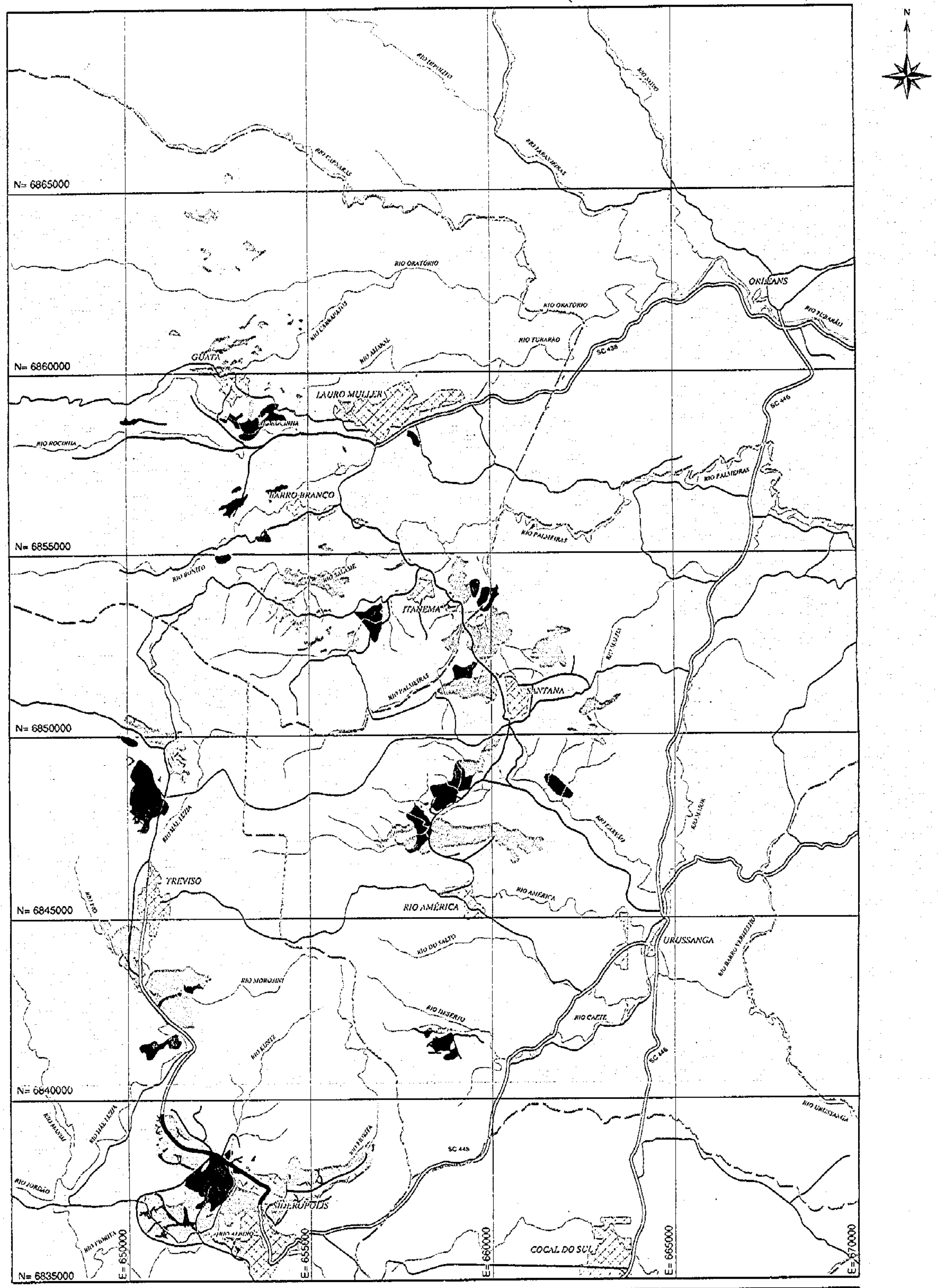
(Northern Area)



Legend:	
Black Reject	Waste Paved Road
Overburden Waste	
Pond	

FIGURE III-2 (1/2) WASTE DUMPS

THE FEASIBILITY STUDY ON RECUPERATION OF MINED OUT AREAS
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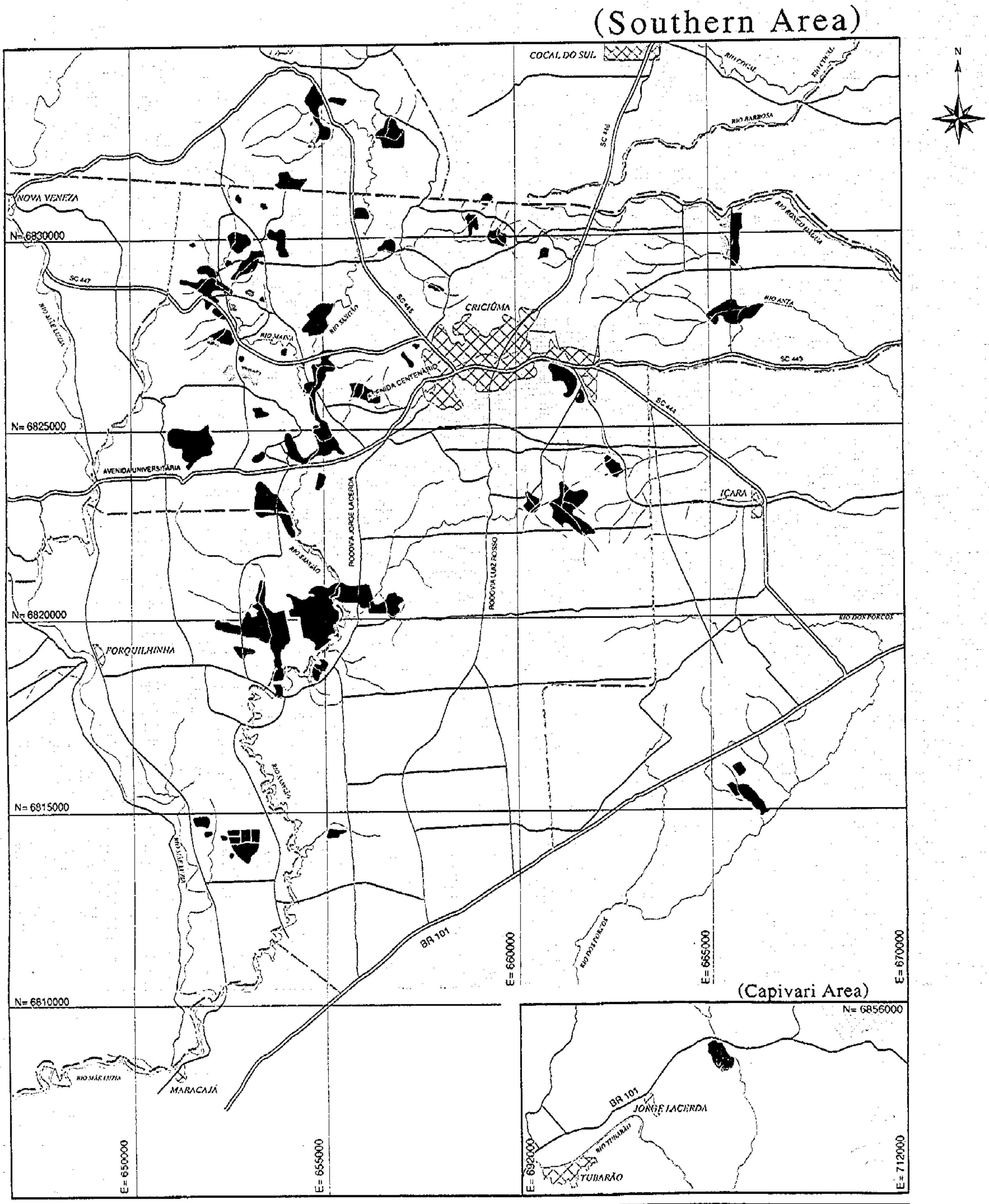

Legend:

- Black Reject
- Overburden Waste
- Pond
- Waste Paved Road

FIGURE III-2 (2/2) **WASTE DUMPS**

THE FEASIBILITY STUDY ON RECUPERATION OF MINED OUT AREAS
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3.12. All of companies have installed settling ponds using pond water for washing. They call this water recycling system a closed circuit but actually it is not[1]. At the outlet of the pond, average effluent pH is less than 3 against the effluent standards of 6 to 9, since river water itself is already polluted and there is no difference between river water and washing plant effluent in terms of pH. The average discharge from active areas is summarized in Table III-3 below:

TABLE III-3

AVERAGE DISCHARGE FROM ACTIVE AREAS

Parameters	Active Mine a/ Average Discharge	Santa Catarina Discharge Standard
pH	2.9	5 to 9
Iron (mg/l)	473	15
Sulfate (mg/l)	3,274	1 b/
Aluminum (mg/l)	117	0.1 c/

a/ Collected during January, February and May 1997 at seven active areas.
b/ Federal standard because the State of Santa Catarina does not specify sulfate norm.
c/ Federal standard because the State of Santa Catarina does not specify aluminum norm.

3.13. The Team regards the ZETA/IESA guidelines as a good example of responsible mine waste management in southern Santa Catarina and proposes additional specifications in Section II-A of Main Text. However, practically no company is complying with the ZETTA/IESA recommendations despite being required to do so by the environmental operation license issued by FATMA.

C. *FS Sites Studies*

1. Acid Water Treatment

(a) Geochemical Assessment

(i) Objective

3.14. The objective of the geochemical characterization of mining wastes was to gather relevant chemical data needed to develop effective plans for mitigating the effects of acid rock drainage (ARD) from abandoned and active coal mining sites in southern Santa Catarina.

(ii) Methods

3.15. Solid waste samples were collected from each of the four FS sites using a Case 580H backhoe. Test pits were dug to a maximum depth of 4 m. Each pit was logged (material types, depth to water

[1] The settling pond is not exclusively used for the washing plant and other waters are running into the same pond.

table, pH and EC of water, final depth of pit) and samples collected according to waste types, coloration, mineralogy and degree of saturation. A total of 152 samples were collected and shipped to FUCRI/UNESC for analysis. A subset of these samples were analyzed for total metals and leachable metals using United States Environmental Protection Agency (US EPA) Method 1312. An Acid-Base Accounting (ABA) program based on guidelines provided in the US EPA Document EPA 600/2-78-054 methods, was also performed on selected samples.

(iii) Geochemical Characteristics of Mine Waste

3.16. The results of the total and leachable metals analyses and the ABA tests performed on mine waste samples collected at the FS sites are summarized below. Overburden wastes (sandstone) have very low sulfur concentrations and also negligible neutralization potential. These wastes are not a source of poor quality leachate but would be suitable for construction purposes. Most black reject samples contained high concentrations of sulfur in both non-oxidized and oxidized form. All but one sample indicated negligible neutralization potential. All but a few samples exhibited negative neutralization potential which indicates the materials will produce acidity on exposure to air and water. Concentrations of Al, Ca, Fe, Mn, Cr and Zn were detected but are not thought to be a problem. Concentrations of As, Cd, Cu, Pb and Hg were close to or at the detection limits. Leachates from the EPA 1312 procedure contained detectable concentrations of Al, Ca, Cu, Cr, Fe, Mn and Zn. Total and leachable metal concentrations are mostly weakly correlated. Leachable metal concentrations are correlated with the leachate pH. The geochemical characterization of the individual FS sites are presented in Section II-C-II of Main Text.

(b) Treatability Tests

3.17. Bench-scale treatability tests were performed as part of the ARD feasibility study at the Environmental Research Center at FUCRI/UNESC during February and March of 1997. They include waste neutralization tests, biocide treatment of acidic mine wastes, acid water neutralization and precipitation tests, and passive biological treatment tests. The results of these treatability tests are presented in FS Sites Study, Section II-C-II of Main Text.

2. *Remedial Alternatives for FS Sites*

(a) Fiorita Remedial Alternatives

(i) Description

3.18. Due to the lack of reclamation during and after mining activities, the dragline mining method resulted in deposition of large conical piles of coarse bouldery sandstone waste throughout the site about

230 ha in area (Figure III-3), leaving ponds and lakes sporadically located along the north and south highwalls or surrounded by overburden wastes. Along roads or in shallow streams in the site, black shale wastes or washing plant rejects were dumped. Those black wastes are presumed to have been brought in from somewhere else outside the FS site for illegal disposal, since there were no coal washing facilities during mining operations in the site.

3.19. Overburden waste itself does not contain pyrite and is not a source of ARD. In addition, due to hard sandstone, overburden waste, even after many years of negligence, is in a very stable condition without any serious surface erosion, which generally causes landslide or river bed rising. Prevention measures against such problems caused by erosion would not be required for the Fiorita remediation. Overburden waste dumps were therefore treated mainly from a land use or landscape standpoint. Then, two simple alternatives for its remediation were considered, i.e., (i) re-grading and covering with grass seeded clay or (ii) leave it as it is.

3.20. Three alternatives for each FS site were developed by creating three distinct groupings of remedial actions for acid water treatment. However, since overburden waste dumps exist only in the Fiorita FS site, the reclamation of overburden waste dumps would be required, resulting in six remedial alternatives for the Fiorita FS site.

3.21. **Alternative 1**: The features of this alternative are source removal, on-site disposal, passive treatment and overburden waste dump reclamation (Figure III-4). Black reject material and exposed pyritic shales are thought to be the primary source of acidity and metal contamination to the Rio Fiorita. Those source materials would be excavated and disposed of by either placing them under a minimum of one meter water in one of several existing on-site ponds or placing them in an engineered on-site waste repository which is covered with a wet cover or capillary barrier system (Figure III-5). Following removal of the pyritic shales, the excavated areas would be covered with an oxygen limiting vegetated cover system to prevent the oxidation of any pyritic shales in the foot wall of the pit that may have been exposed during excavation. Small acidic seeps and streams entering the Rio Fiorita would be treated through passive biological treatment systems in constructed aerobic or anaerobic wetlands (Figure III-6). Overburden waste dumps would be re-contoured, re-graded and covered with grass seeded clay. The remedial actions are as follows:

1. Excavation and on-site disposal of exposed reactive waste;
2. Subaqueous disposal in existing on-site ponds;
3. Construction of an on-site waste repository;
4. Construction of passive wetland treatment systems;
5. Control of channel erosion and installation of aeration drop structures;

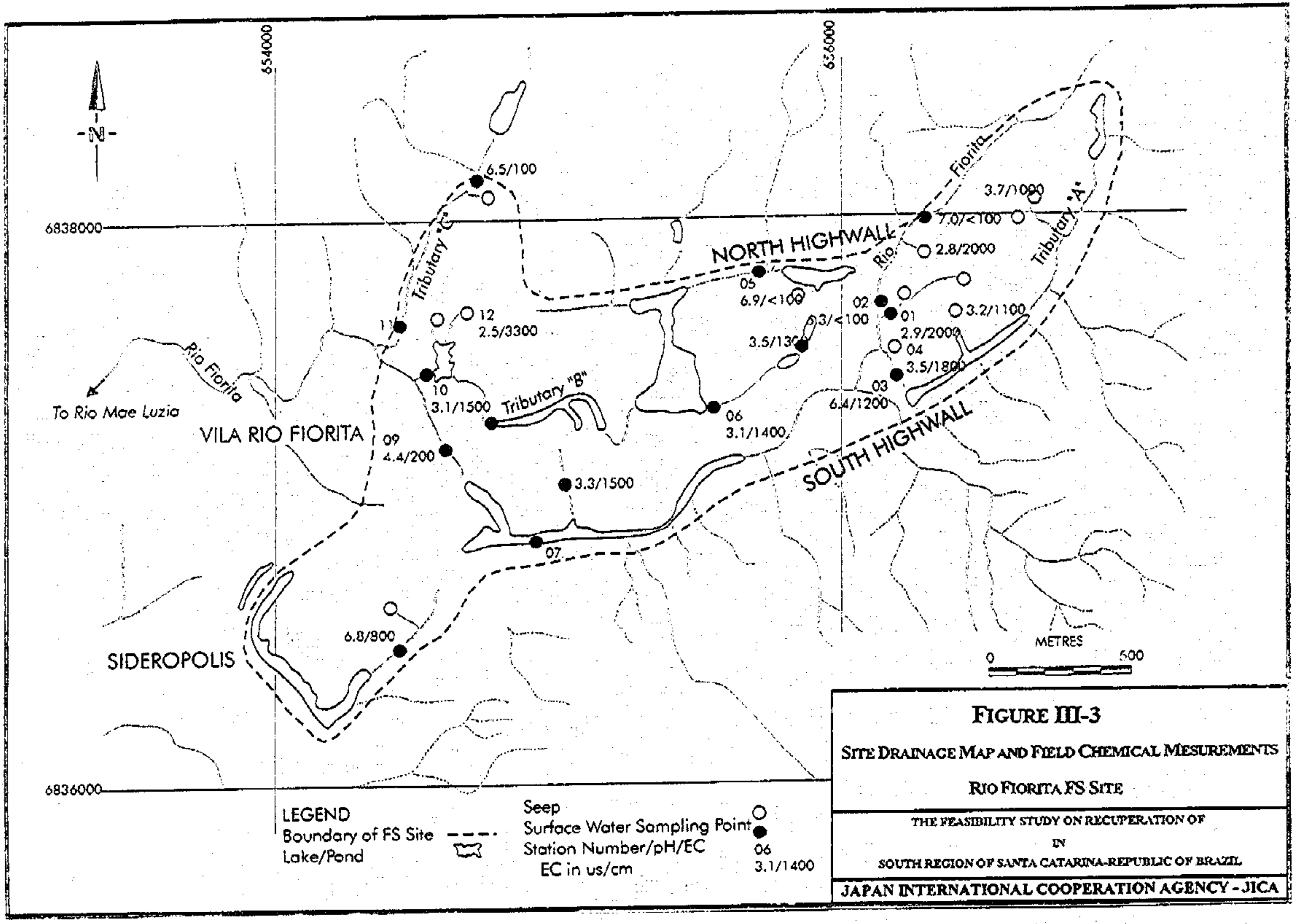

FIGURE III-3

SITE DRAINAGE MAP AND FIELD CHEMICAL MESUREMENTS

RIO FIORITA FS SITE

THE FEASIBILITY STUDY ON RECUPERATION OF

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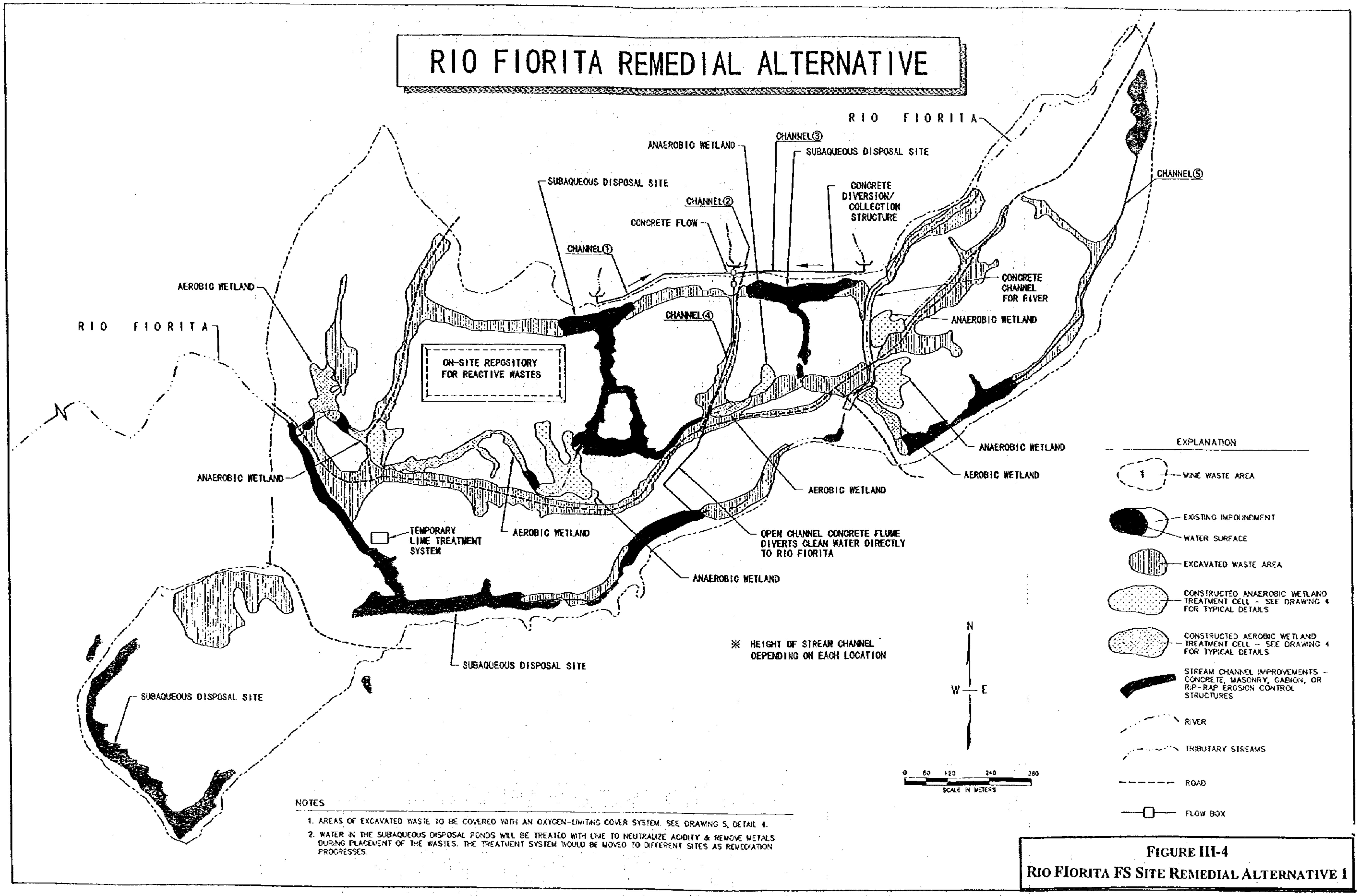

FIGURE III-4
RIO FIORITA FS SITE REMEDIAL ALTERNATIVE 1

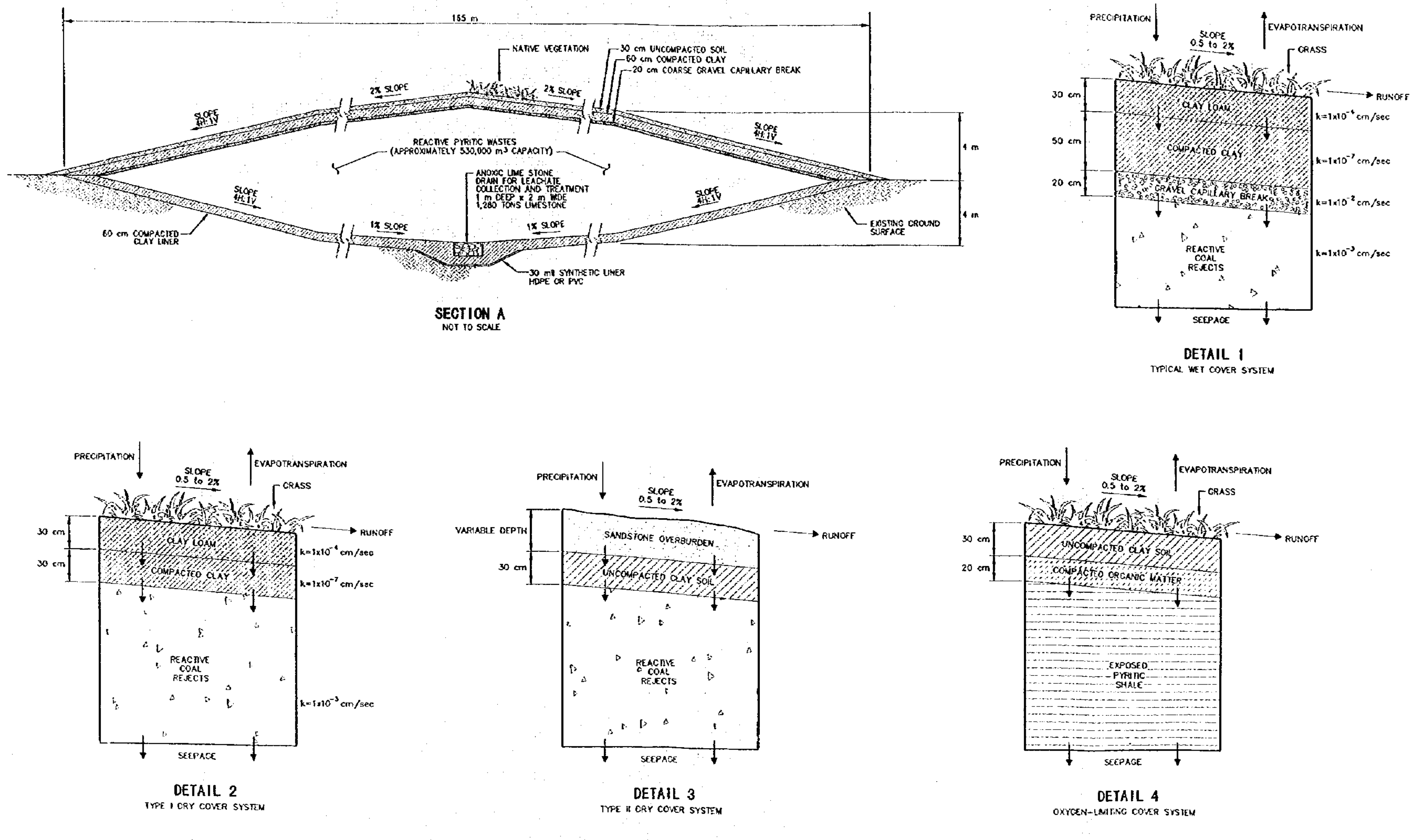

FIGURE III-5
RIO FIORITA FS SITE COVER TYPE OPTIONS

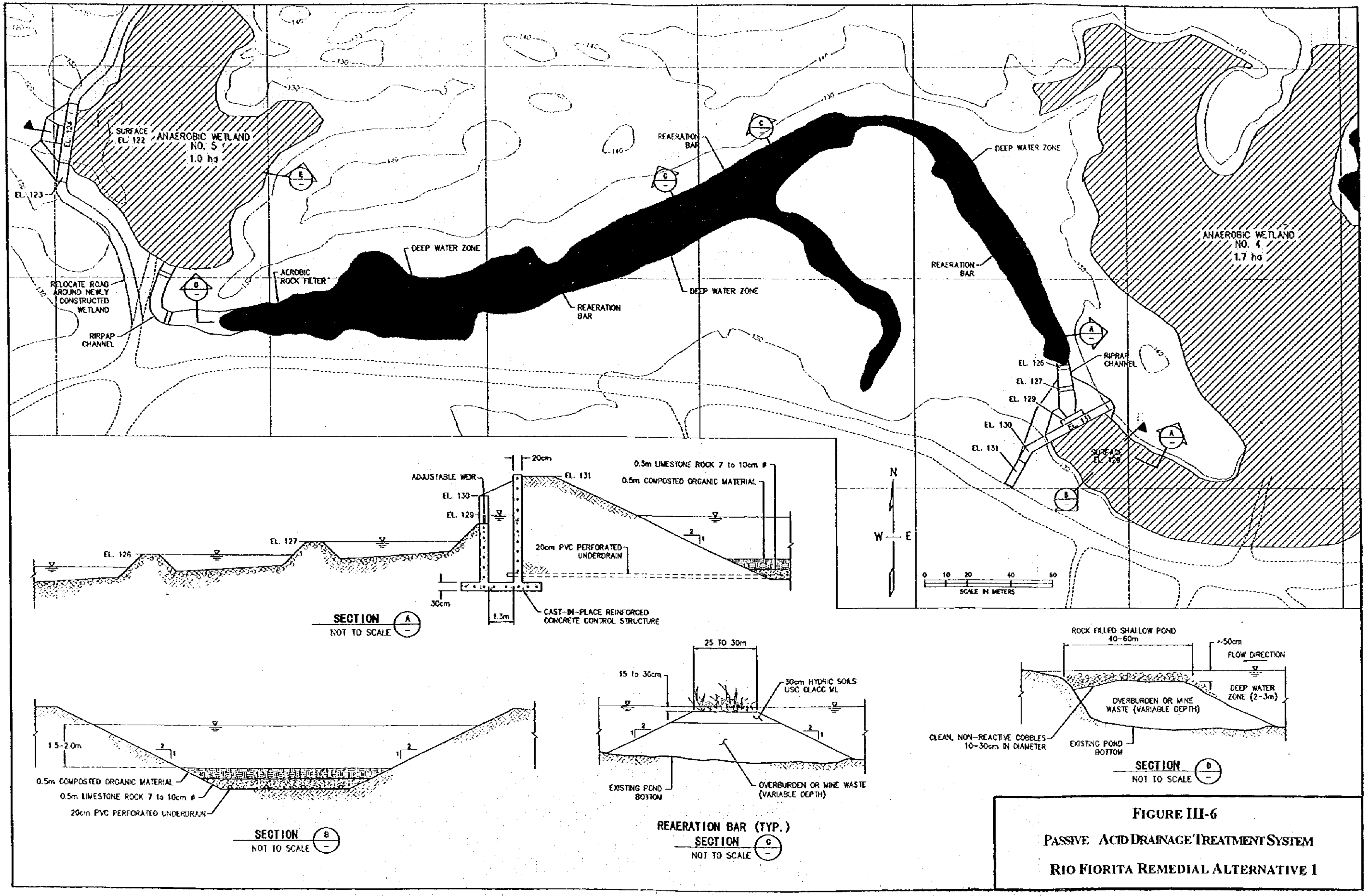

FIGURE III-6

PASSIVE ACID DRAINAGE TREATMENT SYSTEM

RIO FIORITA REMEDIAL ALTERNATIVE 1

6. Diversion of clean water; and
7. Overburden reclamation (single layer dry cover).

3.22. **Alternative 2**: The features of this alternative are source containment under wet cover systems, passive treatment and overburden waste dump reclamation (Figure III-7). A major difference from Alternative 1 is source material disposal. Black reject material and pyritic shales would be left in place and capped with a wet cover system. However, limited reactive wastes, those located in water courses and in the area with the potential for water levels to fluctuate through the wastes and the threat of damage to a cover system during floods. Passive wetlands, channel, erosion control, aeration drop structures, clean water diversion and overburden waste dumps reclamation are identical with Alternative 1. The remedial actions are as follows:

1. Covering of reactive wastes with a wet cover system;
2. Limited excavation and on-site disposal of exposed reactive wastes;
3. Construction of passive wetland treatment systems;
4. Control of channel erosion and installation of aeration drop structures;
5. Diversion of clean water; and
6. Overburden reclamation (single layer dry cover).

3.23. **Alternative 3**: The features of this alternative are source control, passive treatment and overburden waste dump reclamation (Figure III-8). A major difference with Alternative 2 is a reactive waste covering system. Black reject material and pyritic shales would be left in place and capped with a dry cover. The procedure of limited excavation and on-site disposal of exposed reactive wastes is identical with Alternative 2 except for the covering system. Passive wetland and overburden waste dumps reclamation are identical with Alternative 1 and 2. The remedial actions are as follows:

1. Covering of reactive wastes with dry soil cover systems;
2. Limited excavation and on-site disposal of exposed reactive wastes;
3. Construction of passive wetland systems;
4. Control of channel erosion and installation of aeration drop structures;
5. Diversion of clean water; and
6. Overburden reclamation (single layer dry cover).

3.24. **Other alternatives**: The only difference between Alternatives 1, 2 and 3 is that Alternatives 4, 5 and 6 eliminate overburden dumps reclamation. All other actions are identical.

(ii) Remedial Cost and Effectiveness Estimates

3.25. The numerical simulation model was constructed to predict water quality after taking mitigation measures for the Fiorita FS site as shown in Section II-B of Main Text.. Together with load reduction effectiveness estimated for the alternatives, cost estimates are summarized on Table **Figure**

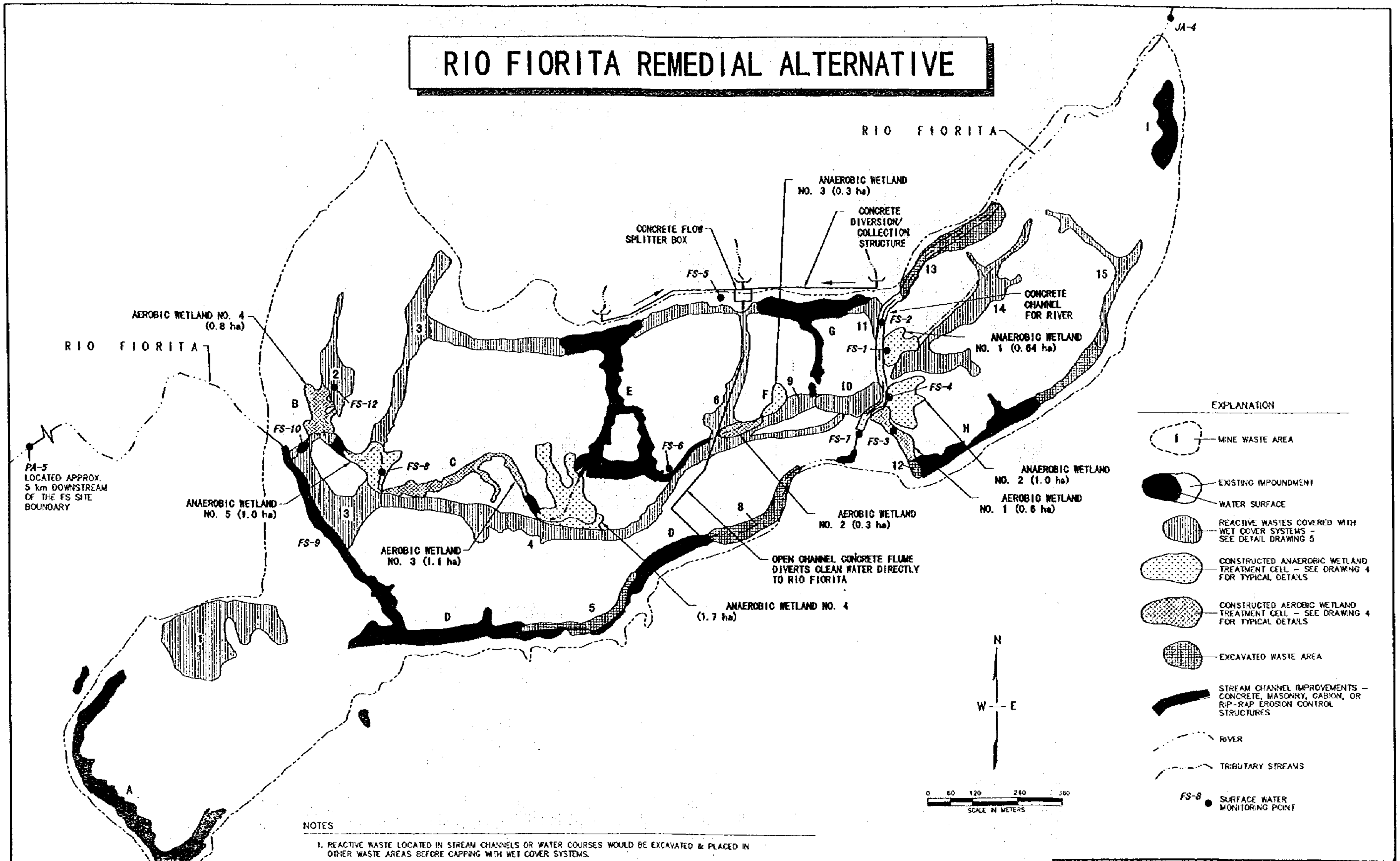

FIGURE III-7

RIO FIORITA FS SITE REMEDIAL ALTERNATIVE 2

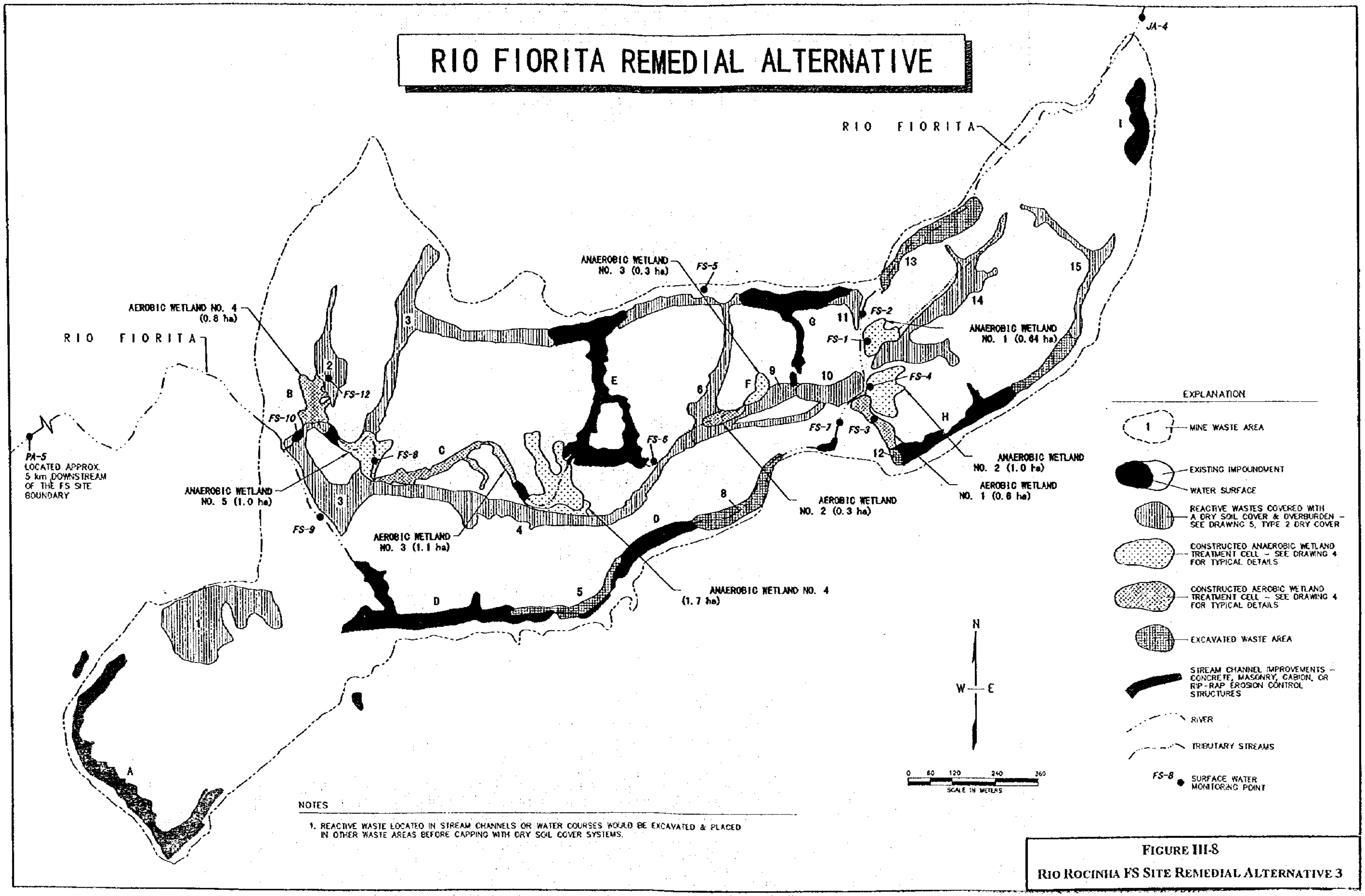

FIGURE III-8

RIO ROCINHA FS SITE REMEDIAL ALTERNATIVE 3

III-4 below. Details are presented in Section II-D of Main Text.

TABLE III-4

FIORITA REMEDIAL COST AND EFFECTIVENESS

	Estimated Loads Reduction(%)	pH [a/]	Cost (R$ million)
Alternative 1	90 - 98	4.6 - 5.0	12.4
Alternative 2	60 - 70	3.8 - 4.0	11.2
Alternative 3	20 - 40	3.5 - 3.7	8.4
Alternative 4	90 - 98	4.5 - 5.0	7.3
Alternative 5	60 - 70	3.8 - 4.0	5.6
Alternative 6	20 - 40	3.5 - 3.7	2.8

a/ Estimated at the downstream boundary of the FS site (Current pH = 3.5).

3.26. In the most effective alternative (Alternative 1), metals and acidity concentrations are expected to be reduced by as much as 90 to 98 percent. In spite of the greatest reductions, it would not meet the existing Brazilian surface water quality norms. Since the current estimation do not count on the effect of overburden waste reclamation, there is no difference between Alternatives 1, 2, 3 and Alternatives 4, 5, 6 in terms of pH, respectively.

(b) Rocinha Remedial Alternatives

(i) Description

3.27. The Rocinha FS site is approximately 71 ha in area, straddling the Rio Rocinha, which used to be the site of several coal washing plants (Figure III-9). Coarse rejects were deposited extensively as valley fill and side hill dumps mainly on the north bank of the Rio Rocinha until they became a flat elevated terrace. Wash plant fines were apparently discharged directly into the Rio Rocinha. Fines were also deposited in numerous settling basins or impoundments. In the course of valley filling, the water of the Rio Pazza Dez, a tributary of the Rio Rocinha, was blocked to the Rio Rocinha by the dumped rejects over original extensive cobble and gravel deposits, and a short cut tributary to the Rio Rocinha was artificially created. Extensive valley filling as occurred at the coal washing area resulted in obliteration of the original valley trace of the Rio Pazza Dez. Currently, coarse rejects are being excavated and re-washed to recuperate coal.

3.28. **Alternative 1**: The features of this alternative are source containment, passive treatment and erosion controls (Figure III-10). Pyritic black reject dumps would be left in place and capped with a wet cover or capillary barrier. Prior to capping, the waste dumps would be re-graded and re-contoured. Surface drainage channels would also be installed to collect and transport runoff away from the capped areas to reduce erosion during intense rainfall events (Figure III-11). Lime would be also applied to

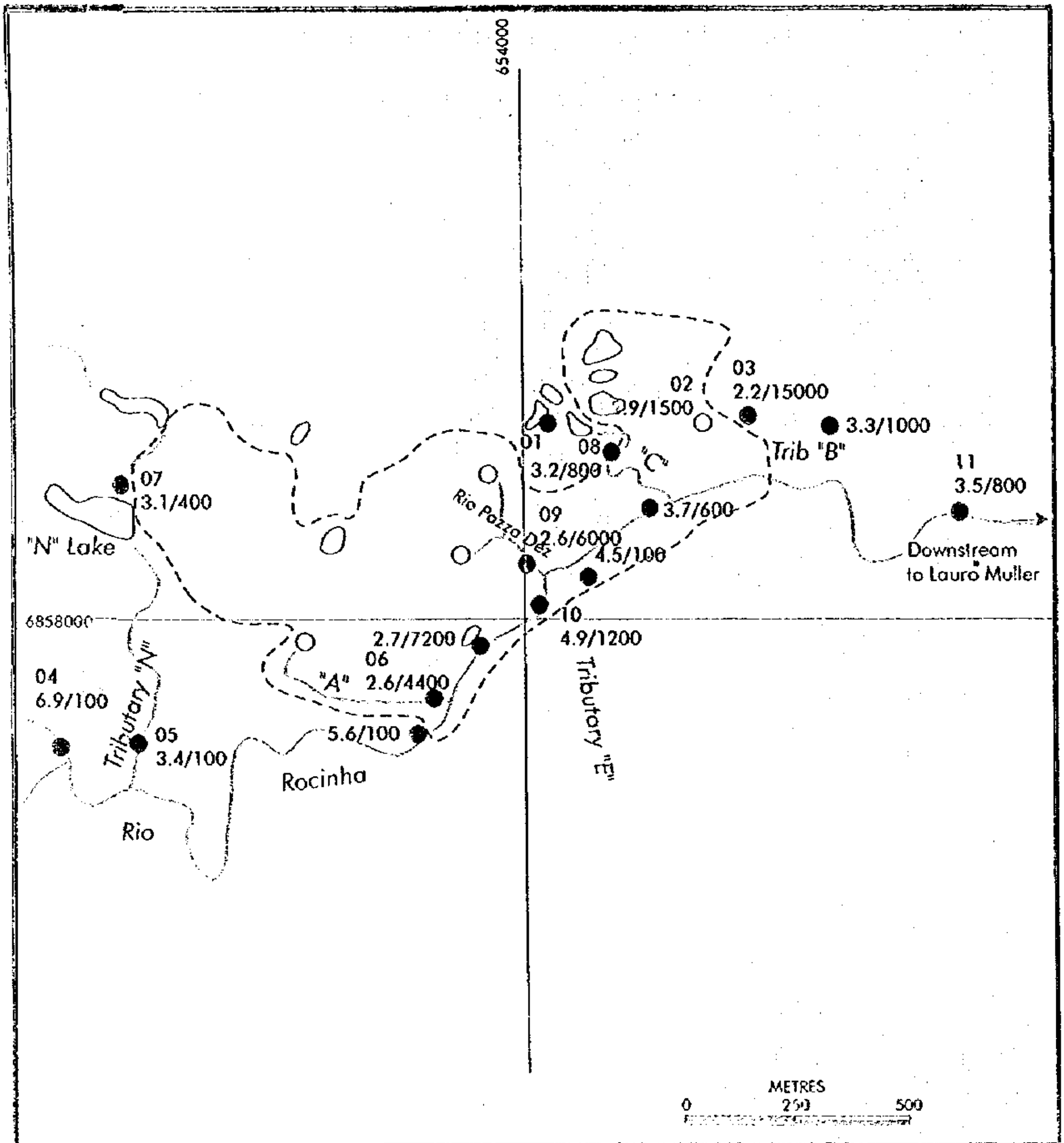

FIGURE III-9

SITE DRAINAGE MAP AND FIELD CHEMICAL MESUREMENTS

RIO ROCINHA FS SITE

THE FEASIBILITY STUDY ON RECUPERATION OF

IN

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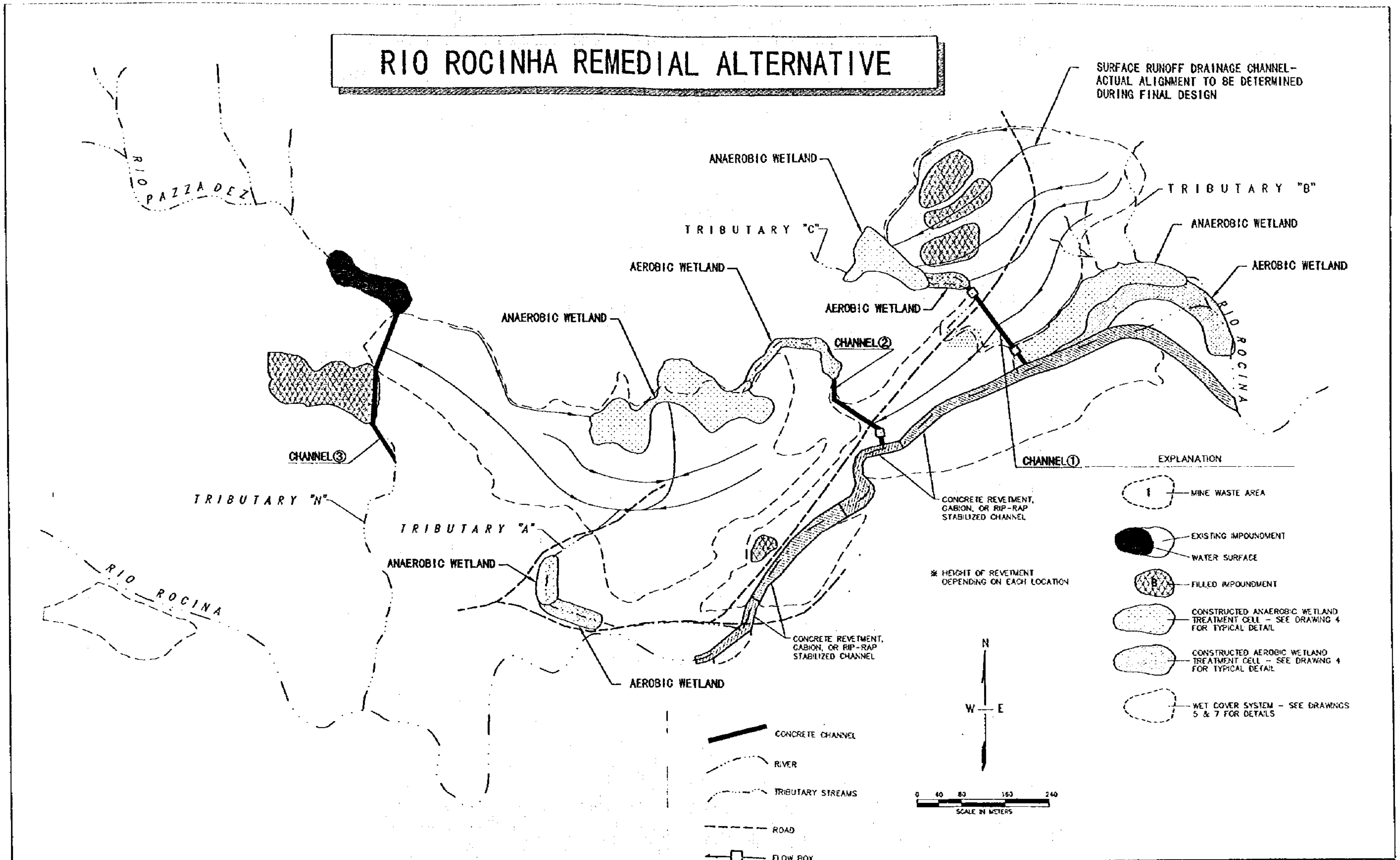
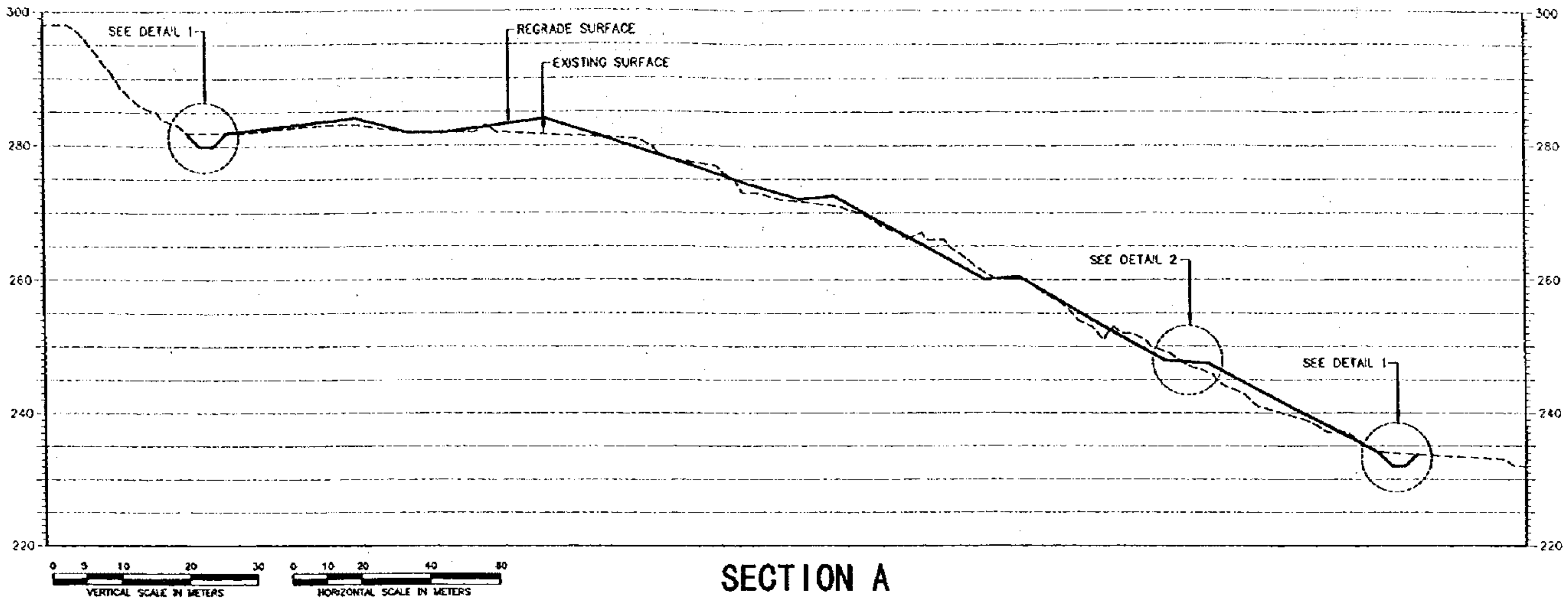
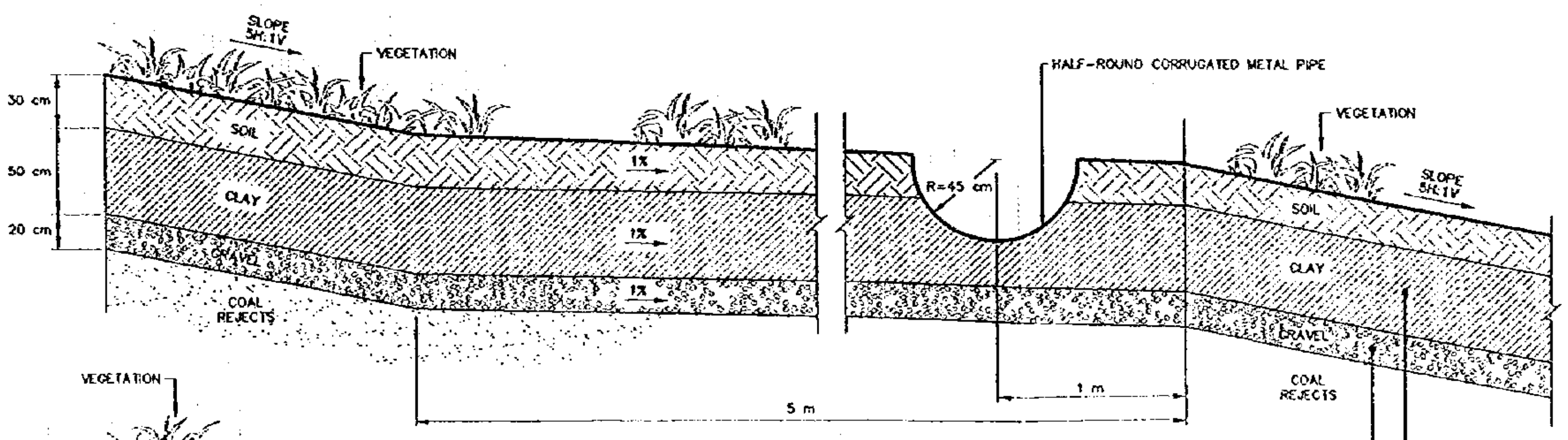


FIGURE III-10
RIO ROCINHA FS SITE REMEDIAL ALTERNATIVE 1



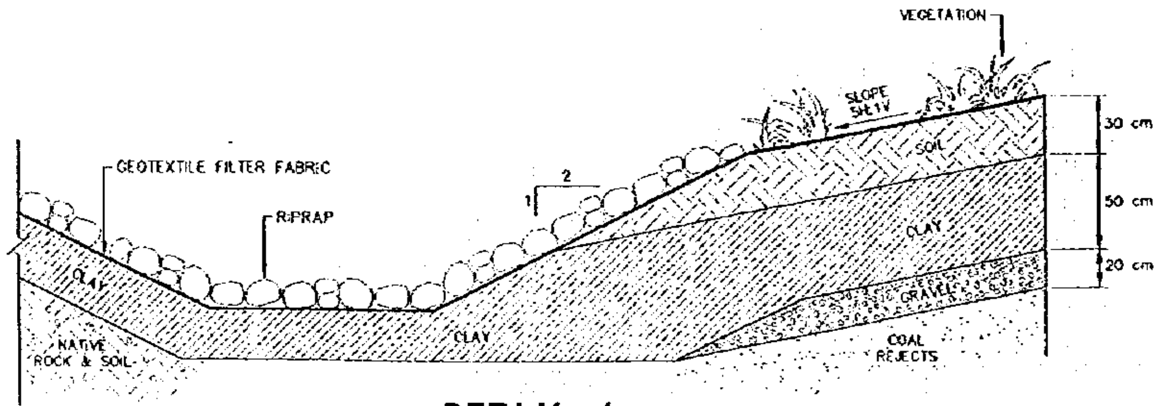
SECTION A



DETAIL 2

NOTE

1. APPLY HYDRATED LIME OR FINELY GROUND LIMESTONE TO THE SURFACE OF THE REACTIVE COAL REJECTS DURING FINAL GRADING PRIOR TO INSTALLATION OF THE WET COVER SYSTEM.



DETAIL 1

FIGURE III-11
FS SITE ALTERNATIVE I SECTION AND DETAILS
RIO ROCINHA

the surface of reactive waste piles prior to capping. Existing surface ponds would be drained and filled to prevent seepage into the underlying wastes. Several acidic seeps and streams would be treated through passive biological treatment systems, including both anaerobic and aerobic wetlands. Clean water in the Rio Pazza Dez above the FS site would be intercepted and diverted to the Rio Rocinha in a concrete-lined channel. A potion of the flow from the Rio Pazza Dez is believed to currently flow underground through reactive wastes then discharges into the channel at RS-9. The remedial actions are as follows:

1. Covering of reactive wastes with an oxygen-limiting wet cover system;
2. Applying lime to reactive waste dumps;
3. Limited excavation and on-site disposal of exposed reactive wastes;
4. Draining and filling surface water impoundments;
5. Construction of passive wetland treatment systems;
6. Control of channel erosion and installation of aeration drop structures;
7. Diversion of clean water; and
8. Stabilizing the Rio Rocinha river channel.

3.29. **Alternative 2**: The features of this alternative are source containment, passive treatment and erosion controls (Figure III-12). Differences are reactive waste covering systems, using a dry soil cover instead of a wet cover system used in Alternative 1, and no application of lime to the waste surfaces in this alternative. The remedial actions are as follows:

1. Covering of reactive wastes with a dry cover system;
2. Limited excavation and on-site disposal of exposed reactive wastes;
3. Draining and filling surface water impoundments;
4. Construction of passive wetland treatment systems;
5. Control of channel erosion and installation of aeration drop structures;
6. Diversion of clean water; and
7. Stabilizing the Rio Rocinha river channel.

3.30. **Alternative 3**: The features of this alternative are source containment and erosion controls (Figure III-13). A difference is that the passive wetland treatment systems described under Alternatives 1 and 2 are omitted from this Alternative 3. The remedial actions are as follows:

1. Covering of reactive wastes with a dry cover system;
2. Limited excavation and on-site disposal of exposed reactive wastes;
3. Draining and filling surface water impoundments;
4. Control of channel erosion and installation of aeration drop structures;
5. Division of clean water; and
6. Stabilizing the Rio Rocinha river channel.

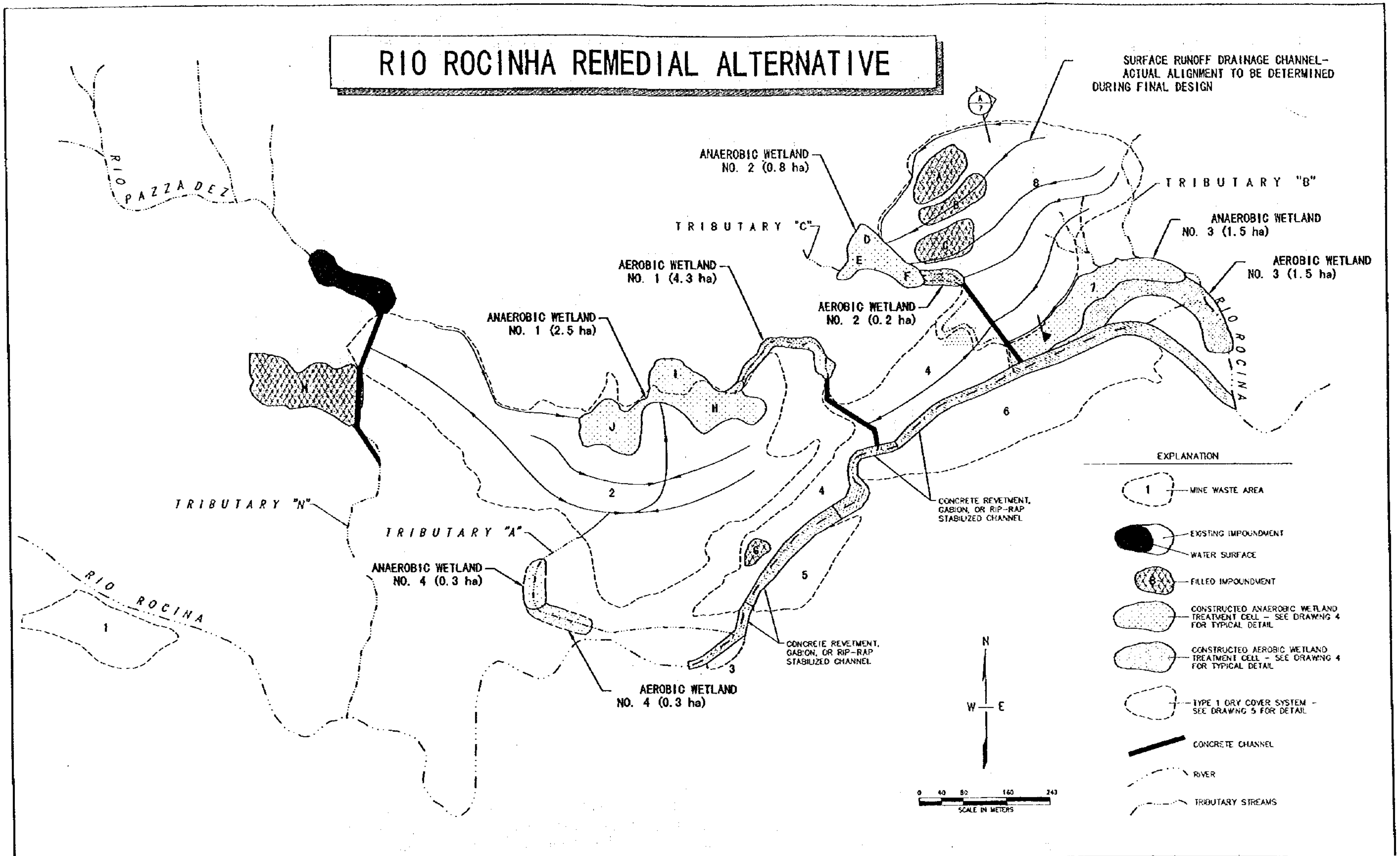


Figure III-12

Rio Rocinha FS Site Remedial Alternative 2

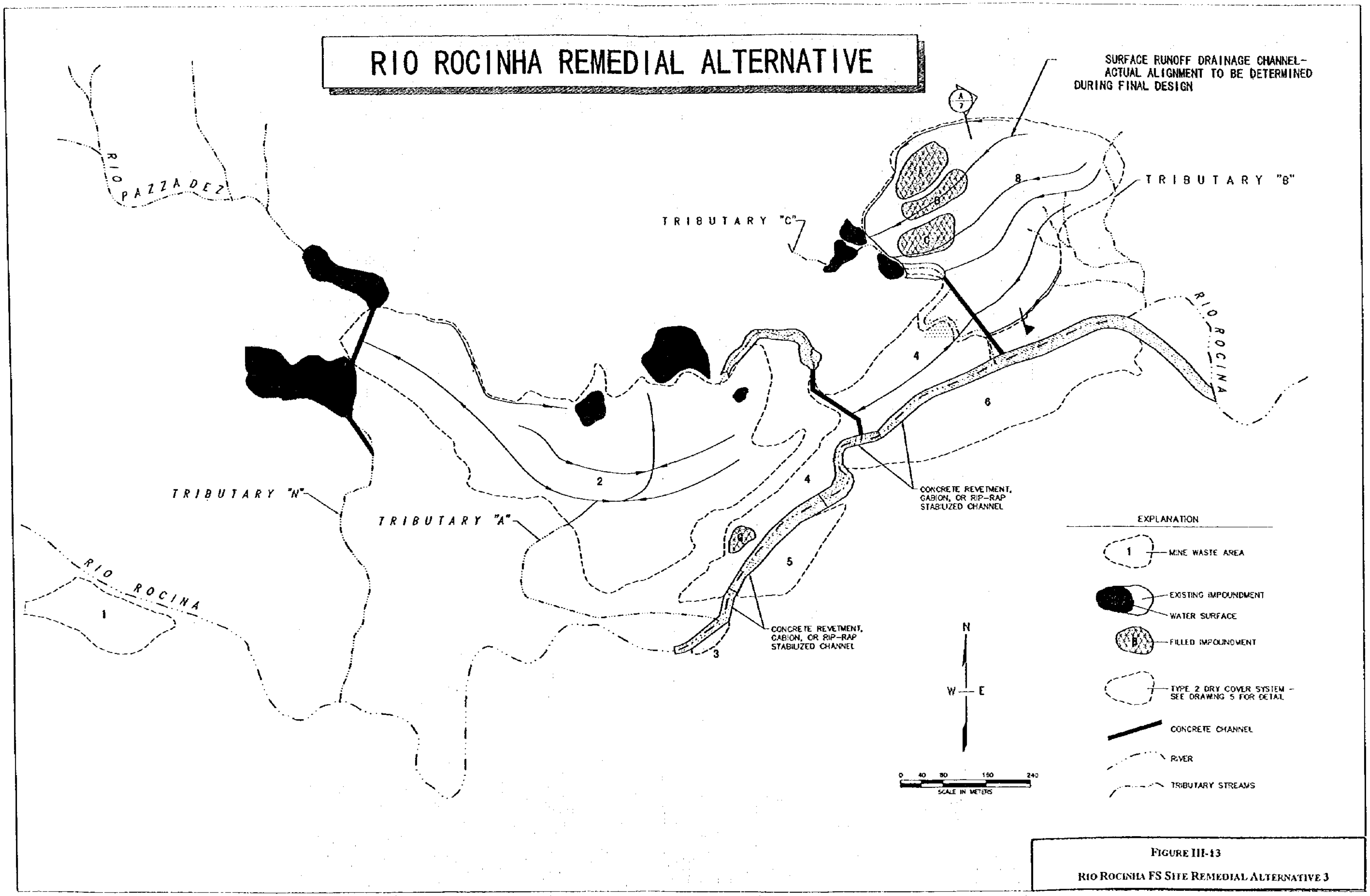


FIGURE III-13

RIO ROCINHA FS SITE REMEDIAL ALTERNATIVE 3

(ii) Cost and Effectiveness Estimates

3.31. The numerical simulation model was constructed to predict water quality after taking mitigation measures for the Fiorita FS site as shown in Section II-B of Main Text. Together with load reduction effectiveness estimated for the alternatives, cost estimates are summarized in Table III-5 below. Details are presented in Section II-D of Main Text.

TABLE III-5

ROCINHA REMEDIAL COST AND EFFECTIVENESS

	Estimated Loads Reduction(%)	pH [a/]	Cost (R$ million)
Alternative 1	up to 95	less than 4.5	8.1
Alternative 2	60 - 70	3.6 - 3.8	5.1
Alternative 3	25 - 30	less than 3.5	3.5

a/ Estimated at the monitoring point (RS-11) slightly downstream of the FS site boundary (Current pH = 3.1)

3.32. In the most effective alternative (Alternative 1), metals and acidity concentrations are expected to be reduced by up to 95 percent. In spite of the greatest reductions, it would not meet the existing Brazilian surface water quality norms.

(c) Carvão Remedial Alternatives

(i) Description

3.33. The main feature of the Carvão FS site is the flowing from the abandoned Mina Santana's decline portal. The portal opens onto an area (less than 2 ha) and the surface stream drains into an unnamed rock channel which flows into a 100 m-long culvert. The culvert drains into an incised valley which joins the Rio Carvão. The volumetric flow rate from the portal varies from 4.3 to 20 m^3/min. The pH of the water is relatively high, about 4.5 standard units.

3.34. The mine drainage from Mina Santana, however, is not the major source of pollution to the Rio Carvão. Drainage from the massive coal reject dumps located upstream of the unnamed stream contributes 50 percent of the acidity load, 89 percent of the aluminum load, and 75 percent of the iron load immediately downstream of the confluence of this stream and the Rio Carvão because the rejects are currently being actively re-washed to recover part of the residual coal content (Figure III-14). Despite this large load contribution, the waste piles were not included in the Rio Carvão FS site.

3.35. **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

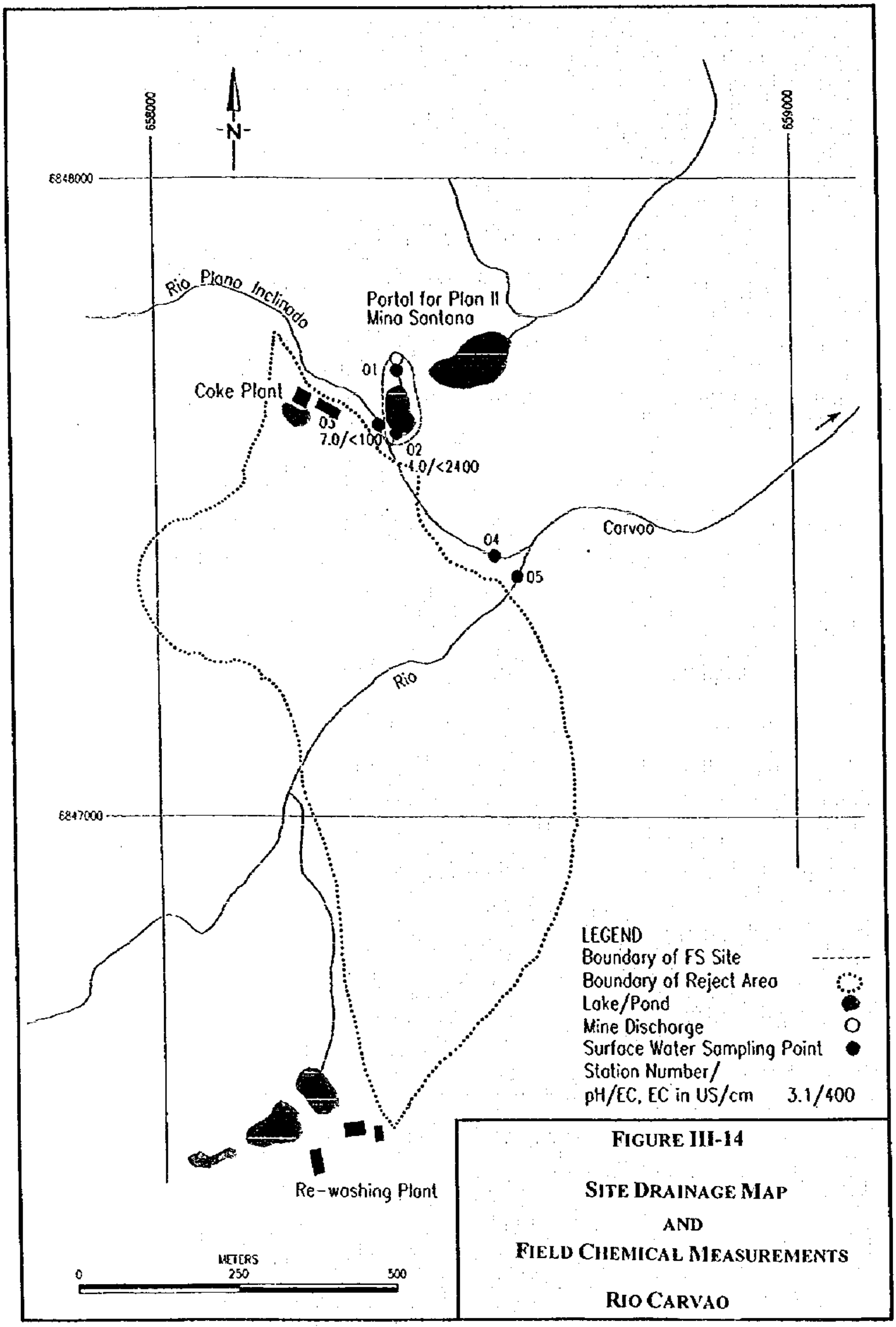


FIGURE III-14

SITE DRAINAGE MAP

AND

FIELD CHEMICAL MEASUREMENTS

RIO CARVAO

portal (Figure III-15). The design of the treatment plant would be patterned after the process known as the High Density Sludge (HDS) process (Figure III-16).

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

3.37. **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 (Figure III-17). 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.

(ii.) Remedial Cost and Effectiveness Estimates

3.38. The simulation model using the simple equation with assumption of a completely mixed condition was constructed to predict water quality after taking mitigation measures for the Carvão FS site as shown in Section II-B of Main Text. Together with load reduction effectiveness estimated for the alternatives, cost estimates are summarized in Table III-6 below. Details are also presented in Section II-D of Main Text..

TABLE III-6

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.

3.39. 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 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.

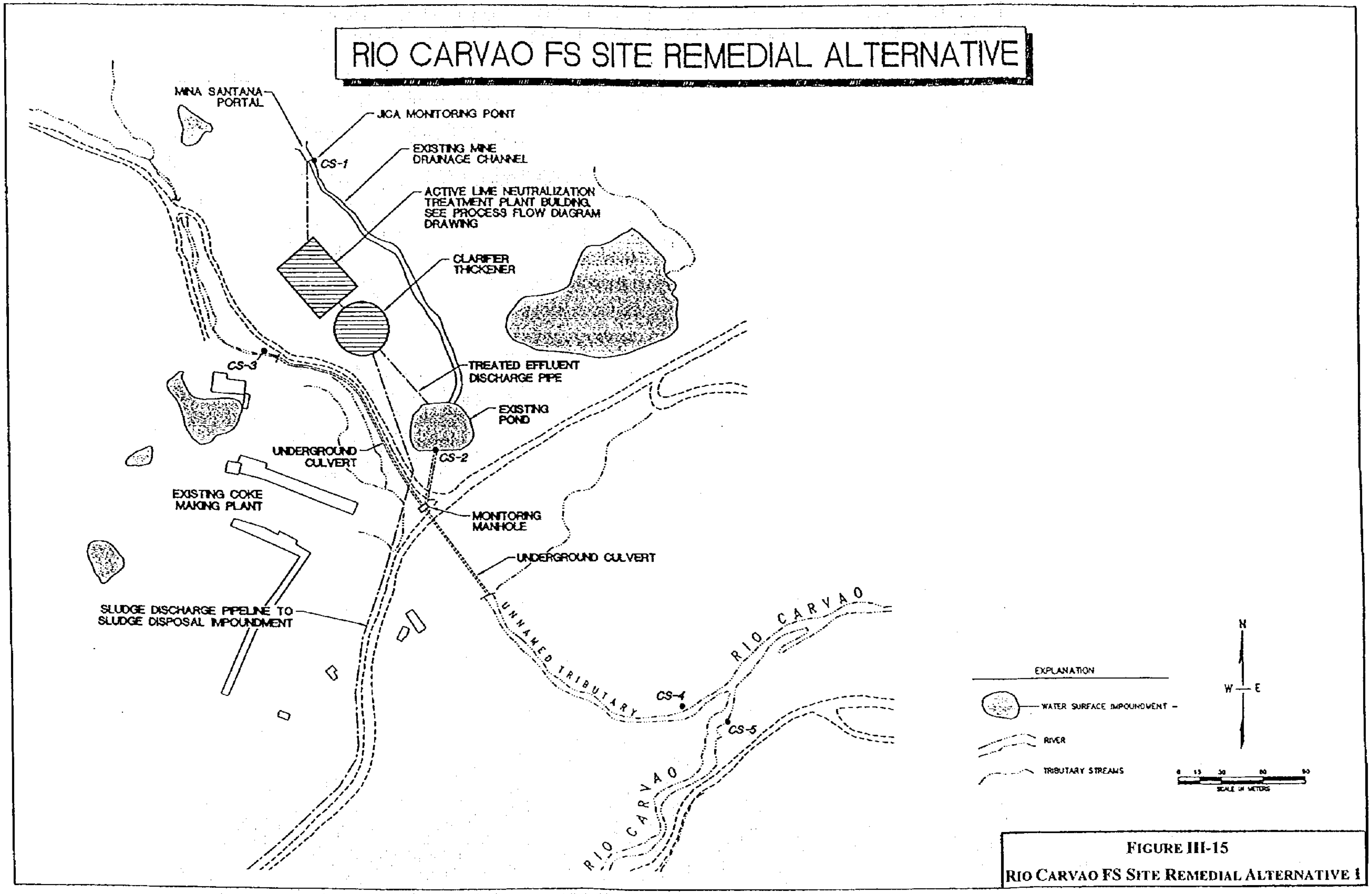
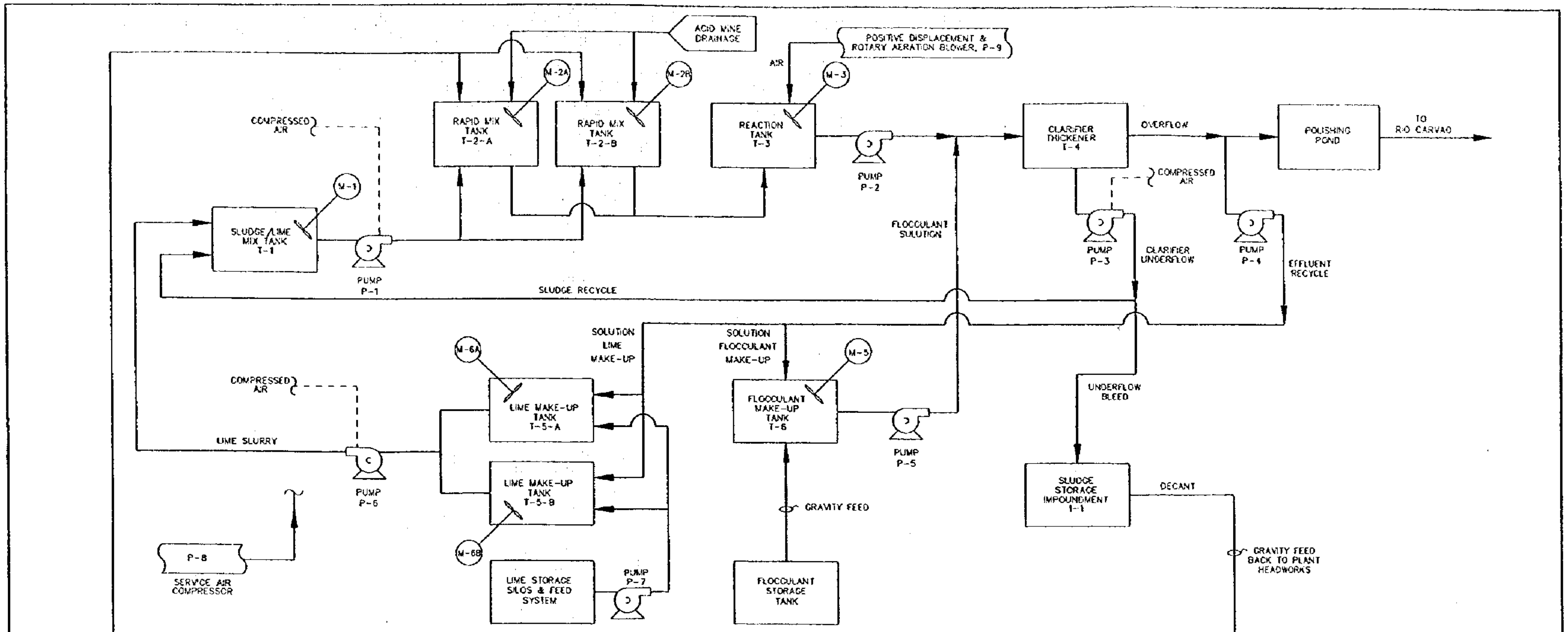


FIGURE III-15
RIO CARVAO FS SITE REMEDIAL ALTERNATIVE 1



Equipment Number	Equipment Description	Size or Capacity	Materials of Construction	Hydraulic Retention Time	Inflow Rate	Overflow Rate	Underflow Rate	Height	Width or Diameter
T-1	Sludge and lime mix tank, 1 each	154 m3	Epoxy coated steel	30 minutes	10.3 m3/min	10.3 m3/min	0 m3/min	5 m	D = 6.3 m
T-2 A&B	Rapid mix tanks, 2 each	15 m3 ea	Epoxy coated steel	1 minute	30.7 m3/min	30.7 m3/min	0 m3/min	3 m	D = 2.5 m
T-3	Neutralization reaction tank, 1 each	307 m3	Epoxy coated steel	10 minutes	30.7 m3/min	30.7 m3/min	0 m3/min	5 m	D = 9 m
T-4	Solids contact type clarifier/thickener	14736 m3	Epoxy coated steel	8 hours	30.7 m3/min	19.1 m3/min	11.6 m3/min	10 m	D = 43 m
T-5 A&B	Lime slurry make up tanks, 2 each	24 m3 ea	Fiber Reinforced Plastic	8 hours	0.1 m3/min	0.1 m3/min	0 m3/min	3 m	D = 3 m
T-6	Flocculant make up tank	1 m3	Fiber Reinforced Plastic	24 hours	0.01 m3/min	0.01 m3/min	0 m3/min	1 m	D = 1.1 m
P-1	Reagent slurry transfer pump, 2 in parallel	12 m3/min	Dual diaphram, 316 SS	NA	NA	NA	NA	NA	NA
P-2	Clarifier feed pumps, 2 in parallel	30.7 m3/min ea	Centrifugal, 304 SS	NA	NA	NA	NA	NA	NA
P-3	Sludge pump	11.6 m3/min	Dual diaphram, SS	NA	NA	NA	NA	NA	NA
P-4	Make up water feed pump	1 m3/min	Centrifugal, 304 SS	NA	NA	NA	NA	NA	NA
P-5	Flocculant metering pump	0.1 m3/min	Piston type, plastic	NA	NA	NA	NA	NA	NA
P-6	Lime slurry feed pumps, 2 in parallel	1 m3/min ea	Dual diaphram, 316 SS	NA	NA	NA	NA	NA	NA
P-7	Dry lime feed system	20 kg/min	Screw auger, carbon steel	NA	NA	NA	NA	NA	NA
P-8	Service air compressor, 2 in parallel	15000 L/min ea	Reciprocating type, air cooled	NA	NA	NA	NA	NA	NA
P-9	Reaction tank aeration blower	21000 L/min	Positive displacement	NA	NA	NA	NA	NA	NA
M-1	Sludge/lime tank motorized mixer	NA	High speep motorized mixer	NA	NA	NA	NA	NA	NA
M-2 A&B	Rapid motorized mixers, 1 each tank	NA	High speep motorized mixer	NA	NA	NA	NA	NA	NA
M-3	Reaction tank motorized mixer	NA	Slow speed motorized mixer	NA	NA	NA	NA	NA	NA
M-5	Flocculant tank motorized mixer	NA	Laboratory type mixer	NA	NA	NA	NA	NA	NA
M-6 A&B	Lime slurry motorized mixer, 1 each tank	NA	High speep motorized mixer	NA	NA	NA	NA	NA	NA
I-1	Sludge storage impoundment	95 hectares	Earthen impoundment with capacity for 20 years sludge production, assumes 10 meter depth		NA	NA	NA	NA	NA

FIGURE III-16
LIME NEUTRALIZATION TREATMENT
PROCESS FLOW DIAGRAM

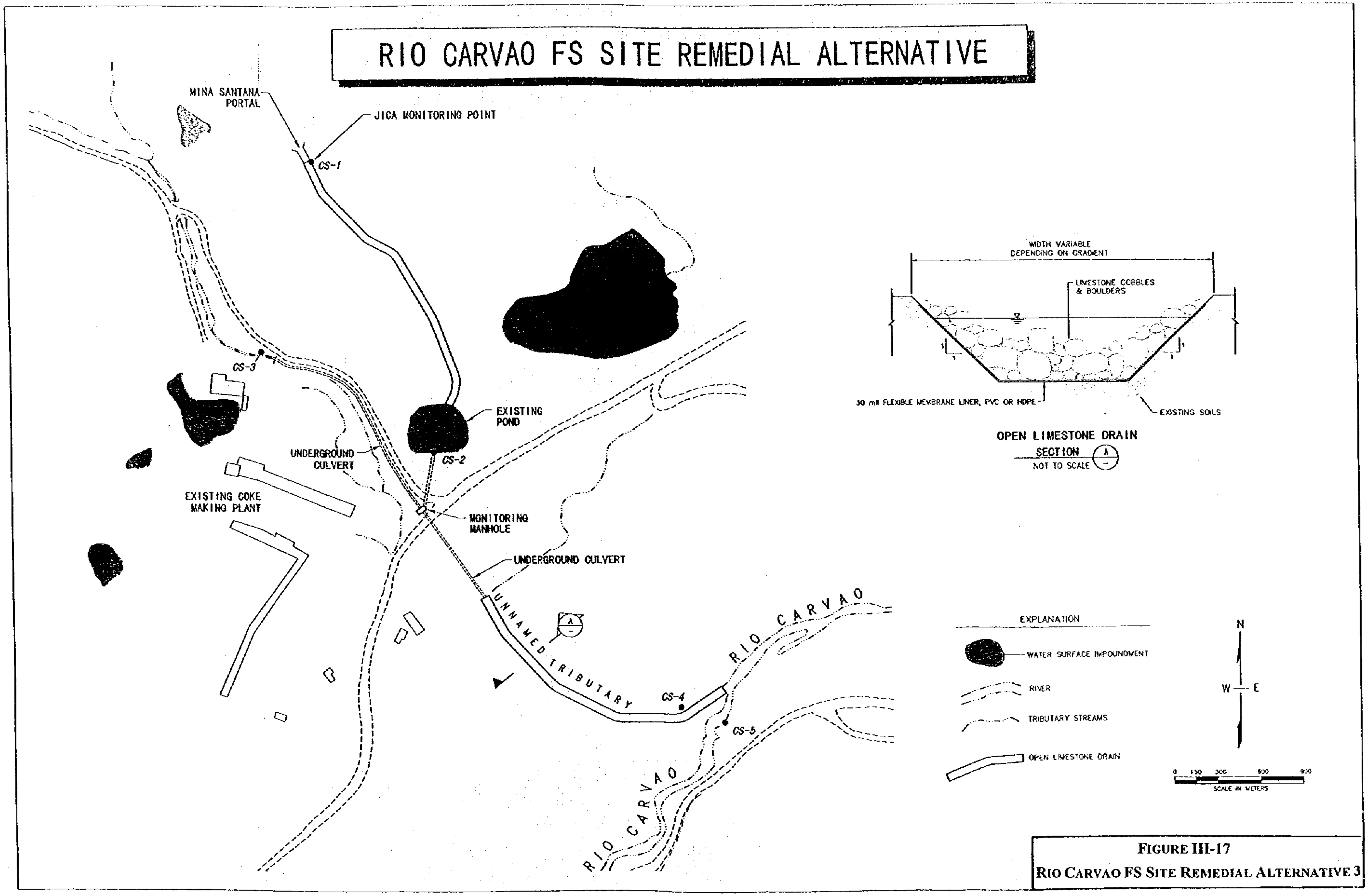


FIGURE III-17
RIO CARVAO FS SITE REMEDIAL ALTERNATIVE 3

Alternative 2 would not be physically feasible. In the overall remediation program, Alternative 3 would be only a practical mitigation alternative for improvement of the whole Urussanga river basin.

(d) Capivari Remedial Alternatives

(i) Description

3.40. Since the mid-1940s, uncontrolled disposal of wastes occurred in the marshy flats surrounding the Rio Estiva dos Pregos (Figure III-18). Extensive waste materials were transported by railway from the CSN's Capivari washing plant and disposed of in a low-lying area of peaty soils. A large acid lake (pH 3) was created by gravity, because those soils are extremely soft and was unable to sustain weight of the dumped wastes and sank together with the wastes. Subsequently, dykes were constructed to contain the wastes in the current location. The areas required for remediation total 240 ha, i.e. 80 ha of the acid lake, 80 ha of exposed waste and 80 ha of undisturbed but polluted area south and southeast of the lake.

3.41. The Rio Estiva do Pregos has been diverted into two ditches upstream of the site and north of the major Brazilian highway, BR-101 and both enter the site. The western branch passes under BR-101 and is immediately diverted east by a dike along the northern boundary of the waste disposal area. There is no surface water discharge from the acid lake to the river. Very little seepage into the Rio Estiva dos Pregos occurs along the northern and northeastern dykes. The river appears to be slightly above the water of the acid lake along the northern boundary since the quantity of water in the stream is significantly decreased in the course of flowing from the northern boundary down to the south while the pH of the water changes from 6 to 3.7.

3.42. **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 (FigureIII-19). 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 remedial actions are as follows:

1. Construction of a groundwater cut-off wall;
2. Filling the impoundment with inert material;
3. Covering of reactive wastes and impoundment with a wet cover system; and
4. Construction of passive wetland systems.

3.43. **Alternative 2**: The features of this alternative are surface water diversion, source containment,

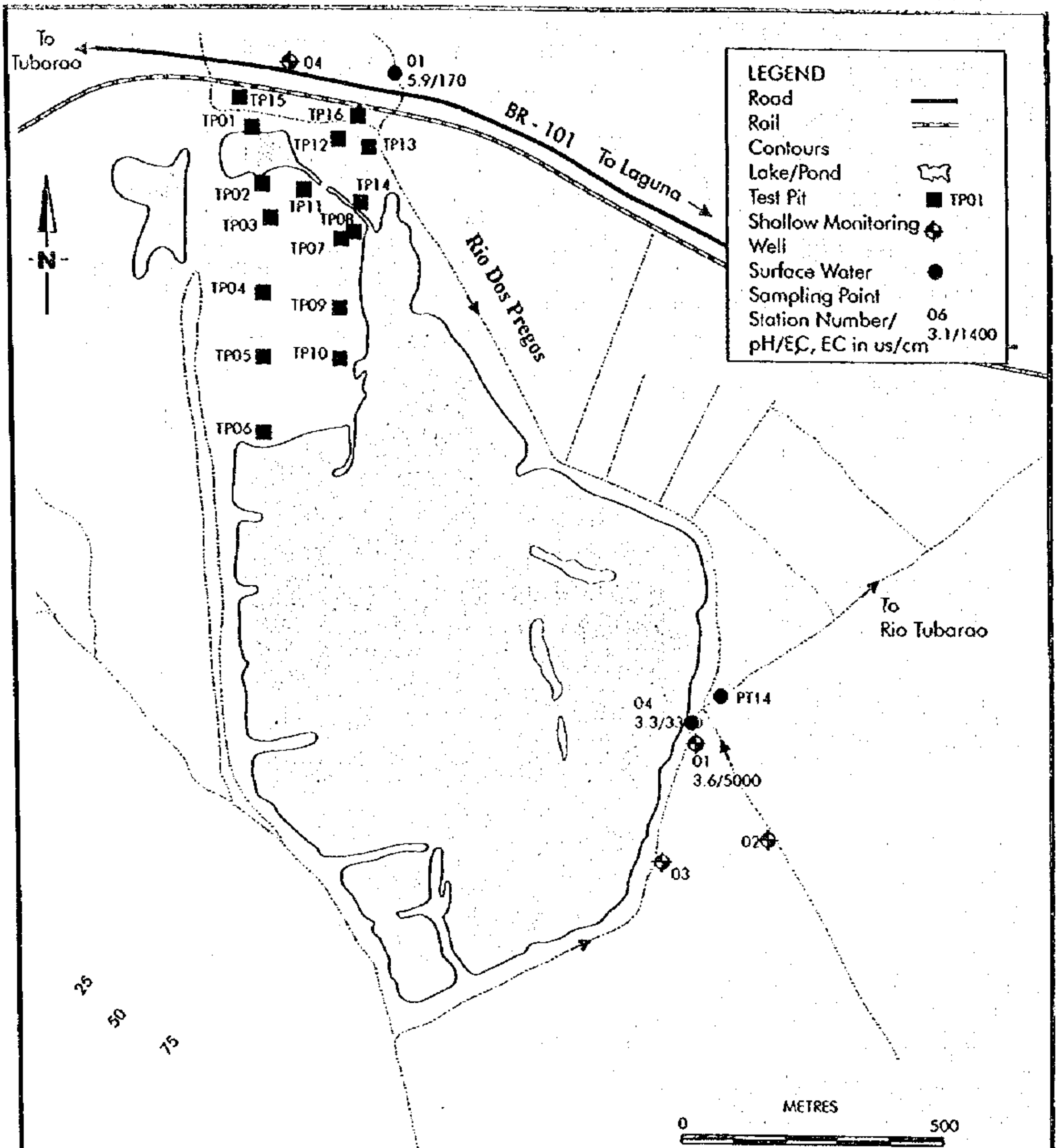


FIGURE BI-18

SITE DRAINAGE MAP AND FIELD CHEMICAL MESUREMENTS

CAPIVARI FS SITE

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

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

CAPIVARI REMEDIAL ALTERNATIVE

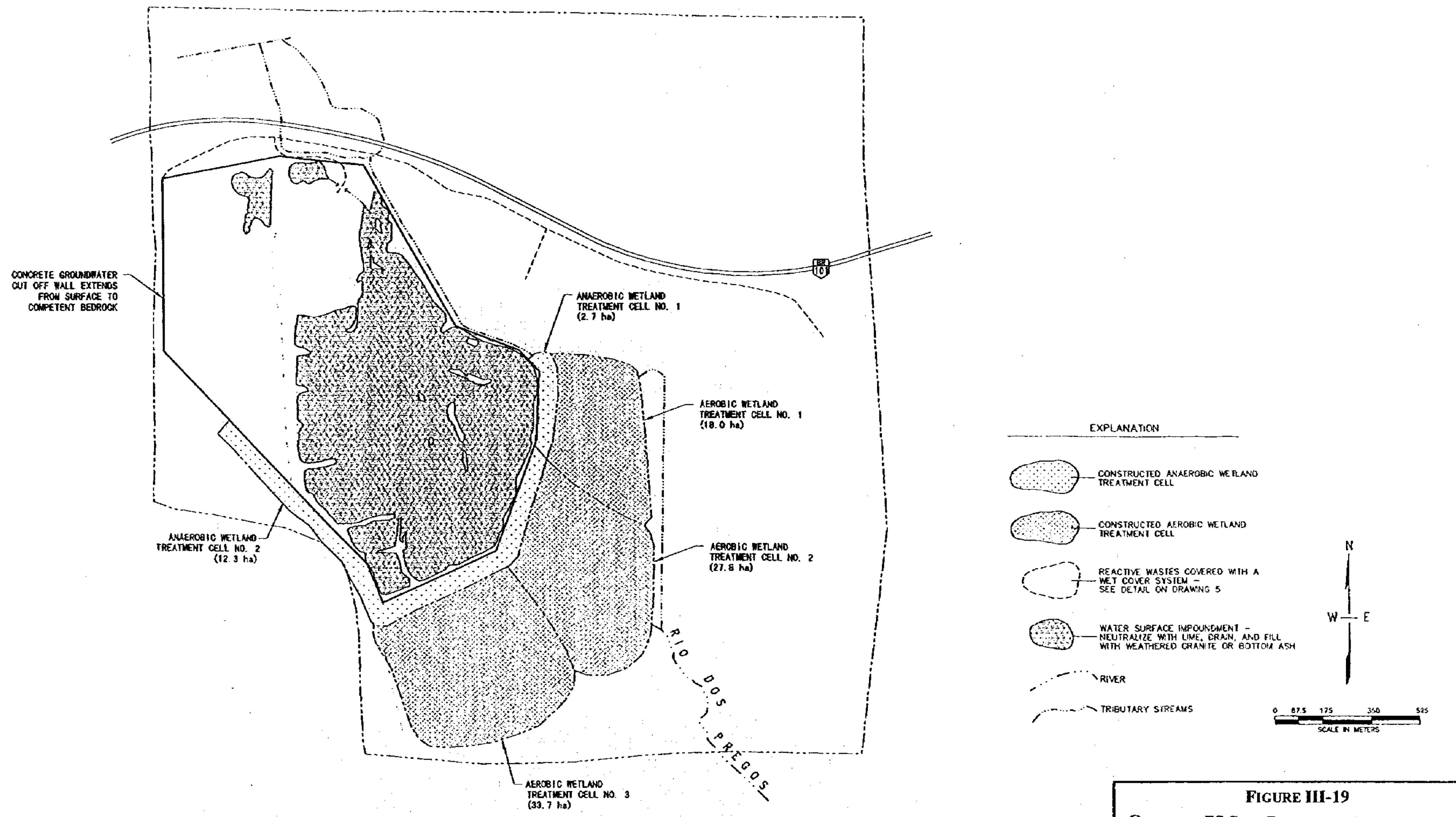


FIGURE III-19
CAPIVARI FS SITE REMEDIAL ALTERNATIVE 1

impoundment closure and passive treatment (Figure III-20). 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:

1. Clean water diversion;
2. Filling the impoundment with inert material;
3. Covering of reactive wastes and impoundment with a wet cover system; and
4. Construction of passive wetland systems.

3.44. **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 (Figure III-21). 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:

1. Filling the impoundment with inert material; and
2. Covering of reactive wastes and impoundment with dry soil cover systems.

(ii) Remedial Cost and Effectiveness Estimates

3.45. The simulation model using the simple equation with assumption of a completely mixed condition was constructed to predict water quality after taking mitigation measures for the Carvão FS site as shown in Section II-B of Main Text. Together with load reduction effectiveness estimated for the alternatives, cost estimates are summarized on Table III-7 below. Details are also presented in Section II-D of Main Text.

TABLE III-7

CAPIVARI REMEDIAL COST AND EFFECTIVENESS

	Loads Reduction Rate (%)	pH [a/]	Cost (RS 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).

3.46. In Alternative 1, the construction cost of the cut-off wall would be almost prohibitive.

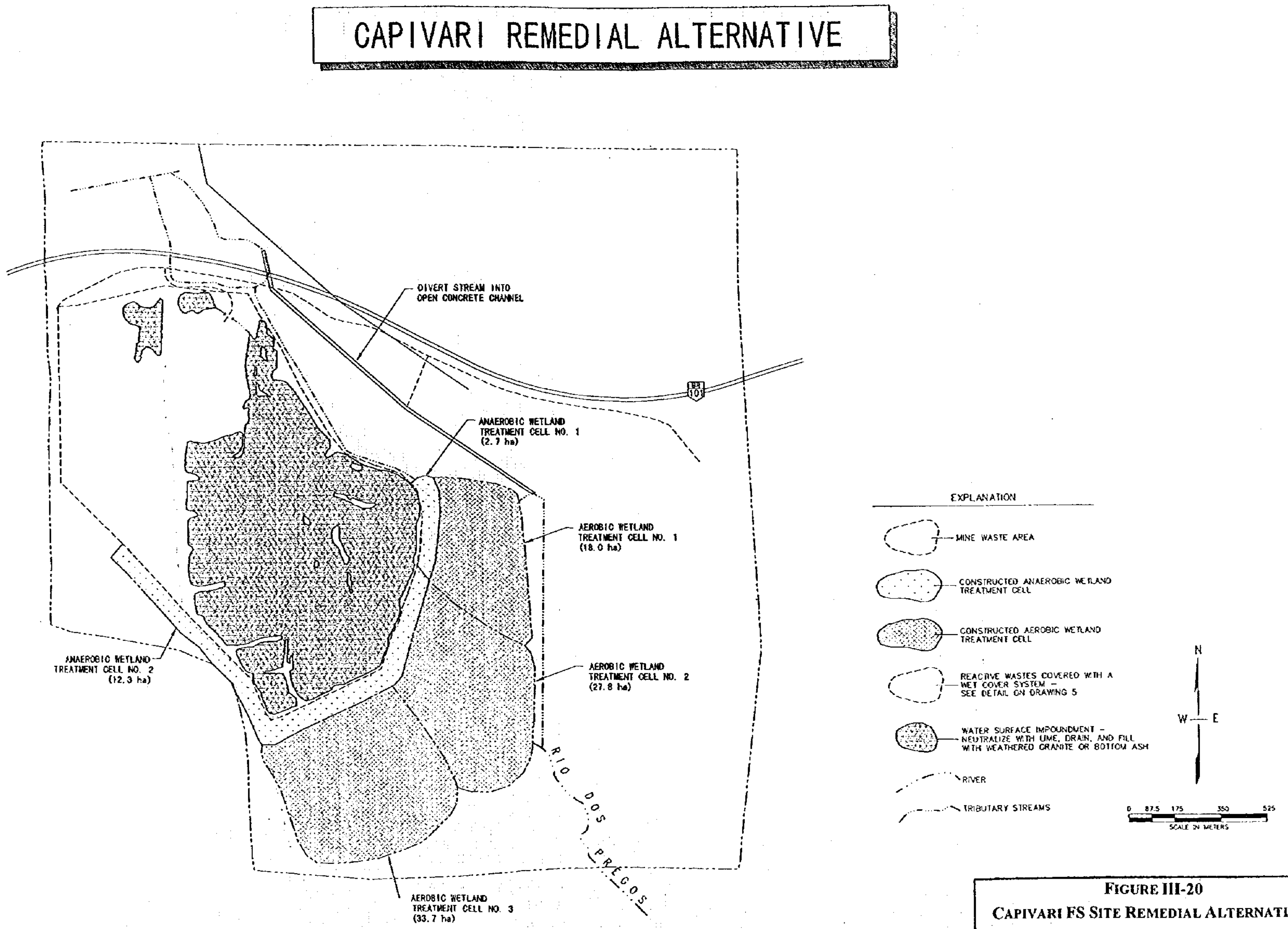


FIGURE III-20
CAPIVARI FS SITE REMEDIAL ALTERNATIVE 2

CAPIVARI REMEDIAL ALTERNATIVE

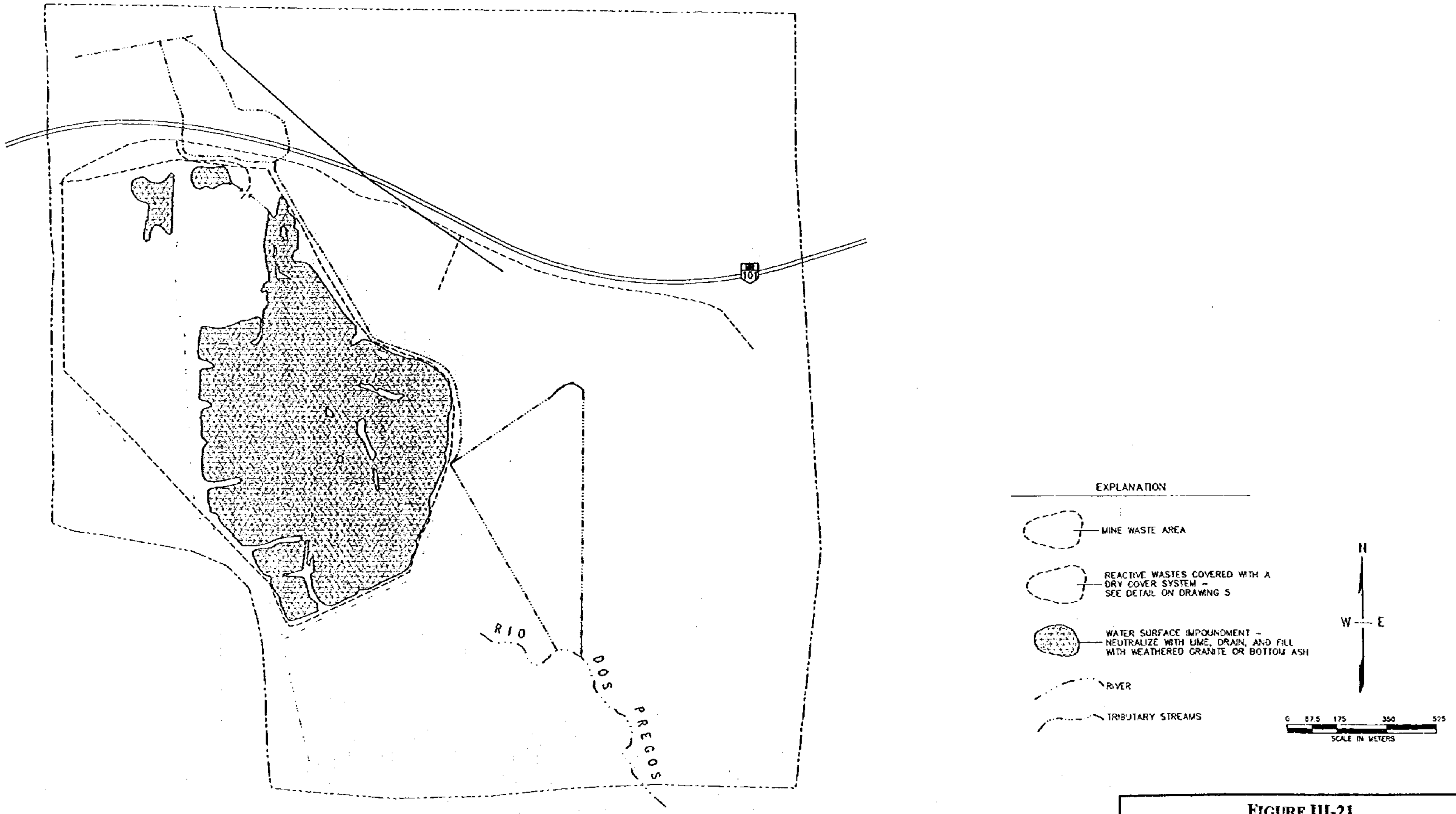


FIGURE III-21
CAPIVARI FS SITE REMEDIAL ALTERNATIVE 3

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*

3.47. 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, has little impact. Both heavy metal concentrations and pH levels remain practically unchanged;

- ⇨ Using more effective technologies, i.e., wet cover or capillary system and passive wetland treatment, would not 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 would allow natural healing forces originating from growing water plants and increased bacteria activity to play, thus further neutralizing the water. Overall remediation for washery reject dumps should be based on the combination of wet cover system and passive wetland;

- ⇨ The active treatment would achieve loads reduction by nearly 100 percent. As in the case of the Carvão FS site, which is being surrounded by discharges of 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.

- ⇨ 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.

3.48. ***Land use restriction.*** After remediation, limited areas, such as black shale waste disposal areas, channel improvements, water diversion structures, wetland treatment systems, etc., must be protected from human activity that would degrade these facilities. However, these areas are expected to be suitable for livestock grazing and waterfowl and wildlife habitat. More intensive human activity such as residential development, farming or timber production would have to be restricted, specifically in the areas capped with wet cover systems. On the other hand, reclaimed overburden waste areas are expected to be suitable for a variety of land uses, including park land and recreation, livestock grazing, timber production, or other uses.

D. *Overall Remediation*

1. Approach to Overall Remediation

3.49. Technologies applicable to the region's acid rock drainage (ARD) mitigation, including design criteria, are presented in Section II-C-1 of Main Text. However, due to the fact that this is only a pre-feasibility study, individual pollution sources as well as waste dumps in the whole study area have not been fully identified to discuss specific designing for individual waste dumps. It is therefore assumed that remedial actions taken in the FS sites study could be applicable for overall remediation. 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. Overall waste dumps are classified into several patterns with similar characteristics in terms of remedial actions using database parameters such as waste type, topographical type and whether it is "with river" or "without river".

3.50. Overall remedial actions for overburden waste dump are based on the Fiorita study. However, washery reject treatment was eliminated from overall overburden remedial actions, since reject is 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 coefficient 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 action is with or without river bank protection work (revetment). The remedial actions are as follows:

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

3.51. Overall remedial actions for washery reject dump 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 wet cover system is relatively expensive, another category was added, which is a reject dump not directly connected with rivers and groundwater 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 Main Text. The remedial actions are as follows:

(A) Wet cover and wetland

1. Re-grading;
2. Road construction;
3. Wet covering;
4. Channel construction;
5. Wetland construction:
6. Re-vegetation; and
7. River revetment, if the river exists in the dump area.

(B) Dry cover (This is identical to the overburden remedial actions without river flow.)

1. Overburden waste re-grading;
2. Road construction;
3. Dry covering; and
4. Re-vegetation.

2. Overall Remediation Cost Estimates

3.52. Unit costs (R$1000/ha) for varying waste dumps according to the above definitions are summarized in Table III-8.

3.53. Overall costs include those for remediation of abandoned, active and inactive areas. However, it should be noted that remediation costs for the active and inactive areas do not include investments needed for current operations to comply with environmental regulations.

3.54. Estimated overall remedial costs are presented in Tables III-9 through III-11.

TABLE III-8

ESTIMATED OVERALL REMEDIAL UNIT COSTS

Waste Type	Topo-Type	River	Unit Costs (R$1,000/ha)
	Saw	River Flow	29.1
	Saw	No River	25.8
Overburden (White Waste)	Heap	River Flow	26.6
	Heap	No River	23.2
	Flat	River Flow	20.9
	Flat	No River	17.5
	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

TABLE III-9

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
Overhead	18,840	17,890
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 III-10

OVERALL REMEDIAL COST ESTIMATES BY LAND STATUS (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	14,355
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	85,528
Forquilhinha	Black Shale	Flat	River flow	165.5	14,284	191.2	16,502			356.7	30,785
	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	Sew	No river	5.0	129					5.0	129
	White Waste	Sew	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	1,395	191.0	14,843			209.0	16,243
	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(sew)	No river	25.0	644					25.0	644
		Pond(sew)	River flow	61.0	1,778					61.0	1,778
	White Waste	Flat	River flow	10.0	209					10.0	209
	White Waste	Sew	No river	113.0	2,911					113.0	2,911
	White Waste	Sew	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(sew)	River flow			2.0	58	6.0	175	8.0	233
	White Waste	Sew	No river	50.0	1,288					50.0	1,288
	White Waste	Sew	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					36.7	3,225	36.7	3,225
	Water	Pond(flatBS)	River flow			4.0	345			4.0	345
		Pond(sew)	No river			1.0	26			1.0	26
		Pond(sew)	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	Sew	No river	322.8	8,315					322.8	8,315
	White Waste	Sew	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	85,193	278.3	16,742	4,723.8	273,603

TABLE III-11

OVERALL REMEDIAL COST ESTIMATES BY LAND STATUS (WET/DRY COVER SYSTEMS)

Unit: $R x 1000

Municipality	Waste Type	Topo Type	River	Abandoned Area (ha)	Abandoned $Rx1000	Active Area (ha)	Active $Rx1000	Inactive Area (ha)	Inactive $Rx1000	Total Area (ha)	Total $Rx1000
Capivari de Baix	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	30,785
	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	56.8	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			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	15,354	169.3	9,871	35.6	2,057	628.1	27,282
Siderópolis	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	2,193			120.8	2,193
	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
Uruçanga	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	889.5	37,653
		Grand Total		3,292.0	162,411	1,153.5	69,521	278.3	16,742	4,723.8	248,673

E. *Overall Water Quality Simulation*

3.55. Overall water quality simulation aimed at mitigated water quality prediction was conducted for the three affected river basins, i.e., Rio Tubarão, Rio Urussanga and Rio Araranguá, except for their tidal areas.

1. Numerical Simulation Model

3.56. The numerical simulation model consists of a flow model and a water quality model. The flow model simulates the flow volume of the river and the water quality model simulates the water quality of the river. Figure III-22 (page 86) shows the structure of the boxes in the simulation model.

3.57. The following is the mass balance equation by the model used to calculate the concentrations of various parameters in each box.

$$C_i = \frac{1}{Q_i} \{Q_{i-1}\, C_{i-1} + (Q_N - \Sigma Q_{AC} - \Sigma\, Q_{AB})\, C_N + \Sigma L_{AC} + \Sigma L_{AB}\}$$

Q_i: River flow volume (m^3/s)
C_i: Concentration in the box (mg/l)
C_N: Concentration of the uppermost area (mg/l)
Q_N: Inflow volume from the catchment area (m^3/s)
Q_{AC}: Inflow volume from active mines (m^3/s)
Q_{AB}: Inflow volume from abandoned mines (m^3/s)
$\Sigma\ L_{AC}$: Load amount from active mines (mg/s)
$\Sigma\ L_{AB}$: Load amount from abandoned mines (mg/s)

2. Assumption of Pollution Load

3.58. The simulation conditions for the load amounts from active and abandoned mines and the precipitation mechanisms of iron and aluminum ions were set up as follows:

(a) Pollution load from active mines

3.59. Based on the hypothesis that pollution load increases in proportion to coal production from active mines, pollution load from active mines was estimated by calculating the load per unit of coal production, using active mine's effluent monitoring results and their coal production records except for Metropolitana Company, whose coal production was one order of magnitude larger than the other monitored mines. Using this unit load and the coal production of each active mine, the pollution load from all of active mines were estimated. The set up water quality of the active mine's effluent is presented in Table III-12.

TABLE III-12

POLLUTION LOAD FROM ACTIVE MINES

pH	(-)	2.81
SO4	(mg/l)	2,838
Dis. Fe	(mg/l)	391
Al	(mg/l)	123

(b) Pollution load from abandoned areas

3.60. The abandoned mine areas are classified as washery reject areas and overburden waste areas. Washery reject areas generally have a high potential for acidic water generation. On the other hand, overburden waste areas have a low potential for acidic water generation. However, overburden areas tend to be pollution sources due to the mixture of pyrite contained overburden or illegal dumping of washery waste. In this model, the pollution load per unit of waste area (ha) was estimated based on the monitoring data from the Rocinha and Fiorita FS sites, as representative of the washery reject area and the overburden waste area, respectively. The set up water quality of the effluent discharged from washery reject areas and overburden waste areas are presented in Table III-13.

TABLE III-13

POLLUTION LOAD FROM ABANDONED AREAS

		Washery reject areas	Overburden waste areas
pH	(-)	3.3	3.2
SO4	(mg/l)	645.0	494.0
Dis.Fe	(mg/l)	94.8	29.5
Al	(mg/l)	44.8	32.7

3. *Prediction of Water Quality Improvement Effects*

(a) Scenarios

3.61. Improvements in water quality generated by taking the acid water control measures were estimated by using the simulation model on the assumption that pollution load from all of the abandoned mines would be evenly reduced at fixed rates of 90% and effluent discharge from all active areas would comply with Brazilian effluent standard. The scenarios assumed are described in para. 3.04 of this chapter.

(b) Equation

3.62. The following is the prediction equation.

$$C_i = \frac{1}{Q_i} \{Q_{i-1} C_{i-1} + (Q_N - \Sigma Q_{AC} - \Sigma Q_{AB}) C_N + \Sigma L_{AC}' + \alpha \Sigma L_{AB}\}$$

$\Sigma L_{AC}'$: Pollution load when all active areas would comply with Brazilian effluent standards.(mg/s)
α : Pollution load reduction rates 90% of those from all of the abandoned mines

(c) Prediction Results

3.63. Table III-14 summarizes results of the case study, including pH values and improvement rates. The characteristics of the findings are as follows:

- ⇨ Scenario I: The largest improvement effect was generated by assuming that acid water is controlled at both active and abandoned mines. The water quality of all the rivers was improved by achieving an average pH value of 5.5, except for the Rio Sangão in the Rio Araranguá basin. In the most effective points, the pH was increased up to 6-7. However, there are some less effective points where pH levels remain below 4. As for the Rio Sangão, the improvement effects were very small and, even at the most effective point, the pH value was about 5. Figure III-22 shows the comparison between the current pH value and predicted pH value in scenario I.

- ⇨ Scenario II: pH was increased up to 4.5-5.0 in average, including the lower and upper areas in the Rio Tubarão and Rio Urussanga. The pH of the upper areas, however, remains below 4.0. In the Rio Araranguá, both branches remains below 4.0 due to the effect of the active mine's effluent.

- ⇨ Scenario III: Relatively large improvement effect was observed in the Rio Mae Luzia in the Rio Araranguá basin, as the average pH was increased to over 4.0. In other rivers, pH remained less than 4.0.

(d) Evaluation

3.64. Based on the existing reports regarding phytoplankton and zooplankton in acidified lakes, a decrease in species richness and diversity of phytoplankton with decrease in pH was observed and the greatest changes in composition were found in the pH interval 5-6, below which characteristic species may often establish large populations in acidified lake. An effect of pH on zooplankton was not observed until lake pH dropped below values of 5-5.5. In the lake with pH less than 5.0, many species are completely eliminated (Green & Leuven, 1986). An effect of pH on benthos was observed in the pH interval 5-6 in the Kitakami river (Hukusima, 1986) and an effect of pH on the high trophic level began below pH value of 6.0 (Sakamoto, 1991). Summarizing the existing reports, the negative effects of pH on aquatic life are found in the pH interval 5-6. These studies imply the possibility of restoring the ecosystem in the polluted rivers, if the pH level can be increase to more than 5, as in Scenario I.

3.65 The pH was increased to more than 5.0 on average for all the rivers except for the Rio Sangão only in Scenario I. These case study results indicate the importance of taking measures for both active and abandoned mines to recover the ecosystem in the polluted rivers. Recovery of the pH to over 5.0 in the Rio Sangão is considered to be difficult because of the narrow catchment area, no large branches with clean water, and intensive concentration of mines.

TABLE III-14

SUMMARY OF CASE STUDIES (pH Values : Improvement Rates)

Unit: -

River			Current condition			Scenario 1 - 90% load redction for Abandoned mine - Regulation for Active mine			Scenario 2 90% load redction for Abandoned mine			Scenario 3 Regulation for Active mine		
			Average	Max	Min	Average	Max	Min	Average	Max	Min	Average	Max	Min
Rio Tubarao		pH (-)	3.8	6.0	2.4	5.3	6.9	3.7	4.9	6.9	3.7	3.9	6.0	2.4
		Increasing rate	1.0	-	-	1.4	1.7	1.2	1.3	1.5	1.0	1.0	1.4	1.0
Rio Urussanga		pH (-)	3.5	4.3	2.8	5.3	6.4	4.3	4.4	5.4	3.6	3.9	5.0	2.9
		Increasing rate	1.0	-	-	1.5	1.8	1.4	1.3	1.4	1.0	1.1	1.3	1.0
	Rio Mae Luzia	pH (-)	3.4	3.7	3.1	5.4	7.0	4.3	3.8	4.9	3.5	4.3	7.0	3.3
		Increasing rate	1.0	-	-	1.6	1.9	1.2	1.1	1.4	1.0	1.2	1.9	1.0
Rio Ararangua														
	Rio Sangao	pH (-)	2.8	3.3	2.5	4.5	5.3	4.0	3.3	3.7	2.9	3.1	3.7	2.7
		Increasing rate	1.0	-	-	1.6	1.7	1.6	1.2	1.2	1.1	1.1	1.14	1.08

* Values are annual average
** Increasing rate: Case # / Present condition
*** Brazilian ambient standard: pH 6-9

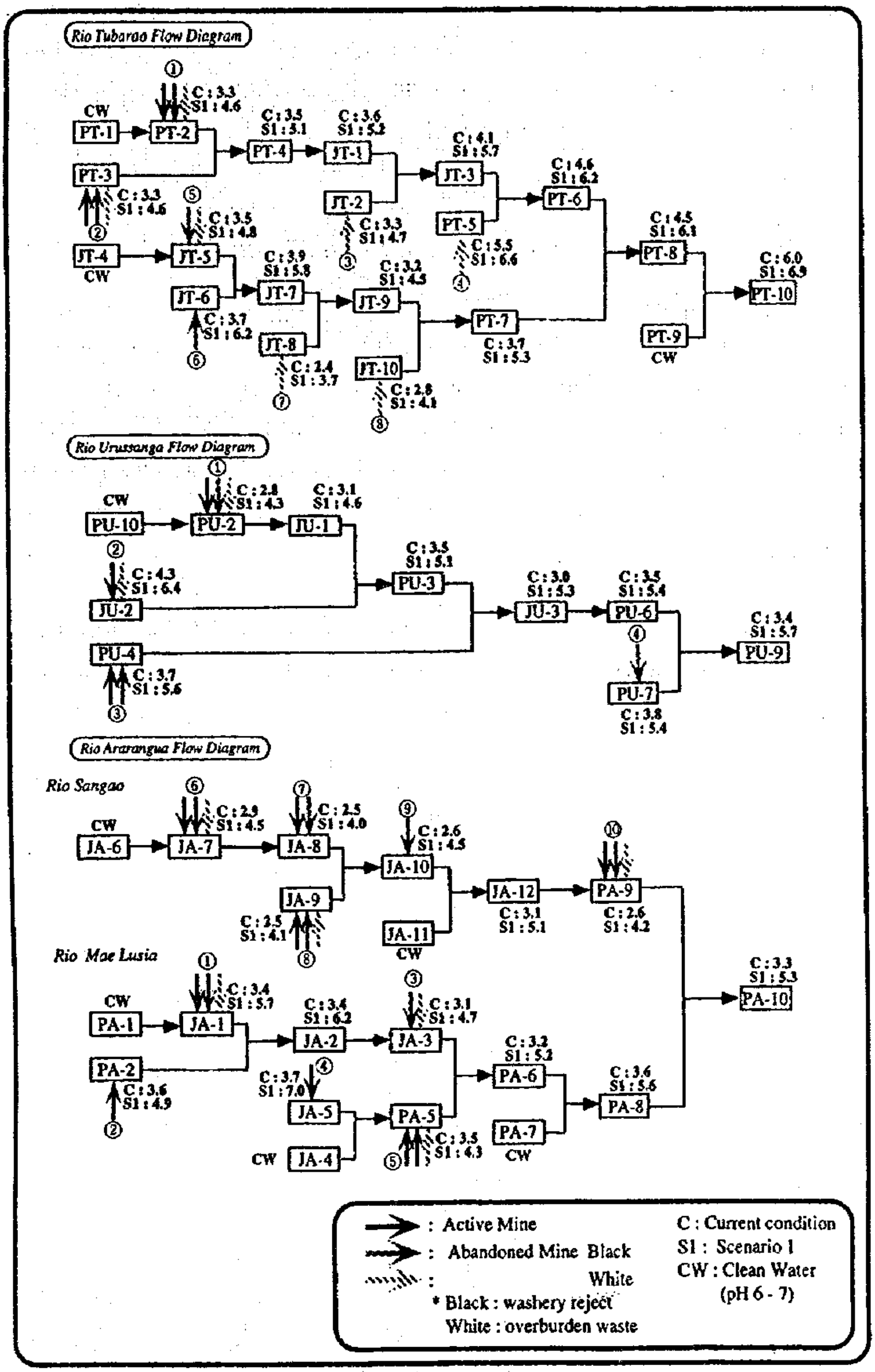


FIGURE III-22 CURRENT PH VALUES AND PREDICTED ONES IN SCENARIO I

3.66. The water quality of all the rivers will not achieve the Brazilian ambient criteria pH 6-9, even if Scenario I is selected. However, as some aquatic life can inhabit water with a pH value of 5.0 or greater, the execution of Scenario I would enhance the self-purification capacity by neutralization of acid with organic materials originating from aquatic life, and would prevent dissolution and leaching of some kinds of heavy metals. Therefore, water quality will be restored in the long term by implementing Scenario I.

F. *Conclusions and Recommendations*

3.67. The water quality simulation shows that even Scenario I would not entirely restore water quality to the level required by existing Brazilian norms for surface water quality in the affected rivers. Neither Scenario II nor Scenario III would achieve any meaningful improvement. Only Scenario I, which is expected to achieve more than pH 5 in the large part of the region's river systems, would reduce acidity and metal concentrations to reach significant levels that would allow natural healing forces originated from growing water plants and increased bacteria activity to play, thus further neutralizing the water.

3.68. It is recommended that not only remediation of mined-out areas but also rehabilitation of active areas, including current operation practices, be incorporated into an overall remedial program. Scenario II or Scenario III would not solve the problem.

CHAPTER IV. STRATEGY AND PROGRAM FOR RECUPERATING MINED-OUT AREAS

A. REMEDIATION STRATEGY

1. Conclusions of the Technical Evaluation

4.01. As discussed in Chapter III above, the mined-out areas are so polluted that the most economical cover system, i.e., dry soil cover system, has little impact. Both heavy metal concentrations and pH levels remain practically unchanged. Using more effective methods, i.e., wet cover or capillary break system and passive wetland treatment, would also not 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 acidity and metal concentrations resulting from these methods would allow natural healing forces originating from growing water plants and increased bacteria activity to play, thus further neutralizing the water. Simulation models built by the JICA Team to test water quality show that the water outside the FS sites partially meets Brazilian norms.

4.02. The technical evaluation further shows that:

1. Using wet cover for the whole black reject area[1] is relatively expensive. However, as in-depth analysis indicates that dry cover may be used in polluted areas not directly connected with rivers or ground water reserves with little risk and similar results (425 ha), a wet/dry cover system could be used. It is in fact the most cost effective method.

2. Active areas (i.e., areas still being used by mining companies for waste disposal and washing) are much more polluted than abandoned areas[2]. Thus, remediation of abandoned areas will most likely not bring any improvement unless active areas are also remedied.

2. Proposed Remediation Strategy

4.03. Given the conclusions of the FS study, particularly the fact that the areas to be remedied are so polluted that no cost-effective method would restore water quality to the level of Brazilian ambient standards for surface water, several alternatives are possible:

- **Do nothing.** This alternative is not acceptable because the pollution problem will continue and most likely get worse;

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[1] Total polluted area: 4724 ha, Black reject area: 2,526 ha, Overburden waste area: 2,198 ha

[2] Abandoned area: 3,292 ha, Active area: 1,154 ha, Inactive area: 278 ha

- **Make mining companies comply with environmental regulations. Do not do any remediation.** This alternative does not appear feasible because it is not reasonable to expect mining companies to discharge mining water according to norms when the surrounding rivers where the discharged water will finally end up remain polluted; and

- **Address the problem using the most cost-effective approach, i.e., using a wet/dry cover system.**

4.04. To solve the problem requires remediation. There is no other alternative. Also, as discussed above, although the water inside the FS sites does not meet Brazilian standards, outside the SF sites partially meets these standards. Even if it did not, growing water plants and increased bacteria activity in the FS sites will further neutralize the water and eventually achieve Brazilian standards.

4.05. However, to minimize the risks, a two phase approach is proposed. In the first phase, remediation would be limited to active areas. As mentioned above, active areas are the most polluted and their clean up is a *sine qua none* condition for the success of any remediation program. As these areas are still being used by mining companies in their normal extraction and beneficiation activities, the first phase should also include measures to help these companies conduct their operations in an environmentally responsible manner and address the issue of strengthening FATMA (and other agencies involved in monitoring mining operations, such as DNPM) to ensure that mining companies fully comply with environmental regulations, particularly with regard to water discharge and recuperation of mined-out land.

4.06. It is only when active areas are totally remedied and mining companies are in full compliance with environmental regulations that the second phase focusing on remediation of abandoned areas would be implemented. This strategy is safer, cheaper, and easier to manage.

- Safer because no remediation investment will be made unless mining companies properly discharge used water and comply with environmental regulations. Measures and actions to strengthen FATMA and DNPM and improve mining operations would be implemented first. Thus, the financial loss resulting from an eventual project failure (e.g., mining companies' non-compliance to environmental regulations) would therefore be relatively small;

- Cheaper because remediation of active areas, coupled with environmental compliance of mining companies, are likely to lower pollution loads in abandoned areas, thus decreasing their remediation cost; and

- Easier to manage because breaking the project down into two phases facilitates financing as well as implementation.

4.07. **It should, however, be noted that unless the two phases are implemented, no significant benefits are to be expected.**

B. Remediation Cost and Benefits

1. Cost Estimates

4.08. The total cost of the remediation program has been estimated using the following assumptions:

- The overall remediation program will use a wet/dry cover system. Prices for the major items of the program (labor, equipment, spare parts, and materials, such as cement, gravel, limestone, sand, clay, etc.) have been calculated using quotations given by local construction companies, such as SETEP (*Sociedade de Estudos de Topografia e Construções*), and double-checked with the *Departemento de Estradas de Rodagem de Santa Catarina*; and
- It is likely that mining companies which own 81% of the polluted land will do the remediation work themselves as they are equipped to do so. This may also be the case for the municipalities (owners of 7% of the polluted land) which can rely on the Santa Catarina Government to help them carry out the work[3]. Thus, 88% of the remediation is likely to be done by force account instead of being contracted out. For simplicity, we assume that the Santa Catarina Government will also help the private individuals, owners of the remaining 12%, so that all the work would done by force account. Thus, the market prices for materials estimated above would be decreased by 15%, while costs such as depreciation, profits, etc. would be ignored.

4.09. Table IV-1 below shows that the total cost of the remediation program is estimated at R$145.0 million, including 10% physical contingency, i.e., an average cost per hectare of R$30,700.

TABLE IV-1

TOTAL REMEDIATION COST

	R$million
Materials	98.2
Consumables	10.0
Parts	10.2
Seeds, Chemicals, etc.	7.2
Engineering	6.2
Contingency	13.2
Total	145.0

[3] Santa Catarina's Agriculture Secretariat as well as the Road Construction Department of the Transportation Secretariat have the necessary equipment to do the work by force account.

4.10. Abandoned areas account for about two thirds of the total cost (R$93.5 million and active areas (including some 278 ha currently not used by mining companies because of a temporary stoppage of production) for about one third (R$51.5 million).

2. *Benefit Estimates*

4.11. An in-depth study undertaken with UNESC's assistance to quantify the likely social and economic benefits to the region resulting from the remediation of the environmental damages caused by coal mining pollution appears in Section III of Main Text.. A summary of the quantifiable benefits is shown on Table IV-2 below.

TABLE IV-2

SUMMARY OF BENEFITS
(R$ million)

	Minimum	Maximum
Land Pollution		
- Increase in Land Value	77.0	191.2
- Forestry Resources	19.5 every 7 years	19.5 every 7 years
- Fauna and Flora	2.3/year from year 5	9.3/year from year 5
- Recreational Use	2.2/year from year 5	8.5/year from year 5
Water Pollution		
- Higher Water Cost	13.3/year	28.7/year
- Additional Investments	52.5	52.5
- Bringing Water to Non-Connected Areas	1.0/year	1.0/year
- Rice Cultivation	5.0/year	14.8/year
- River Fishing	0.6 in year 5 to 16.7 in year 25	1.2 in year 5 to 35.2 in year 25
- Fisheries Resources*	33.2 in 5 years	33.2 in 5 years
Land and Water		
- Tourism Development*	1.1/year	1.1/year

Source: JICA Team's estimates
* Benefits contingent upon other measures.

4.12. The project also generates many important non-quantifiable benefits such as improvement of environmental protection in Santa Catarina and arresting pollution of ground water. The calculations also ignore the multiplier effect of increased economic activity and production as a result of the remediation. These are described in Annex Section III and should be taken into account when evaluating the merits of the project.

3. *Economic Viability of the Project*

4.13. Taking the economic value of the cost estimated in Table IV-1 above (i.e., total cost of R$145.0 million minus taxes estimated to average 16%) and only minimum benefits as calculated in Table IV-2 (Base case), the project's economic rate of return (ERR) is estimated to be 16.8%, assuming an implementation period of 10 years. Sensitivity analysis, assuming an increase in cost and a decrease in benefits of 15%, shows that the ERR remains acceptable at 14.3%.

C. *THE FIRST PHASE: ENVIRONMENTAL IMPROVEMENT OF MINING OPERATIONS AND REMEDIATION OF ACTIVE AREAS*

1. *Description*

4.14. The first phase would have two components:

1. **An institutional strengthening component** to address the needs of FATMA, DNPM and other public agencies involved in monitoring coal mining operations, as well as those of the mining companies themselves. Financing would include staff training, improvement of operating policies and procedures, equipment, such as vehicles and computers, to increase staff efficiency, water quality monitoring equipment (mining companies only), as well as improvements of the coal mining's policy and institutional framework as described in paras. 2.58 - 2.72 of Chapter II above; and

2. **An investment component** to finance the remediation of the active areas and other capital requirements of mining companies (such as water neutralization plants) to help them comply with environmental regulations.

4.15. *Remediation investments would start only when mining companies have improved their operations (with the assistance financed under the project) and fully comply with environmental regulations.* This phased approach minimizes risks and simplifies project execution, as efforts are first concentrated on implementing the institutional strengthening component and on ensuring that mining companies properly carry out the water neutralization investments. This simplification should improve the project's chances of success.

2. *First Phase Cost Estimates and Financing*

4.16. Cost estimates of the first phase as well as illustrative financing schemes are presented on Table IV-3 below for discussion. They are not based on detailed project information which does not exist at present. Their main purpose is to give an order of magnitude of the project. Detailed cost estimates will be prepared when the decision to go ahead with the project is taken.

TABLE IV-3

PHASE I: PROJECT COST AND FINANCING

	R$ MILLION	%
Cost		
- Institutional Strengthening Component	5.3	7.4
- FATMA	(3.3)	(4.6)
- DNPM	(1.0)	(1.4)
- Mining Companies	(1.0)	(1.4)
- Investment Component	66.7	92.6
- Remediation of Active Areas	(51.5)	(71.5)
- Water Neutralization[a]	(15.2)	(21.1)
Total	**72.0**	**100.0**
Financing		
- Mining Companies	51.7	71.8
- Remediation	(36.5)	(50.7)
- Water Neutralization[a]	(15.2)	(21.1)
- Santa Catarina Government	10.0	13.9
- Remediation	(10.0)	(13.9)
- Federal Government	10.3	14.3
- Remediation	(5.0)	(6.9)
- Technical Assistance	(5.3)	(7.4)
Total	**72.0**	**100.0**
Sources of Financing		
- Loan from International Lenders[b]	40.0	55.5
- Mining companies	11.7	16.3
- Federal Government	10.3	14.4
- Santa Catarina Government	10.0	13.8
Total	**72.0**	**100.0**

[a] Passive wetlands. This investment is needed only to the extent that mining water cannot be evacuated from the mines fast enough to be contaminated with pyrite acidity. A thorough assessment should be done during project preparation. On the other hand, investments, such as improvements of settling ponds or closed circuit systems, may be needed to make current operations in compliance with environmental regulations. They should also be estimated at the time of project preparation.

[b] In addition to the loan from bilateral or multilateral lenders, it is possible that JICA accept to finance partly or totally the strengthening of DNPM and/or FATMA on a grant basis.

4.17. Mining companies would finance about 72% of the total cost of the first phase, including 100% of the water neutralization cost and over 70% of the remediation cost. However, they are expected to recuperate most of it through an increase in land value[4]. The sector as a whole would not be financially affected, although the situation may be different at the individual company level, depending on the value of the land. Mining companies would also benefit from technical assistance available under the project to improve mining operations.

4.18. Contribution by Santa Catarina state would amount to R$10 million (about 14% of the total project cost). However, it is expected to recover most of it, if not all, through increases in sales taxes resulting from the recuperation work. In addition, Santa Catarina would receive resources from the Federal Government to strengthen FATMA.

4.19. Finally, the Federal Government would contribute the remaining R$10.3 million (14% of the project cost) but, like Santa Catarina, it would also recuperate part of it through an increase of profit taxes brought about by the recuperation activities.

4.20. An external loan in an amount of R$40 million would be contracted from bilateral or multilateral lenders to help finance the investment component (remediation and water neutralization). These funds would be passed on to BADESC (Banco de Desenvolvimento do Estado de Santa Catarina, Santa Catarina's development bank) for on-lending to mining companies at prevailing market conditions. It is possible that, in addition to the external loan from bilateral or multilateral lenders, JICA accept to finance the strengthening of DNPM and/or FATMA on a grant basis.

3. *Organization, Management and Implementation*

(a) Overall Coordination

4.21. Because of the important role that the state of Santa Catarina will play (either as the borrower of the external loan or as the main public institution responsible for the remediation program), it is proposed that the Special Projects Division within the Office of the Governor be the project's overall coordinator. It will be assisted by FATMA. Also, a Project Management Unit (PMU) would be created within the Special Projects Division to help manage and coordinate the various components of the program. PMU's main tasks are to: (i) monitor overall project implementation. This includes preparing periodic progress reports for the Brazilian authorities as well as for the external lender(s) and helping solve technical problems which may arise during implementation; and (ii) be the external lenders' main contact. The Unit will have a small technical staff and will report directly to the Governor.

[4] Mining companies are expected to finance R$36.5 million toward the cost of remediation, while the value of the recuperated land is estimated between R$32.1 million and R$76.5 million.

(b) The Institutional Strengthening Component

4.22. Given the importance of strengthening FATMA, as well as the central role it will play in the project, it is proposed that FATMA be responsible for the implementation of this component under PMU's overall supervision, with the exception of DNPM strengthening, which would be managed by DNPM itself. The principles governing the implementation and disbursement of funds for the various beneficiary agencies are as follows:

- **Coal Mining Policy and Institutional Framework.** A federal commission composed of representatives of MME, DNPM and SIECESC would be established to prepare a program aimed at strengthening the policy and institutional framework for coal mining operations along the lines of the recommendations in paras. 2.58 to 2.72 of Chapter II;

- **FATMA** would prepare and implement a strengthening program based on the directives outlined in paras. 2.112 to 2.126 (pages 34 to 37) above. Disbursements of funds will be conditioned upon the successful implementation of the various actions included in the strengthening program;

- **DNPM** will be asked to make a comprehensive assessment of its needs and to prepare a plan of action to improve its capacity to monitor the activities of coal mining companies. Approval of such a plan would be a condition of disbursement of funds for DNPM's technical assistance; and

- **Mining Companies.** There are at present six companies extracting and washing coal in Santa Catarina. They all need strengthening, although the needs may vary from company to company. To help them prepare strengthening programs (including detailed mining plans specifying waste materials control measures) tailored to their specific needs, funds for short-term consultant services would be available under the project. Approval of individual strengthening programs would be a condition of disbursements for technical assistance to each mining company. Given the delicate financial situation of most of them, subject to the Brazilian authorities' approval, it is proposed to provide the technical assistance on a grant basis. This would also provide an added incentive for the mining companies to comply to environmental regulations.

(c) The Investment Component

(i) *Financial Arrangements*

4.23. Funds for remediation would be on-lent from the Federal Government or the state of Santa Catarina (depending on who is the borrower of the external loan) to BADESC for re-lending to mining companies. Terms and conditions for the transfer of funds (i) from the Federal Government or the state of Santa Catarina to BADESC and (ii) from BADESC to the mining companies (interest rates and maturity of the subloans, foreign exchange risk, subproject risks, subproject appraisal and supervision, disbursement of funds, etc.) would be agreed between the various parties during project preparation. However, they should, by and large, reflect on-going market conditions in Brazil.

(ii) *Administrative Arrangements*

4.24. BADESC would manage the investment component under PMU's overall supervision. The bank would be responsible for appraising the remediation proposals (subprojects) presented by mining companies, for assessing their soundness, for disbursing the funds and supervising the implementation of the remediation work. BADESC would assume the project risk and be responsible for loan collection.

4.25. FATMA and DNPM would be responsible for ensuring that remediation proposals are technically and environmentally sound. They should approve the proposals before the bank can finance them. Refusal by a mining company to remedy mined-out land would result in the revocation of its operating license.

D. THE SECOND PHASE: REMEDIATION OF ABANDONED AREAS

1. Governing Principles

4.26. The second phase would consist of recuperating the 3,292 hectares of land abandoned after being mined-out and left without any remediation. As discussed in para 4.07 above, it is imperative that all the polluted land be remedied for the environmental benefits to materialize.

4.27. As a principle, owners of the polluted land should be responsible for the remediation as they will benefit through an expected increase in the value of the land which could be substantial. As shown on the table below, 76% of that land belong to mining companies, 14% to private individuals and the remaining 10% to municipalities. These owners are thus expected to pay for the remediation cost.

TABLE IV-4

OWNERSHIP OF ABANDONED AREAS
(IN HECTARES)

	Polluted Land	
	(ha)	(%)
Private Individuals	448	14
Mining Companies [a]	2,504	76
Municipalities	340	10
Total	3,292	100

Source: JICA Study Team
[a] Including CSN (*Companhia Siderúrgica Nacional*)

4.28. However, given the externalities and the fact the present owners may not be the original polluter, it is proposed that the Federal Government and the state of Santa Catarina also help by contributing 10% each toward the total remediation cost. The cost sharing among the different parties involved would be as follows:

- Landowners:	80%
- Santa Catarina state	10%
- Federal Government	10%

4.29. A landowner who select not to remedy his land may do so by giving it to the municipality where the land is located. Like the first phase, funds would be made available through BADESC to help landowners who do not have the cash to finance the remediation work.

4.30. A commission chaired by FATMA and composed of representatives of AMREC and Santa Catarina state would be established to oversee the remediation process. SIECESC and representatives of individual landlords could also participate as observers. The commission's main responsibilities would be to: (i) check the authenticity of land titles; (ii) approve remedial proposals presented by landowners; (iii) register land donations to municipalities by landowners who do not want to remedy; and (iv) ensure that the whole process is fair and transparent.

2. *Description*

4.31. Like the first phase, the second phase would have two components:

1. **A technical assistance component** to (i) help landowners prepare remedial proposals as well as loan requests to BADESC; and (ii) support the work of the Commission in areas where its technical expertise is lacking; and

2. **An investment component** to help finance the remediation cost.

3. *Second Phase Cost Estimates and Financing*

4.32. At this stage, cost and financing of the second phase can only be rough estimates. Firmer costs would be calculated when the first phase is completed and a technical assessment conducted on the level of pollution reduction achieved. The rough cost estimates are presented on Table IV-5 below only for discussion and to show the magnitude of the project.

TABLE IV-5

PHASE II: PROJECT COST AND FINANCING

	R$ MILLION	%
Cost		
- Technical Assistance Component	5.0	5.1
- Remediation Commission	(0.5)	(0.5)
- Landowners	(4.5)	(4.6)
- Investment Component	93.5	94.9
Total	**98.5**	**100.0**
Financing		
- Landowners[1]	74.8	75.9
- Mining Companies[2]	(56.9)	(57.8)
- Private Individuals[2]	(10.2)	(10.3)
- Municipalities[2]	(7.7)	(7.8)
- Santa Catarina Government	11.8	12.0
- Remediation[1]	(9.3)	(9.4)
- Technical Assistance	(2.5)	(2.6)
- Federal Government	11.9	12.1
- Remediation[1]	(9.4)	(9.5)
- Technical Assistance	(2.5)	(2.5)
Total	**98.5**	**100.0**
Sources of Financing		
- Loan from International Lenders[3]	60.0	60.9
- Landowners[3]	14.8	15.0
- Santa Catarina state	11.8	12.0
- Federal Government	11.9	12.1
Total	**98.5**	**100.0**

[1] Based on the cost sharing formula on para. 4.28

[2] Based on landownership structure as shown on Table IV-4

[3] Assuming a debt/equity ratio of 80:20, i.e., landowners will finance the recuperation with a loan from BADESC (through international lenders) representing 80% of the cost and will cover the remaining 20% with their own funds.

4. *Organization, Management and Implementation*

(a) Overall Coordination

4.33. The Remediation Commission would be the overall coordinator of the project. It is, *inter alia*, responsible for (i) managing the technical assistance funds available under the project to help landowners prepare remedial proposals and loan requests to BADESC; (ii) monitoring overall project implementation progress; and (iii) relations and contacts with the Brazilian authorities and the external lender(s).

(b) The Investment Component

4.34. Like in the first phase, funds for remediation would be passed to BADESC for re-lending to landowners at the same conditions as in the first phase. BADESC would be responsible for appraising the remedial proposals, for assessing their soundness, for disbursing the funds and supervising the implementation of the remediation work. It would assume the project risk and would be responsible for loan collection.

POST SCRIPT

PS1. In spite of indication from the title of this Study, "Feasibility Study on Recuperation of Mined-Out Areas", the Team's conclusions and recommendations have turned out to be the clean-up of active mining and reject re-washing areas first. In addition to the fact that the four FS sites are so polluted that even using most effective technologies would not restore water quality to the level required by existing Brazilian norms for surface water quality within the FS sites themselves, the active areas are much more polluted than the abandoned areas, so that remediation of the abandoned areas will most likely not bring any improvement unless the active areas are also remedied.

PS2. Remediation of both areas (active and abandoned) and full compliance of mining companies with Brazilian environmental regulations would have the results of bringing the pH level of the water to more than pH 5, due to significant reduction of acidity and metal concentrations. This would allow natural healing forces originated from growing water plants and increased bacteria activity to play, thus further neutralizing the water.

PS3. To solve the problem requires remediation. There is no other alternative. Since , in addition to the most polluted area, the active areas (1,432 ha) account for less than half the abandoned area (3,292 ha), a two phase approach is proposed to minimize the risks. In the first phase, remediation would be limited to the active areas. In response to a strong request from the counterpart, FATMA, the proposed program has included improvement of coal mining operations and strengthening of environmental protection in Santa Catarina with a view to formulating a comprehensive program aimed at ensuring that this severe pollution from coal mining and non compliance with environmental regulations would not occur again in the future. It is only when active areas are totally remedied and mining companies are in full compliance with environmental regulations that the second phase focusing on remediation of the abandoned areas would be implemented. **It should, however, be noted that unless the two phases are implemented, no significant benefits are to be expected.**

PS4. **NEXT STEPS FOR THE FIRST PHASE:** Given the project's change of focus (from remediation of abandoned mined-out areas to active areas), the Team recommends that more work be needed to complete the Study prior to implementation of the first phase. This additional work includes, *inter alia,* (a) review of individual mining and reject re-washing plans to have a better handle of the project cost; and (b) thorough assessment of the financial condition of the mining companies to ensure that they can meet their financial obligations under the project.