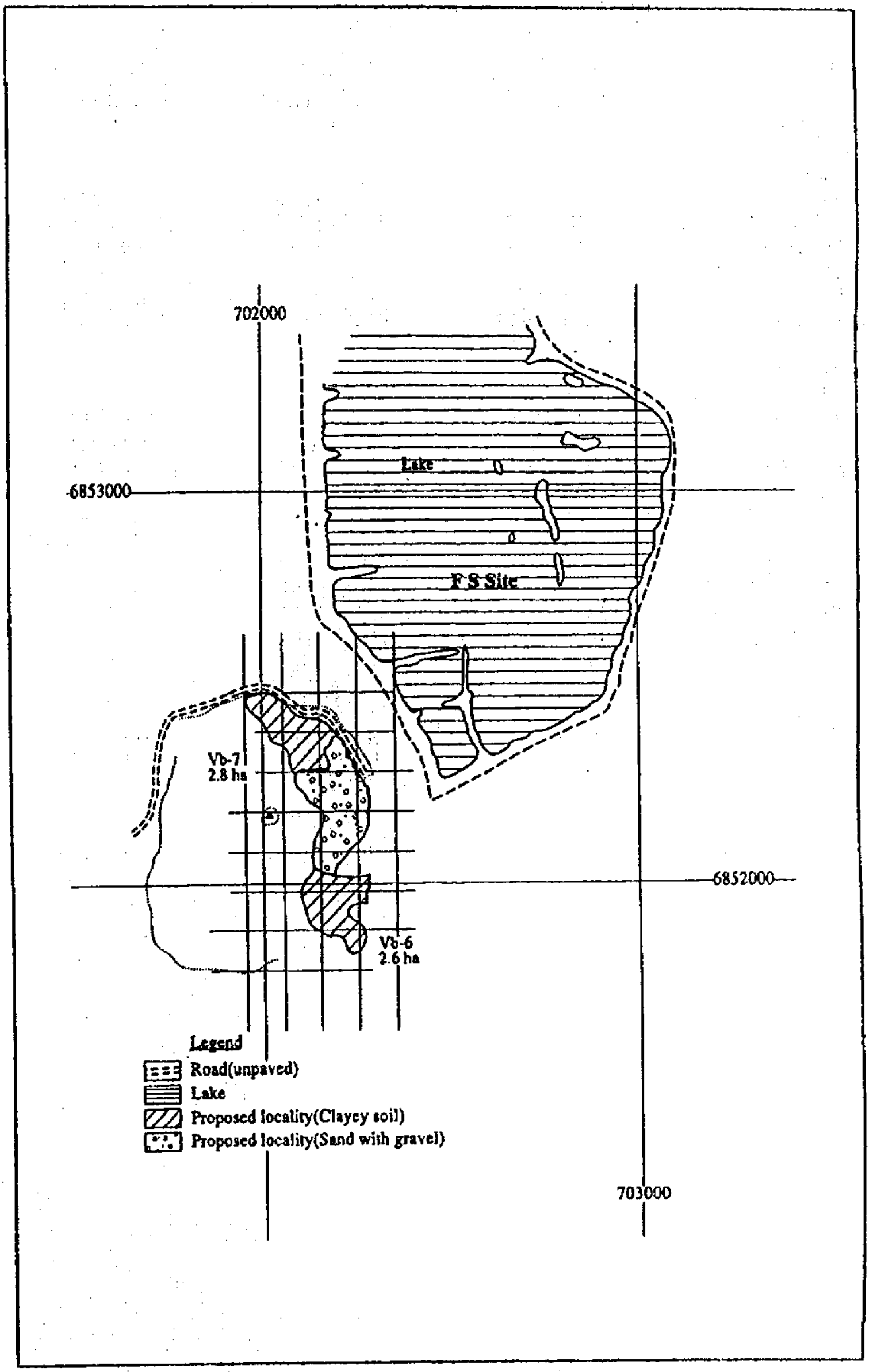


FIGURE F-7 CLAYEY SOIL (CAPIVARI-2)

TABLE F-5

GENERALIZED PROPERTIES OF CLAYEY SOIL

Locality	Rocinha	Fiorita	Capivari
	Clayey silt & Clay	Clayey silt & Clay	Clay with sand
Number of sample	4	4	2
Item			
[General]			
Density ρ t (t/m3)	1.837 - 1.960	1.824 - 1.936	1.840 - 2.100
Dry density ρ t (t/m3)	1.528 - 1.782	1.367 - 1.676	1.598 - 1.903
Water contents W (%)	9.2 - 20.2	15.5 - 33.3	1.0 - 1.5
Specific gravity Gs	2.71	2.71	2.71
void ratio e	0.520 - 0.773	0.616 - 0.981	0.423 - 0.695
Degree of saturation Sr (%)	41.66 - 70.88	68.18 - 92.15	5.887 - 6.598
[Size composition]			
Gravel (%)	<0.1	<0.2	23.2 - 25.2
Sand (%)	13.5 - 30.1	5.7 - 32.2	40.3 - 49.8
Silt (%)	20.9 - 45.3	32.7 - 48.9	6.0 - 25.4
Clay (%)	41.2 - 55.5	35.1 - 52.2	9.1 - 21.1
Silt/Clay	0.90 - 2.65	0.88 - 1.23	0.28 - 2.79
Classification (Triangle chart)	Clay	Clay	Sandy loam & Sandy clay loam
[Consistency]*			
Liquid limit LL (%)	36.03 - 53.91	43.03 - 52.82	45.23
Plastic limit PL (%)	23.27 - 28.04	28.51 - 28.73	29.54
Plasticity Index IP	12.76 - 25.87	14.52 - 24.09	15.69
Consistency Index Ic	1.72 - 2.04	1.41 - 1.54	1.92
[Condition of compaction]			
Dry density ρ t (g/cm3)	1.506 - 1.720	1.480 - 1.610	1.696 - 1.920
Optimum moisture content (%)	18.70 - 25.50	19.5 - 26.00	12.40 - 17.20
[Permeability]			
Coeficient of permeability k (cm/sec)	2.88E-05 (max)	5.35E-04 (max)	5.66E-06 (max)
	Impermeable	4.47E-06(min)	9.25E-07 (mir

*: only clay samples

(b) **Rocinha**

11. Clayey soil is identified as clay by the triangle classification chart (U.S. Bureau of Soil and Chemistry). By means of Unified Classification, it is classified as fat or lean clay. In general, this type of soil has plasticity (puttylike properties) under natural condition and considerable strength when air dried. And it also exhibits very low hydraulic conductivity (less than 2.88×10^{-5} cm/sec in coefficient of permeability). The density ranges from 1.849 to 1.960 g/cm^3. Due to high plasticity and low permeability, this clayey soil is considered an appropriate material for covering pollution sources.

(c) **Fiorita**

12. Clayey soil is identified as clay by the triangle classification chart and exhibits low hydraulic conductivity. Density ranges from 1.824 to 1.936 g/cm^3. Fine clayey silt is suitable for covering pollution sources and the coarse material may possibly be used for surface soil.

(d) **Capivari**

13. Clayey soil is identified as sandy loam and sandy clay loam by the triangle chart and exhibits very low hydraulic conductivity. Density ranges from 1.840 to 2.100 g/cm^3. It is also suitable material for covering pollution sources.

3.4 Soil for Overall Remediation

14. A total of 47 soil exploitation sites (739.4 ha) is proposed for covering material for the whole polluted area. They are summarized below:

Northern Area (between grid N=6835000 and N=6865000)

Number of Sites	Area (ha)	Volume (1,000m3)	Distance(km)*	Soil Type
34	454.1	20,850	4.01	Clayey soil

* average distance between waste dumps and borrow pits

Southern Area (south of grid N=6835000)

Number of Sites	Area (ha)	Volume (1,000m3)	Distance(km)	Soil Type
6 + (unspecified)	130+(125.3)	5,240+(4,186)	3.70/(less than 1)	Clayey soil

Capivari Area

Number of Sites	Area (ha)	Volume (1,000m3)	Distance(km)	Soil Type
7	30.2	604	2.05	Clayey soil

15. Since almost all waste dumps in the southern area are surrounded by the soil rich Palermo formation, clayey soil is selected for remediation. Details are given in Tables F-6 (1/3) through (3/3), and Figures F-2 (1/2) and (2/2). Top soil distributions in the mountainous and hilly areas, which are studied for the FS site remediation, are scarce. For overall remediation covering materials, the following should be considered:

i) Search for top soil in the plain area south of Criciuma; and
ii) Investigate the possibility of using clayey soil with sand, weathered rocks of the Rio Bonito formation as substitute for top soil.

TABLE F-6 (1/3)

CLAY AND CLAYEY SOIL
(HAULING VOLUME AND DISTANCE)

Overburden Waste and Black Reject

(Northern Area)

No.	Area	Waste No.	Waste	Area (ha)	Covring Volume (m3)	Borrow Pit No.	Borrow area (ha)	Capacity (m3)	Road(in Barrow (km)	Paved road (km)	Unpaved (km)	Non road (km)	Road(in Waste (km)	Total distance (km)	Volume(m3) x distance(km)
1	Guata North	G-1	OW	5.0	25,000	Gb-1	10.0	927,000	0.30	1.00	6.00	-	0.20	7.50	187,500
2	Guata North	G-2	OW	28.0	140,000	Gb-1	(10.0)	(927,000)	0.30	1.00	5.00	-	0.50	6.80	952,000
3	Guata North	G-3	OW	6.0	30,000	Gb-1	(10.0)	(927,000)	0.30	1.00	4.00	-	0.20	5.50	165,000
4	Guata North	G-4	OW	15.0	75,000	Gb-1	(10.0)	(927,000)	0.30	1.00	4.80	-	0.70	6.80	510,000
5	Guata North	G-5	OW	4.0	20,000	Gb-1	(10.0)	(927,000)	0.30	1.00	3.50	-	0.20	5.00	100,000
6	Guata North	G-6	OW	1.0	5,000	Gb-1	(10.0)	(927,000)	0.30	1.00	4.00	-	0.10	5.40	27,000
7	Guata North	G-7	OW	4.0	20,000	Gb-1	(10.0)	(927,000)	0.30	1.00	1.40	-	0.20	2.90	58,000
8	Guata North	G-8	OW	38.0	190,000	Gb-1	(10.0)	(927,000)	0.30	2.20	1.00	-	0.80	4.30	817,000
9	Guata North	G-9	OW	5.0	25,000	Gb-1	(10.0)	(927,000)	0.30	2.20	1.90	-	0.30	4.70	117,500
10	Guata North	G-10	OW	4.0	20,000	Gb-1	(10.0)	(927,000)	0.30	2.20	1.80	-	0.10	4.40	88,000
11	Guata North	G-11	OW	0.5	2,500	Gb-1	(10.0)	(927,000)	0.30	2.20	2.60	-	0.10	5.20	13,000
12	Guata North	G-12	OW	1.5	7,500	Gb-1	(10.0)	(927,000)	0.30	2.20	2.60	-	0.10	5.20	39,000
13	Guata North	G-13	OW	0.5	2,500	Gb-1	(10.0)	(927,000)	0.30	2.20	2.80	-	0.10	5.40	13,500
14	Guata North	G-14	OW	0.5	2,500	Gb-1	(10.0)	(927,000)	0.30	2.20	2.80	-	0.10	5.40	13,500
15	Guata North	G-15	OW	5.0	25,000	Gb-1	(10.0)	(927,000)	0.30	2.20	1.30	-	0.10	3.90	97,500
16	Guata North	G-16	OW	1.0	5,000	Gb-1	(10.0)	(927,000)	0.30	2.20	0.80	-	0.10	3.40	17,000
17	Guata North	G-17	OW	15.0	75,000	Gb-1	(10.0)	(927,000)	0.30	2.00	-	-	0.40	2.70	202,500
18	Guata North	G-18	OW	3.0	15,000	Gb-1	(10.0)	(927,000)	0.30	3.10	0.40	-	0.10	3.90	58,500
19	Guata North	G-19	OW	1.0	5,000	Gb-1	(10.0)	(927,000)	0.30	3.40	0.50	-	0.10	4.30	21,500
20	Guata North	G-20	OW	1.5	7,500	Gb-1	(10.0)	(927,000)	0.30	4.10	0.40	-	0.10	4.90	36,750
21	Guata North	G-21	OW	0.5	2,500	Gb-1	(10.0)	(927,000)	0.30	4.00	-	-	0.10	4.40	11,000
22	Guata North	G-22	OW	1.0	5,000	Gb-1	(10.0)	(927,000)	0.30	4.50	0.10	-	0.10	5.00	25,000
23	Guata North	G-23	OW	5.0	25,000	Gb-1	(10.0)	(927,000)	0.30	3.70	-	-	0.20	4.20	105,000
24	Guata North	G-24	OW	10.0	50,000	Gb-1	(10.0)	(927,000)	0.30	3.20	-	-	0.30	3.80	190,000
				156.0	**780,000**		**10.0**	**927,000**						**4.96**	3,865,750
25	Rio Rocinha	R-1	BR	11.4	57,000	Gb-1	(10.0)	(927,000)	0.30	-	0.80	-	0.60	1.70	96,900
26	Rio Rocinha	R-2	BR	45.0	225,200	Rb1-8	12.6	356,000						1.83	652,830
27	Rio Rocinha	R-3	OW	18.0	90,000	Gb-1	(10.0)	(927,000)	0.30	6.50	0.10	-	0.30	7.20	648,000
				74.4	**372,200**		**12.6**	**356,000**						**3.76**	1,397,730
28	Barro Branco	B-1	OW	20.8	104,000	Bb-1	5.6	134,400	0.10	-	0.40	-	0.20	0.60	62,400
29	Barro Branco	B-2	OW	3.4	17,000	Bb-2	2.4	57,600	0.05	-	-	-	0.15	0.20	3,400
30	Barro Branco	B-3	OW	8.0	40,000	Bb-3	4.0	96,000	0.07	-	-	-	0.35	0.42	16,800
31	Barro Branco	B-4	OW	8.0	40,000	Bb-4	15.4	369,000	0.20	-	-	0.10	0.50	0.35	14,000
32	Barro Branco	B-5	OW	8.8	44,000	Bb-4	(15.4)	(369000)	0.45	-	-	0.50	0.15	1.10	48,400
33	Barro Branco	B-6	OW	7.6	38,000	Bb-3	(4.0)	(96000)	0.05	-	3.40	-	0.15	3.60	136,800
34	Barro Branco	B-7	BR	8.0	40,000	Bb-5	4.4	105,000	0.25	-	1.75	-	0.30	2.30	92,000
				64.6	**323,000**		**31.8**	**762,000**						**1.16**	373,800
35	Itanema	I-1	OW	38.4	192,000	Ib-1	130.8	5,232,000	0.20	-	-	-	0.25	0.45	86,400
36	Itanema	I-2	OW	69.4	347,000	Ib-2	15.2	608,000	0.40	-	0.40	-	0.50	1.30	451,100
37	Itanema	I-10	OW	12.1	60,500	Ib-1	(130.8)	(5,232,000)	0.10	-	-	-	0.15	0.25	15,125
38	Itanema	I-11	OW	1.1	5,500	Ib-1	(130.8)	(5,232,000)	0.25	-	0.25	0.10	0.05	0.55	3,025
39	Itanema	I-12	OW	18.0	90,000	Ib-1	(130.8)	(5,232,000)	0.30	-	-	0.30	0.20	0.80	72,000
40	Itanema	I-13	BR	43.2	216,000	Ib-1	(130.8)	(5,232,000)	0.30	-	1.30	-	0.30	1.90	410,400
41	Itanema	I-14	OW	10.4	52,000	Ib-1	(130.8)	(5,232,000)	0.50	-	3.60	-	0.30	4.40	228,800
42	Itanema	I-15	OW	71.8	359,000	Ib-1	(130.8)	(5,232,000)	0.50	-	4.00	-	0.40	4.90	1,759,100
43	Itanema	I-15	BR	8.2	41,000	Ib-1	(130.8)	(5,232,000)	0.50	-	4.00	-	0.40	4.90	200,900
44	Itanema	I-16	OW	150.4	752,000	Ib-1	(130.8)	(5,232,000)	0.70	-	5.00	-	0.80	6.50	4,888,000
45	Itanema	I-16	BR	26.6	133,000	Ib-1	(130.8)	(5,232,000)	0.70	-	5.00	-	0.80	6.50	864,500
46	Itanema	I-17	OW	89.0	445,000	Ib-1	(130.8)	(5,232,000)	0.70	-	6.60	-	0.70	8.00	3,560,000
47	Itanema	I-17	BR	22.3	111,500	Ib-1	(130.8)	(5,232,000)	0.70	-	6.60	-	0.70	8.00	892,000
48	Itanema	I-18	OW	72.6	363,000	Ib-1	(130.8)	(5,232,000)	0.70	-	7.60	-	0.50	8.80	3,194,400
49	Itanema	I-19	OW	31.2	156,000	Ib-1	(130.8)	(5,232,000)	0.70	-	10.80	-	0.60	12.10	1,887,600
50	Itanema	I-19	OW	25.4	127,000	Ib-1	(130.8)	(5,232,000)	0.70	-	10.80	-	0.60	12.10	1,536,700
				690.1	**3,450,500**		**146.0**	**5,840,000**						**5.81**	20,050,050
51	Carvao	C-1	BR	10.6	53,000	Cb-1	5.6	314,000	0.10	-	-	0.05	0.90	1.05	55,650
52	Carvao	C-1	BR	122.6	613,000	Cb-1,2	5.6	352,000	0.20	-	-	0.25	0.90	1.35	827,550
53	Carvao	C-2	OW	41.6	208,000	Cb-3	6.4	358,000	0.25	-	-	0.20	0.60	1.05	218,400
54	Carvao	C-3	OW	47.2	236,000	Cb-7	14.4	576,000	0.25	-	1.50	-	0.60	2.35	554,600
55	Carvao	C-4	OW	44.8	224,000	Cb-4	4.0	224,000	0.15	-	1.00	-	2.00	3.15	705,600
56	Carvao	C-4	OW	40.0	200,000	Cb-5	9.2	294,000	0.20	-	0.25	-	1.80	2.25	450,000
57	Carvao	C-4	OW	106.4	532,000	Cb-6	8.8	554,000	0.15	-	2.80	-	1.20	4.15	2,207,800
58	Carvao	C-5	BR	25.0	125,000	Cb-7	(14.4)	(576000)	0.70	-	4.50	-	0.50	5.70	712,500
				438.2	**2,191,000**		**54.0**	**2,672,000**						**2.62**	5,732,100
59	Deserto	D-1	BR	31.4	157,000	Db-1	25.6	1,024,000	0.10	-	-	0.80	0.35	1.25	196,250
60	Deserto	D-2	BR	6.8	34,000	Db-1	(25.6)	(1024000)	0.10	-	0.60	1.00	0.25	1.95	66,300
				38.2	**191,000**		**25.6**	**1,024,000**						**1.37**	262,550
61	Treviso	T-1	OW	28.2	141,000	Tb-1	5.2	291,000	0.15	-	-	-	0.40	0.55	77,550
62	Treviso	T-1	OW	72.8	364,000	Tb-2	5.2	374,000	0.10	-	0.75	-	0.75	1.60	582,400
63	Treviso	T-2	BR	8.8	44,000	Tb-1	(5.2)	(291,000)	0.15	-	0.20	0.30	0.30	0.95	41,800
64	Treviso	T-2	OW	7.2	36,000	Tb-1	(5.2)	(291,000)	0.15	-	0.20	0.30	0.30	0.95	34,200
65	Treviso	T-3	OW	6.8	34,000	Tb-1	(5.2)	(291,000)	0.15	-	1.20	0.30	0.30	1.95	66,300
66	Treviso	T-4	OW	2.8	14,000	Tb-1	(5.2)	(291,000)	0.15	-	1.40	0.30	0.30	2.15	30,100
67	Treviso	T-5	BR	112.8	564,000	Tb-3	48.4	2,420,000	0.50	1.30	5.00	-	0.25	7.05	3,976,200
				239.4	**1,197,000**		**58.8**	**3,085,000**						**4.02**	4,808,550
68	Riopio	P-1	BR	2.2	11,000	Pb-1	12.0	816,000	0.25	-	1.00	-	0.80	2.05	22,550
69	Riopio	P-1	OW	108.0	540,000	Pb-1	(12.0)	(816,000)	0.25	-	1.00	-	0.80	2.05	1,107,000
70	Riopio	P-2	BR	34.8	174,000	Pb-1	(12.0)	(816,000)	0.25	-	2.60	-	0.40	3.25	565,500
71	Riopio	P-3	OW	200.8	1,004,000	Pb-2	16.0	1,152,000	0.35	-	-	0.20	1.00	1.55	1,556,200
72	Riopio	P-4	OW	19.0	95,000	Pb-2	(16.0)	(1,152,000)	0.35	-	-	0.20	1.00	1.55	147,250
	Subtotal			**364.8**	**1,824,000**		**28.0**	**1,968,000**						**1.86**	3,398,500
73	Sideropolis	S-1	OW	100.8	504,000	Sb-1	20.0	1,260,000	0.45	1.70	3.00	-	0.70	5.85	2,948,400
74	Sideropolis	S-1	OW	73.8	369,000	Sb-2	12.8	512,000	0.20	1.70	4.40	-	1.00	7.30	2,693,700
75	Sideropolis	S-2	BR	129.6	648,000	Sb-1	(20.0)	(1,260,000)	0.45	1.70	3.00	-	0.70	5.85	3,790,800
76	Sideropolis	S-2	BR	4.8	24,000	Sb-1	(20.0)	(1,260,000)	0.45	1.70	3.00	-	0.70	5.85	140,400
77	Sideropolis	S-2	BR	4.4	22,000	Sb-1	(20.0)	(1,260,000)	0.45	1.70	3.00	-	0.70	5.85	128,700
78	Sideropolis	S-3	OW	350.6	1,753,000	Sb-3	29.2	1,868,000	0.35	-	1.20	-	1.30	2.85	4,996,050
	Subtotal			**664.0**	**3,320,000**		**62.0**	**3,640,000**						**4.43**	14,698,050
79	Rio Fiorita	F-1	BR	21.0	105,050	Fb-3	3.5	140,000	0.10	1.50	0.30	0.00	1.40	3.30	346,665
80	Rio Fiorita			(21.0)	(105,050)	Fb-1*	21.8	436,000	0.30	0.00	0.00	0.10	1.40	1.80	189,090
	Subtotal			**21.0**	**105,050**		**25.3**	**576,000**						**2.60**	535,755
	Total			**2750.7**	**13,753,750**		**454.1**	**20,850,000**						**4.01**	55,122,835

*;substitute

TABLE F-6 (2/3)

CLAY AND CLAYEY SOIL
(HAULING VOLUME AND DISTANCE)

Overburden Waste and Black Reject
(Southern Area)

No.	Area	Waste No.	Pile No.	Waste	Area (ha)	Covering Volume (m3)	Borrow pit No.	Borrow area (ha)	Capacity (m3)	Road(in Borrow) (km)	Paved road (km)	Unpaved (km)	Non road (km)	Road(in Waste) (km)	Total distance (km)	Volume(m3) x distance(km)
81	Sangao upper	Su-1	100	BR	6.0	30,000	Nb	1.0	30,000	0.05	-	-	0.50	0.20	0.75	22,500
82	Sangao upper	Su-1	97.98	BR	20.5	102,500	Nb	3.4	102,500	0.10	-	-	0.50	0.65	1.25	128,125
83	Sangao upper	Su-1	99	OW	10.0	50,000	Nb	2.5	50,000	0.05	-	-	0.50	0.05	0.60	30,000
84	Sangao upper	Su-2	101	BR	40.0	200,000	Ab-1	12.0	360,000	0.17	-	1.93	0.10	0.30	2.50	500,000
85	Sangao upper	Su-3	102	BR	10.0	50,000	Ab-1	(12.0)	(360,000)	0.17	-	1.68	0.10	0.15	2.00	100,000
86	Sangao upper	Su-4	104	BR	8.0	40,000	Ab-1	(12.0)	(360,000)	0.17	-	2.58	0.10	0.15	3.00	120,000
87	Sangao upper	Su-4	105	BR	11.0	55,000	Nb	1.8	55,000	0.07	-	-	0.50	0.20	0.77	42,350
88	Sangao upper	Su-4	106	BR	20.0	100,000	Nb	3.3	100,000	0.10	-	-	0.50	0.25	0.85	85,000
89	Sangao upper	Su-5	109	BR	7.0	35,000	Ab-2	20.7	620,000	0.20	-	0.20	0.40	0.20	1.00	35,000
90	Sangao upper	Su-6	103	BR	14.0	70,000	Ab-1	(12.0)	(360,000)	0.17	-	2.50	0.10	0.23	3.00	210,000
	Subtotal				146.5	732,500		44.7	1,317,500						1.74	1,272,975
91	Sangao middle	Sm-1	147	BR	40.0	200,000	Ab-4	24.9	747,500	0.23	-	4.47	0.20	0.30	5.20	1,040,000
92	Sangao middle	Sm-2	110	BR	2.0	10,000	Ab-2	(20.7)	(620,000)	0.20	-	1.80	0.40	0.10	2.50	25,000
93	Sangao middle	Sm-2	111	BR	10.0	50,000	Ab-2	(20.7)	(620,000)	0.20	-	2.15	0.40	0.25	3.00	150,000
94	Sangao middle	Sm-2	112	BR	28.0	140,000	Ab-5	25.2	755,000	0.25	-	4.35	-	0.40	5.00	700,000
95	Sangao middle	Sm-3	152	BR	123.0	615,000	Ab-5	(25.2)	(755,000)	0.25	-	4.15	-	1.10	5.50	3,382,500
96	Sangao middle	Sm-3	156	BR	8.0	40,000	Nb	1.3	40,000	0.06	-	-	0.50	0.20	0.76	30,400
97	Sangao middle	Sm-3	153	BR	9.0	45,000	Ab-4	(24.9)	(747,500)	0.23	-	1.37	0.20	0.20	2.00	90,000
98	Sangao middle	Sm-4	157.158	BR	56.0	280,000	Nb	9.3	280,000	0.15	-	-	0.50	0.80	1.45	406,000
99	Sangao middle	Sm-4	155	BR	7.0	35,000	Nb	1.1	35,000	0.05	-	-	0.50	0.20	0.75	26,250
	Subtotal				283.0	1,415,000		61.8	1,857,500						4.13	5,850,150
100	Sangao down	Sd-1	165,166,167	BR	245.7	1,228,500	Ab-8	79.9	2,399,500	0.45	-	1.25	0.30	1.00	3.00	3,685,500
101	Sangao down	Sd-1	167	BR	12.5	62,500	Nb	2.1	62,500	0.70	-	-	0.50	0.30	1.50	93,750
102	Sangao down	Sd-2	159,160,161,163	BR	157.2	786,000	Ab-8	(79.9)	(1,751,000)	0.45	-	2.05	0.30	1.20	4.00	3,144,000
103	Sangao down	Sd-2	162	BR	8.0	40,000	Ab-8	(79.9)	(1,751,000)	0.45	-	2.00	0.30	0.25	3.00	120,000
104	Sangao down	Sd-2	164	BR	7.0	35,000	Ab-8	(79.9)	(1,751,000)	0.45	-	2.00	0.30	0.20	3.00	105,000
	Subtotal				430.4	2,152,000		82.0	2,462,000						3.32	7,148,250
105	Sangao branch	Sb	116	BR	18.0	90,000	Nb	3.0	90,000	0.10	-	-	0.50	0.20	0.80	72,000
106	Sangao branch	Sb	117,118	BR	78.0	390,000	Nb	13.0	390,000	0.18	-	-	0.50	0.50	1.18	460,200
	Subtotal				96.0	480,000		16.0	480,000						1.11	532,200
107	Maina	M-1	129	BR	3.0	15,000	Nb	0.5	15,000	-	-	-	0.50	0.10	0.60	9,000
108	Maina	M-1	127	BR	2.0	10,000	Nb	0.3	10,000	-	-	-	0.50	0.06	0.56	5,600
109	Maina	M-1	126,124,125	BR	24.0	120,000	Nb	4.0	120,000	0.10	-	-	0.50	0.30	0.90	108,000
110	Maina	M-2	131	BR	27.0	135,000	Nb	4.5	135,000	0.10	-	-	0.50	0.30	0.90	121,500
111	Maina	M-2	135	BR	1.5	7,500	Ab-3	11.9	357,500	0.16	-	1.06	-	0.08	1.30	9,750
112	Maina	M-2	132,136	BR	29.0	145,000	Ab-3	(11.9)	(357,500)	0.16	-	1.64	-	0.40	2.20	319,000
113	Maina	M-2	133	BR	3.0	15,000	Ab-3	(11.9)	(357,500)	0.16	-	1.77	-	0.07	2.00	30,000
114	Maina	M-2	130	BR	24.0	120,000	Ab-3	(11.9)	(357,500)	0.16	-	1.44	-	0.40	2.00	240,000
115	Maina	M-3	137,138	BR	72.0	360,000	Nb	12.0	360,000	0.17	-	-	0.50	0.70	1.37	493,200
116	Maina	M-3	142	BR	3.5	17,500	Ab-3	(11.9)	(357,500)	0.16	-	2.14	-	0.20	2.50	43,750
117	Maina	M-3	141	OW	4.5	22,500	Ab-3	(11.9)	(357,500)	0.16	-	2.14	-	0.20	2.50	56,250
118	Maina	M-3	134	BR	2.0	10,000	Nb	0.3	10,000	-	-	-	0.50	0.07	0.57	5,700
119	Maina	M-4	139	OW	4.0	20,000	Ab-3	(11.9)	(357,500)	0.16	-	2.00	-	0.07	2.23	44,600
120	Maina	M-4	140	OW	2.0	10,000	Ab-3	(11.9)	(357,500)	0.16	-	2.00	-	0.07	2.23	22,300
121	Maina	M-5	145	OW	4.0	20,000	Nb	0.5	20,000	0.10	-	-	0.30	0.10	0.50	10,000
122	Maina	M-5	146	BR	12.0	60,000	Nb	2.0	60,000	0.10	-	-	0.50	0.30	0.90	54,000
123	Maina	M-5	149	BR	2.5	12,500	Ab-4	(24.9)	(747,500)	0.23	-	3.10	0.20	0.07	3.60	45,000
124	Maina	M-5	148	BR	3.0	15,000	Ab-4	(24.9)	(747,500)	0.23	-	2.99	0.20	0.08	3.50	52,500
125	Maina	M-5	150	OW	12.0	60,000	Nb	2.00	60,000	0.10	-	-	0.50	0.17	0.77	46,200
126	Maina	M-5	151	OW	17.0	85,000	Ab-4	(24.9)	(747,500)	0.23	-	3.10	0.20	0.20	3.73	317,050
	Subtotal				252.0	1,260,000		38.0	1,147,500						1.61	2,033,400
127	Mae Luzia	L	154	BR	78.0	390,000	Ab-4	(24.9)	(747,500)	0.23	-	0.07	0.20	0.50	1.00	390,000
128	Mae Luzia	LS-1	170	BR	6.9	34,350	Nb	1.1	34,350	0.05	-	-	0.50	0.25	0.80	27,480
129	Mae Luzia	LS-2	168	BR	34.0	170,000	Ab-8	(79.9)	(1,751,000)	0.45	-	3.85	0.30	0.40	5.00	850,000
130	Mae Luzia	LS-2	169	BR	28.0	140,000	Ab-8	(79.9)	(1,751,000)	0.45	-	3.95	0.30	0.30	5.00	700,000
	Subtotal				146.9	734,350		1.1	34,350						2.68	1,967,480
131	Roncon upper	Ru	108	BR	0.5	2,500	Nb	0.1	2,500	-	-	-	0.50	0.05	0.55	1,375
132	Roncon upper	Ru	107	BR	7.5	37,500	Nb	0.2	37,500	-	-	-	0.50	0.15	0.65	24,375
133	Roncon middle	Rm	119,120	OW	25.0	125,000	Ab-2	(20.7)	(620,000)	0.20	-	4.30	0.40	0.30	5.20	650,000
134	Roncon middle	Rm	121,122	BR	30.0	150,000	Ab-2	(20.7)	(620,000)	0.20	-	4.30	0.40	0.60	5.50	825,000
135	Roncon middle	Rm	123	BR	50.0	250,000	Ab-2	(20.7)	(620,000)	0.20	-	5.20	0.40	0.70	6.50	1,625,000
	Subtotal				113.0	565,000		0.3	40,000						5.53	3,125,750
136	Criciuma	Cr	113	BR	3.8	19,000	Nb	0.6	19,000	-	-	-	0.50	0.50	1.00	19,000
137	Criciuma	Cr	114	BR	4.0	20,000	Nb	0.7	20,000	-	-	-	0.50	0.15	0.65	13,000
138	Criciuma	Cr	115	BR	16.0	80,000	Nb	2.6	80,000	0.08	-	-	0.50	0.30	0.88	70,400
	Subtotal				23.8	119,000		3.9	119,000						0.86	102,400
139	Dos Porcos	Dp	171	BR	8.8	44,000	Nb	1.5	44,000	0.06	-	-	0.50	0.15	0.71	31,240
140	Dos Porcos	Dp	172	BR	36.0	180,000	Nb	6.0	180,000	0.12	-	-	0.50	0.60	1.22	219,600
	Subtotal				44.8	224,000		7.5	224,000						1.12	250.840
	Total				1,536.4	7,681,850		255.3	7,681,850						2.90	22,283,445
	Grand total				4,287.1	21,435,600		709.4	30,275,850						3.61	77,406,280

Nb; From Nearby clay distribution area

TABLE F-6 (3/3)

CLAY AND CLAYEY SOIL
(HAULING VOLUME AND DISTANCE)

Black Reject

(Northern Area)

No.	Area	Waste No.	Waste	Area (ha)	Covring Volume (m3)	Borrow Pit No.	Borrow area (ha)	Capacity (m3)	Road(in Barrow (km)	Paved road (km)	Unpaved (km)	Non road (km)	Road(in Wast (km)	Total distance (km)	Volume(m3) x distance(km)
1	Rocinha	R-1	BR	11.4	57,000	Gb-1	10.0	927,000	0.30	-	0.80	-	0.60	1.70	96,900
2	Rocinha	R-2	BR	45.0	225,200	Rb1-8	12.6	356,000						1.83	652,830
				56.4	**282,200**		**12.6**	**1,283,000**						**2.66**	749,730
3	Barro Branco	B-7	BR	8.0	40,000	Bb-5	4.4	105,000	0.25	-	1.75	-	0.30	2.30	92,000
				8.0	**40,000**		**4.4**	**105,000**						**2.30**	92,000
4	Itanema	I-13	BR	43.2	216,000	Ib-1	130.8	5,232,000	0.30	-	1.30	-	0.30	1.90	410,400
5	Itanema	I-15	BR	8.2	41,000	Ib-1	(130.8)	(5,232,000)	0.50	-	4.00	-	0.40	4.90	200,900
6	Itanema	I-16	BR	26.6	133,000	Ib-1	(130.8)	(5,232,000)	0.70	-	5.00	-	0.80	6.50	864,500
7	Itanema	I-17	BR	22.3	111,500	Ib-1	(130.8)	(5,232,000)	0.70	-	6.60	-	0.70	8.00	892,000
				100.3	**501,500**		**130.8**	**5,232,000**						**4.72**	2,367,800
8	Carvao	C-1	BR	10.6	53,000	Cb-1	5.6	314,000	0.10	-	-	0.05	0.90	1.05	55,650
9	Carvao	C-1	BR	122.6	613,000	Cb-1,2	5.6	352,000	0.20	-	-	0.25	0.90	1.35	827,550
10	Carvao	C-5	BR	25.0	125,000	Cb-7	14.4	576,000	0.70	-	4.50	-	0.50	5.70	712,500
				158.2	**791,000**		**25.6**	**1,242,000**						**2.02**	1,595,700
11	Deserto	D-1	BR	31.4	157,000	Db-1	25.6	1,024,000	0.10	-	-	0.80	0.35	1.25	196,250
12	Deserto	D-2	BR	6.8	34,000	Db-1	(25.6)	(1,024,000)	0.10	-	0.60	1.00	0.25	1.95	66,300
				38.2	**191,000**		**25.6**	**1,024,000**						**1.37**	262,550
13	Treviso	T-2	BR	8.8	44,000	Tb-1	5.2	291,000	0.15	-	0.20	0.30	0.30	0.95	41,800
14	Treviso	T-5	BR	112.8	564,000	Tb-3	48.4	2,420,000	0.50	1.30	5.00	-	0.25	7.05	3,976,200
				121.6	**608,000**		**53.6**	**2,711,000**						**6.61**	4,018,000
15	Riopio	P-1	BR	2.2	11,000	Pb-1	12.0	816,000	0.25	-	1.00	-	0.80	2.05	22,550
16	Riopio	P-2	BR	34.8	174,000	Pb-1	(12.0)	(816,000)	0.25	-	2.60	-	0.40	3.25	565,500
	Subtotal			**37.0**	**185,000**		**12.0**	**816,000**						**3.18**	588,050
17	Sideropolis	S-2	BR	129.6	648,000	Sb-1	20.0	1,260,000	0.45	1.70	3.00	-	0.70	5.85	3,790,800
18	Sideropolis	S-2	BR	4.8	24,000	Sb-1	(20.0)	(1,260,000)	0.45	1.70	3.00	-	0.70	5.85	140,400
19	Sideropolis	S-2	BR	4.4	22,000	Sb-1	(20.0)	(1,260,000)	0.45	1.70	3.00	-	0.70	5.85	128,700
	Subtotal			**138.8**	**694,000**		**20.0**	**1,260,000**						**5.85**	4,059,900
20	Rio Fiorita	F-1	BR	21.0	105,050	Fb-3	3.5	140,000	0.10	0.00	0.35	0.00	1.40	3.30	346,665
21	Rio Fiorita			(21.0)	(105,050)	Fb-1*	21.8	2,180,000	0.30	0.00	0.00	0.10	1.40	1.80	189,090
	Subtotal			**21.0**	**105,050**		**25.3**	**2,320,000**						**2.60**	535,755
	Total			**679.5**	**3,397,750**		**314.9**	**15,993,000**						**4.20**	14,269,485

*:substitute

(Southern Area)

No.	Area	Waste No.	Waste	Area (ha)	Covering Volume (m3)	Borrow pit No.	Borrow area (ha)	Capacity (m3)	Road(in Borrow) (km)	Paved road (km)	Unpaved (km)	Non road (km)	Road(in Waste) (km)	Total distance (km)	Volume(m3) x distance(km)
22	Sangao upper	Su-1	BR	6.0	30,000	Nb	1.0	30,000	0.05	-	-	0.50	0.20	0.75	22,500
23	Sangao upper	Su-1	BR	20.5	102,500	Nb	3.4	102,500	0.10	-	-	0.50	0.65	1.25	128,125
24	Sangao upper	Su-2	BR	40.0	200,000	Ab-1	12.0	360,000	0.17	-	1.93	0.10	0.30	2.50	500,000
25	Sangao upper	Su-3	BR	10.0	50,000	Ab-1	(12.0)	(360,000)	0.17	-	1.68	0.10	0.15	2.00	100,000
26	Sangao upper	Su-4	BR	8.0	40,000	Ab-1	(12.0)	(360,000)	0.17	-	2.58	0.10	0.15	3.00	120,000
27	Sangao upper	Su-4	BR	11.0	55,000	Nb	1.8	55,000	0.07	-	-	0.50	0.20	0.77	42,350
28	Sangao upper	Su-4	BR	20.0	100,000	Nb	3.3	100,000	0.10	-	-	0.50	0.25	0.85	85,000
29	Sangao upper	Su-5	BR	7.0	35,000	Ab-2	20.7	620,000	0.20	-	0.20	0.40	0.20	1.00	35,000
30	Sangao upper	Su-6	BR	14.0	70,000	Ab-1	(12.0)	(360,000)	0.17	-	2.50	0.10	0.23	3.00	210,000
	Subtotal			**136.5**	**682,500**		**42.2**	**1,267,500**						**1.82**	1,242,975
31	Sangao middle	Sm-1	BR	40.0	200,000	Ab-4	24.9	747,500	0.23	-	4.47	0.20	0.30	5.20	1,040,000
32	Sangao middle	Sm-2	BR	2.0	10,000	Ab-2	(20.7)	(620,000)	0.20	-	1.80	0.40	0.10	2.50	25,000
33	Sangao middle	Sm-2	BR	10.0	50,000	Ab-2	(20.7)	(620,000)	0.20	-	2.15	0.40	0.25	3.00	150,000
34	Sangao middle	Sm-2	BR	28.0	140,000	Ab-5	25.2	755,000	0.25	-	4.35	-	0.40	5.00	700,000
35	Sangao middle	Sm-3	BR	123.0	615,000	Ab-5	(25.2)	(755,000)	0.25	-	4.15	-	1.10	5.50	3,382,500
36	Sangao middle	Sm-3	BR	8.0	40,000	Nb	1.3	40,000	0.06	-	-	0.50	0.20	0.76	30,400
37	Sangao middle	Sm-3	BR	9.0	45,000	Ab-4	(24.9)	(747,500)	0.23	-	1.37	0.20	0.20	2.00	90,000
38	Sangao middle	Sm-4	BR	56.0	280,000	Nb	9.3	280,000	0.15	-	-	0.50	0.80	1.45	406,000
39	Sangao middle	Sm-4	BR	7.0	35,000	Nb	1.1	35,000	0.05	-	-	0.50	0.20	0.75	26,250
	Subtotal			**283.0**	**1,415,000**		**61.8**	**1,857,500**						**4.13**	5,850,150
40	Sangao down	Sd-1	BR	245.7	1,228,500	Ab-8	79.9	2,399,500	0.45	-	1.25	0.30	1.00	3.00	3,685,500
41	Sangao down	Sd-1	BR	12.5	62,500	Nb	2.1	62,500	0.70	-	-	0.50	0.30	1.50	93,750
42	Sangao down	Sd-2	BR	157.2	786,000	Ab-8	(79.9)	(2,399,500)	0.45	-	2.05	0.30	1.20	4.00	3,144,000
43	Sangao down	Sd-2	BR	8.0	40,000	Ab-8	(79.9)	(2,399,500)	0.45	-	2.00	0.30	0.25	3.00	120,000
44	Sangao down	Sd-2	BR	7.0	35,000	Ab-8	(79.9)	(2,399,500)	0.45	-	2.00	0.30	0.20	3.00	105,000
	Subtotal			**430.4**	**2,152,000**		**82.0**	**2,462,000**						**3.32**	7,148,250
45	Sangao branch	Sb	BR	18.0	90,000	Nb	3.0	90,000	0.10	-	-	0.50	0.20	0.80	72,000
46	Sangao branch	Sb	BR	78.0	390,000	Nb	13.0	390,000	0.18	-	-	0.50	0.50	1.18	460,200
	Subtotal			**96.0**	**480,000**		**16.0**	**480,000**						**1.11**	532,200
47	Maina	M-1	BR	3.0	15,000	Nb	0.5	15,000	-	-	-	0.50	0.10	0.60	9,000
48	Maina	M-1	BR	2.0	10,000	Nb	0.3	10,000	-	-	-	0.50	0.06	0.56	5,600
49	Maina	M-1	BR	24.0	120,000	Nb	4.0	120,000	0.10	-	-	0.50	0.30	0.90	108,000
50	Maina	M-2	BR	27.0	135,000	Nb	4.5	135,000	0.10	-	-	0.50	0.30	0.90	121,500
51	Maina	M-2	BR	1.5	7,500	Ab-3	11.9	357,500	0.16	-	1.06	-	0.08	1.30	9,750
52	Maina	M-2	BR	29.0	145,000	Ab-3	(11.9)	(357,500)	0.16	-	1.64	-	0.40	2.20	319,000
53	Maina	M-2	BR	3.0	15,000	Ab-3	(11.9)	(357,500)	0.16	-	1.77	-	0.07	2.00	30,000
54	Maina	M-2	BR	24.0	120,000	Ab-3	(11.9)	(357,500)	0.16	-	1.44	-	0.40	2.00	240,000
55	Maina	M-3	BR	72.0	360,000	Nb	12.0	360,000	0.17	-	-	0.50	0.70	1.37	493,200
56	Maina	M-3	BR	3.5	17,500	Ab-3	(11.9)	(357,500)	0.16	-	2.14	-	0.20	2.50	43,750
57	Maina	M-3	BR	2.0	10,000	Nb	0.3	10,000	-	-	-	0.50	0.07	0.57	5,700
58	Maina	M-5	BR	12.0	60,000	Nb	2.0	60,000	0.10	-	-	0.50	0.30	0.90	54,000
59	Maina	M-5	BR	2.5	12,500	Ab-4	(24.9)	(747,500)	0.23	-	3.10	0.20	0.07	3.60	45,000
60	Maina	M-5	BR	3.0	15,000	Ab-4	(24.9)	(747,500)	0.23	-	2.99	0.20	0.08	3.50	52,500
	Subtotal			**208.5**	**1,042,500**		**35.5**	**1,067,500**						**1.47**	1,537,000
61	Mae Luzia	L	BR	78.0	390,000	Ab-4	(24.9)	(747,500)	0.23	-	0.07	0.20	0.50	1.00	390,000
62	Mae Luzia	LS-1	BR	6.9	34,350	Nb	1.1	34,350	0.05	-	-	0.50	0.25	0.80	27,480
63	Mae Luzia	LS-2	BR	34.0	170,000	Ab-8	(79.9)	(2,399,500)	0.45	-	3.85	0.30	0.40	5.00	850,000
64	Mae Luzia	LS-2	BR	28.0	140,000	Ab-8	(79.9)	(2,399,500)	0.45	-	3.95	0.30	0.30	5.00	700,000
	Subtotal			**146.9**	**734,350**		**1.1**	**34,350**						**2.68**	1,967,480
65	Roncon upper	Ru	BR	0.5	2,500	Nb	0.1	2,500	-	-	-	0.50	0.05	0.55	1,375
66	Roncon upper	Ru	BR	7.5	37,500	Nb	0.2	37,500	-	-	-	0.50	0.15	0.65	24,375
67	Roncon middle	Rm	BR	30.0	150,000	Ab-2	(20.7)	(620,000)	0.20	-	4.30	0.40	0.60	5.50	825,000
68	Roncon middle	Rm	BR	50.0	250,000	Ab-2	(20.7)	(620,000)	0.20	-	5.20	0.40	0.70	6.50	1,625,000
	Subtotal			**88.0**	**440,000**		**0.3**	**40,000**						**5.63**	2,475,750
69	Criciuma	Cr	BR	3.8	19,000	Nb	0.6	19,000	-	-	-	0.50	0.50	1.00	19,000
70	Criciuma	Cr	BR	4.0	20,000	Nb	0.7	20,000	-	-	-	0.50	0.15	0.65	13,000
71	Criciuma	Cr	BR	16.0	80,000	Nb	2.6	80,000	0.08	-	-	0.50	0.30	0.88	70,400
	Subtotal			**23.8**	**119,000**		**3.9**	**119,000**						**0.86**	102,400
72	Dos Porcos	Dp	BR	8.8	44,000	Nb	1.5	44,000	0.06	-	-	0.50	0.15	0.71	31,240
73	Dos Porcos	Dp	BR	36.0	180,000	Nb	6.0	180,000	0.12	-	-	0.50	0.60	1.22	219,600
	Subtotal			**44.8**	**224,000**		**7.5**	**224,000**						**1.12**	250,840
	Total			**1,457.9**	**7,289,350**		**250.3**	**7,551,850**						**2.79**	21,107,045