8. ECONOMIC ASPECTS OF MINING OPERATIONS

142. Given its geological characteristics (especially the high ash content), Santa Catarina's coal must be consumed near the mines. The sulfur content of the ROM coal has a maximum value of 4.5% in the Barro Branco seam and 6.0% in the Bonito seam. Submitted to washing reduces the ash content from 62% to between 35% and 42%, and the total sulfur content from 4.5% to between 1.8% and 2.5%. With these characteristics, the region's coal is mainly used in power plants and in the cellulose, food and petrochemical industries. Secondary uses include gasification in the ceramics industry and as an energy source in cement plants.

8.1 Principal Consumers

143. The region's coal is mainly used for power generation at Eletrosul's Jorge Lacerda thermoelectric complex located in Caprivari de Baixo. The plant has an installed capacity of 482 MW and consumes about 1,320,000 tons of CE 4500 per year. This represents about 65% of coal sales in 1995. Indeed, thermoelectric generation represents a viable alternative for the sustainable development of the coal sector. Prospects for the growth of steam coal consumption are linked to the start-up operation of Jorge Lacerda IV, a power generation plant with a capacity of 350 MW, scheduled for early 1997, which may consume up to 125,000 tons of CE 4500 per month. Another possibility is a stronger energy demand, which will gradually increase capacity utilization at existing power plants, currently operating at 40%. At 80% capacity utilization, coal consumption would increase from the present 120,000 tons per month to more than 170,000 tons per month.

Table I-11

Coal Consumption by Sector, 1991-1996
(In percent)

	1991	1992	1993	1994	1995
Power generation	38.5	53.9	65.4	65.0	65.0
Cement	45.0	24.6	20.0	18.6	19.3
Coke Industry	7.2	6.3	2.9	4.4	1.3
Paper/Cellulose	3.0	2.4	1.6	1.5	0.3
Mining	0.8	2.2	0.0	1.7	4.6
Food Industry	1.6	2.5	3.8	3.1	3.8
Ceramics	3.0	3.6	4.0	4.2	3.7
Textile	0.3	0.3	0.3	0.4	0.3
Agroindustry	0.1	0.1	0.0	0.0	0.0
Other industry	0.1	3.0	1.2	0.8	1.5
Total	100.0	100.0	100.0	100.0	100.0
Total Sales (Million tons)	2.787	2.014	1.996	2.031	2.031

144. Coal's other uses have tended to diminish over the past few years. The cement industry which, consumed 45% of the coal production in 1991, only accounted for 19% in 1995. The ceramics and food industries maintained their shares of around 3.7-3.8%, but the coke industry reduced its consumption of Santa Catarina's coal from 7.1% in 1991 to about 1.3% in 1995 as a result of stronger competition from imported coke, mainly from China. Total coal consumption, which reached 2.7 million tons in 1991, decreased to about 2.0 million per year since 1992.

8.2 Transport and Storage

145. Almost all the coal consumed for power generation is shipped by train through the Dona Teresa Cristina railway which links the production areas of Siderópolis, Urussanga, and Criciúma to Tubarão and Imbituba.

146. The coal is stored in two open places near the thermoelectric power plant in Capivari de Baixo city. The stocks now amount to about 1.5 million tons, while they reached more than three million a few years ago. Shipping infrastructure, coal handling and storage at the Imbituba port are now virtually inactive.

8.3 Disposal of "Bottom Ash" and "Fly Ash"

147. The waste generated by coal burning for boilers appear in two forms: wet ash or bottom ash and dry ash or fly ash. Bottom ash (or wet ash), which represents 55% of total ash, is used in the isolation and refractory industry and can be sold for $1.18/ton. The portion which is not sold is stored in flat areas close to the power plant. Dry ash or fly ash (45% of total ash) is largely used by the cement industry and can be sold for about $26.65/ton.

8.4 Gas Emissions

148. Gases generated by the furnaces are treated by electrostatic precipitators, which in the case of the Jorge Lacerda thermoelectric complex operate with coal having a sulfur content in the range of 1.8% to 2.3%. The precipitators function with an extraction of particulate material efficiency of 96%-98%, but do not prevent emissions of SO_x and NO_x.

8.5 Environmental Aspects of Thermal Generation

149. As a result of its high ash content, low calorific value, high sulfur content, and above all, its low beneficiation efficiency, the region's coal faces major difficulties to compete with other available sources of energy. High ash and sulfur content present major problems. Besides increasing transportation costs, ash generates problems in terms of dust emissions and waste disposal. Sulfur, for its part,

constitutes an important limiting factor due to more and more restrictive emissions regulations from environmental authorities. Finally, the low beneficiation rate (about 30% at the Barro Branco seam) makes productivity improvements at mine level a sine qua none condition for the economic and financial viability of the sector. At present, the mining sector is operating at an average capacity utilization rate of 50%-60%. An increase in that rate to 80%-90% would result in a cost reduction of between 15% to 25%.

150. The Bonito seam has a higher beneficiation rate (about 50%) and presents therefore better prospects. However, the factors influencing extraction, including geological characteristics are still insufficiently known and need to be studied more comprehensively.

151. Another bright prospect for Santa Catarina's coal is the possibility of using the coal without washing in fluidized bed combustion technology. This is being studied by Metropolitana, CELESC (*Centrais Eletricas de Santa Catarina*), and the Treviso Municipality.

152. In conclusion, the viability of the coal mining sector in Santa Catarina depends on the following factors:

- ⇒ Productivity improvement at the mine and reduction of administrative costs;
- ⇒ Economies of scale through higher capacity utilization;
- ⇒ Consumption of high ash content coal near the mine;
- ⇒ Development of clean burning technology of high ash and sulfur content coal, such as the fluodized bed combustion method;
- ⇒ Higher beneficiation rate through development of the Bonito seam;
- ⇒ Improvement of the sector investment capacity; and
- ⇒ Adaptation of production and utilization processes to environmental and health requirements.

9. SOCIAL ASPECTS OF MINING OPERATIONS

9.1 Work Environment in Underground Mine

153. The work environment in underground mines is very different from surface activities. Mine workers are subject to higher risks of accidents due to the nature of the work itself or to the equipment/machinery used. He is also exposed to accidents caused by falling rocks from the mine roof and endures more difficult working conditions due to dust, humidity, high temperatures, noise, weak lighting, gases and vibrations generated by blasting.

154. Mining work is considered the most dangerous and is classified by the Federal legislation in category 4, the highest in Brazil. This classification sets the work day at a maximum of six hours and allows special retirement after 15 years of work in the mining face.

155. The environment in underground mines is artificial and requires a perfect control of all the parameters involved to guarantee satisfactory working conditions and to ensure adequate productivity. The diversity of conditions and the high volatility of the environmental factors inside the underground mine require constant vigilance.

156. However, while it is true that the work environment in underground mines is hostile, it is not necessary dangerous. The belief that it is dangerous has generated much distortions in the analysis and evaluation of that activity. The working conditions in Santa Catarina's mines are, unfortunately, not representative of the sector in the world. Here, it is not rare to find factors exceeding maximum acceptable limits (Table I-12). There is also a general deficiency in evaluating the environmental parameters, which makes control and monitoring difficult. In addition, Santa Catarina's mining companies do not possess equipment and safety procedures considered mandatory in other countries, such as rescue teams, self rescuer for carbon monoxide, self-contained breathing apparatus for rescue teams, explosion proof electric equipment, etc. This condition allows some cost savings, but at the expense of the workers' safety and, in the final analysis, results in a higher social cost.

157. There is a lack of specific legislation for coal mining adapted to its special conditions and needs. Existing laws are flawed with inconsistencies, being extremely restrictive in some areas and completely lax in others. For example, the velocity of air flow is defined, but the minimum supply of fresh air is not; or the limitation of SiO_2 dust content in air for inhalation is stipulated, but there is no description of dust explosivity or inflammability. A strengthening of the legal framework for coal mining is indispensable to protect the workers while improving the attractiveness of this activity.

9.2 Jobs and Remuneration

158. The different types of jobs existing today in coal mining are very similar to those existing in the past. The miner as an independent entity from the mine who has the freedom to contract assistants and is paid by production as a contractor has basically disappeared. The function still exists today at some mines, but the working conditions have changed. The miner is an employee like other employees and is submitted to the same rules and norms existing in the company. He receives a basic salary corresponding to a stipulated minimum production and a premium for extra production. The other jobs have also remained basically unchanged with machine operators, mechanics, and electricians appearing as the most attractive financially.

Table I-12

Typical Environmental Conditions in Underground Coal Mines

	Noise	Dust Threshold			Temperature	Illumination	Gas (ppm)					Humidity
	(dB)	mg/m³	Value	SiO_2	(C)	lux	CO	CO_2	SO_2	H_2S	NO_2	(%)
Surface	94.0	4.59	(0.85)	7.5	—	—	—	—	—	—	—	—
Galleries	70.0	1.79	(1.09)	5.3	26.2	—	—	—	—	—	—	87
Conveyer belt gallery	81.0	10.0	(0.50)	14.3	—	—	—	—	—	—	—	—
Exhaust fan (13m)	104.5	—	—	—	—	—	—	—	—	—	—	—
Face fan	93.5	—	—	—	—	—	—	—	—	—	—	—
Blasting (50m)	127.0	—	—	—	—	—	—	—	—	—	—	—
Face	—	1.0	(1.77)	4.3	29.5	15	30	2,700	1.0	none	none	97
Mining machine	—	—	—	—	27.7	—	—	—	—	—	—	—
Roof drill (stopper)	96.0	—	—	—	—	—	—	—	—	—	—	—
Mining lentern	—	—	—	—	—	500	—	—	—	—	—	—
Standards	87 (for six hours work/day)	—	—	—	25.0 (for heavy conditions of continuos work)	none	*39	*3,900	*4	none	none	none

* Up to 48 hours/week

Source: Fundacentro

159. Operating mining equipment is quite a special task, whose skills are transferred through on-the-job training to an assistant who works with an operator with a view to replacing him in the future. This type of training and learning is general for almost all jobs in mining and tends to perpetuate errors and bad practices difficult to correct in the future. Formal training programs recently adopted by some companies try to remedy this situation.

160. The quality of the work force is lower than normal because the sector is in crisis and, given its low remuneration levels, cannot compete with the other sectors for better manpower. Thus, the mining sector basically has senior experienced workers waiting to go on special retirement and unskilled ones who cannot find jobs outside mining. Face with that reality, mining companies find it extremely difficult to improve the quality of its work force.

161. The table below shows the salary scale in the mining industry. The lowest salary is R$327.71 per month, including the premium for risky work. This salary is paid to unskilled workers. Including work at night, commuting time and overtime, a worker can make 50% more than the base salary in his category.

Table I-13

Salary Scale

	R$/ month
Production Supervisor	739.88
Section Foreman	596.17
Electrician	541.25
Mechanics	541.25
Machine Operator	541.25
Machine Assistant	453.64
Unskilled	327.71

9.3 Fringe Benefits

162. Besides the reduced number of hours per work day and special retirement, mining workers do not receive any other advantage from the Government. Through bargaining, the workers obtained some special benefits from the companies. These are spelled in a collective agreement and consist essentially of commuting transportation to the mine, work uniform, one liter of milk per day and overtime rate equivalent to 100% of the normal hour rate.

9.4 Work Accidents and Injuries

163. From a safety standpoint, the greatest concern is with underground mines where work conditions and accident risks is much higher than surface mining. Since 1974, when mechanized mining

was introduced, the number of accidents has decreased, but unfortunately statistics are not available to quantify this statement.

164. Over the first ten years (1974 to 1984) of mechanized mining, the companies and the Government did not implement any effective measures to prevent accidents and work related illnesses. The workers and their own labor unions also did not press the issue. It was only in the mid-1980s that Governmental organizations and their labor unions began to monitor the companies so that they started to improve safety conditions in their mines.

165. Despite substantial efforts to improve mining safety conditions, much more is required to achieve to make coal mining safe and hygienic (Table I-14). To achieve better mining safety conditions, workers and their employers need to understand the hazards. To this end, staff training programs must be improved to make their qualifications better so as to prevent accidents and improve work conditions.

166. Accidents are reported monthly to the regional representative of the Ministry of Labor and to DNPM in case of death, heavy injury or loss time of more than seven days. Unfortunately, neither DNPM or the Labor Ministry have up to date statistics to better understand the issue.

Table I-14

Fatalities at Santa Catarina's Coal Mines

	1984	1986	1987	1989	1992	1993	1994	1995
Collapsing roof	2	4	3	2	0	1	2	2
Electricity	1	2	1	3	0	0	5	0
Machines	2	0	1	0	0	0	1	0
Gas poisoning	0	0	0	2	0	0	0	0
Dust/Gas explosion	31	0	0	0	0	0	0	0
Blasting	0	0	0	1	0	0	0	0
Total	36	6	5	8	0	1	8	2
Production (ROM million tons)	17.9	17.2	13.4	13.9	5.5	6.0	5.7	5.0
Fatalities/million tons	2.005	0.349	0.372	0.575	0.000	0.165	1.404	0.401

9.5 Diseases Specific to Mining Work

167. With the generalization of mechanization, the first cases of pneumoconiosis appeared, when it was still unknown for mining workers. In mid-1985, DNPM and the Labor Ministry introduced new rules demanding the use of water spray against dust caused by drilling and coal transfers, and also improvement in the mine ventilation system which constituted the first effective step in pneumoconiosis control. From 1969 to 1987, a total of 2,567 cases was registered at the Labor Ministry Regional Office from a total population of 14,000 coal mining workers.

168. For pneumoconiosis control, annual medical exams are conducted by the companies to detect new cases. According to the pneumoconiosis grade (classified as P0, P1, P2 and P3), the affected worker is removed from the coal mining face (P0 and P1) or even from the underground operation (P2 and above). They may also require a special pension from the Government, and, in some cases, an early retirement for permanent incapacity.

9.6 Post-Retirement Work

169. A typical miner retires at about 40 years old, i.e., with still many productive years before him. However, his chances of finding a new job are limited because of his specific skills. Generally, they become self-employed, working as painters, gardeners, carpenters, electricians, mechanics, taxi drivers, etc. There is no organized assistance to help retired miners make a conversion to other activities. Besides these aspects of age and skills, retired miners face other handicaps, such as bad health and a reputation for being difficult to manage.

10. MAJOR ISSUES

10.1 The Environmental Issue

(a) Miners' point of view

170. Environmental awareness is recent in the world and in Brazil as well, particularly in the mining region. It is only in the mid-1980s that the region started to be aware of the damages caused to the environment by mining activities. Miners as an integral part of the process tend to defend the activity, but recognize that the negative impact is immense and that measures should be taken to repair the damages. Like other people, miners think that the owners are the main culprits. They have made enough money and should take care of the problem.

(b) Owners' point of view

171. The mining companies believe they have only done what was expected of them. They had faithfully followed the Federal Government's directives, supplying the country in energy during the wars, offering an alternative to the country's energy problems during the oil crises, and supporting the national steel industry. During all that time, the industry complied with existing regulations and helped the Government which was exploiting coal through CSN. After all the efforts to achieve the objectives which were imposed on it, the mining industry found that the rules of the game have changed and that the Government has abandoned them. In addition, the industry is being blamed for the damages caused to the environment and is supposed to assume alone all the remediation costs.

172. The situation is different today. The sector has been weaken by 10 years of negative policy with regard to coal and is struggling to survive. It cannot be burdened by any other charge. The position of the industry is that any environmental damage done before 1985 is the sole responsibility of the Government. The industry is prepared to repair the damages done after that date, provided that they receive some financial assistance of the Government and that the role of coal in Brazil's energy matrix is made clear.

(c) Government's Point of View

173. The position of the different Government agencies involved in the issue: FATMA, DNPM and the Labor Ministry is very similar with regard to what needs to be done. All these agencies make inspections, ask for improvements and have the power to interfere in the production process, including stopping an activity. However, none of them has the necessary infrastructure to effectively enforce existing regulations on the industry. Also, interfering in the production process is not an easy action to do, when due account is taken of all the parameters.

174. The legislation, like the action of the enforcement agencies, not always acts to facilitate the activity and sometimes actually generates larger problems like the impasse in the Nova Próspera Mineração S.A. case, where a large mine was closed and about 480 miners dismissed because a municipal law issued in December 1995 extended the protected area prohibiting mining to encompass more than 80% of the mining concession.

175. No enforcement agency acts deliberately to paralyze a productive activity on which hundreds of families depend. On the other hand, companies usually are reluctant to take measures which involve costs, and often take excuse of the enforcement agencies' actions to delay investments.

176. Specifically, DNPM is responsible for controlling all mining and washing activities. For new projects, it requires the inclusion of environmental and safety protection measures. It monitors the work through annual mining plans that companies should submit for approval and analyses the results through the annual mining report.

177. DNPM also conducts semestrial inspection visits and intervenes in cases of accident or complaint. DNPM does this work through its Criciúma office which is established with CPRM (*Companhia de Pesquisa dos Recoursos Minerais*) and called *Projecto Carvão em Criciuma* (Criciuma Coal Project).

178. The Ministry of Labor also has a regional representative who, however, does not exclusively deals with coal mining. His actions mainly consist of inspections made following complaints. He can also act in coordination with state and federal representatives. This, however, rarely happens.

179. The labor legislation related to coal mining is the most inadequate and incomplete, often generating interpretation and adaptation problems. In fact, some aspects of the legislation is inapplicable and, as such, is ignored. For example, the section 22.1.4 in NR-22 (a resolution of the Labor Ministry on underground mining work) requires new workers to be trained in surface mining work for at least one year before being allowed to work in underground mines. Another problem, which makes action of the Ministry of Labor inefficient, is the absence of staff with mining experience.

180. On environmental matters, the actions of FATMA, the state environmental enforcement agency overlap with those of federal and municipal agencies. The overlap with some of DNPM's actions generates confusion and a duplication of administrative procedures. FATMA is responsible for reviewing Environmental Impact Assessments (EIAs) and for granting Environmental Operating Licenses. FATMA is also responsible for enforcement of environmental regulations and has the power to impose special conditions to an activity, if deemed necessary. Like the other Government agencies, FATMA has in its jurisdiction an enormous quantity of tasks to be performed in a very large area, but does not dispose of an adequate structure to do the work efficiently.

(d) Affected Community's Point of View

181. The affected community has the feeling that it has not received from the mining companies an adequate response for solving the problem. It also has not received a clear explanation with the regard to the potential risks it has been exposed to. This lack of communication gives credence to movements against coal mining. These movements tend to radicalize and ask for a complete closure of mining activities as the only way to solve the problem.

(e) General Community's Point of View

182. Ecological causes tend to become popular. Environmental protection programs are often the theme of many politicians. The community in general favors actions taken to protect the environment. In the specific case of coal mining, there is a prejudice in the general population against an activity which has polluted the region over the last 50 years. There is a need for the companies to act on the environmental front and to clearly explain its activities to the community. There is also a need for a technical and impartial evaluation which would objectively lay out for the general population the effects of mining activities on the environment and propose solutions to remedy them. This partnership between the society

and the mining companies is fundamental to establish a pact which would allow the rational exploitation of a natural resource, while preserving the well-being of the community and its environment.

10.2 The Economic Issue

(a) Miners' Point of View

183. Coal mining does not appear any more to be a viable option for those entering the job market. The salary level is low and the prospects of professional growth, as well as the stability of the employment are bleak. Over the recent past, there has not been a renewal in the staff of the mining companies. In fact, there has been a substantial reduction in the mining work force over the last six years (Table 6). Presently the only source of labor available consists exclusively of former miners who are looking for an opportunity to complete the time necessary for special retirement. For most of them, this is the unique motivation to return working in a mine. So, even when they defend the activity, they do it for themselves, and not as a career possibility for their children.

(b) Owners' Point of View

184. The companies have been living for a long time in the expectation of a definition by the Government of the role of coal in Brazil's energy matrix as the means to give a new impulsion to the sector. Most of the companies are in a very difficult financial situation and none has the capacity to invest. A short-term prospect is the scheduled start-up operation of the Jorge Lacerda IV power plant. This would increase coal demand and help reestablish the financial situation of the sector. Currently negotiations are taking place for supplying coal to Eletrosul's Jorge Lacerda thermoelectric complex. This may have major consequences for some companies' future.

(c) Municipalities' Point of View

185. No municipal administration will deny that coal mining is an important way to accelerate development in the area. Coal mining is needed to create employment and has a significant multiplier effect on the region's development. Municipalities want to encourage thermoelectric power generation near the mines as a way to make coal mining viable. They are also looking for ways to minimize the environmental impact to remove the principal obstacle to continued coal production.

(d) General Community's Point of View

186. Ideas and opinions are diverse here, but the dominant one appears to be that all the aspects of an activity as controversial as coal mining needs to be discussed in detail by everybody so that a consensus solution could emerge which would minimize conflicts between the coal industry and environmental protection.

11. CONCLUSIONS AND RECOMMENDATIONS

187. Prospects for coal mining are relatively good. As a result of continued strong economic growth in Brazil, energy demand is expected to remain high. ELETROSUL is expanding its thermal electric complex at Jorge Lacerda by adding a forth unit, while its 20-year Development Plan (1995-2015) foresees the construction in Santa Catarina of 14 new units with a total installed capacity of 1750 MW during 2000-2015. As a result, coal demand is expected to increase eleven-fold from 1.3 million tons in 1996 to 14.7 million in 2015. World Bank projections also foresee a strengthening of coal prices, which are expected to reach US$49/ton (US coal) in 2005 up from their present low level of US$36.9/ton.

188. Given the favorable price trends and some restructuring[3], continued coal mining in Santa Catarina could be an economically viable proposition. Under certain conditions, the sector would be able to compete with import and meet Eletrosul's demand for coal. However, without a marked improvement of mining and environmental regulations and a substantial strengthening of public agencies responsible for monitoring mining activity and enforcement of environmental protection, this expected increase in mining activity is likely to result in an environmental disaster. The region is already classified as a national endangered area by a 1980 Federal Decree, which allows it to obtain special Government assistance to repair the damages done to the environment from past mining exploitation.

189. In order to permit the sector to meet Brazil's demand for steam coal, while protecting the environment, it is recommended that the Brazilian authorities act on the following fronts simultaneously:

11.1 Improving the Policy Framework.

190. Brazil's coal mining policy as formulated by a commission composed of representatives of the Ministry of Mining and Energy (MME), DNPM, ELETROBRAS and coal mining companies, including SNIEC (*Sindicato Nacional da Industria de Exploitação do Carvão) and* SIECESC, clearly defines the roles of the private sector and the Government in the sector. Coal exploration, production and commercialization should be entirely left to the initiative of the private sector without interference (or subsidies) from the Government. The public sector should limit its role in the sector to promoting efficient and cleaner production technologies, ensuring workers' safety and protecting the environment. These principles are sound and should lead to an efficient exploitation of Brazil's coal mining resources.

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[3] Average production cost of Santa Catarina's coal mining companies is high as a result of the large number of companies in the sector, which prevents economies of scale. There appears to be inefficiencies in individual companies, as well. Some restructuring is bound to occur as less efficient companies are squeezed by tight prices and competition.

191. As part of its commitment, the Government disengaged itself from coal production and commercialization. It abolished CAEEB, which was responsible for the commercialization of all the coal produced in Brazil, leaving prices to be freely set between mining companies and coal users. It abolished CSN and privatized its subsidiary Carbonifera Prospera, signaling the public sector's total withdrawal from coal production.

192. However, the Government continued to subsidy diesel oil prices, a direct competitor of coal as an industrial fuel, because of its impact on inflation. This measure tends to depress coal prices and many mining companies have difficulty competing and are incurring losses. Some have stopped operating. While removing fuel price subsidies may negatively affect the viability of certain activities, it is recommended that the Government undertake a comprehensive study on the topic with a view to improving long-term energy pricing in Brazil.

11.2 Improving the Legal Framework

193. Mining (both research and exploitation) is regulated by the Federal Government. The basic legislation is the 1967 Mining Code which covers all mining activities. There is no specific legislation for coal mining, despite its special characteristics and environmental impact. Given the expected substantial expansion of coal mining production in the coming years, it would seem advisable to introduce specific legislation to better regulate this activity.

11.3 Improving Health and Safety Norms

194. As discussed in Chapter IX of this report, working conditions in Santa Catarina's underground mines are unhealthy and unsafe. Noise, temperature and dust levels often exceed maximum acceptable limits. Most companies do not possess equipment and safety procedures considered mandatory in other countries, such as rescue teams, self rescuer for carbon monoxide, self-contained breathing apparatus for rescue teams, explosion proof electric equipment, etc.

195. Existing laws are also flawed with inconsistencies, being extremely restrictive in some areas and completely lax in others. For example, the velocity of air flow is defined, but not the minimum supply of fresh air; or the limitation of SiO_2 dust content in air for inhalation is stipulated, but there is no description of dust explosivity or inflammability. There is an urgent need to strengthen existing legislation to protect the health and safety of coal mining workers, while improving the attractiveness of this activity.

11.4 Improving Environmental Regulation

196. Existing environmental laws, both at the federal and state levels, are basically sound. They spell out in some detail the environmental obligations of the mining companies, as well as the procedures for EIAs and public consultation and participation, which are adequate. However, regulations are generally lacking to implement the laws, particularly with regard to land reclamation and reject disposal.

197. As discussed in Chapter VII of this report, in 1984, to comply with SEMA's directives, Santa Catarina's mining companies contracted two consulting firms to help define the regulation and control of waste dumps, as well as the methods of disposal, reclamation and re-vegetation. However, very little was put in practice, least translated into regulations. Some of the more important measures which were not implemented include: (i) the obligation to treat the water leaching through the waste piles; (ii) the use of clay for impermeabilization; and (iii) the requirement to compact layers of waste with compactors. These should now be revived and, if necessary, updated with a view to translating them into regulations.

198. Regulations concerning effluent discharge are generally adequate but not complied with by mining companies. They argue that the surrounding environment is so polluted with pH levels in the river bodies as low as 2-3 that there is no need to neutralize mining water before discharge as required by law. This emphasized the need to repair the mistakes of the past without which there would not be any substantial progress in environmental improvement of coal mining activity.

11.5 Strengthening the Regulatory and Enforcement Agencies

199. Being an activity regulated by the Federal Government, coal mining falls under the supervision of both DNPM (technical aspects) and FATMA (environmental aspects). Both agencies have competent and dedicated staff, but they are overworked and underpaid. DNPM maintains a strong presence in Santa Catarina with a staff of 32, of whom 18 are university graduates. However, most of them are in the capital, Florianópolis. Its southern region's office located in Criciúma (where all the coal mines are) has only four professionals (two Geologists and two assistants) seconded by CRPM, to do the inspection and monitoring of coal mining companies. The situation is similar for FATMA which has a staff of 212 but only 17 in the southern region (Criciúma and Tubarão). Strengthening of DNPM and FATMA's regional offices is a *sine qua none* condition for progress in environmental protection in southern Santa Catarina. A technical and financial program aimed at strengthening FATMA has been prepared for discussion with, and approval by, the Brazilian authorities. It is recommended that a similar effort be done for DNPM.

200. Another important issue which needs to be resolved is a clear understanding and delineation of responsibilities between the two agencies with regard to monitoring of coal mining activity. Legally,

both agencies are responsible, but in practice DNPM does most of the work on an *ad hoc* basis and puts the emphasis on the technical and mining aspects rather than on environmental considerations. The two agencies should agree on a periodic program for monitoring coal mining companies with clear division of work so that environmental issues are not neglected. Another alternative would be for FATMA to delegate esponsibility for environmental monitoring of mining companies to DNPM so that the latter is totally in charge of all the monitoring work, including environmental aspects. This solution makes sense from a technical point of view. It also avoids duplication of work which would inevitably arise when two agencies inspect a same company with different objectives. Finally, it releases FATMA's overworked staff from a technical task for which they may not be well prepared. FATMA will retain all its prerogatives with regard to EIAs and environmental licensing of mining companies.

11.6 Improving the Mining Companies' Operation

201. In parallel to strengthening the regulatory and environmental enforcement agencies, there is a need to improve the capacity of mining companies to conduct their operations in an efficient and environmentally sound way. The review of mining operations in Chapter VI shows that all the companies operate with valid environmental licenses but are generally not complying with environmental regulations. Some companies try to reduce the environmental impact of their operations by restricting truck traffic during the night, watering roads to reduce dust formation, and covering trucks to prevent spilling. However, they do not generally dispose of rejects properly and their discharged effluent has pH values two to three times lower than the norms (2.9-3.4 compared to the norms of 6.0-9.0) and heavy metal content often exceeding FATMA standards by more than ten times (see Table 8).

202. In neighboring state Rio Grande do Sul where environmental norms and standards are similar to those in Santa Catarina, mining companies have no difficulty to comply. Some are doing a wonderful job reclaiming the land disturbed by open pit mining, returning the areas to their original pre-mining state. Effluent standards are generally met. Some companies even neutralize wastewater for reuse in the mine or in the washing station, discharging very little into the ground and river bodies.

203. There is no reason why Santa Catarina's mining companies could not comply with environmental regulations. Most companies have the technical capability to do so.. They are not doing it partly because the surrounding environment is already polluted and it is not in their corporate culture to do it, partly because they are not under pressure to do it, and partly because this involves extra work and adds to the production cost.

204. It will take time to change this situation, particularly given the tight financial situation which most companies are in. Since the number of companies in the sector is relatively small[4], it is recommended that Santa Catarina's authorities develop specific programs adapted to the needs of the individual companies and negotiate with each of them a plan to bring them to compliance over a given period of time. If needed, technical and financial assistance from the state would be available to help the mining companies carry out the improvement program for which they have signed off.

[4] There are at present six operating companies

B. PROPOSED STRENGTHENING PROGRAM FOR FUNDAÇÃO DO MEIO AMBIENTE (FATMA)

1. BACKGROUND

1. Brazil's legal and institutional framework for environmental protection is very decentralized. The Federal government mainly defines the country's environmental strategy, provides policy directives and guidelines and issues global environmental norms and regulations. With a few exceptions (e.g., petroleum, energy and mining), enforcement of environmental regulations is left to state and municipal authorities.

2. However, the 1988 Constitution also allows states to enact laws in quite a large number of areas, including forestry, hunting, fisheries, conservation of soils and natural resources, protection of the environment and tourism assets, and pollution control. This has become a source of conflict and confusion as federal and state laws proliferate, duplicate and, at times, conflict one another. Institutions also tend to multiply, both at the federal and state levels, making delineation of responsibilities more difficult.

3. In the state of Santa Catarina, environmental policy is spelled out in the state law No. 5793 of October 5, 1980. This law entrusts environmental protection to the *Secretaria de Estado do Desenvolvimento Urbano e Meio Ambiente, SDM* (Secretaria of Urban Development and the Environment), which is responsible for "integrating the actions of the Federal Government concerning the Environment with those of the state and municipalities'. This law also created FATMA and entrusted it with the task of carrying out the state of Santa Catarina's environmental policy.

2. MAIN OBJECTIVES

4. FATMA's main objectives are as follows:

a) enforce environmental regulations in Santa Catarina;

b) manage the environmental licensing system and ensure that polluters carry out the agreed preventive measures. The emphasis is put on solid waste (urban, industrial and hospital) coming from the following sources: (i) industries classified in the list of activities potentially polluting, such as coal mining, and pig farming; (ii) hotels and camping; (iii) hospitals and clinics; and (iv) public water sanitation systems;

c) maintain the cleanliness of the state's beaches and enforce water quality standards;

d) monitor fisheries activities on behalf of the federal government;

e) execute programs aimed at creating parks and forestry reserves;

f) carry out special projects, including scientific and technological research for the defense and ecological conservation; and

g) participate in the analysis of the state's natural resources potentiality with a view to promote their rational exploitation.

3. ORGANIZATION AND STAFFING

5. FATMA is organized in three main departments (Exhibit 1): (i) Administrative and Financial; (ii) Pollution Control (industrial, rural and urban); and (iii) Environmental Studies. There are also eight regional offices, which carry out most of the monitoring and enforcement work. They are described in more detail below:

◊ *Regional office of the Vale do Rio do Peixe*

Main Office: Municipality of Joaçaba
Main pollution sources: pig and chicken farming
Number of staff positions: 3. (2 active staff and one on leave of absence.

◊ *Regional Office of Planalto Serrano*

Main Office: Municipality of Lages
Main pollution sources: Paper and cellulose industries
Number of staff positions: 6. (4 active staff, one vacant position, and one on sick leave status.

◊ *Regional Office of the Wset*

Main Office: Chapecó
Main pollution sources: Pig farming
Number of staff positions: 2 (both active).

◊ *Regional Office of Planalto Norte*

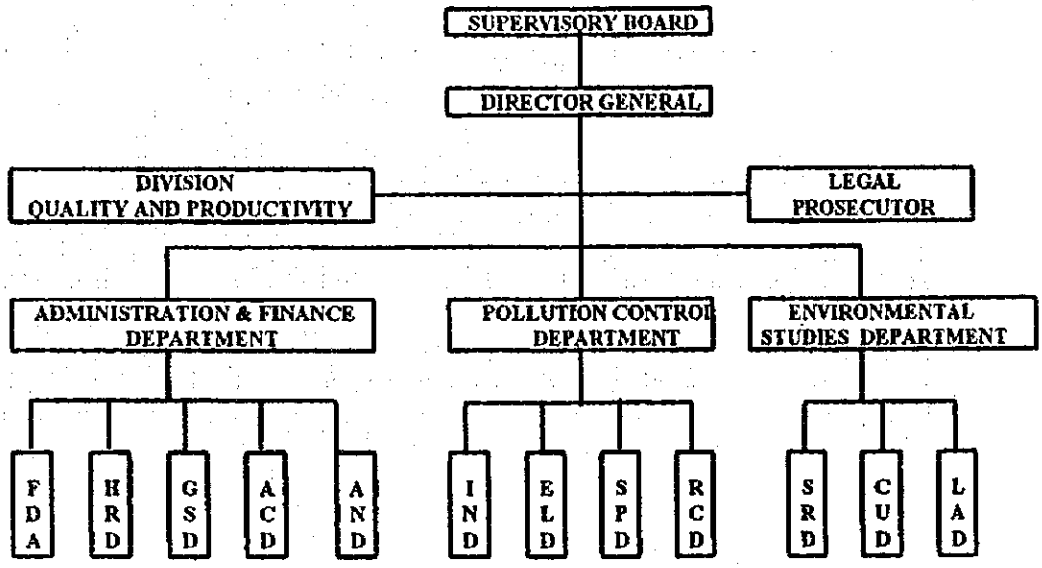
Main Office: Canoinhas e Mafra
Main pollution sources: Furniture making
Number of staff positions: 4 (2 active staff, one vacant position and one seconded to other agencies).

◊ *Regional Office of Vale do Itajai*

Main Office: Blumenau
Main pollution sources: Textile Industry
Number of staff positions: 7 (4 active staff, one contractor, one on leave of absence status and one seconded to other agencies).

EXHIBIT 1

FATMA'S ORGANIZATIONAL STRUCTURE



FDA: Finance and Administration Division
HRD: Human Resources Management Division
GSD: General Services Division
ACD: Accounting Division
AND: Administration and Cadastre Division
IND: Inspection Division
ELD: Environmental Licensing Division
SPD: Special Projects Division
RCD: Regional Coordination Division
SRD: Studies and Research Division
CUD: Conservation Units Division
LAD: Lab Analysis Division

◊ *Regional Office of the North*

Main Office: Joinville (Headquarters of the FATMA/GTZ project)
Main pollution sources: Mechanical industry;
Number of staff positions: 13 (3 active staff, one contractor and 9 working on the GTZ project).

◊ *Regional Office of the Grande Florianópolis*

Main Office: Florianópolis
Main activities: Environmental licensing and inspection of coastal areas
number of staff positions: 16 (13 active staff and 3 seconded to FATMA from other agencies).

◊ *Regional Office of the South*

Main Office: Criciúma/Tubarão
Main pollution sources: Coal mining and ceramics
Number of staff positions: 17, of whom 6 (all active) in Tubarão and 11 (9 active staff and 2 on leave of absence) in Criciúma.

6. FATMA has a total of 212 staff, of whom 16 work exclusively for the GTZ (Deutche Geselschaft für Technische Zusasammenasbeit) project, 13 are seconded to FATMA from other organizations, 13 are on leave of absence status. FATMA staff exhibits the following particularities:

⇒ Excluding the 13 staff on leave of absence and the 16 recruited to work exclusively on the GTZ project, out of the remaining 183 staff, only 59 (32%) are in the regional offices where most of the enforcement work is done. The remainder 124 (or about two thirds) are in the Florianópolis headquarters.

⇒ Ninety of FATMA's total active staff of 183 (i.e., about 50%) are environmental control technicians[1] and essentially work on environmental licensing, leaving only 93 (including support staff) to work on other activities, such as inspection, enforcement of environmental regulations, research, etc.

4. OPERATIONS AND MAIN TASKS

4.1 Environmental Licensing

7. FATMA's major task is environmental licensing, which occupies about 50% of its staff. Environmental licensing is required by law (No. 5793 of October 15, 1980) for all "new and expansion enterprises whose activities are included in the list of activities considered potentially harmful to the environment". To obtain the required environmental licensing, an enterprise goes through the following steps:

- **First step: Completion of the FCE** (*Formulário de Caracterização do Empreendimento - Project Identification Form)* which contains the basic information on the project such as: description of the project, localization, type of activity, production, inputs used, etc. The FCE is reviewed by FATMA which should approve it and recommend the project for the second step of the process;

- **Second step: Preparation of the OB** (*Orientaçao Básica*), which includes: identification of the promoter, description of the project to be licensed, type of licensing, completion of

[1] The number and professional categories of the 90 environmental technicians are as follows: 13 biologists, 11 geographers, 8 civil engineers, 6 biochemists, 6 industrial chemistry specialists, 5 sanitary engineers, 5 chemists, 4 agronomists, 4 administrators, 4 lawyers, 3 forestry specialists, 2 surveyors, 2 librarians, 2 accountants, 2 pedagogues, 2 chemical engineers, 2 mechanical engineers, 2 architects, one veterinarian 2 economists, one sociologist, one editor, one oceanographer, and one artistic education specialist.

administrative procedures (documents required by the municipality, authorization of DNPM, publication of the licensing request as per CONAMA resolution 006/82 of January 24, 1986, etc.), environmental impact assessment (EIA), if required and a pollution control plan to be prepared according to FATMA's guidelines. Coal mining projects involving extraction, beneficiation and use of coal should also submit an *Instruçao Normativa IN 01* which describes in detail (i) geological and geotechnical surveys done to help assess the risks of underground water pollution; (ii) surface water drainage system to be used in the project; (iii) proposals to collect, remove and treat underground mining water; and (iv) transport and disposal of wastes; and

- **Third step: Granting of the environmental licensing**. It is done by FATMA following a careful review of the request and related documentation (including EIA) and inspections and site visits to the project area. The inspection and control by FATMA do not exclude those of the municipality or other state and federal organisms. The licensing is always subject to the enterprise realizing the project according to an agreed timetable and that environmental conditions are complied with.

8. While environmental licensing is undoubtedly important, it should not occupy half of its staff to the detriment of other equally important tasks, such as control of urban pollution. There is also a need to strengthen FATMA's representation in the regions where most of the monitoring and enforcement of compliance to the requirements of the environmental licensing is done.

4.2 Environmental Impact Assessment.

9. EIA is required by the 1988 Brazilian Constitution for any civil work or economic activity with potential harmful effects on the environment. The EIA must be done and approved *before the authorization to start construction or activity is given.* The EIA must be *public*, involving public consultation and participation in the process. This public consultation and participation process should not, however, violate the industrial and commercial secrets that the project sponsor companies are entitled to keep. Brazil's EIA system presents the following characteristics:

⇒ *Nature*: EIA is a legal instrument of Brazil's national environmental policy. As such, the EIA process must end with a decision whether the project should be approved or rejected;

⇒ *Responsibilities*: CONAMA is responsible for setting the norms and criteria for the licensing of potentially polluting activities. However, state and municipal authorities can supplement and/or establish their own norms. This is a potential area of conflict and/or duplication and confusion. Generally, state and municipal authorities only adapt the federal norms to suit their particular local situation;

⇒ *Scope*: CONAMA resolution No. 001/86 specifies activities for which an EIA is required, e.g., major infrastructure projects, such as dam or road construction, hazardous waste disposal facility and mining projects. An EIA must include, *inter alia*, the following elements, which are then summarized in a report called RIMA (*Relatório de Impacto Ambiental*):

  - ◊ Comprehensive survey of existing scientific literature and adequate legal reference, field work and investigation, and detailed lab analysis;

- ◊ Definition of the geographical limits of the project's direct and indirect impacts. In any case it should include the whole river basin where the project is located;

- ◊ Compatibility and consistency of the project with the Government's plans and programs (CONAMA Resolution No. 001/86);

- ◊ Ex-ante study of the project area (before establishment of the project) covering the physical, biological (the natural ecosystems) and socio-economical (environmental diagnostic of the area) aspects (Decree No. 88-351/83 and Art. No. 6 of the Resolution 001/86). An initial description of the project site is an important element to objectively assess the merits of the project by comparing the "with" and "without" project situations;

- ◊ Identification and evaluation of all the possible impacts (positive and negative; direct and indirect; short, medium and long terms; temporary and permanent; their degree of reversibility as well as their cumulative or synergetic characteristics;

- ◊ Description of proposed measures aimed at correcting or mitigating the negative impact on the environment. CONAMA Resolution No. 0011/85 stipulates that the EIA should spell out the remedy measures, including a description of the control equipment and effluent treatment systems, together with an evaluation of their efficiency;

- ◊ Inclusion of proposed compensatory measures;

- ◊ Inclusion of disaster prevention measures; and

- ◊ Estimation of the social costs and benefits. It is extremely important from a social point of view to identify the winners and losers (the segments of the population which are going to benefits and those which are going to lose as a result of the project).

⇒ *EIA Team*: The EIA should be done by a multidisciplinary team independent from the project sponsor. The team will be technically responsible for the conclusions of the work.; and

⇒ *Public Participation:* The public can follow, or assist in, the work of the EIA team to the extent that its participation does not affect the industrial secret to which the sponsor company is entitled to protect. In addition, the RIMA should be extensively advertised and published in the State Official Journal, as well as in a major regional or local newspaper. Access to EIAs is a constitutional right of the Brazilian citizen. The EIA is prepared in two phases. At the *Comment Phase*, any person, institution, environmental association, or public ministry can make written comments to the team on the work being carried out.. At the *Public Audience Phase*, the preliminary results of the EIA are presented to the public in a meeting organized by FATMA. The comments (officially recorded) will be used by FATMA, together with the RIMA, to make a decision with regard to the project. The public audience is the last step in the EIA process.

10. FATMA only requests EIA with consultations with the affected communities in public audiences for large projects. It is also FATMA's policy to require EIA for all coal mining projects irrespective of their size. In 1995, FATMA requested the preparation of EIA for nine projects, including two gas projects, four road construction projects, a beer factory (Antártica), a tourism project (Porto da Barra da Lagoa da Conceiçao) and a hydroelectric project For small projects, FATMA only requests a simplified form of EIA/RIMA called *Relatório de controle ambiental* (RCA).

4.3 Monitoring and Enforcement of Regulations on Polluting Activities

11. In Santa Catarina, the main sources of pollution are (i) industrial and municipal solid wastes; (ii) pig and chicken farming; and (iii) hazardous wastes (petroleum by products and hospital wastes). In the southern region of the state, the main source of pollution by far is coal mining extraction and beneficiation.

12. The major environmental problems associated with coal mining include: (i) improper effluent disposal; (ii) improper accumulation, transport, utilization and/or disposal of solid mining wastes; (iii) air pollution; (iv) damages to forests and vegetation; (v) noise pollution; (vi) installation and operation of equipment without FATMA authorization; and (vii) non-immediate communication to FATMA of accidents with potential damages to the environment.

13. In enforcing compliance with environmental regulations, FATMA can impose the following penalties:

a) *Warning* when the infraction is a first offense, is light, and does not have a potential risk on public health;

b) *Fines* when the polluter has not corrected the infraction noted in the warning, did not remedy to the situation within the time period specified ,or when there is a risk to public health. The fines can be *light* (when there is no damages to the fauna, flora or to materials); *serious* (when there is negative impact on public health or damages to the fauna, flora or other natural resources) and *very serious* (when there is risk to human life). The fines vary from R$8.35 to R$338.5 per day for light fines; R$164.5 to R$677.2 for serious fines; and R$420.8 to R$1,025.3 for very serious fines. Payment of the fines does not exempt the polluter from remedying to the situation;

c) *Restriction of financing* when the predator does not pay the fines, or when he recidivates for the third time in three years;

d) *Closure of the activity* when there is a serious risk to public health if the activity continues;

e) *Seizure or destruction of the work or construction* when the construction has been made without authorization or done in violation of the agreement or norms stipulated in the approved project; and

f) *Environmental remediation.* The obligation for the predator to remedy to the situation can be imposed on top of a fine.

14. In 1995, FATMA gave 171 warnings and 49 fines. The sanctions are executed by administrative order, with recourse to police force if necessary to execute the seizure or destruction decisions. Legal recourse is used when the fines have not been paid after a given period.

15. FATMA believes it cannot effectively monitor coal mining pollution in the present organizational structure and suggests the creation of a special unit entirely devoted to the control of the sector activities, including environmental licensing. The unit would have six staff (five technicians and a trainee), three

vehicles and adequate computing and lab equipment. Its resources would come from the licensing of mining activities.

4.4 Special Projects

Clean Beach Program.

16. FATMA has developed a program aimed at preserving the quality of the beaches which is one of the most valuable natural asset of the state. Through FATMA's labs at headquarters in Florianópolis and in Criciúma (FUCRI), the program analyses the quality of water in the main beaches and classifies them into four categories using criteria defined in CONAMA resolution No. 20 of June 18, 1985: Excellent, Very Good, Satisfactory and Inadequate. The results are also published in newspapers throughout the state to inform the population about the real situation of the beaches. This indeed provides a strong incentive to the municipalities to act and protect one of their main sources of income (tourism).

Management of Water Resources in Santa Catarina Project (FATMA GTZ)

17. The major objective of the project is to improve FATMA's capacity to control industrial pollution through a strengthening of its technical and legal bases for managing water resources. In this regard, the project aims at:

- ⇒ Formulating and applying water resources planning methods;
- ⇒ Developing the technical and legal bases for the provision of water resources;
- ⇒ Design norms for the conditioning, transportation, separation, treatment and disposal of industrial solid wastes;
- ⇒ Establishing and operating networks to quantitatively and qualitatively characterize water resources;
- ⇒ Standardize the environmental licensing process;
- ⇒ Updating the industrial cadastre;
- ⇒ establishing an environmental data bank;
- ⇒ Modernizing and expanding the state lab system;
- ⇒ Training FATMA technical staff; and
- ⇒ Transferring advanced wastewater treatment technologies.

18. The project started in March 1994 under the co-management of FATMA and FUNDEMA (*Fundação Municipal do Meio Ambiente*), the environmental agency of the Joinville municipality and is expected to be completed by mid-1998.

Micro-Basin Project (IBRD)

19. The main objectives of the project are to recuperate and preserve the productive capacity of soils and reduce rural pollution, thus increasing productivity and income of small producers in the micro-basins. The project aims at encouraging the adoption of adequate practices of soil and water management and redefining the use of the land according to its agrosylvopastoral aptitude.

20. The project includes (i) training and human resource development; (ii) mapping, planning and monitoring of land uses; (iii) enforcement of environmental legislation; and (iv) protection of parks and forestry reserves.

Mata-Atlântica Project

21. The project aims at protecting the remaining Floresta Atlântica of the Santa Catarina state, thus consolidating the biosphere reserve of the state through its zoning and monitoring, the establishment of state preservation units, and the introduction of an integrated inspection system, environmental education and scientific research programs. The project is, however, stalled.

5. FINANCIAL RESOURCES

22. FATMA's resources mainly come from budgetary allocations by the state. For 1996, its allocation was set at R$ 6,4 million for the following expenses: staff compensation, maintenance, purchase of equipment and investments. However, the resources must be appropriated monthly by the Treasury of the state. At present, the rate of appropriation amounts to about R$30,000 per month, while FATMA's expenses (theoretically covered by the budget) exceed $R100,000.

23. To compensate for the budgetary shortfalls, FATMA uses the funds coming from environmental licensing and other services it provides (such as RIMA and lab analyses) available in the state environmental fund (FEPEMA). This, however, barely allows it to meet indispensable expenses, such as staff compensation and operating costs. FATMA's financial situation must be addressed urgently.

6. MAIN ISSUES

24. FATMA faces a number of important issues which hamper its efficiency. They are described below:

a) *Institutional Problems* resulting from (i) lack of coordination among the different agencies, institutions and associations involved in environmental protection: FATMA, IBAMA, DNPM, municipalities, other state and federal agencies and NGOs; (ii) large number of laws, decrees, and resolutions which make their interpretation and application difficult; and (iii) overlapping responsibility among regulatory and enforcing agencies;

b) *Organizational Problems* as evidenced by an imbalance between the number of staff at headquarters and in the regional offices where most of the regulatory and enforcement work is done. There appears also to be a need for more decentralization of staff and authority to the regional offices;

c) *Operational Problems*. Policies and procedures are not uniform, resulting in different treatments for similar situations within the institution. It is also urgent to update the MIS to facilitate exchange of information within the institution. Finally, many regional offices lack the basic equipment (e.g., labs, vehicles) to properly do their work;

d) *Management Problems*: Work planning seems to be insufficient. There is, for example, no system to evaluate the impact of the work and no basic guidelines nor prioritization of issues, resulting in the institution reacting to problems rather than addressing issues;

e) *Human Resources Problems*: Staff is insufficient in number and of poor quality. At all levels, they appear overworked and unmotivated. Training to increase staff technical expertise is a high priority. Also, there seems to be a need to improve compensation and strengthen career planning; and

f) *Financial Problems*: Budgetary appropriations issues should be solved urgently. FATMA needs adequate financial resources to function.

25. Strengthening of FATMA is a *sine qua none* condition for any environmental improvement in Santa Catarina.

7. PROPOSED STRENGTHENING PROGRAM

26. The following strengthening program has been prepared with the assistance of FATMA's Criciúma regional office for consideration by the Santa Catarina's authorities. While it covers the institution as a whole, the emphasis is obviously on the southern regional office where coal mining is located.

27. As discussed in Section 6 above, FATMA's problems are numerous. Some are due to its own internal organization and management; others result from the state of Santa Catarina's legal and institutional setup for environmental protection and budgetary practices. They are beyond FATMA's control but need nevertheless to be addressed as they impact on FATMA's performance.

7.1 Defining FATMA's Role and Responsibilities and Improving Inter-Agency Coordination

28. It is proposed that a working group, chaired by SDM and composed of representatives of FATMA, CONSEMA, DNPM, associations of municipalities, IBAMA and other federal agencies, be established to review existing laws and decrees with a view to clearly delineate the roles of these different agencies in environmental protection. Particular emphasis should be placed on defining the responsibilities of FATMA, DNPM, and the municipalities in monitoring coal mining activity and in enforcing environmental regulations to that sector.

29. Following that work, FATMA, DNPM, and AMREC (*Associação dos Municipios da Região Carbonífera*), the Association of Municipalities in the Coal Mining Region would enter into an agreement to coordinate their activities with regard to monitoring and control of coal mining pollution. While FATMA's strengthening is being addressed in this report, it is also recommended that resources be made available to help improve the municipalities' and DNPM's enforcement capability.

7.2 Strengthening Work Planning and Programming

30. Being the state of Santa Catarina's environmental agency, FATMA's responsibilities are

enormous. There is therefore a need to plan to set priorities and efficiently allocate scarce staff resources[2]. FATMA should introduce systematic work planning and programming at the institution's main levels. It is recommended that regional offices, divisions (*Gerências*) and departments (*Diretorias*) prepare annual work programs which would be discussed and agreed with top management. Progress in achieving the agreed work programs would be an important element in the assessment of managers' performance.

31. The divisions/departments' work programs would be integrated to form the institution's overall work program. FATMA could also use these work programs as inputs to prepare annual "business plans" for discussion and agreement with SDM on the institution's priority tasks and expected performance during the year. In many other countries, institutions similar to FATMA with important responsibilities and little resources have successfully used this approach to agree on priority works with their governing authorities and avoid excessive pressure and conflicting demands on their time and resources. Rigorous planning could also help cope better with crises which inevitably arise when dealing with environmental protection.

7.3 Improving Internal policies and procedures

32. FATMA's internal policies and procedures are not uniform and, at times, contradictory. A working group should be established within FATMA to review the institution's policies and practices with a view to standardizing them. It is also recommended that an Operations Manual be prepared to guide staff in their work and avoid inconsistent practices.

7.4 Strengthening Regional Offices

33. As discussed in Section 3 above (Organization and Staffing), most of the enforcement of environmental regulations falls on the eight regional offices, but they lack both personnel and equipment to do the work efficiently. At present, only about one third of FATMA's staff is in the regional offices, the remainder two thirds work in the Florianópolis headquarters. It is recommended that FATMA review the amount of work carried out at headquarters and in the regional offices with a view to better allocating available staff resources. A preliminary analysis shows that the current proportions could easily be reversed, i.e., two thirds of the staff in the regional offices and one third at headquarters.

34. In addition to staff transfers, the regional offices should have the necessary resources and authority to efficiently carry out their enforcement responsibilities. For this reason, the regional coordination division should report directly to the Director General. That Division could also provide

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[2] Section V (Operations and Main Tasks) shows that about 50% of FATMA staff work mainly on environmental licensing. While this task is undoubtedly important, it should not be done at the expense of other equally important activities, such as enforcement of environmental regulations or monitoring of water quality.

technical support to the regional coordinators in specific areas where their expertise is lacking, such as legal matters, prosecution of polluters, special test analyses, etc.

35. In the Southern Regional office which, in addition to other tasks, has the responsibility of enforcing environmental regulations on coal mining companies, the Coordinator proposes the creation of a special unit entirely devoted to the monitoring and control of coal mining activities (para. 15 above). This proposal merits to be studied further in the context of this comprehensive effort at strengthening FATMA.

7.5 Putting Staff Development First

36. As a public service agency, FATMA's main asset is the quality of its staff. As mentioned in Section VI (Main Issues), staff appears overworked and unmotivated. To remedy the situation, FATMA should take the following actions:

- ⇒ Introduce a comprehensive training program to upgrade the skills of its staff, particularly the technical ones;
- ⇒ Assess existing recruitment and personnel management policies with a view to improving staff career development prospects; and
- ⇒ Review existing salary structures with a view to introducing financial incentives to retain and motivate valuable staff. There may be a need to reform the whole compensation policy to link more closely work categories and pay. FATMA may also want to consider introducing a bonus system, which has worked well in similar organizations.

7.6 Promoting FATMA's Image

37. Like many environmental agencies in other countries, FATMA's work is little known to the general public, which often views it as a nuisance or an obstacle to economic development. The measures proposed above to strengthen the institution, particularly the improvement in the technical expertise of FATMA staff, will go a long way in improving the image of the institution. However, FATMA may consider launching a public relations campaign to disseminate its successes and to obtain support for its work from the population.

7.7 Increasing Financial Resources

38. FATMA's budget is inadequate for it to carry out its work properly. In 1996, FATMA was allocated a budget of $R6.4 million (about US$6.3 million), but appropriations were slow and insufficient to cover all of FATMA's priority needs. Regional offices lack the basic equipment (vehicles, labs and other monitoring devices) to properly inspect potentially polluting industries. Staff are poorly paid and, as a result, moral is low.

39. Under the proposed *Santa Catarina Environmental and Coal Mining Management Improvement Project* for which a loan from bilateral or multilateral lending institutions is being requested, the following actions would be financed to strengthen FATMA:

a) Capital expenditures to strengthen and modernize FATMA's work equipment (vehicles, labs, computers, etc.);

b) Technical assistance to help FATMA carry out the strengthening measures outlined above, including reviewing its organizational structure, improving its internal policies and procedures, formulating a comprehensive training program for its staff, reforming its compensation policy, and launching a public relations program to improve its image with the general public (A to F above);

c) Establishment of a MIS to accelerate the flow of information within the institution and to improve communication with the regional offices; and

d) Creation of a fund to recruit short-term experts in areas where FATMA lacks expertise or finance special tests and analyses.

40. The external loan cannot, however, finance recurrent expenditures, such as staff salaries, FATMA's maintenance and operating costs without which the institution will not be able to function properly. It is therefore imperative that the Government of Santa Catarina agree to increase FATMA's budget. Appropriations problems will also need to be solved. These will represent the Brazilian contribution to the financing of the project. It is proposed that a SDM/FATMA working group be established to look into this budget issue and make recommendations on ways and means to provide FATMA with adequate financial resources to fulfill the functions for which it was created.

A-I. WASTE DUMPS SURVEY

1. Database

1. Almost all waste dumps have been surveyed to understand the Southern Santa Catarina's pollution problems and all findings have been compiled into a database, which is available at the FATMA office and the DNPM office in Criciúm. Parameters used for the description of waste dumps are as follows:

2. ***Rank***: Rank (map, aerophotography and others) indicates accuracy and source material:

- *map*: waste dumps within the JICA's map (1:20,000);
- *aerophotography*: waste dumps beyond the designated mapping area but within the JICA's aerophotography (1:30,000); and
- *others:* waste dumps beyond the JICA's aerophotography and identified by other means such as DNPM's old aerophotography, FUCRI's information and/or site inspection.

3. ***Waste type***: Waste type (black shale, white waste and water) indicates waste material:

- *black shale*: rejects after coal washing, which consist of re-washable, waste (not re-washable) and fine;
- *white waste*: overburden wastes; and
- *water*; polluted acid water only.

4. ***Topo type***: Topo type (flat, slope, heap, saw, pond, road and river bank) indicates shape and condition of waste dumps:

- *flat*: scattered on a flat ground;
- *slope*: scattered on an inclined ground;
- *heap*: piled waste;
- *saw*: overburden wastes dumped by dragline;
- *pond*: acid water ponds created by mining activity such as those at the pit highwall;
- *road*: road paved with black shale; and
- *river bank*: black shale exposed along the river bank.

5. ***Area type***: Area type (mountain top, mountain area, flat area and along river) indicates topographical situation surrounding waste dumps.

6. Other parameters include area's name, located municipality, the river and river basin to which a waste dump belongs, original polluter, current land owner, type of operation (mining, washing and coke manufacturing), operation status (active, inactive and abandoned), dumped area (ha) and dumped volume (1,000 m3).

7. Estimates of area (ha) and volume (m^3): Waste dumps delineated on the JICA's maps or acrophotographies was measured with a planimeter for area calculation. The actual disturbed area, which means the area measured by a planimeter, is larger than the area of surface mining approved by DNPM, probably due to dumping or disturbing beyond the licensed boundary. Concerning volume estimate, differing approaches were taken for differing waste dumps and locations.

- ⇨ Black reject: The amounts of waste in the Fiorita and Rio Rochinha FS sites were estimated using the detailed FS site maps (1:1,000) and by means of cross-sectional method. For the rest of dumps, it was assumed that the total amount of reject (less above mentioned black waste), which were estimated from historical ROM coal production in Santa Catarina and average yield between 1925 and 1994 as shown in Table A-1, were prorated according to their areas (ha).

- ⇨ Overburden waste: It was assumed that the amount of overburden waste in every waste dump was the one reported to DNPM by mining companies.

2. Summary of Waste

8. Together with compilation of groundwater reserves[1] and locations of waste dump in the map, results of the waste dumps survey are summarized in the following tables and figures:

- Table A-2 Summary of Waste;
- Table A-3 Waste Dumps by Rivers;
- Table A-4 Land Ownership and Land Status;
- Table A-5 Original Polluters;
- Figures A-1. (1/2) & (2/2) Land Status; and
- Figures A-2. (1/2) & (2/2) Groundwater Reserves.

[1] Source: Projeto Gerenciamento Costeiro do Estado de Santa Catarina by NUPESE.

TABLE A-1

BRAZILIAN PRODUCTION OF RUN OF MINE COAL

(UNIT: 1,000 metric tons)

Year		Santa Catarina	Rio Grande do Sul	Parana	San Paulo	Total	Yield (%)
1925	*	85	307	-	-	392	(60.0)
1930	*	46	336	3	-	385	(60.0)
1935	*	151	689	-	-	840	(60.0)
1940	*	266	1,065	3	2	1,336	(60.0)
1945	*	816	1,140	98	19	2,073	(60.0)
1950	*	1,005	855	99	-	1,959	(60.0)
1955	*	1,326	948	75	-	2,349	(60.0)
1960	*	1,439	646	75	-	2,160	(60.0)
1965		2,240	904	227	-	3,371	(60.0)
1966		2,462	731	187	-	3,380	58.2
1967		3,097	926	316	-	4,339	52.9
1968		3,490	996	343	-	4,829	49.0
1969		3,707	1,006	415	-	5,128	47.5
1970		3,845	965	362	-	5,172	45.6
1971		4,364	956	346	-	5,666	44.1
1972		4,536	978	345	-	5,859	42.6
1973		4,314	931	321	-	5,566	40.4
1974	**	4,257	919	317	-	5,492	57.3
1975		5,132	909	268	-	6,309	43.1
1976		6,635	956	285	-	7,876	42.3
1977		8,430	1,329	286	-	10,045	38.9
1978		9,591	1,907	318	-	11,816	37.6
1979		11,638	1,978	327	-	13,943	35.1
1980		13,212	2,529	309	-	16,051	30.6
1981		14,734	2,871	297	-	17,901	32.4
1982		15,504	3,287	312	-	19,104	34.3
1983		16,209	4,724	350	-	21,283	31.8
1984		17,951	4,700	431	-	23,082	32.3
1985		19,164	4,677	466	-	24,307	31.5
1986		17,212	4,833	470	-	22,515	32.9
1987		13,911	4,377	405	-	18,693	35.5
1988		16,437	4,193	354	-	20,984	41.8
1989		13,925	3,998	273	-	18,196	42.7
1990		7,484	3,809	220	-	11,513	41.9
1991		6,684	3,463	269	-	10,416	47.1
1992		5,531	3,484	256	-	9,271	49.9
1993		6,045	3,306	273	-	9,624	47.6
1994		5,700	3,748	305	-	9,753	52.5
Toatl		293,111	104,321	11,417	105	408,954	41.9

Note: * Between 1925 and 1965, ROM coal production data are not available for all the years. Therefor, to amount of the total, it is assumed that productions for the years for which data are missing stayed at the same level of the previous years. For example, production for 1926, 1927, 1928 and 1929 is estimated at 392. Yields are also assumed at 60 %.

** Estimated.

TABLE A-2

SUMMARY OF WASTE

Municiparity	Road (Black Reject)			Black Reject		Pond		Overburden Waste		Total	
	Length (m)	Area (ha)	Volume (1000m3)	Area (ha)	Volume (1000m3)	Area (ha)	Volume (1000m3)	Area (ha)	Volume (1000m3)	Area (ha)	Volume (1000m3)
Capivari de Baixo				80.0	3,680	80.0				160.0	3,680
Criciuma				996.1	45,821			68.5	10,138	1,064.6	55,959
Forquilhinha				356.7	16,408	28.0				384.7	16,408
Icara				44.8	2,061					44.8	2,061
Lauro Muller	29,000	20.0	65	203.7	9,774	4.8		419.6	41,694	648.1	51,532
Sideropolis	7,500	4.4	18	217.5	10,005	103.0		751.4	104,876	1,076.3	114,899
Treviso	17,300	9.3	35	149.6	6,882	22.0		309.8	33,405	490.7	40,322
Urussanga	28,500	21.2	59	246.2	11,349	10.0		633.1	75,589	910.5	86,996
Total	82,300	54.8	177	2,294.6	105,978	247.8		2,182.4	265,702	4,779.6	371,857

TABLE A-3

WASTE DUMPS BY RIVERS

River Basin	River	Black Reject		Pond		Overburden Waste		Total	
		Area (ha)	Volume (1000m3)	Area (ha)	Volume (1000m3)	Area (ha)	Volume (1000m3)	Area (ha)	Volume (1000m3)
Rio Araranguа	Rio Albino					61.0	5,673	61.0	5,673
	Rio Criciuma	80.0	3,680					80.0	3,680
	Rio dos Porcos	44.8	2,061					44.8	2,061
	Rio Fiorita			67.0		492.6	67,604	559.6	67,604
	Rio Kuntz	151.0	6,946	16.0		103.0	16,830	270.0	23,776
	Rio Mae Luzia	149.6	6,882	22.0		231.8	19,666	403.4	26,548
	Rio Maina	208.5	9,591			43.5	6,438	252.0	16,029
	Rio Morosini			19.0		181.8	29,270	200.8	29,270
	Rio Sangao	1,026.8	47,233	28.0		10.0	1,480	1,064.8	48,713
	Sub-total	1,660.7	76,392	152.0		1,123.7	146,961	2,936.4	223,353
Rio Tubarao	Rio Amaral					18.0	2,124	18.0	2,124
	Rio Bonito	40.2	1,849					40.2	1,849
	Rio Capivaras					5.0	590	5.0	590
	Rio Carrapatos					87.0	10,266	87.0	10,266
	Rio Lageado	54.1	2,489	6.5		380.3	39,147	440.9	41,636
	Rio Malha					56.6	2,321	56.6	2,321
	Rio oratorio					54.0	6,372	54.0	6,372
	Rio Palmeiras	42.7	1,964	0.5		41.6	3,507	84.8	5,471
	Rio Rochinha	81.0	4,129	1.3		10.0	1,180	92.3	5,309
	Rio Salame					132.2	10,690	132.2	10,690
	Rio Tubarao	88.0	4,048	80.0				168.0	4,048
	Sub-total	306.0	14,479	88.3		784.7	76,197	1,179.0	90,676
Rio Urussanga	Rio America					7.0	1,092	7.0	1,092
	Rio Anta	50.0	2,300					50.0	2,300
	Rio Carvao	187.2	8,611	5.0		242.0	37,752	434.2	46,363
	Rio Deserto	36.7	1,688	1.5				38.2	1,688
	Rio RancoDagu	38.0	1,748			25.0	3,700	63.0	5,448
	Rio Urussanga	16.0	736					16.0	736
	Sub-total	327.9	15,083	6.5		274.0	42,544	608.4	57,627
Grand Total		2,294.6	105,955	246.8		2,182.4	265,702	4,723.8	371,657

TABLE A-4

LAND OWNERSHIP AND LAND STATUS

Unit:ha

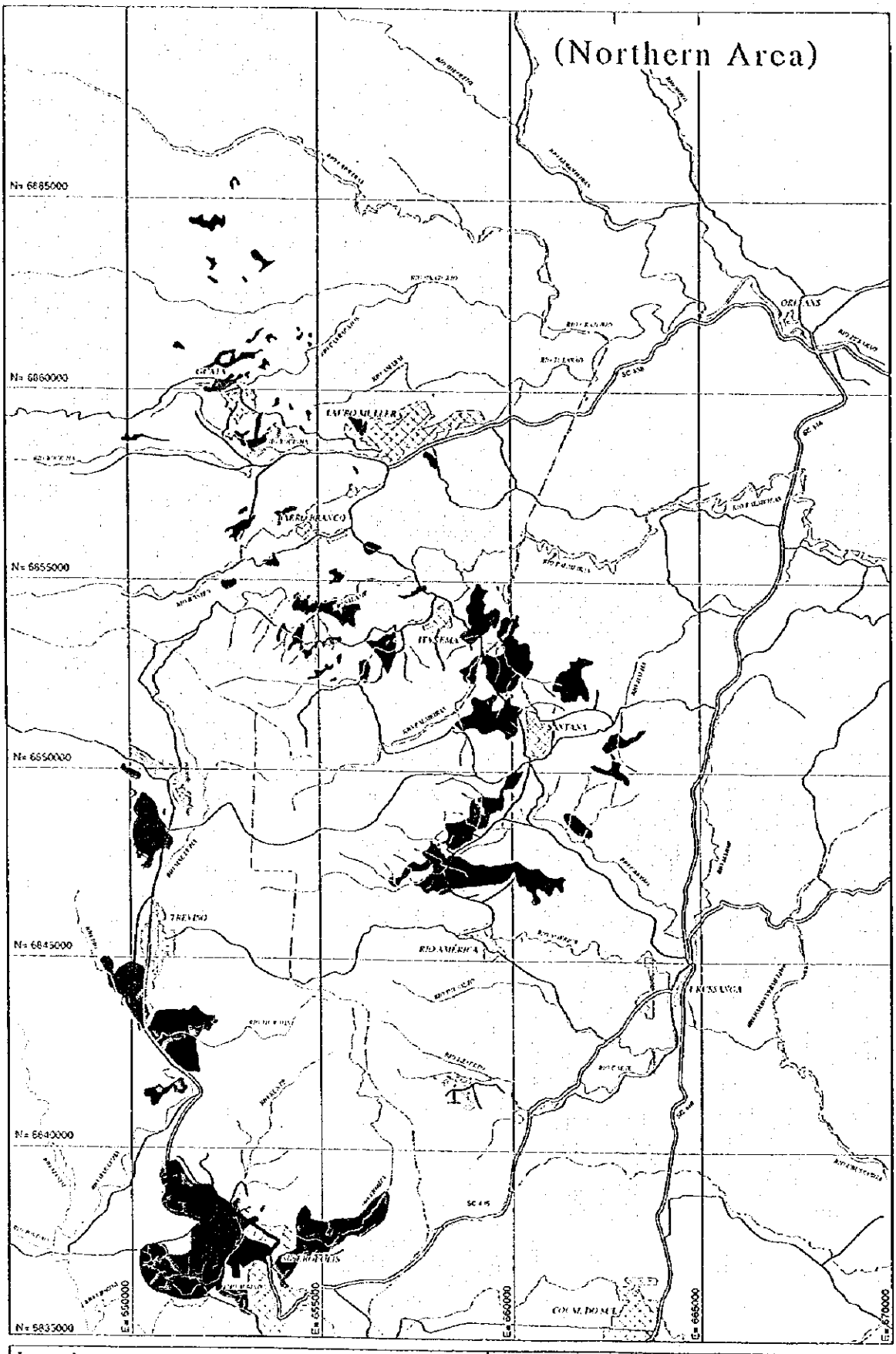
Municipality	Land Ownership	Numbers of Owners	Abandoned	Active	Inactive	Total
Capivari de Baixo	Private Individual	-	-	-	-	-
	Private Company	2	160.0	-	-	160.0
	CSN	-	-	-	-	-
	Public	-	-	-	-	-
	Sub-total	2	160.0	-	-	160.0
Criciuma	Private Individual	12	130.2		-	130.2
	Private Company	13	588.5	163.0	87.0	838.5
	CSN	1	-	-	6.9	6.9
	Public	1	89.0	-	-	89.0
	Sub-total	27	807.7	163.0	93.9	1,064.6
Forquilhinha	Private Individual	1	17.5	-	-	17.5
	Private Company	3	8.0	219.2	-	227.2
	CSN	-	-	-	-	-
	Public	1	140.0	-	-	140.0
	Sub-total	5	165.5	219.2	-	384.7
Icara	Private Individual		-	-	-	-
	Private Company	1	36.0	8.8	-	44.8
	CSN	-	-	-	-	-
	Public	-	-	-	-	-
	Sub-total	1	36.0	8.8	-	44.8
Lauro Muller	Private Individual	10	178.2	8.0	-	186.2
	Private Company	8	245.0	161.3	35.6	441.9
	CSN	-	-	-	-	-
	Public	-	-	-	-	-
	Sub-total	18	423.2	169.3	35.6	628.1
Sideropolis	Private Individual	4	122.0	-	-	122.0
	Private Company	5	286.1	192.0	-	478.1
	CSN	1	359.8	-	-	359.8
	Public	1	111.0	-	-	111.0
	Sub-total	11	878.9	192	-	1,070.9
Treviso	Private Individual	1	-	110.2	-	110.2
	Private Company	4	62.8	128.8	110.6	302.2
	CSN	1	69.0	-	-	69.0
	Public	-	-	-	-	-
	Sub-total	6	131.8	239.0	110.6	481.4
Urussanga	Private Individual	-	-	-	-	-
	Private Company	5	688.9	162.2	38.2	889.3
	CSN	-	-	-	-	-
	Public	-	-	-	-	-
	Sub-total	5	688.9	162.2	38.2	889.3
Total	Private Individual	28	447.9	118.2		566.1
	Private Company	24	2,075.3	1,035.3	271.4	3,382.0
	CSN	1	428.8	-	6.9	435.7
	Public	3	340.0	-	-	340.0
	Total	56	3,292.0	1,153.5	278.3	4,723.8

TABLE A-5

ORIGINAL POLLUTERS

Unit:ha

Company	Municipality	Abandoned	Active	Inactive	Total
Carbonifera Barro Branco S.A.	Lauro Muller	217.6	61.3	35.6	314.5
Companhia Carbonifera Catarinense S.A.	Criciuma	35.5	40		75.5
Massa Falida da Companhia Brasileira	Criciuma	104.5	7		111.5
Carbonifera de Araranguá - CBCA	Forquilhinha	17.5	33		50.5
	Sub-total	122	40		162
Companhia Carbonifera de Urussanga-CCU	Criciuma	188			188
	Sideropolis		40		40
	Urussanga	7	25		32
	Sub-total	195	65		260
Coque Catarinense LTDA - COCALIT	Sideropolis	20.5	152		172.5
Comin	Treviso		16		16
Industria e Comercio de Coque Criciuma LTDA.	Forquilhinha	8	16.2		24.2
Coque Sul Brasileiro Industria e Comercio LTDA. - Coquesul	Criciuma		10		10
Carbonifera Criciuma S.A	Criciuma	98	14		112
	Forquilhinha		170		170
	Lauro Muller	125.8			125.8
	Treviso	34.8			34.8
	Urussanga	19			19
	Sub-total	277.6	184		461.6
Companhia Siderurgica Nacional - CSN	Capivari de Ba	160			160
	Criciuma	290.2		93.9	384.1
	Icara	36	8.8		44.8
	Sideropolis	775.4			775.4
	Treviso	97			97
	Sub-total	1358.6	8.8	93.9	1461.3
Ibracoque Mineracao LTDA - IBRAMIL	Urussanga	1.5			1.5
ICC	Forquilhinha	140			140
Industria e Coqueria de Coque LTDA - INCOL	Criciuma		14		14
Carbonifera Metropolitana S.A.	Criciuma	84.5	78		162.5
	Sideropolis	6			6
	Treviso		6		6
	Sub-total	90.5	84		174.5
Palermo	Lauro Muller	8			8
Industria Carbonifera Rio Deserto LTDA.	Urussanga			38.2	38.2
Carbonifera Treviso S.A.	Lauro Muller	71.8	108		179.8
	Sideropolis	77			77
	Treviso		217	110.6	327.6
	Urussanga	661.4	137.2		798.6
	Sub-total	810.2	462.2	110.6	1383
Unknown	Criciuma	7			7
Grand Total	Lauro Muller	3292	1153.5	278.3	4723.8



Legend:

- Active Area
- Inactive Area
- Abandoned Area
- Pond
- Waste Paved Road

FIGURE A-1(1/2) LAND STATUS

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

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

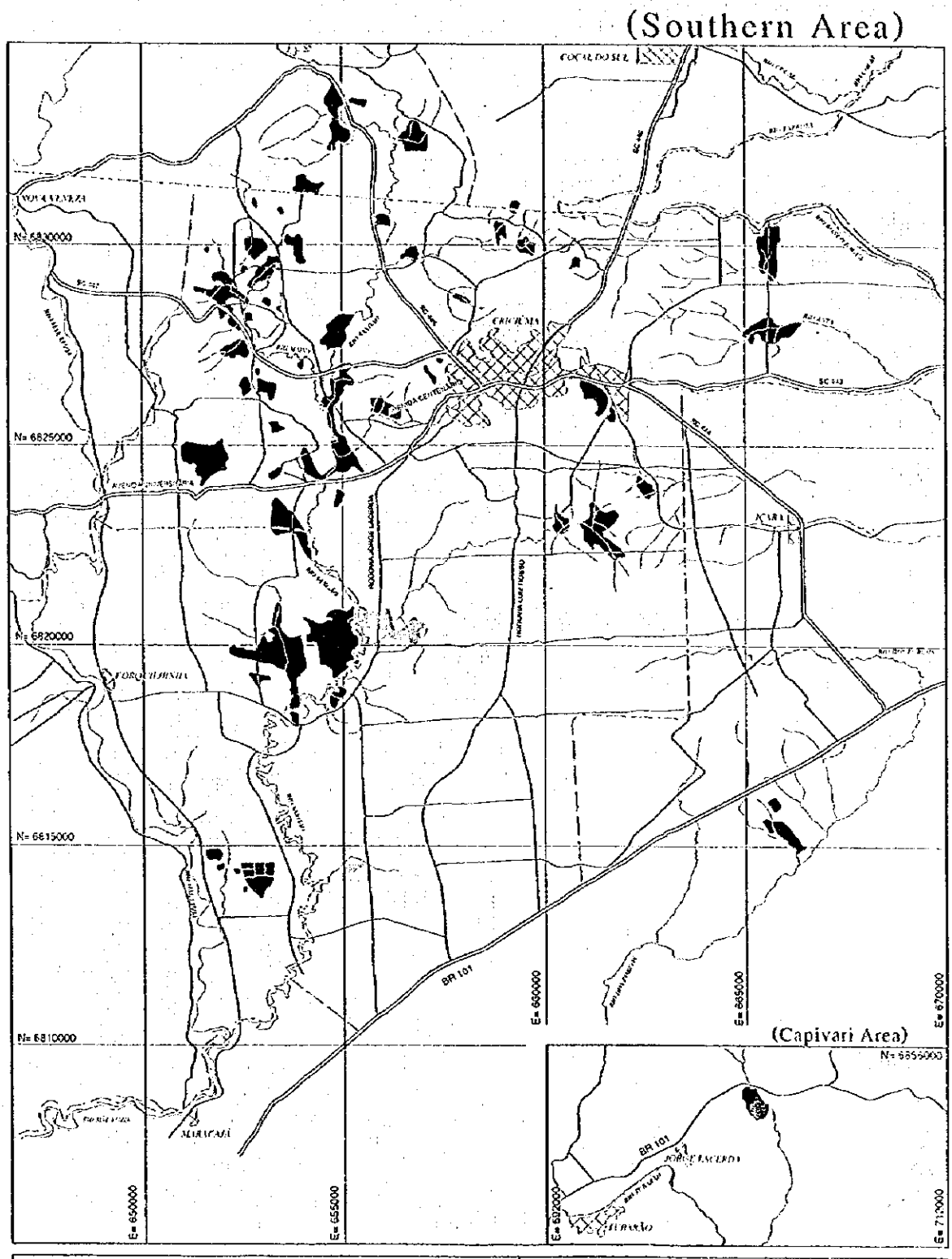
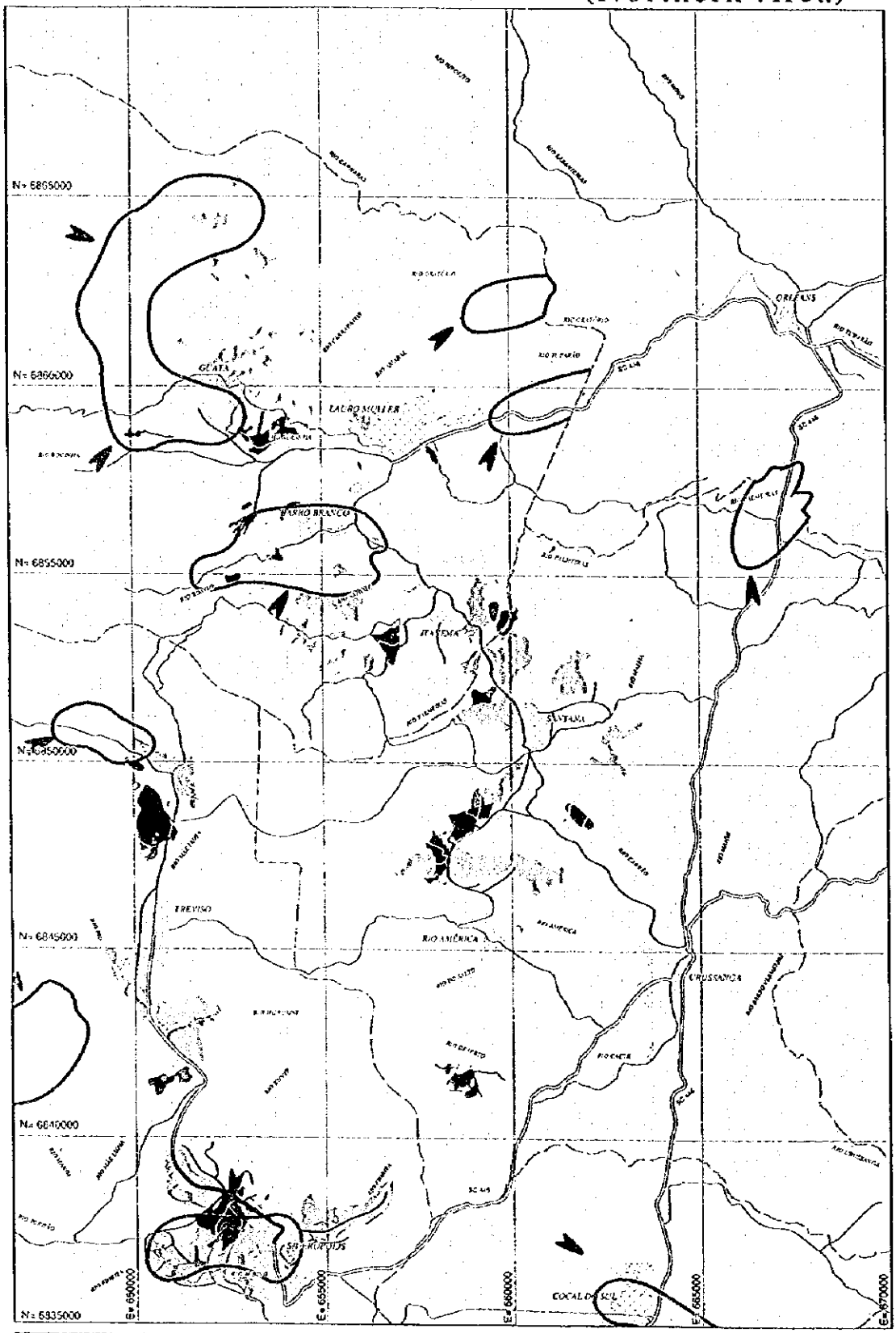


FIGURE A-1(2/2) LAND STATUS

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

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

(Northern Area)



Legend:

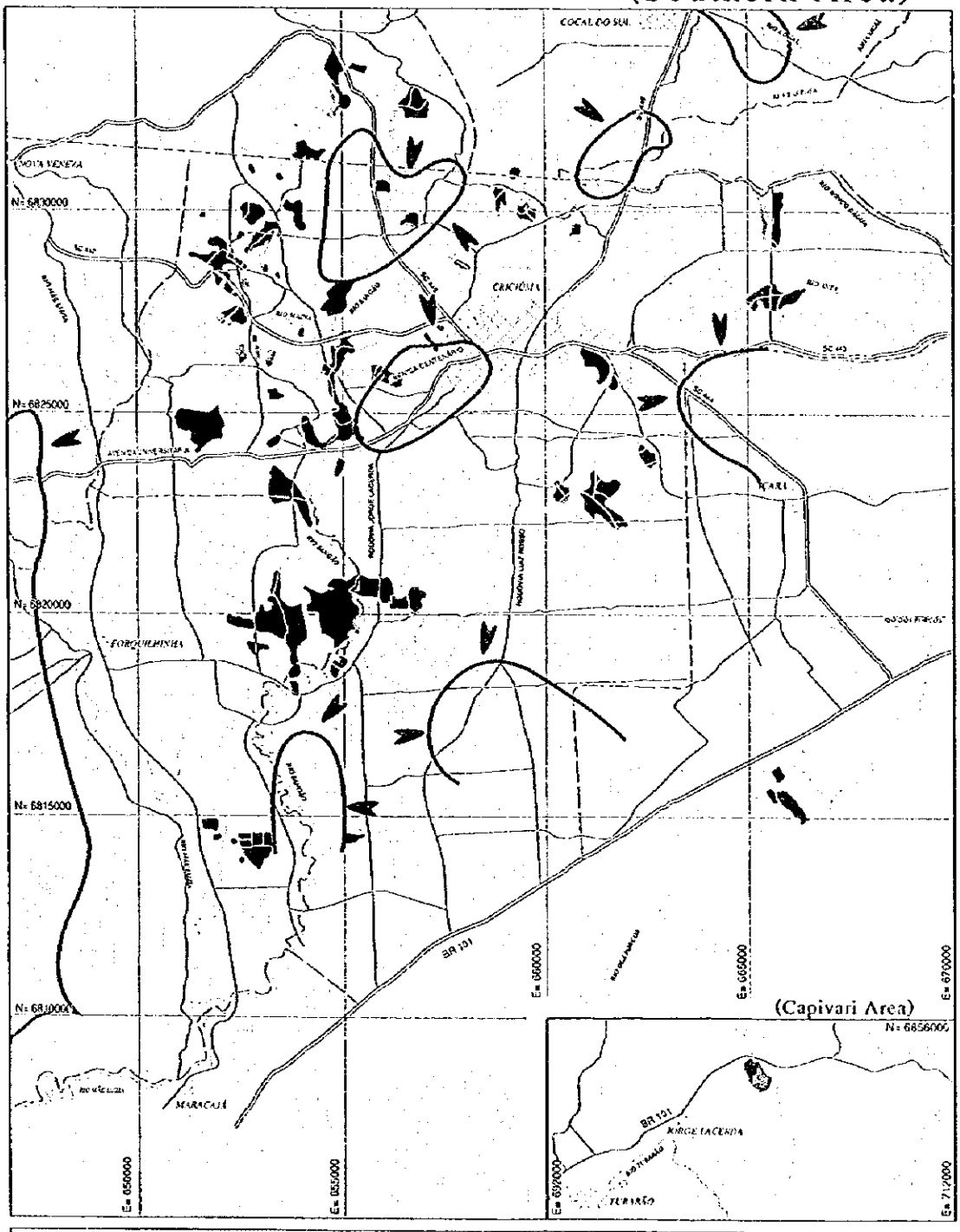
- Black Reject
- Overburden Waste
- Pond
- Waste Paved Road
- Area of Main Aquifer
- Flux Direction of Subterrancan Water

FIGURE A-2(1/2) GROUNDWATER RESERVES

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
- Overburden Waste
- Pond
- Waste Paved Road
- Area of Main Aquifer
- FluxDirection of Subterranean Water

FIGURE A-2(2/2) GROUNDWATER RESERVES

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

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

A. CURRENT POLLUTION PROBLEMS

A-II. COAL INDUSTRY'S ACTIVITIES IN ENVIRONMENTAL PROTECTION CONTROL

1. The team visited nine out of the operating 12 coal mines in May 1996 and 12 out of the operating 21 plants of ROM (run of mine) coal washing and waste re-washing in November 1996 to study their current activities, especially with regard to their pollution control measures to evaluate their environmental protection control activities. Prior to actual inspection, a preliminary study was carried out, which included investigating documents submitted to FATMA by washing companies for comparison with the actual operating site observation. Finally, the Team visited three coal mines again in October 1997 to evaluate the adequacy of the ZETA/IESA report, in which guidelines for the design of acid rock drainage prevention and control systems have been established by ZETA and International Engineering SA, two consulting firms contracted by the mining companies in the State of Santa Catarina. The findings are summarized below.

1. Document Research

2. Washing companies and also mining companies should submit documents to FATMA, which include an annual report, application documents for their annual environmental operation license and periodical reports of effluent chemical analyses. Annual reports only describe production performance, not environmental aspects. These are dealt with in the application document. A license application document is required for individual activities, i.e. washing and waste dumping. In case of mining companies, in addition to the above, an extraction license is required.. The license application for the above activities include identical information, i.e. name, address, municipality, taxation number, activity, location, restrictions, annex documents and license conditions. The restrictions in every application submitted to FATMA always include a statement that prohibits tree and/or plant cutting. The license conditions consist of two parts, i.e. general and special conditions. They are summarized below.

3. General conditions for washing plant license are summarized as follows:

- Operation: description of the operation, including washing material, product, capacity, equipment, etc.
- Environmental control: establishment of a closed circuit system or compliance with effluent standard as stipulated in article 19 of the regulation No. 14.250/81

4. Special conditions for washing plant license are summarized as follows:

- Submission of a reclamation plan, a settling pond cleaning plan or an effluent control plan or correction of violated conditions, stating the deadline to complete it.
- Reporting of effluent chemical analyses (commonly required for all the companies).
  reporting frequency: usually every two months, once a month in special

cases depending on the companies' past conduct

parameters: amount of effluent, pH, acidity, sulfate, suspended solids, sediments, manganese, total iron, copper and zinc

5. General conditions for waste dumping license are summarized as follows:

- Operation: description of the operation including type of waste and waste volume (m^3).
- Environmental control:
  - compliance with dumping and reclamation systems recommended in the ZETA/IESA report
  - effluent control, including permeation-proof structure and ditch to the settling pond
  - compliance with effluent standard as stipulated in article 19 of the regulation No. 14.250/81

6. Special conditions (usually no description except for one case) for waste dumping license are summarized as follows:

- presentation of an environmental remediation plan, including facilities layout with geological information, methods and implementation schedule.

2. Summary of Inspection

7. The location of coal mines, washing plants and coke plants is presented in Figures A-3 (1/2) & (2/2), and Figures A-4 (1/2) & (2/2).

8. Waste dumps for re-washing: Mostly they have their own waste dumps for re-washing but some buy waste for washing. Waste is loaded by a front end loader (FEL) or a backhoe and hauled to the washing plant by truck. When waste dumps are located close to the washing plants, effluent from the waste dumps are collected into the settling pond. When they are located away from the plants, no effluent disposal is done.

9. Washing plants: All of them, including coal mining companies, have installed settling ponds using pond water for washing. They call this water recycling system a closed circuit but actually it is not[2]. The settling pond is not exclusively used for the washing plant and other water runs into the same pond. At the outlet of the pond, effluent pH ranges from 3 to 4.5 against the effluent standards of 6 to 9. Only Mina 03 - Verdinho has small acid water neutralization facilities, using limestone, however nominal. The other companies do not have any neutralization system. Many ponds as well as stockyards have not been constructed with impermeable liners to prevent leakage.

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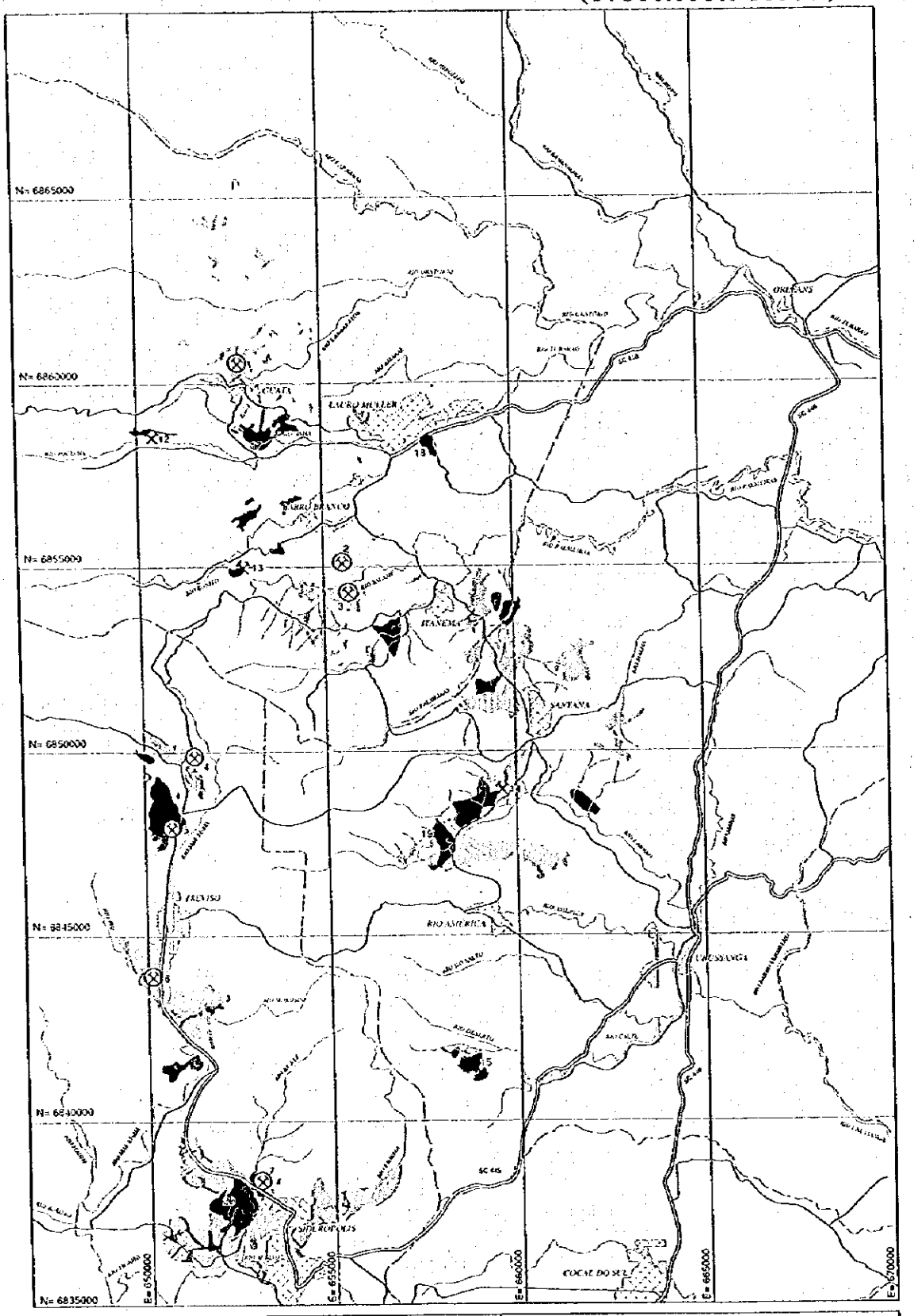
[2] Because water is usually discharged from the circuit.

(Northern Area)



Legend:

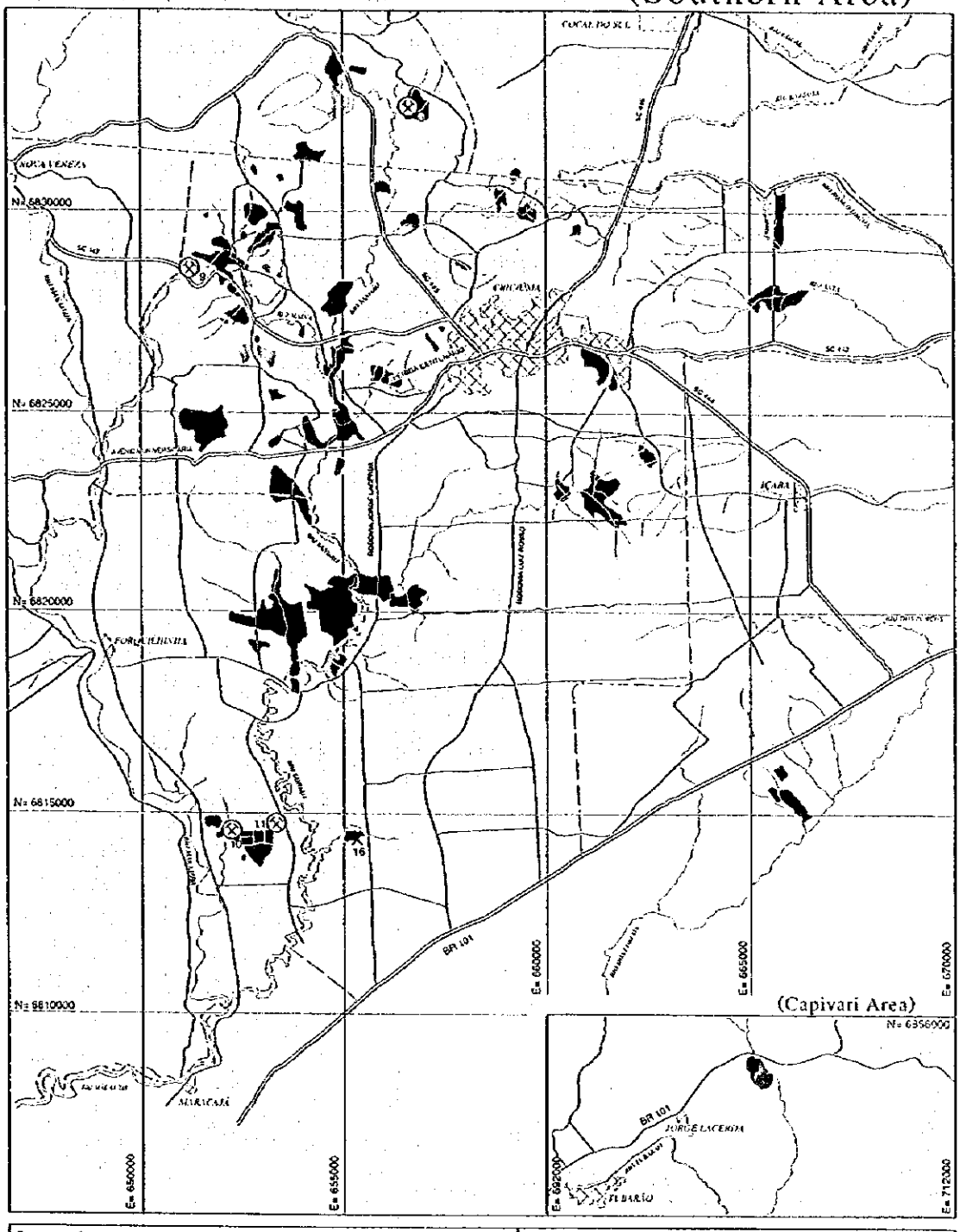
- Black Reject
- Overburden Waste
- Pond
- Active Mine
- Abandoned Mine / Inactive Mine
- Area of Reject Excavation

FIGURE A-3(1/2) COAL MINES LOCATION MAP

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)



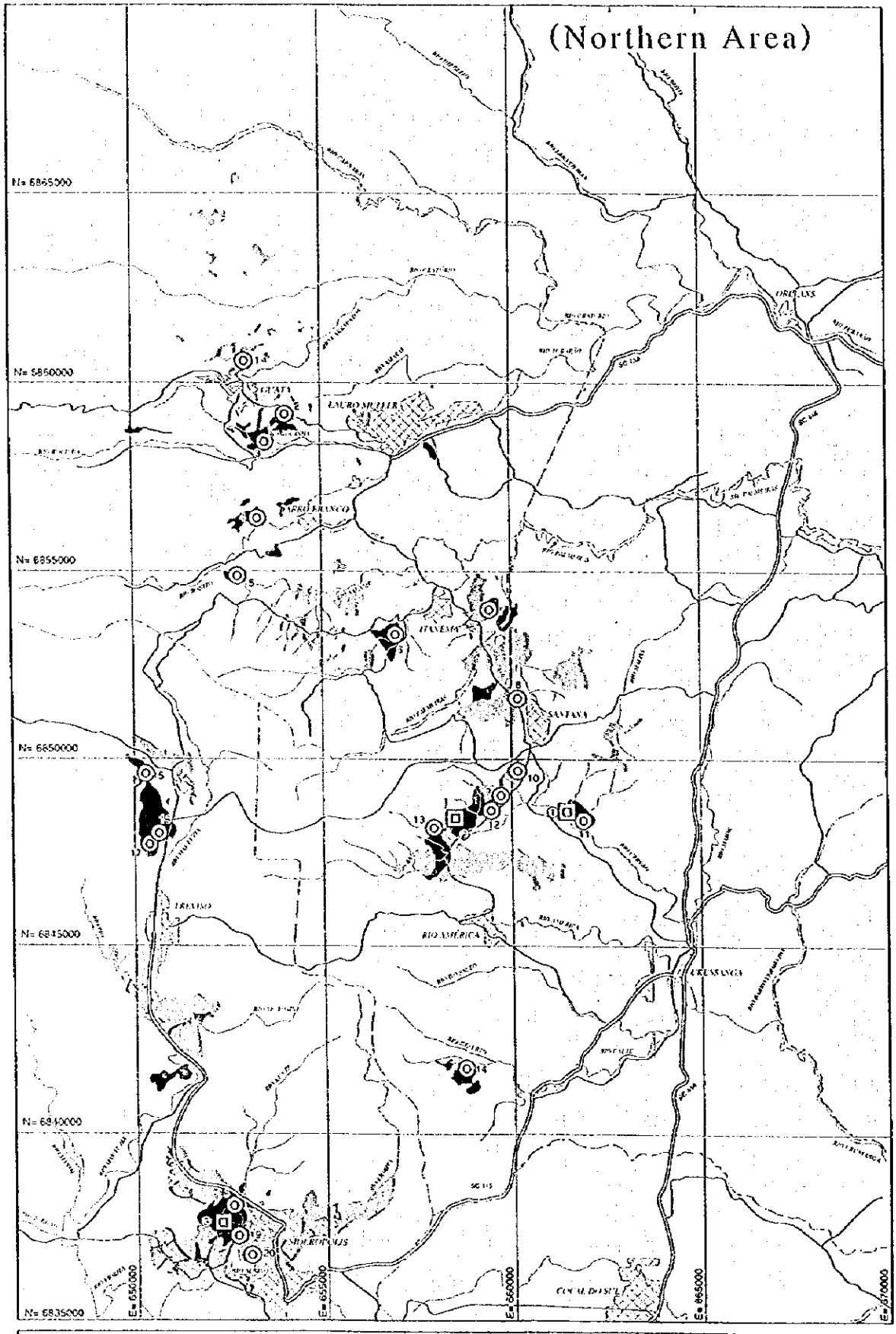
Legend:

- Black Reject
- Overburden Waste
- Pond
- Active Mine
- Abandoned Mine / Inactive Mine
- Area of Reject Excavation

FIGURE A-3(2/2) COAL MINES LOCATION MAP

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

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA



Legend:

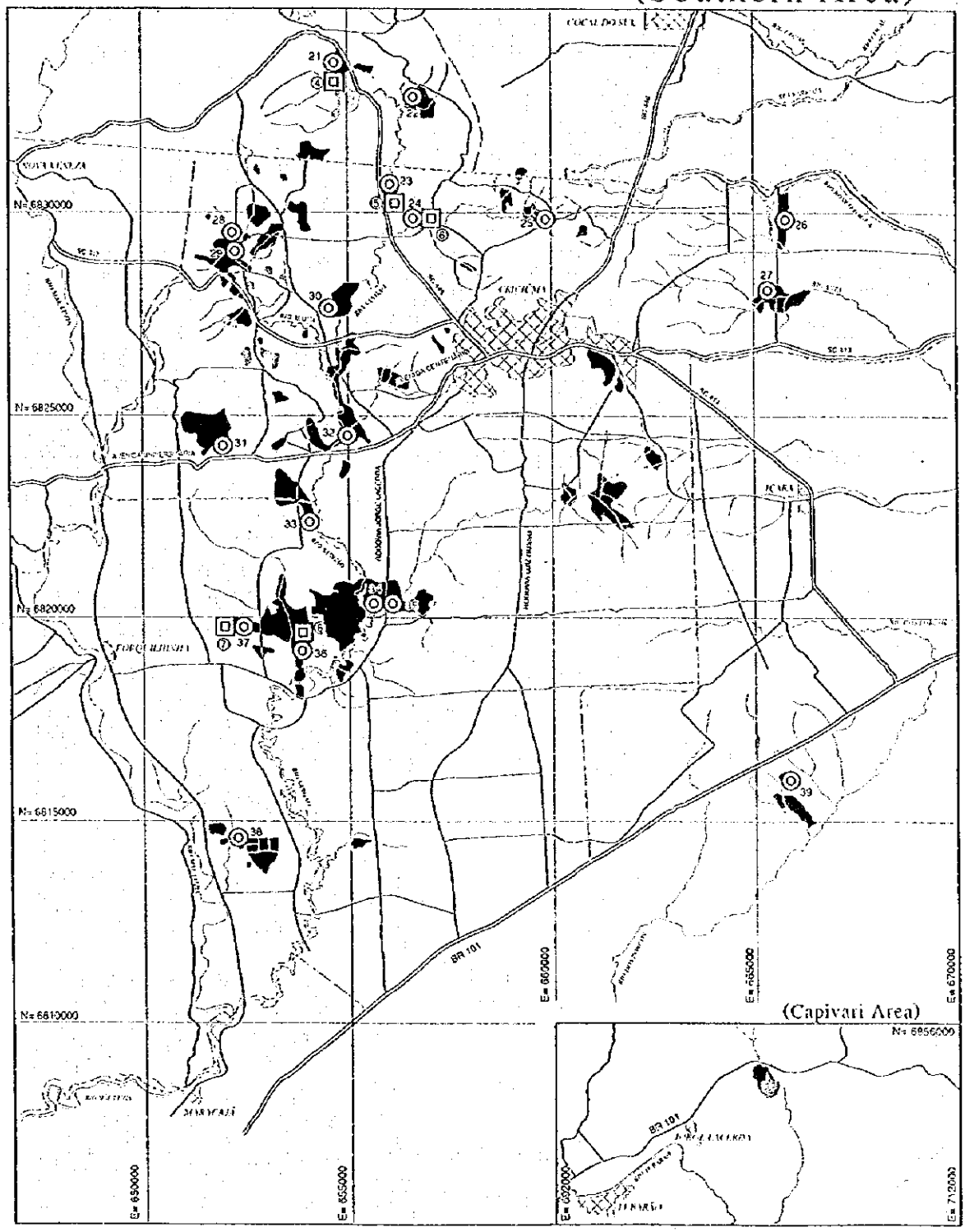
- Black Reject
- Overburdrn Waste
- Pond
- Washing Plant
- Coke Plant

FIGURE A-4(1/2) Washing Plant and Coke Plant Location Map

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
- Overburdrn Waste
- Pond
- Washing Plant
- Coke Plant

FIGURE A-4(2/2) Washing Plant and Coke Plant Location Map

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

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

10. Final waste dumps: At some of open pit mines and washing plants, which have soil and/or clay sources in their own properties, reclamation is being carried out. However the reclamation is imperfect in leveling, covering with clay and re-vegetation. Those who have not clay sources have not reclaimed their waste dumps. Effluent control is superficial. With regard to waste re-washing companies, none are carrying out reclamation work in parallel with production work. Many are dumping waste without any effluent control. No company is fully complying with the ZETA/IESA report's recommendations.

11. Concerning the pH issue, river water itself is already polluted and there is no difference between river water and washing plant effluent. For that reason, FATMA could not ask them to neutralize effluent.

12. **Recommendations**: It is recommended that the following be incorporated into the remediation program in accordance with its progress:

- Waste re-washing activities have many aspects in common with coal mining. However, since the current Brazilian mining law only covers mineral resources, that business is not under DNPM's control. Given DNPM's good knowledge and experience of mining in the region, it is recommended that this activity be brought under DNPM's control.

- Concerning technical aspects, independent effluent control and/or reclamation should be required for re-washable waste sites, washing plants and final waste disposal areas during their operations:

  - Re-washable waste sites: (i.) avoidance of clean water influx into the waste sites from the background; and (ii.) containment of surface water in the waste site by encircled ditches and the impermeable settling ponds.

  - Washing plants: Installation of an exclusive impermeable settling pond for washing water to establish a closed circuit system and another impermeable settling pond for effluent from the other facilities.

  - Final waste refuse dumps: (i.) establishment of a systematic parallel operation, dumping and reclamation at the same time, and separate effluent control, one from a reclaimed area and another from a dumping area; and (ii.) avoidance of clean water influx into the dumping area.

  - A last resort: introduction of a passive or active neutralization system

3. Evaluation of the ZETA/IESA Design Guidelines

13. The ZETA/IESA guidelines are described in Volume I of the 1987 report entitled, *Projeto Preservacao do Meio Ambiente, Deposito de Rejeitos Solidos*. The design recommendations provided in the ZETA/IESA report include clay bottom liners, underdrains, clay and soil covers, and surface drainage systems for new waste disposal facilities. These guidelines are supplemental to the

technologies identified in Section II.C-1 of Main Text.

14. The Team evaluated the adequacy of the ZETA/IESA guidelines and observed the methods of handling coarse rejects practiced by three companies currently conducting mining operations. Methods actually being put into practice were compared with the methods recommended by the ZETA/IESA consortium.

15. The Team reviewed the ZETA/IESA design guidelines to evaluate their potential effectiveness in mitigating ARD from new or existing active mines. In summary, the Team regards the ZETA/IESA guidelines as a precedent for responsible mine waste management in southern Santa Catarina. The guidelines represent a giant step forward in the protection of the environment when compared with current waste disposal practices. Hence, the Team supports the use of the ZETA/IESA guidelines in conjunction with the Team's mitigation planning efforts. The mitigation plans presented in this document should be viewed as supplemental to the ZETA/IESA guidelines, and are not intended to supersede or replace the guidelines.

3.1 ZETA/IESA guidelines

16. The ZETA/IESA guidelines recommend the following actions be taken to mitigate ARD on new and active waste piles:

- Placing clay bottom liners and gravel underdrains to collect leachate in the heaps;
- Spreading and compacting the coal rejects in thin lifts to retard infiltration;
- Creating cells of compacted rejects 10 meters in thickness;
- Grading the terminal slopes of the waste dumps to achieve 50 percent grades;
- Placing 30 centimeter (cm) of compacted clay over the entire surface of each 10 meter cell;
- Installing benches to collect surface runoff at the base of each 10 meter lift;
- Providing surface drainage systems to prevent erosion and channel precipitation safely off the waste piles;
- Installing 10 cm of vegetative soils amended to create a suitable plant growth medium;
- Planting seedlings of selected grasses and legumes at 30 cm on center on all covered surfaces; and
- Creating contour furrows in the soil slopes to prevent erosion.

3.2 Evaluation of current mine waste disposal practices

17. Observations of reject disposal techniques practiced by three large coal producers indicate acid drainage is not being effectively mitigated despite attempts to cap the waste piles with soil or clay covers. Further, attempts at reclaiming waste piles for future land use were unsuccessful at two out of three sites visited by the Team. Based on these observations, the Team concluded that the expense of implementing the current ARD mitigation techniques is largely wasted due to the ineffectiveness of the

resulting soil cover systems and attempts to establish vegetative covers.

18. The effectiveness of current soil covering methods being practiced by some large coal producers is being compromised for the following reasons:

- The slopes of the reject heaps are too steep for constructing effective soil covers;
- No attempt to scientifically select the cover soils is made, so soil selection is random;
- Selected soils are often inappropriate for the limiting infiltration or establishing cover vegetation;
- In most cases, no erosion control measures are implemented and the covers are being severely eroded;
- Seeding efforts have been largely unsuccessful due to erosion and poor soil conditions;
- Only the terminal slopes of the waste dumps are being capped while most of the flat surfaces are left uncovered;
- Infiltration barriers are not compacted or are poorly compacted;
- There appears to be little or no construction quality assurance in the placement of soil covers; and
- In most cases, no seepage collection system is provided to collect and treat ARD from the active waste dumps.

3.3 Recommendations

19. Based on these observations, the Team makes the following recommendations to improve the cost-effectiveness of current ARD mitigation measures:

i.) Slopes of the reject piles should be regraded to less than 30 percent (approximately 17 degrees) to reduce surface erosion and improve the constructability of the soil cover system;

ii.) Improve and standardize the soil cover design to require a minimum of 50 cm of well compacted clay covered by 30 cm of vegetative soils. The low permeability clay layer should consist of clay with an in-place hydraulic conductivity of less than 10^{-7} centimeters per second (cm/sec);

iii.) Low permeability soils need to be uniformly compacted to design standards using appropriate equipment, such as a vibrating sheep's foot or wheel roller. Current soil compaction methods result in irregular, non-uniform compaction and depth of the soil layers;

iv.) Borrow soils need to be tested to ensure they meet their intended design purpose. The selection of borrow soils should be managed by a qualified soil engineer to maintain the integrity of the cover systems;

v.) The vegetative soil layer should be amended to provide essential plant nutrients and create an adequate plant growth medium. Soil amendments may include organic matter, nitrogen, phosphorous, calcium, magnesium, etc. The soil pH should be adjusted as required;

vi.) It is strongly recommended that mining companies consult with EPAGRI on methods of improving the suitability of cover soils for plant growth;

vii.) Design and install effective surface drainage systems to prevent erosion of the soil covers and manage the collection and possible treatment of surface runoff from the waste dumps;

viii.) Design and install seep collection systems to collect and treat ARD seeping from the base of the active waste dumps;

ix.) Improve construction methods and quality control to ensure the soil cover system will function as designed. The placement of the soil cover systems should be managed by a qualified construction engineer;

x.) Reduce the sizes of active disposal heaps, thereby reducing the time the rejects are exposed to weathering conditions;

xi.) Cover systems should be designed to cover all areas of the heaps, including the terrace benches and other flat surfaces. Current practice is to cover only the terminal slopes leaving benches and platforms uncovered;

xii.) Bacteriacides, lime, oxygen consuming materials, or temporary covers should be applied to waste piles that remain uncovered for more than one month. These methods will delay the onset of acid generation until the final cover systems can be installed;

xiii.) Bottom liners and leachate collection systems should be installed under new waste dumps to mitigate impacts to ground water and reduce surface drainage. Leachate collection systems should be designed to convey ARD to passive wetland treatment systems;

xiv.) Passive anaerobic and aerobic wetland treatment systems should be constructed to receive and treat any acidic drainage from the active waste piles;

xv.) Monitoring equipment, such as piezometers, temperature probes, and soil moisture tensiometers should be installed in the capped waste piles to evaluate the long-term effectiveness of the cover systems and identify any potential failures in the systems; and

xvi.) Constructing valley-fill waste dumps should be avoided to prevent the migration of ground water through the heaps. In cases where valley fills are necessary, cut-off walls or drains should be installed between the valley slopes and the pile to retard or intercept the movement of ground water into the heaps.

A-III PRELIMINARY INVESTMENT COST ESTIMATES FOR NEUTRALIZATION OF ACTIVE MINE EFFLUENT

1. The objective of this section is to estimate order of magnitude costs of treating acid drainage from active mines in the overall study area for understanding current pollution conditions. Estimates are based on estimated mine water flow rates and averaged mine water quality from six operating underground mine companies, comparing two treatment methods, i.e., active, chemical neutralization and passive wetland treatment as summarized in Table A-6 below. Details for initial investment of wetland treatment systems for active mines' effluent are presented in Table A-7.

TABLE A-6

PRELIMINARY INVESTMENT COST ESTIMATES FOR NEUTRALIZATION OF ACTIVE MINE EFFLUENT

	Active, Chemical Neutralization	Passive Wetland
Estimated Flow Rate (m3/hr)	823	823
Acidity (mg/l)	2,750	2,750
Average Iron (mg/l)	537	537
Average Manganese (mg/l)	15	15
Initial Capital Costs (R$x1000)	9,230	21,991
Annual Operating Costs(R$x1000/yr)	3,877	53
Sludge Disposal Costs (R$x1000/yr)	115	---
30 Years Total Costs [a] (R$x1000)	50,620	22,539

[a] Assuming 30 years would be the normally expected life cycle of an active treatment system. Expressed as net present value with a discount rate of 10%.

2. The capital costs for active, chemical treatment are lower than those of passive wetland treatment. The operating costs associated with active treatment are very high compared with those of wetland treatment systems. For this reason, active chemical treatment is much more expensive than wetland treatment.

3. Initial costs breakdown for passive wetland and force account costs are summarized in Table A-8 below.

TABLE A-7

WETLAND COSTS CALCULATIONS

Parameter	Quantity	Unit Cost ($US)	Total Cost (1000$US)
Anaerobic Treatment Cells			
Number of Cells (Approx. 1ha/cell)	35		
Area of Anaerobic Cells (ha)	455,000		
Concrete Control Structure (each)	35	36,250.00	1,269
Excavation for Wetland Cells (m3)	910,000	1.19	1,083
Backfilling of Anaerobic Cells Furnish and Install Limestone (m3)	301,600	33.54	10,116
Furnish and Install Organic Matter (m3)	910,100	3.22	2,931
Furnish and Install Clay Liner (m3)	136,600	4.89	668
Furnish and Install Rip Rap (m3)	3,520	61.16	215
- Furnish and Install Underdrains (m)	20,400	12.96	264.38
Subtotal of Anaerobic Treatment Cells			16545.4772
Aerobic Treatment Cells			
Number of Cells	53		
Excavation for Aerobic Cells (m3)	533,000	1.19	634
Furnish and Install Clay Liner (m3)	160,000	4.89	782
Furnish and Install Cobbles (m3)	13,400	6.77	91
Establish Wetland Vegetation (m2)	250,000	0.32	80
Subtotal of Aerobic Treatment Cells			1,587
Mobilization, Demobilization and Site Preparation			907
Engineering and Construction Inspection			952
Contingencies			1,999
Total			21,991

TABLE A-8

WETLAND COST BREAK DOWN FOR ACTIVE MINE EFFLUENT
(UNIT: R$X1000)

	Cost [a/]	FA [b/]	Indexes [c/]
Labor	1,218	0	0
Parts	375	375	1
Tire	51	51	1
Fuel/Lub	411	411	1
Depreciation	279	0	0
Overhead	879	0	0
Cement	164	140	0.85
Sand	21	18	0.85
Gravel	31	26	0.85
Board	229	195	0.85
Timber	25	21	0.85
Nail	7	6	0.85
Stone	289	246	0.85
Mortar	53	45	0.85
Lime stone	11,120	9,452	0.85
Clay	919	782	0.85
Chemical fertilizer	36	30	0.85
Seeds "AZEVEM"	9	8	0.85
Celulose	25	21	0.85
Emulsion	9	7	0.85
Bar	357	303	0.85
Organic matter	933	793	0.85
Pipes	416	354	0.85
Royalty for Clay	277	0	0
Mobilization etc.	907	0	0
Engineering	952	664	
Contingency	1,999	1,395	
Total	**21,991**	**15,344**	

a/ Costs based on contract-out with retail prices for materials

b/ Costs based on Force Account

c/ Multiplier: FA = Cost x Multiplier

B WATER QUALITY MONITORING

1. Introduction

1. The scope of work includes:

- Collection of water and sediment data by field surveys conducted through out the year;
- Investigation of the water quality goals;
- Investigation of the present conditions of the subject river basins;
- Analysis of the contamination mechanisms;
- Construction of the water quality simulation model for the FS sites; and
- Planning of the monitoring system for the rivers.

2. Methods

2. There are three major rivers in the target area, including the Rio Tubarão, Rio Urussanga and Rio Araranguá. The Araranguá basin consists of the two major branches, the Rio Mãe Luzia and Rio Sangão. The following describes the water quality monitoring methods.

2.1 Collected Data

3. Specific background information reviewed for the project included;

- Water quality monitoring data compiled by FATMA for the three rivers of Tubarão, Urussanga and Araranguá;
- Environmental standards and regulations in Brazil and Santa Catarina state;
- Information from the existing unmanned monitoring station installed by the National Center of Treatment for the Control of Pollution by Mines;
- Active mine coal production data supplied by DNPM; and
- Active mine effluent data supplied by DNPM.

2.2 Field Survey

4. The field survey was conducted to monitor the water quality for the three major rivers, the active mine effluent and the groundwater. The field measurements made with the portable meters and sampling for laboratory analysis was conducted by FATMA. The collected samples were analyzed at the FUCRI/UNESC laboratory. Table B-1 and B-2 show the water monitoring plan and time schedule, respectively. The following are the abstracts of each survey.

5. ***Major three rivers***: Considering several factors including the location of the FATMA's existing monitoring points, the distribution of the pollution sources, and the structure of the each river basin, a total of 52 locations were selected for the target three rivers as the monitoring points (Figures B-1 and B-2). The field surveys were conducted once a month from December, 1996 ,to May, 1997. A sediment survey was conducted once in March, 1997.

TABLE B-1

WATER QUALITY MONITORING PLAN

Location	Waters	Treatment of sample	Total point	Frequency: Samples/day	Frequency: days/month	Frequency: months	Total sample	Analysis items in laboratory										Total items	Total number	Parameters measured on site					
FATMA's Point including Control Points	Surface Water	Unfiltered	27	1	1	12	324	SS	SO4	Acidity	Fe							4	1,296	pH	Water temp	TDS	EC	Turbidity	DO
			27	1	1	12	324	As	Cd	Pb	Hg	Cr	Cu	Zn	Mn	COD	BOD	10	3,240	ORP	Color	Odor	Air temp	Velocity	
		Filtered (0.45um)	27	1	1	12	324	Fe	Ca	Mg	Al	Na	K					6	1,944						
	Sediment	-	27	1	1	1	27	IL	COD	Acidity	Fe	Sulfide	pH					14	378	ORP	Color	Odor	Grain size	Appearance	
								As	Cd	Pb	Hg	Cr	Cu	Zn	Mn										
Mine/Coal Preparation	Mine effluent	Unfiltered	10	1	1	4	40	SS	SO4	Acidity	Fe							12	480	pH	Water temp	TDS	EC	Turbidity	DO
			10	1	1	4	40	As	Cd	Pb	Hg	Cr	Cu	Zn	Mn					ORP	Color	Odor	Air temp	Velocity	
		Filtered (0.45um)	10	1	1	4	40	Fe	Ca	Mg	Al	Na	K					6	240						
JICA's Point including Control Points	Surface Water	Unfiltered	25	1	1	12	300	SS	SO4	Acidity	Fe							4	1,200	pH	Water temp	TDS	EC	Turbidity	DO
			25	1	1	12	300	As	Cd	Pb	Hg	Cr	Cu	Zn	Mn	COD	BOD	10	3,000	ORP	Color	Odor	Air temp	Velocity	
		Filtered (0.45um)	25	1	1	12	300	Fe	Ca	Mg	Al	Na	K					6	1,800						
	Sediment	-	25	1	1	1	25	IL	COD	Acidity	Fe	Sulfide	pH					14	350	ORP	Color	Odor	Grain size	Appearance	
								As	Cd	Pb	Hg	Cr	Cu	Zn	Mn										
F/S site	Surface Water	Unfiltered	30	1	1	3	90	SS	SO4	Acidity	Fe							12	1,080	pH	Water temp	TDS	EC	Turbidity	DO
			30	1	1	3	90	As	Cd	Pb	Hg	Cr	Cu	Zn	Mn					ORP	Color	Odor	Air temp	Velocity	
		Filtered (0.45um)	30	1	1	3	90	Fe	Ca	Mg	Al	Na	K					6	540						
	Erosion by rain	Unfiltered	3	2	1	1	6	SS	SO4	Acidity	Fe									pH	Water temp	TDS	EC	Turbidity	DO
								As	Cd	Pb	Hg	Cr	Cu	Zn	Mn			12	72	ORP	Color	Odor	Air temp		
Boring well	Groundwater	Filtered (0.45um)	4	1	1			SO4	Acidity	Fe	Ca	Mg	Al	Na	K			8		pH	Water temp	TDS	EC	Turbidity	DO
																				ORP	Color	Odor	Air temp		
	Groundwater	-	9	1	1	12	108						-					-	-						
Domestic well	Groundwater	-	2	1	1	12	24						-					-	-						
			110			Sum	2,322											Sum	15,620						

*TDS: Total dissolved solid, EC: Electric conductivity, ORP: Oxidation reduction potential, IL: Ignition loss, DO: Dissolved oxygen

***Unfiltered: Analyzed after decantation

**Filtered: Analyzed after 0.45um filteration

TABLE B-2

PROGRESS OF MONITORING

	ITEM	1996 NOV	1996 DEC	1997 JAN	1997 FEB	1997 MAR	1997 APL	1997 MAY	1997 JUN	1997 JUL	1997 AUG	1997 SEP	1997 OCT
WATER QUALITY ANALYSIS													
1	FATMA POINT												
2	MINE/COAL PREPARATION												
3	JICA POINT												
4	F/S SITE												
5	BORING WELL												
6	EROSION												
SEDIMENT ANALYSIS													
7	FATMA POINT												
8	JICA POINT												
WATER QUALITY MEASUREMENT ON SITE													
9	BORING WELL												
10	DOMESTIC WELL												

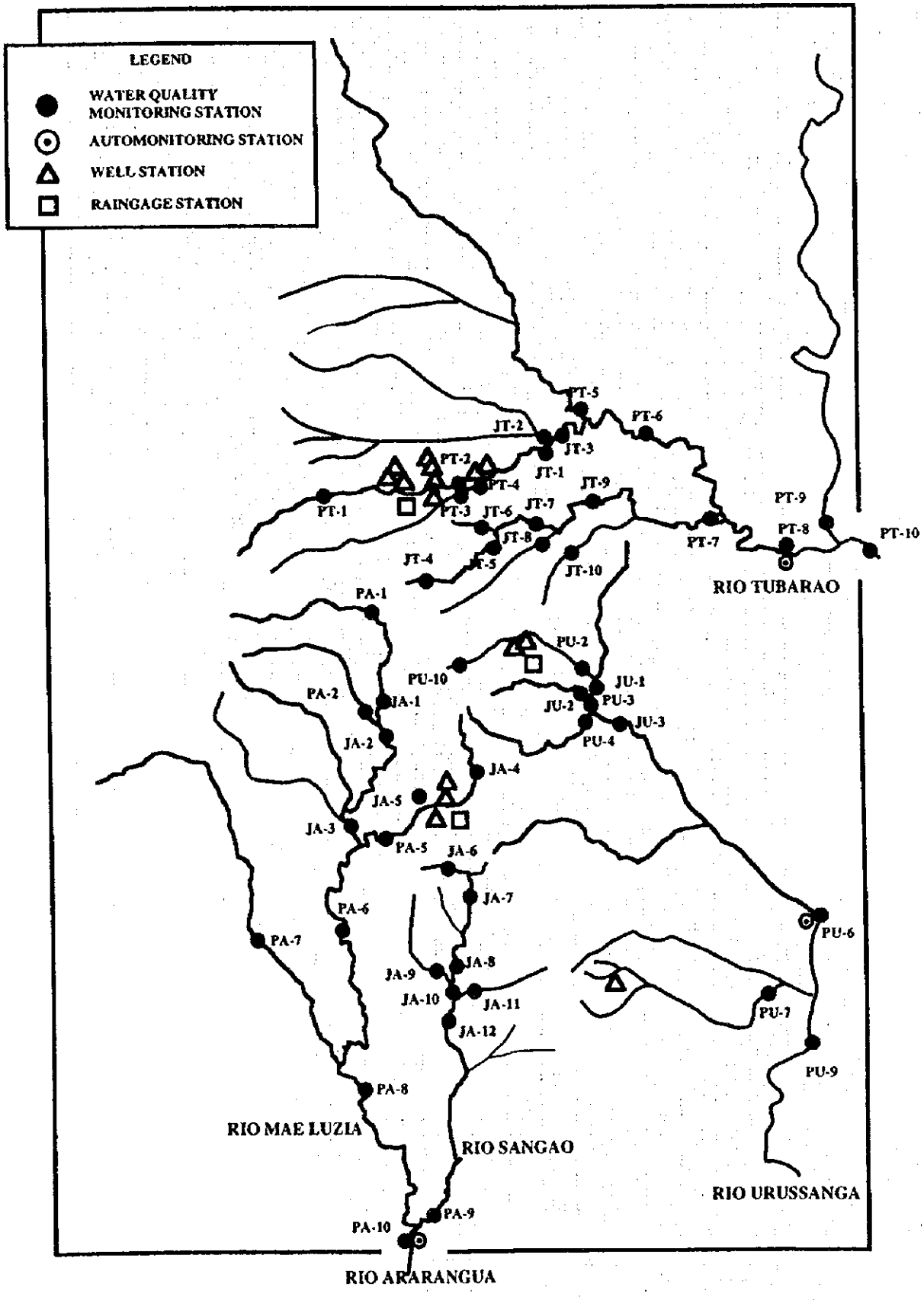


FIGURE B-1 WATER QUALITY MONITORING LOCATION

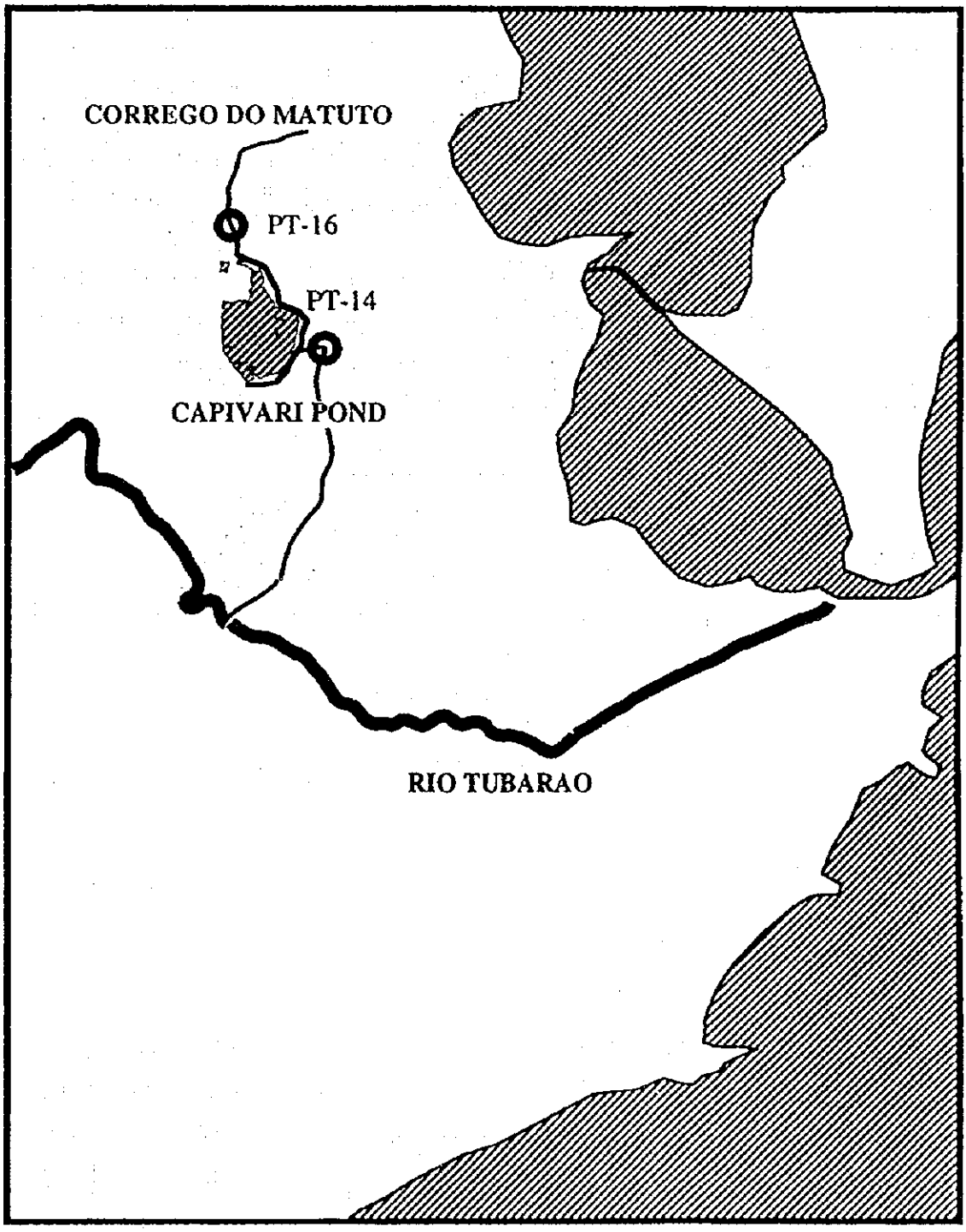


FIGURE B-2 MONITORING LOCATIONS IN CAPIVARI SITE

6. *FS sites*: A total of 30 locations were selected in the four FS sites as the water quality monitoring point (Figures B-3 to B-6). Field surveys were conducted four times, including January, February, March, and May in 1997.

7. *Active mine effluents*: A total of 10 locations were selected at seven active mines as the effluent monitoring points, which were intended to measure the whole effluent from the mine at one monitoring point. Monitoring was conducted three times, including February, May, and July, 1997.

8. *Groundwater*: Groundwater monitoring was conducted at the 17 monitoring wells and the two existing domestic wells. Field measurement for groundwater level and water quality with a portable meters was conducted every month and chemical analysis in the laboratory was conducted four times, including December 1996, January, February, and May, 1997.

2.3 Unmanned water quality monitoring equipment

9. Unmanned water quality monitoring equipment (American SIGMA Flowmeter type 950) was installed at a selected location in each river basin, including Pedras Grandes, Morro da Fumaça, and Maracajá. The monitoring equipment continuously measures water quality, including water temperature, pH, electric conductivity, and water level.

2.4 Quality Assurance

10. To monitor the reliability of the analysis by the laboratory work, the quality assurance, including the precision, accuracy, and cross check, was conducted by the laboratory. As a result of these tests, the reliability of FUCRI/UNESC was mostly satisfactory.

3. Results and Discussions

3.1 Water Quality Goals

11. To determine the water quality goals, by which the effect of mitigation measures to be proposed for the site remediation in the Study is assessed, the water quality standards of Brazil, Japan, USA, world bank, and U.S. EXIM. were studied for comparison. Among them, the Brazilian standards were selected for the goals, since the Brazilian standards are comparable to them. When a limitation value is different between the Federal and the State standards, the stricter one would be used. The U.S. standards for protection of human health were taken in our list. The Brazilian standards have five classes for different water uses. A class to be used for the water quality goals will be determined in the later stage of the Study, taking into consideration water use, remedial costs and benefits.

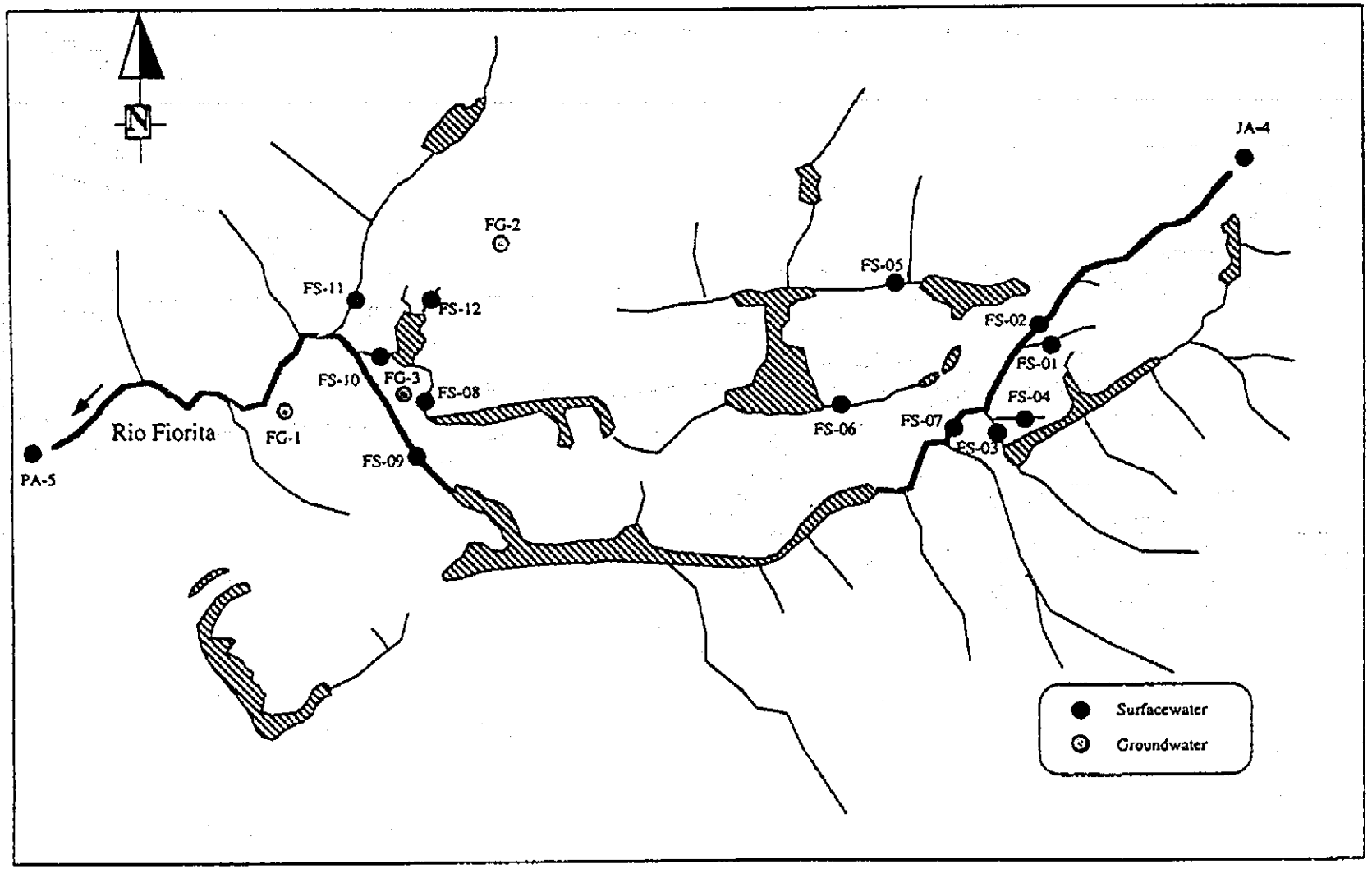


FIGURE B-3 MONITORING LOCATIONS IN FIORITA SITE

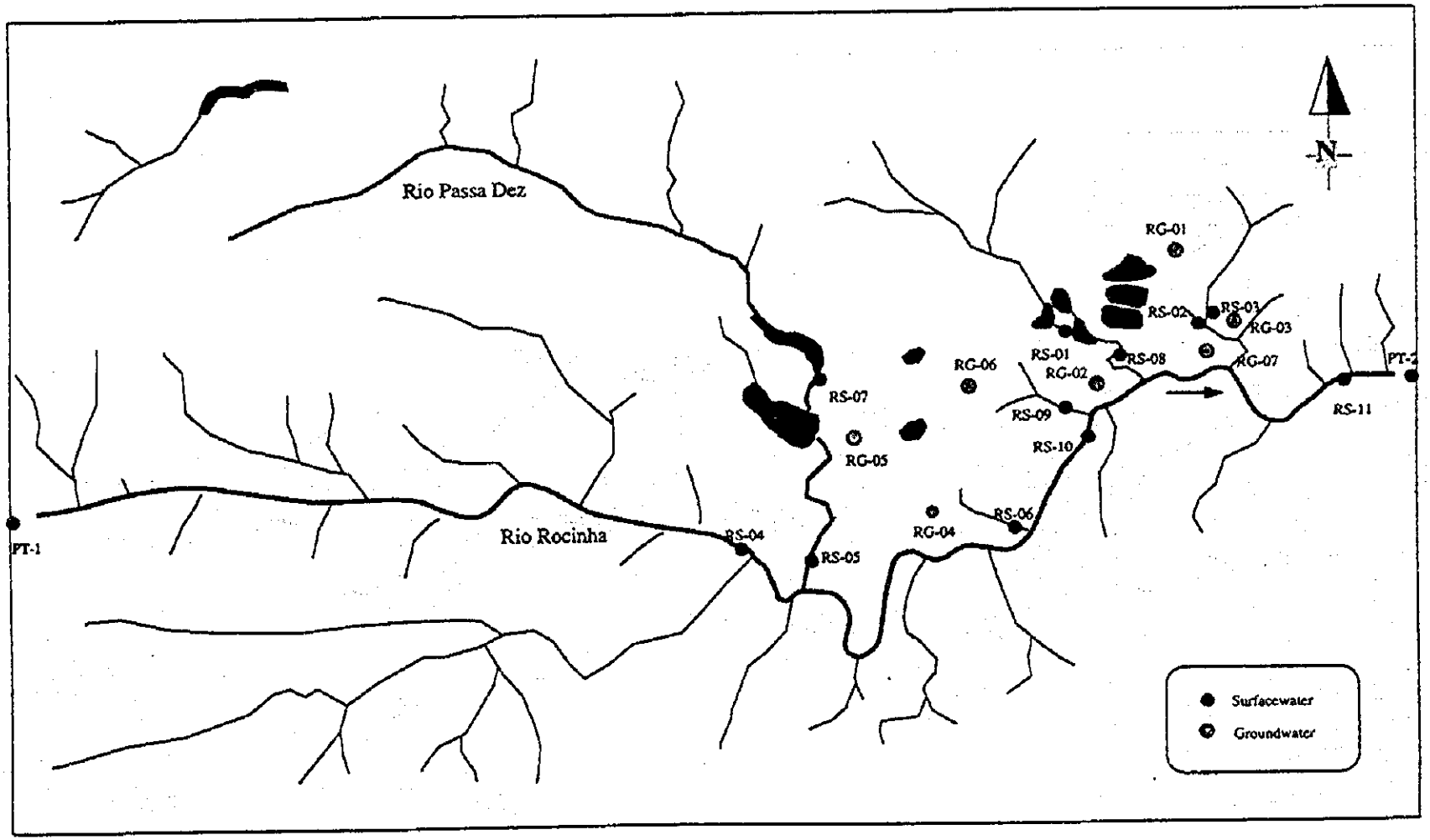


FIGURE B-4 MONITORING LOCATIONS IN ROCINHA SITE

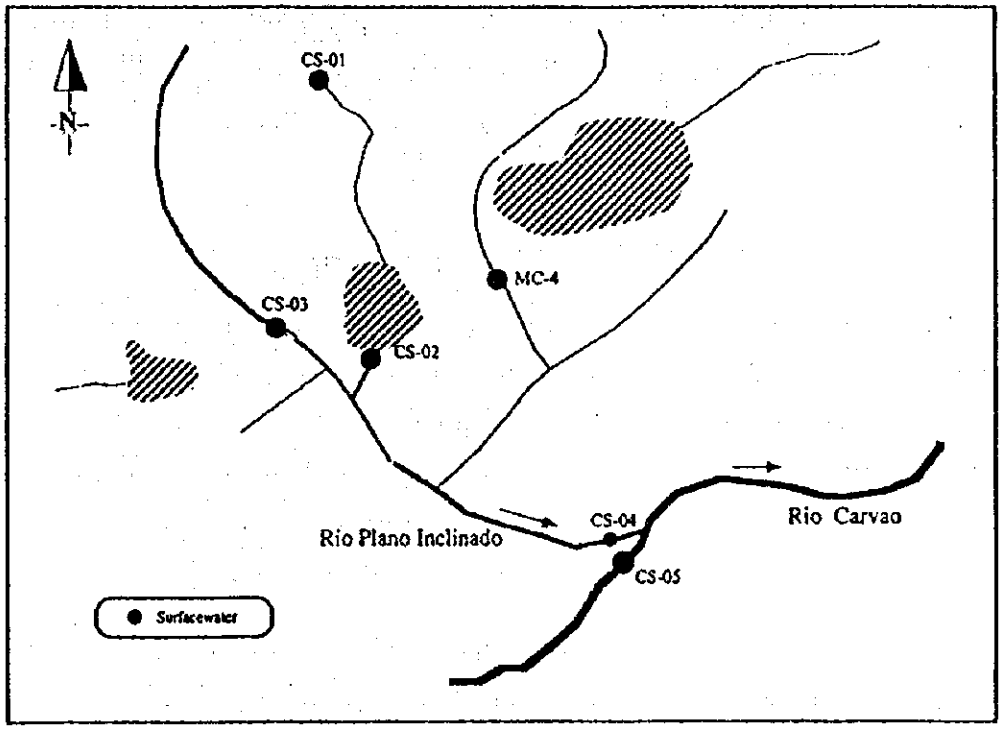


FIGURE B-5 MONITORING LOCATIONS IN CARVAO SITE

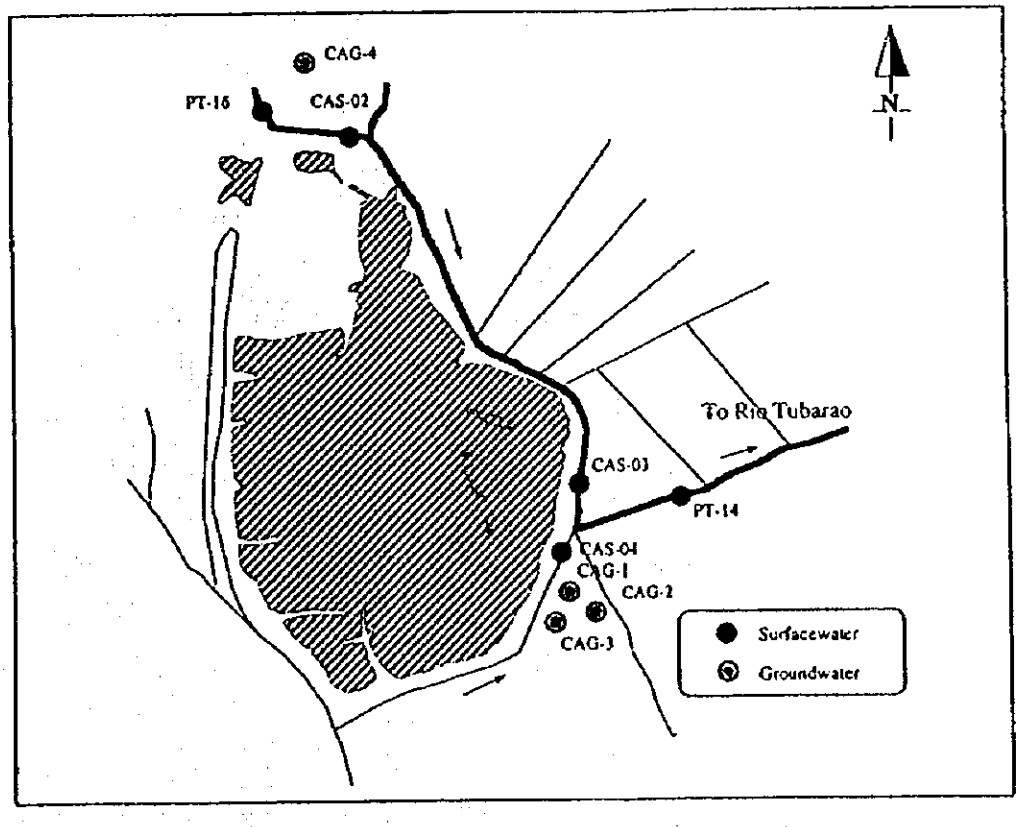


FIGURE B-6 MONITORING LOCATIONS IN CAPIVARI SITE

3.2 Water Pollution Mechanism

12. Acidic water pollution in the region is derived from the oxidation and dissolution reaction of pyrite (FeS2). The principle of acidic water pollution mechanism caused by pyrite in the coal mining area is shown in Figure B-7. The analyses carried out here are correlation between pH and other parameters and multi-regression analysis as summarized below:

(a) Correlation between pH and other parameters

13. The correlation coefficients were calculated by exponential and linear correlation analysis using all of the monitoring data for the three rivers and the two FS sites, Fiorita and Rocinha. The linear correlation could not be observed between pH and other parameters. However, strong exponential correlations were observed between pH and several parameters, including electric conductivity, sulfate, total iron, dissolved iron, zinc, manganese, and aluminum. Especially, the correlation between pH and, acidity and electric conductivity were strong in all of the river basins.

14. The strong correlation between pH and, sulfate and iron show that the acidic water pollution is related to the pyrite's dissolution. As for dissolved iron and total iron, total iron shows the stronger correlation with pH than dissolved iron in all of the basins. Several kinds of iron compounds must be related to the acidic water generation (Figures B-8 and B-9). As for the correlation between pH and heavy metals, zinc and manganese show the strong correlation with pH. Acid conditions generated by the pyrite dissolution process also dissolves the heavy metal sulfides. As for the correlation between pH and light metals, aluminum shows the strongest correlation with pH in all of the monitoring substances as showon in Figure B-10.

(b) Multi regression analysis

15. Based on the correlation analysis, the multi regression analysis was conducted to make clear the relationship between pH and total iron, sulfate, and aluminum. Table B-3 shows the results of the regression analysis. The correlation coefficient R-2 for the multi regression formulas are ranged from 0.770 to 0.915 for all the basins. Aluminum was extracted as the most related index with pH of water. Aluminum is a very abundant element in the soil as complexes with hydroxide, fluoride, sulfate, and organic ligands, and bound in large polymers, and is known as an indicator of acid rain because of its rapid response to the acidification of the soil. Sulfate and iron are also known as the indexes of the acidic water pollution originated from mining operations. These three substances are considered to be suitable as the indexes of the acidic water pollution in this target area.

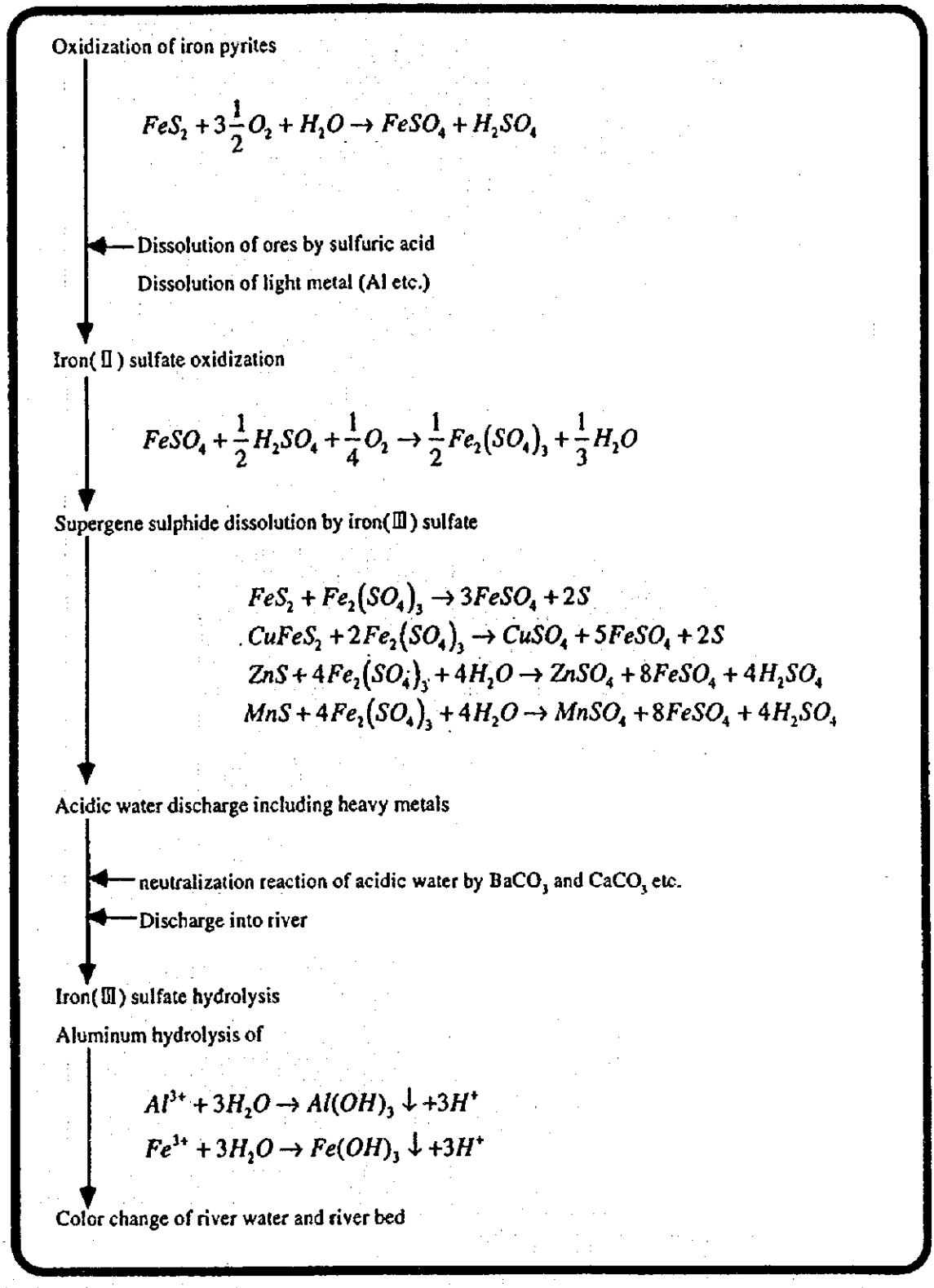
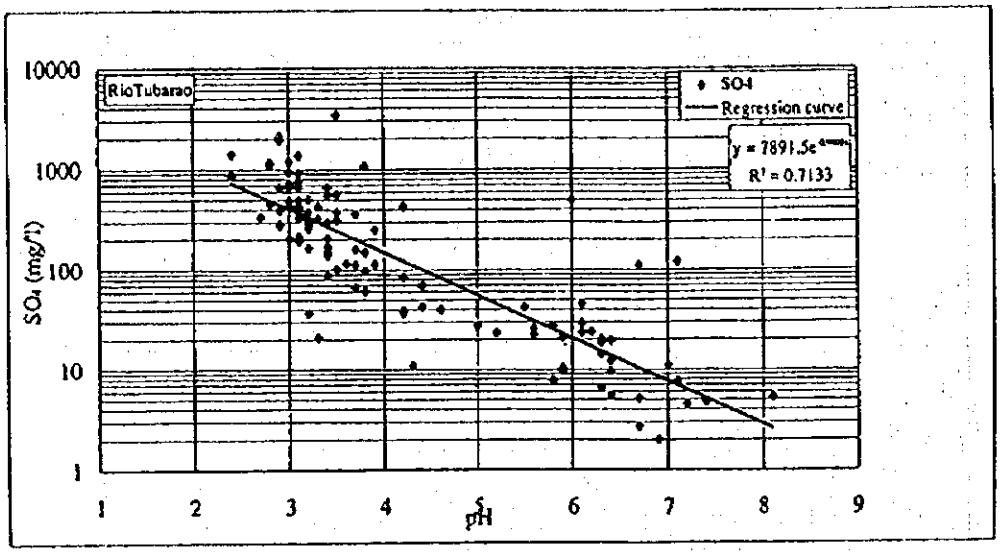
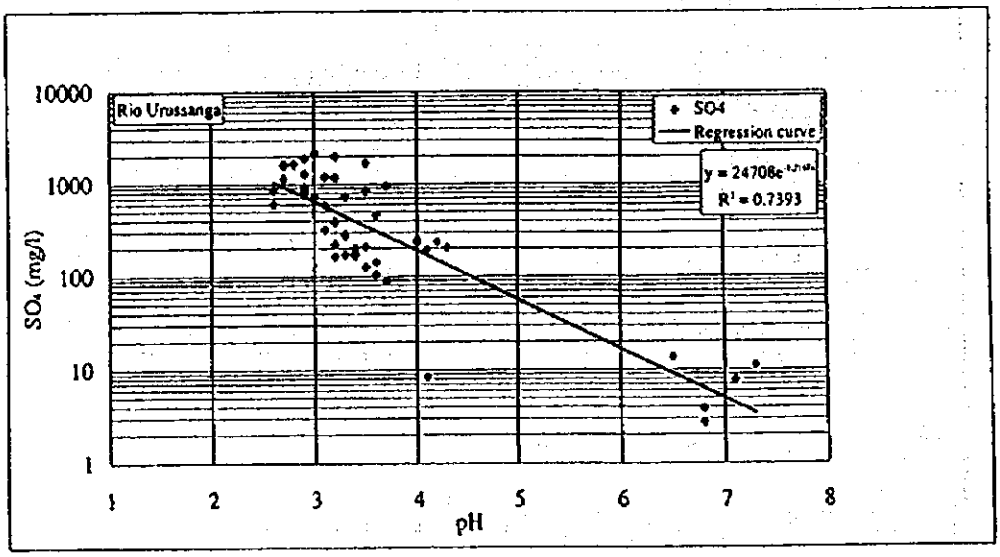


FIGURE B-7 POLLUTION MECHANISM IN COAL MINING AREA





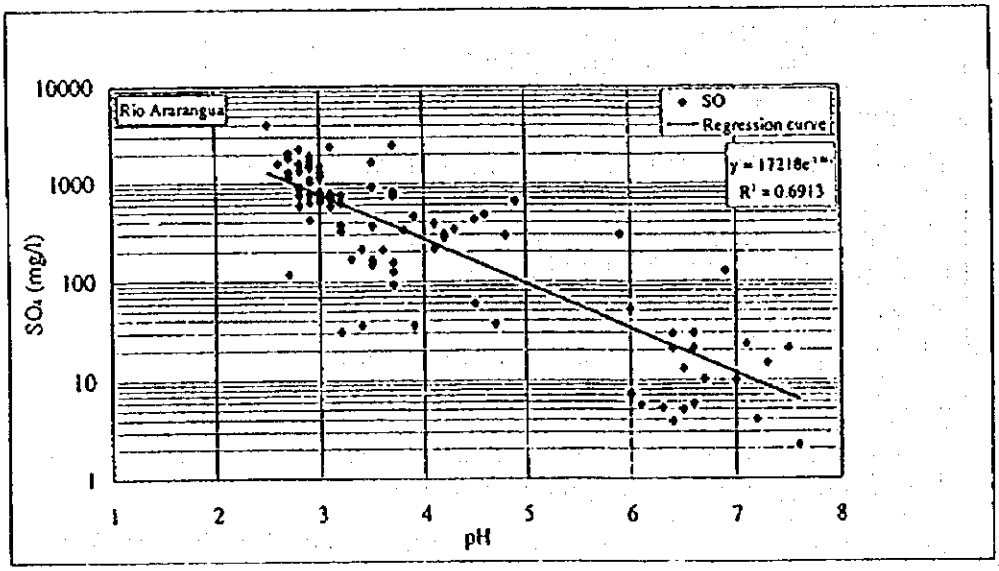
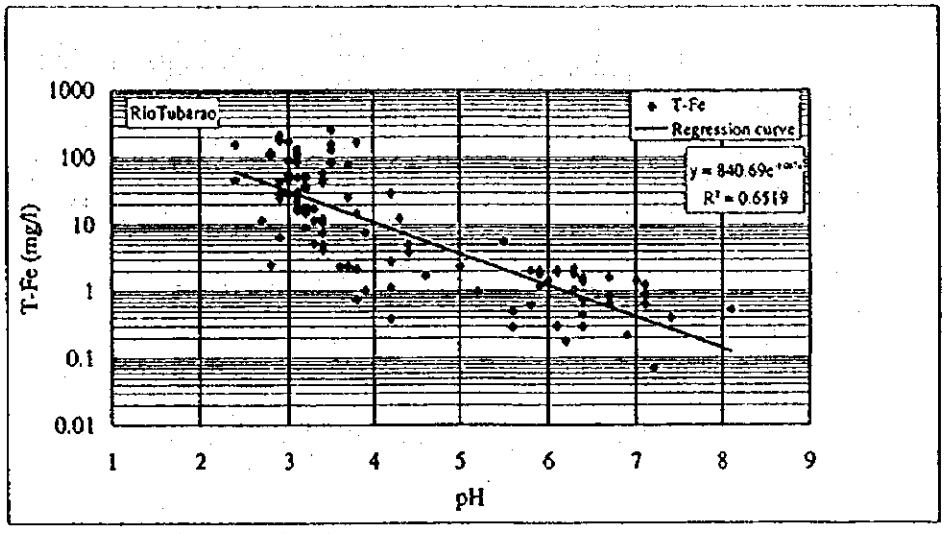
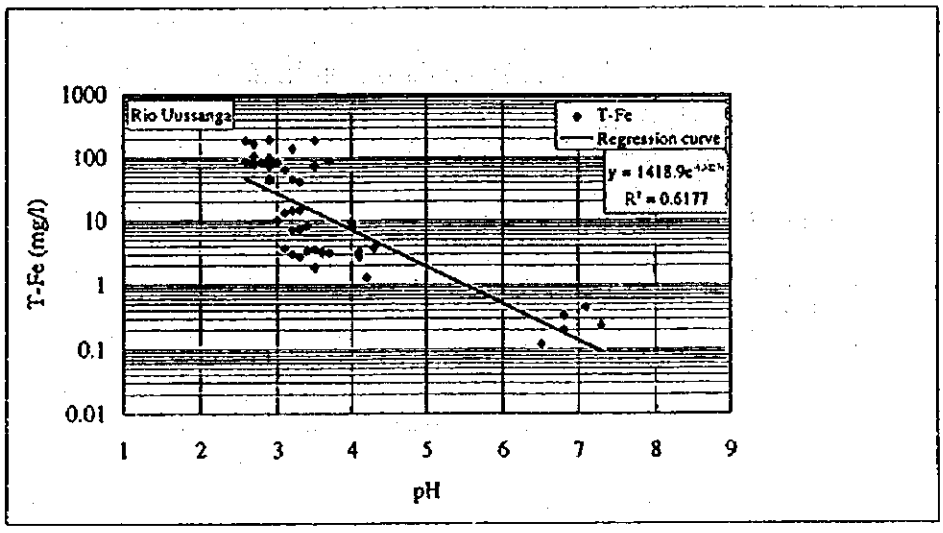


FIGURE B-8 **CORRELATION BETWEEN pH AND SULFATE**





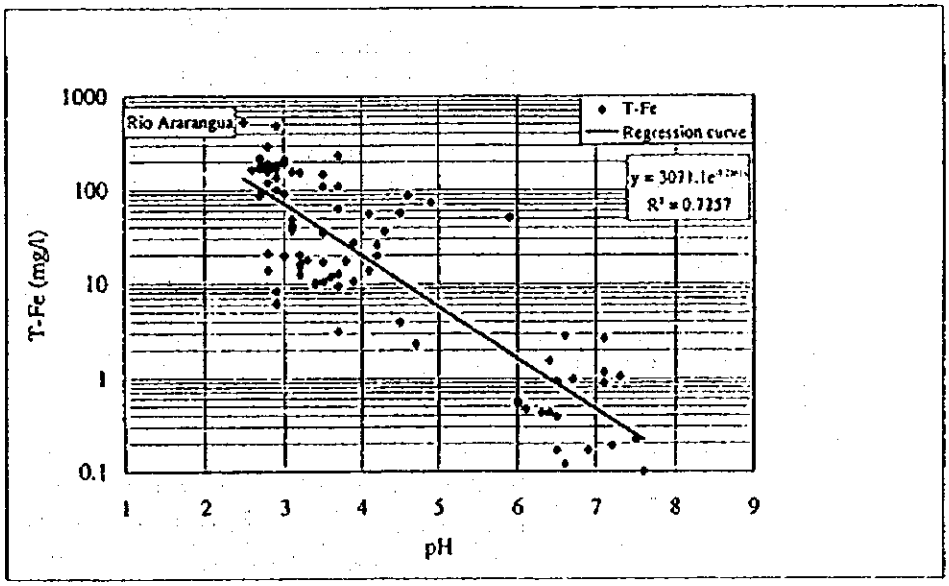
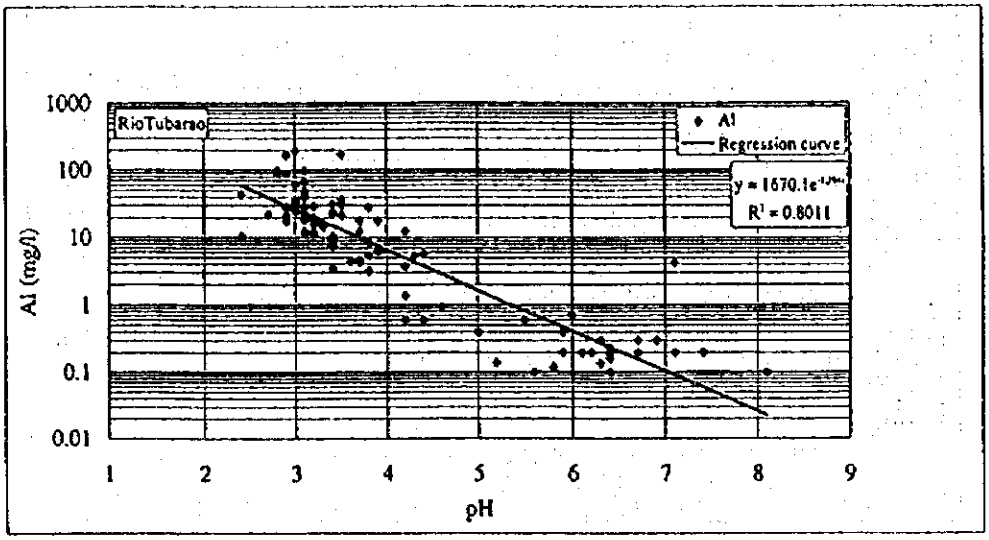
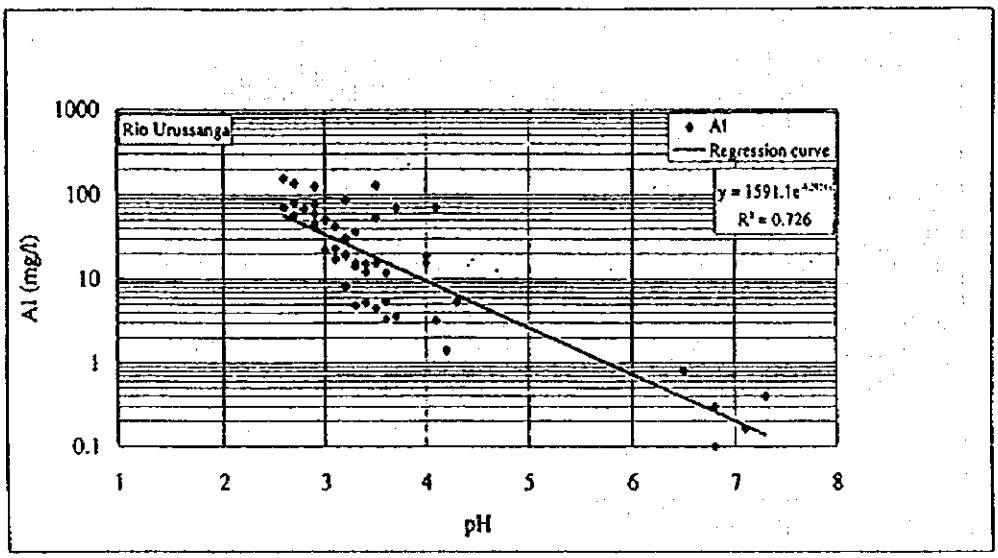


FIGURE B-9 **CORRELATION BETWEEN pH AND TOTAL IRON**





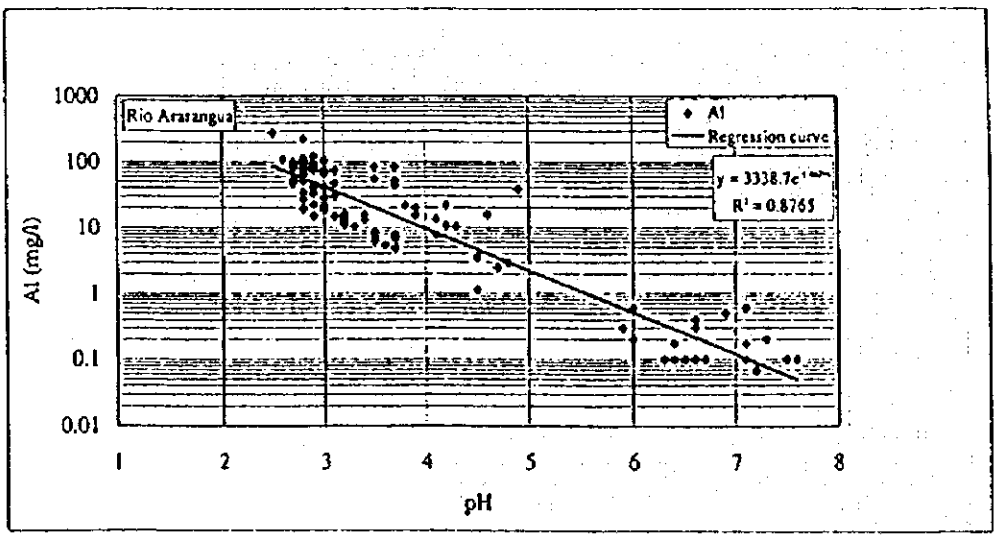


FIGURE B-10 **CORRELATION BETWEEN PH AND ALUMINIUM**

TABLE B-3

RESULT OF MULTI REGRESSION ANALYSIS

Location	R-2 valu / deviation	Regression curve
Tubarao	0.808 / 0.624	$pH = -0.267Log[SO_4] + 0.114Log[T-Fe] - 1.212Log[Al] + 5.461$
Urussanga	0.807 / 0.520	$pH = +0.063.Log[SO_4] + 0.0095Log[T-Fe] - 1.422Log[Al] + 5.237$
Aranrangua	0.898 / 0.551	$pH = -0.937Log[SO_4] + 0.527Log[T-Fe] - 1.169Log[Al] + 6.812$
Fiorita	0.770 / 0.722	$pH = -0.108Log[SO_4] + 0.043Log[T-Fe] - 1.014Log[Al] + 4.769$
Rochinha	0.915 / 0.506	$pH = -0.246Log[SO_4] + 0.530Log[T-Fe] - 1.390Log[Al] + 5.091$