

TAILINGS DISPOSAL SYSTEM AT TROMBETAS BAUXITE MINE<sup>1</sup>

by

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**Abstract.** Mineracao Rio do Norte (MRN) started its bauxite washing operation in 1979. Since then, the tailings have been dumped into nearby Batata Lake. The annual tailings volume is about 18 million m<sup>3</sup> at a solids content of 7-9%. This has caused a serious ecological problem. Early in the operation MRN and the environmental protection authorities decided that a more ecologically acceptable method for tailings disposal should be investigated.

In 1982, the consultants, Bronwell and Carrier Inc., (Lakeland, Florida) started thickening and pumping tests on the tailings deposited in Batata Lake. Pilot tests in a small settling pond were commenced in 1984. As a result of the tests, it was proposed to deposit the thickened tailings in the mined out areas. This will be an innovative method not only in Brazil but also on the worldwide bauxite mining scene.

This paper describes the mining method, industrial facilities, the studies on thickening and pumping, the studies for disposal of the tailings in the mined out areas, the tailings disposal plan and finally the reclamation of the disposal areas.

### Introduction

Mineracao Rio do Norte was created in 1967 to operate the Trombetas bauxite mine. The shareholders are Companhia Vale do Rio Doce (46%), Alcan (24%), Companhia Brasileira de Alumínio

(10%), Norks Hydro (5%), and Reynolds Aluminum (5%).

The mining operations are located in the Amazon region, Para State, on the right bank of the Trombetas River. This river is a tributary of the Amazon, joining it from the north, at about 800 km from the mouth of the Amazon (Figure 1).

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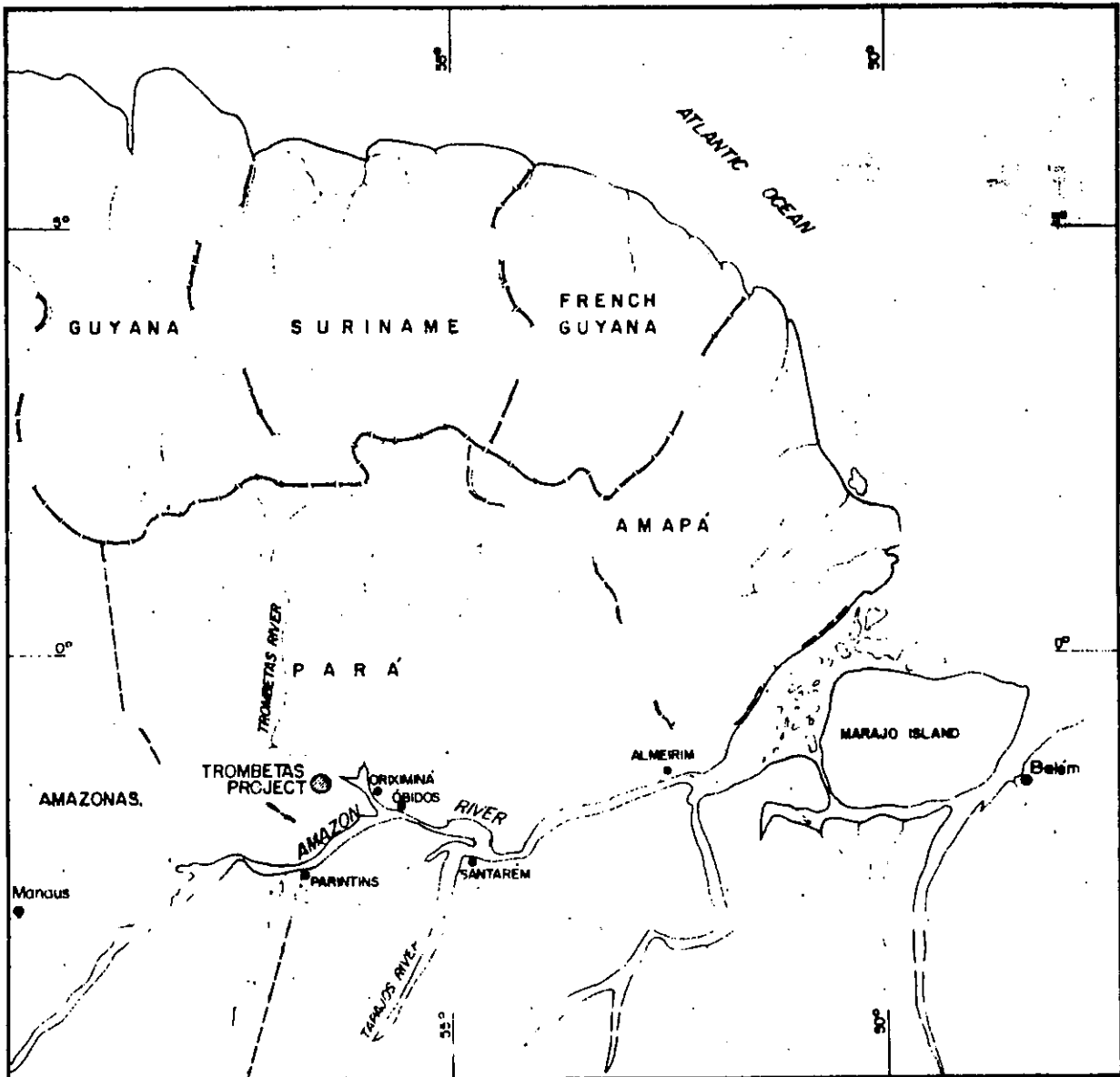
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The beneficiation operations are presently situated at Porto Trombetas. Facilities also include the shiploader, offices, shops, warehouses, and power plant. Around Porto Trombetas there is a complete mine town with hospital, supermarket, school, and recreational facilities.

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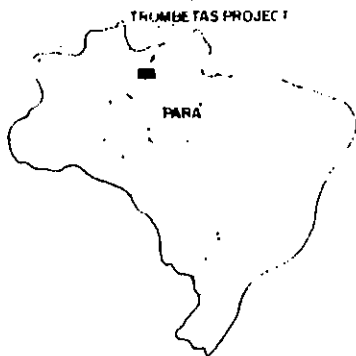


FIG - 01

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PROJ.			
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MINERAÇÃO RIO DO NORTE S.A. TROMBETAS PROJECT			
TÍTULO II <b>LOCATION MAP</b>			
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The Trombetas bauxite project started operations in 1979. The rated annual capacity was 3.35 million tonnes of product. Several improvements raised the production capacity to 5.0 million tonnes/year. The main users of the Trombetas bauxite at present are Brazil (36%), Venezuela (33%), Canada (26%), USA (2%), UK (2%), and West Germany (1%).

### Geology

The Trombetas bauxite occurs on extensive plateaux with elevations between 50 and 200 meters. The typical profile (Figure 2) shows a tall dense vegetation overlying a thin (0.50 m) soil. Below the soil is a yellow kaolinitic clay whose thickness can reach 11 meters. The clay overburden passes to nodular bauxite, up to 2.5 meters thick, consisting of ferruginous pisolites and gibbsite nodules in a clay matrix. The nodular bauxite is presently being treated as waste, although studies are being carried out aimed at recovering this bauxite. The next layer is the ferruginous laterite which averages 2 meters in thickness. The succession described above represents the overburden that overlies the massive bauxite layer which reaches a thickness of 7 meters.

Trombetas massive bauxite is essentially gibbsitic (trihydrate) containing less than 1% boehmite (monohydrate). The main minerals are gibbsite, kaolinite, hematite and goethite. The top of the bauxite layer is harder than the rest, reflecting a higher iron content. The middle and bottom sections of the layer show variable texture: granular, friable, and porous. Closer to the base of the horizon, there are blocks of bauxite disseminated in a clay matrix resulting in an irregular contact. Vertical pipes of kaolinitic clay penetrate the basal portion of the massive bauxite. This clay and

the irregular contact result in a dilution of the ore grade.

The reserves of massive bauxite of MRN are roughly 500 million tonnes on a washed basis. The average grade is 50.24% available alumina (av.  $\text{Al}_2\text{O}_3$ ), 4.25% reactive silica (re.  $\text{SiO}_2$ ), and 9.66% iron oxide ( $\text{Fe}_2\text{O}_3$ ). The ore bodies occur on several plateaux in the area (Figure 3).

The average recovery at the washing plant is 74% by weight. The remaining 26% represents the tailings that are mainly clay.

### Mining

Present mining operations are being carried out in the Saraca I concession (see Figure 3). Here the ore body covers some 232 ha.

The mining method is similar to the strip mining used in surface coal mines. The mining cuts are 28 m wide and 600 to 1000 m long. The mining stages are: clearing the forest, stripping, drilling and blasting, excavation and loading, hauling, and finally the rehabilitation of the mined out areas (Figure 4).

CAT D8L tractors fitted with adequate protection equipment fell the tress, and the wood with no commercial value is burned. In the stripping operation two diesel draglines (BE-480W) with 17 cubic yard buckets, one electric dragline (BE-60W) with a 26 cubic yard bucket and a motorscraper fleet are used. Three electro-hydraulic Liebherr back-hoes with 8.3  $\text{m}^3$  buckets excavate the bauxite.

Only the top half of the bauxite layer is hard enough to require blasting. Blastholes are drilled by 6 inch augerdrills mounted on trucks. The explosive is ammonium nitrate

A

Topsoil  
0 to 50 cm.

Yellow Clay  
0 to 11.0 m.

Modular Bauxite  
0 to 2.5 m.

Ferruginous Laterite  
0 to 2.0 m.

Massive Bauxite  
0 to 7.0 m.

Variegated Clay

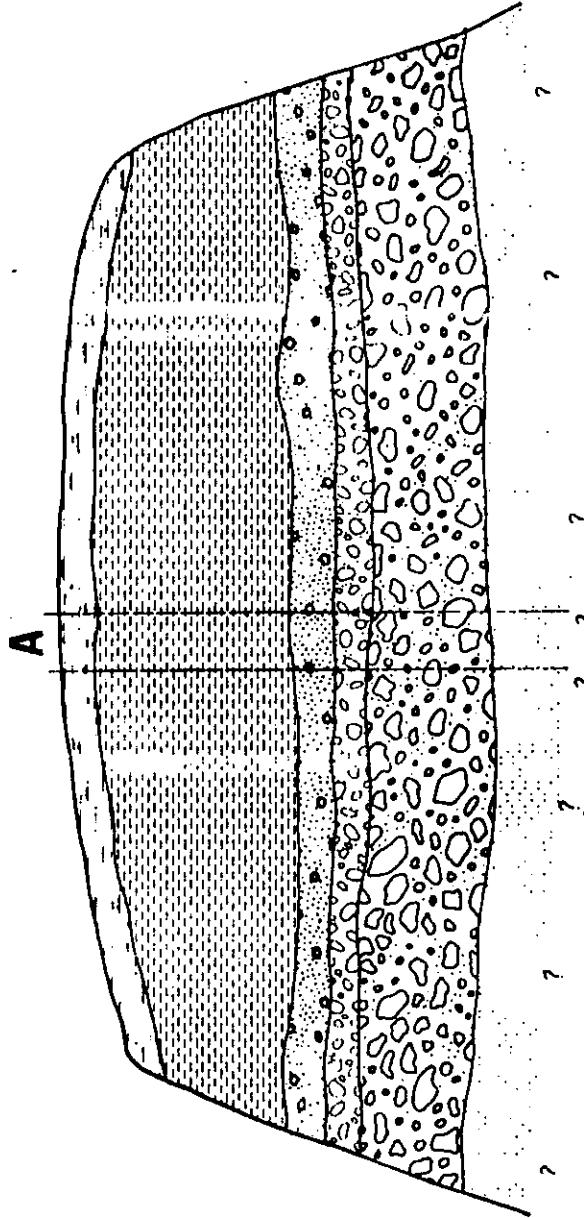
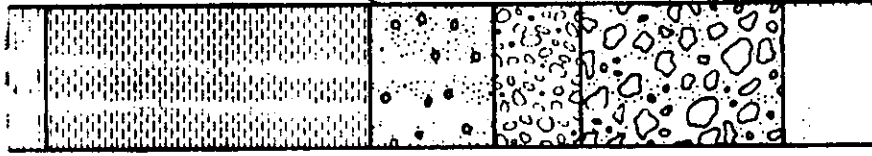


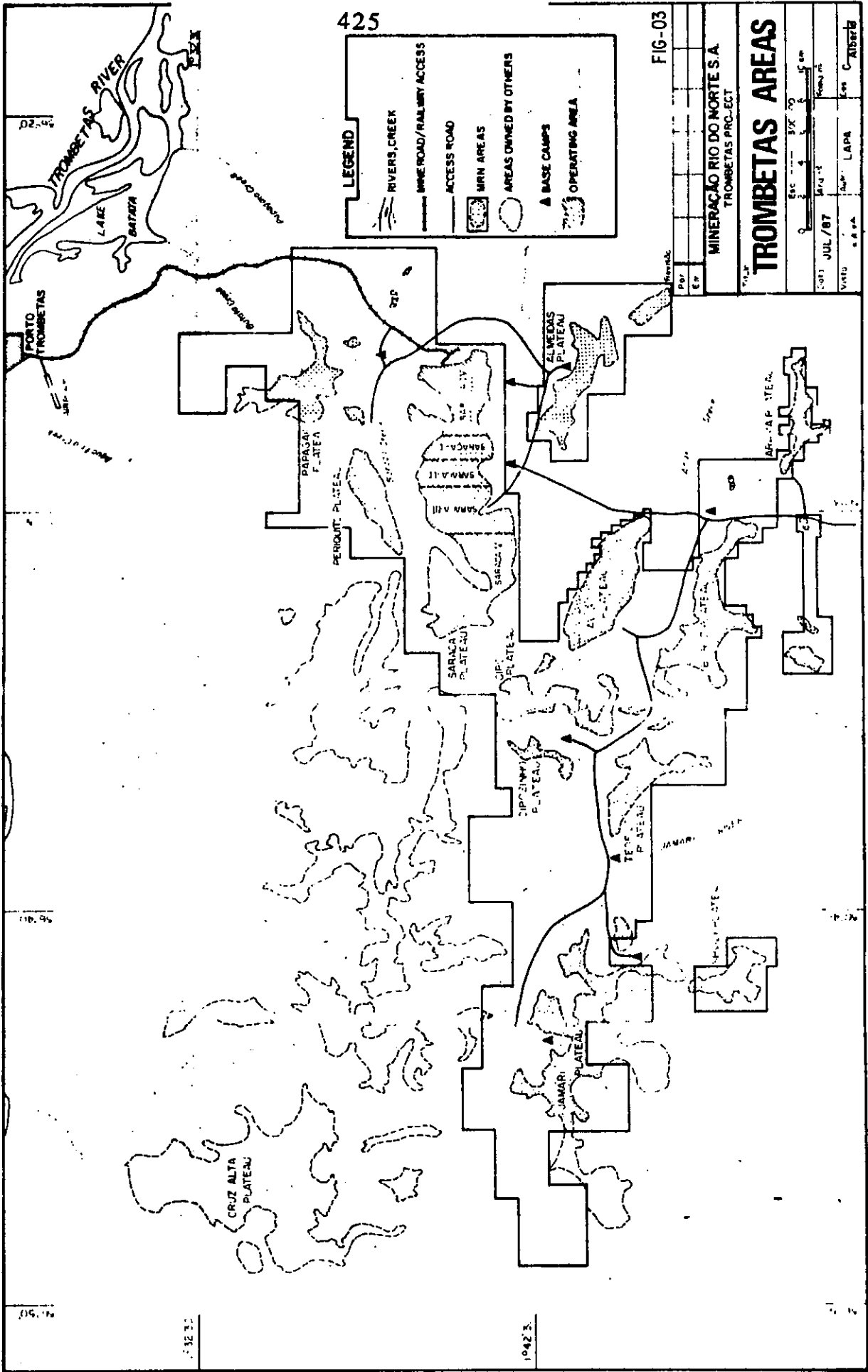
FIG - 02

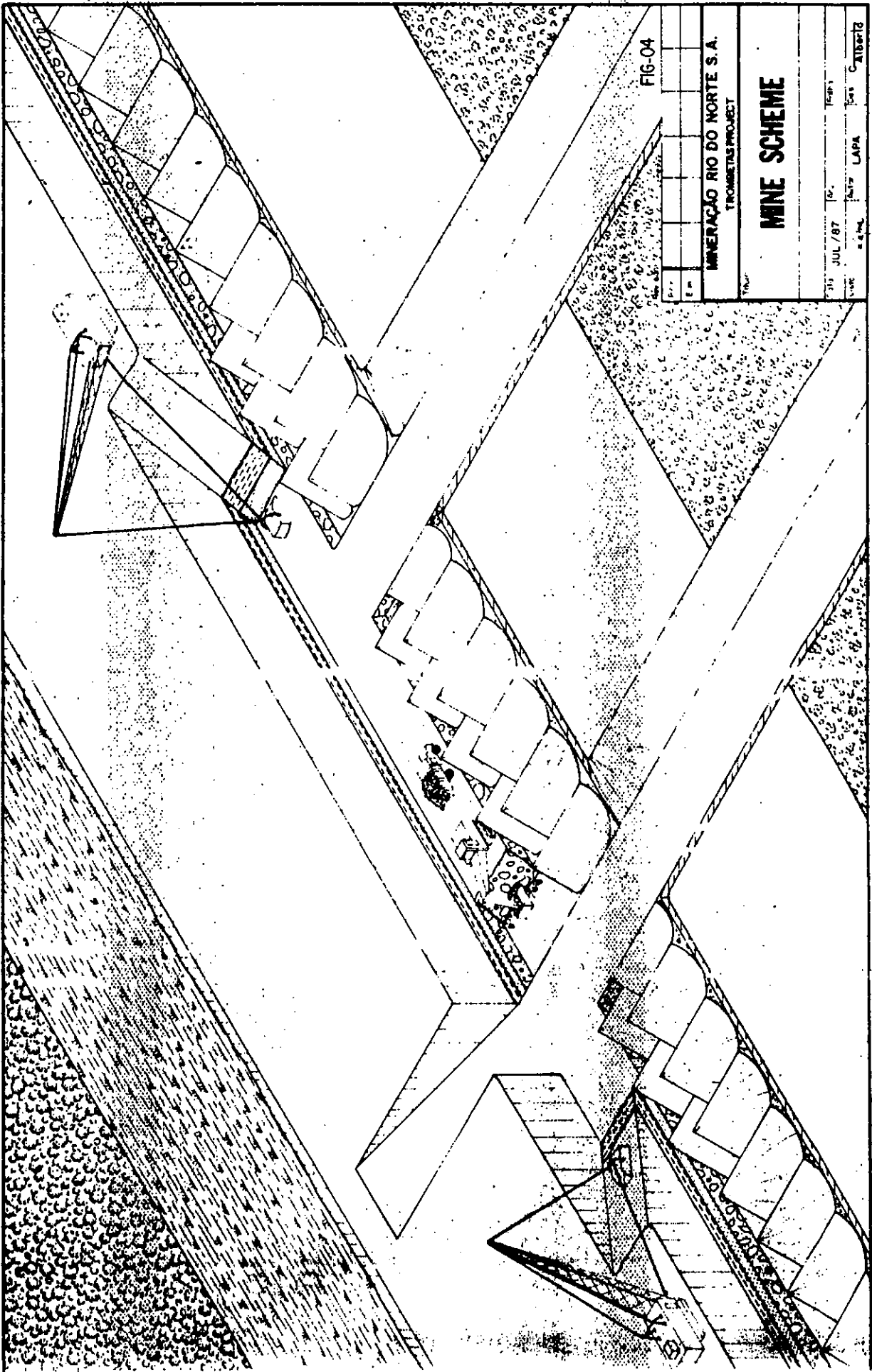
MINERAÇÃO RIO DO NORTE S.A.  
TROMBETAIS PROJECT

TYPICAL SECTION

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Drawn  
Scale  
Date





mixed with used engine oil. In the presence of water, an explosive slurry is used. The bauxite is hauled into trucks to the crusher.

When mining is completed, the area is rehabilitated. The piles of spoil left by the draglines are graded, returning the topography roughly to its original form. The topsoil is spread, and finally the mined out areas are revegetated using native tree species.

### Beneficiation

As explained in the geological description, the inclusions of kaolinitic clay in the bauxite layer and the irregular contact with the base clay are the main causes of clay contamination in the bauxite. The clay content of the bauxite is reflected in the levels of available alumina and reactive silica. Therefore the beneficiation process at Trombetas consists of size reduction, washing and classifying. This process washes out clay and the result is a decrease in the reactive silica and an increase in the available alumina content.

After being crushed to 3 inches, the bauxite is loaded in 80 ton railcars to be transported 28 km to the beneficiation plant located at Porto Trombetas.

The beneficiation plant produces four types of bauxite: wet coarse bauxite with 12% moisture, dry coarse bauxite with 5% moisture, fine bauxite with 15% moisture, and a superfine product with 15% moisture (Figure 5).

The tailings, as a result, are less than 400 mesh. The disposal of these fine tailings has been studied with primary emphasis on the protection of the ecology.

In shipping 5 million

tonnes/year of bauxite, 1.7 million tonnes of tailings solids are produced. The solids content of the slurry is 7 to 9%.

### Tailings

#### History

Since the start of the operations, the tailings have been discharged into Batata Lake (Figure 7).

These tailings consist of fine solid particles, chemically inert, and water. The particles are composed of aluminum oxide (21%), silicates (48%), and iron oxides. At the beginning the tailings particle size was less than 150 mesh. Since 1986 when the recovery of the fraction less than 150 mesh and greater than 400 mesh began, the tailings particle size has been less than 400 mesh (Figure 6).

The progressive silting of the lake, and the concern about the environment, moved MRN to start basic studies on the tailings for analyzing disposal alternatives.

MRN engaged, in 1982, the services of Bromwell and Carrier Inc. as consultants. In 1984, a series of pilot tests were conducted complementing the laboratory tests.

Field and laboratory tests included determination of density, compressibility, permeability, viscosity, Atterberg limit and pumping tests (Figures 8, 9, and 10).

#### Study of Alternatives

Based on the test results, several alternatives for disposal of the tailings were studied and had their operating cost and investment evaluated (Figure 11). The solution chosen comprises relocating the washing plant close to the mine and

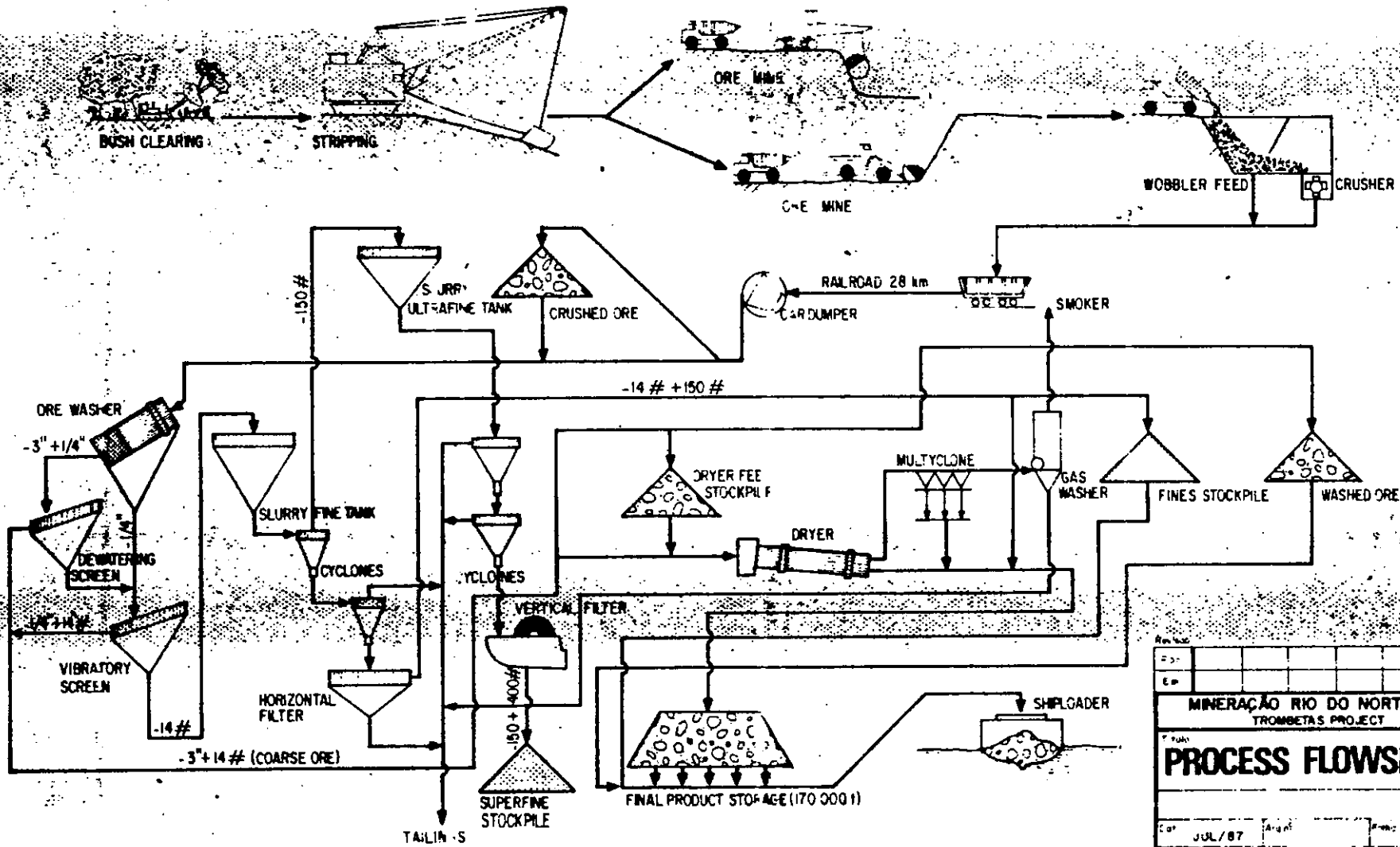


FIG-05

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<b>PROCESS FLOWSHEET</b>				
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BAUXITE TAILINGS

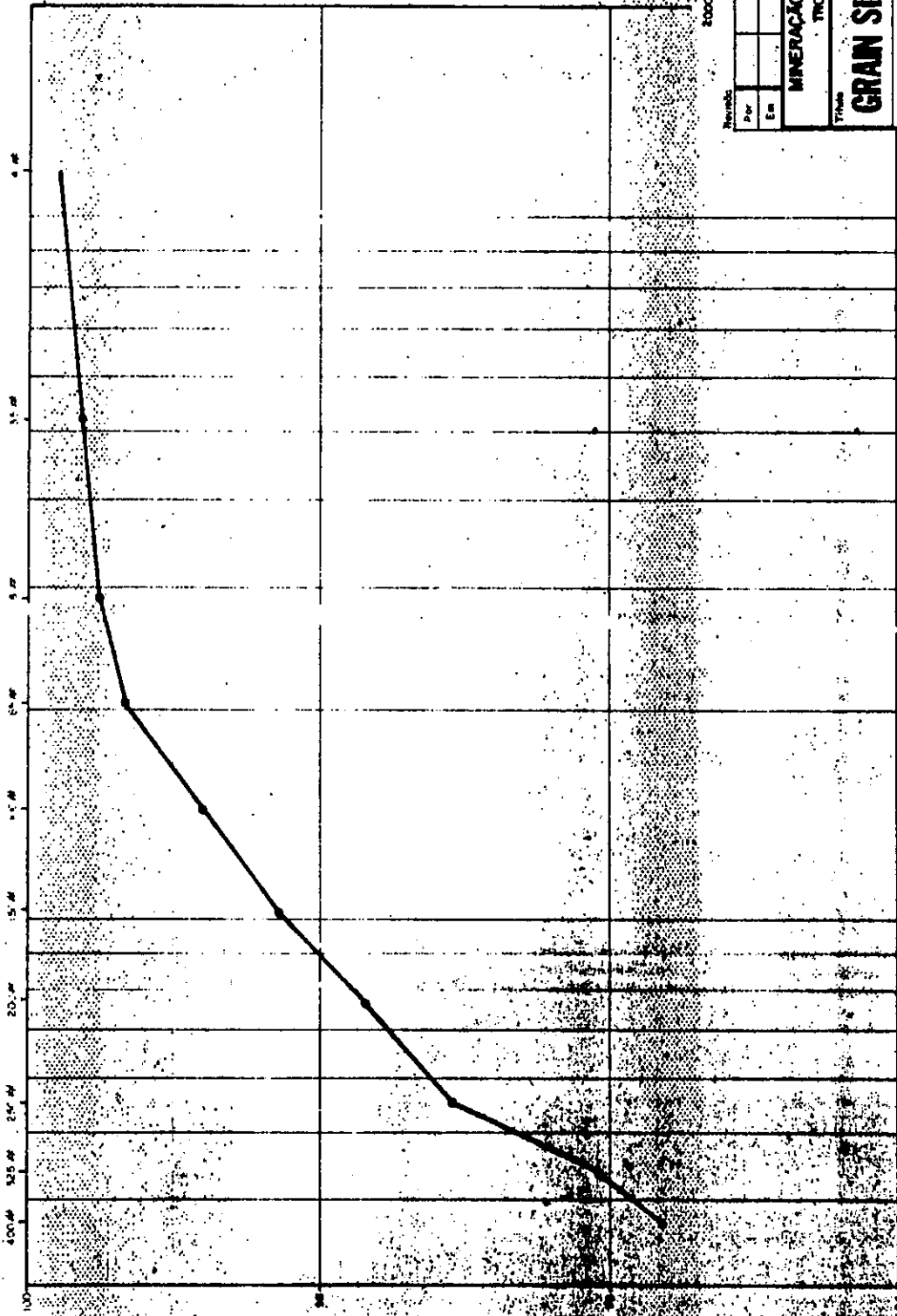


FIG-06

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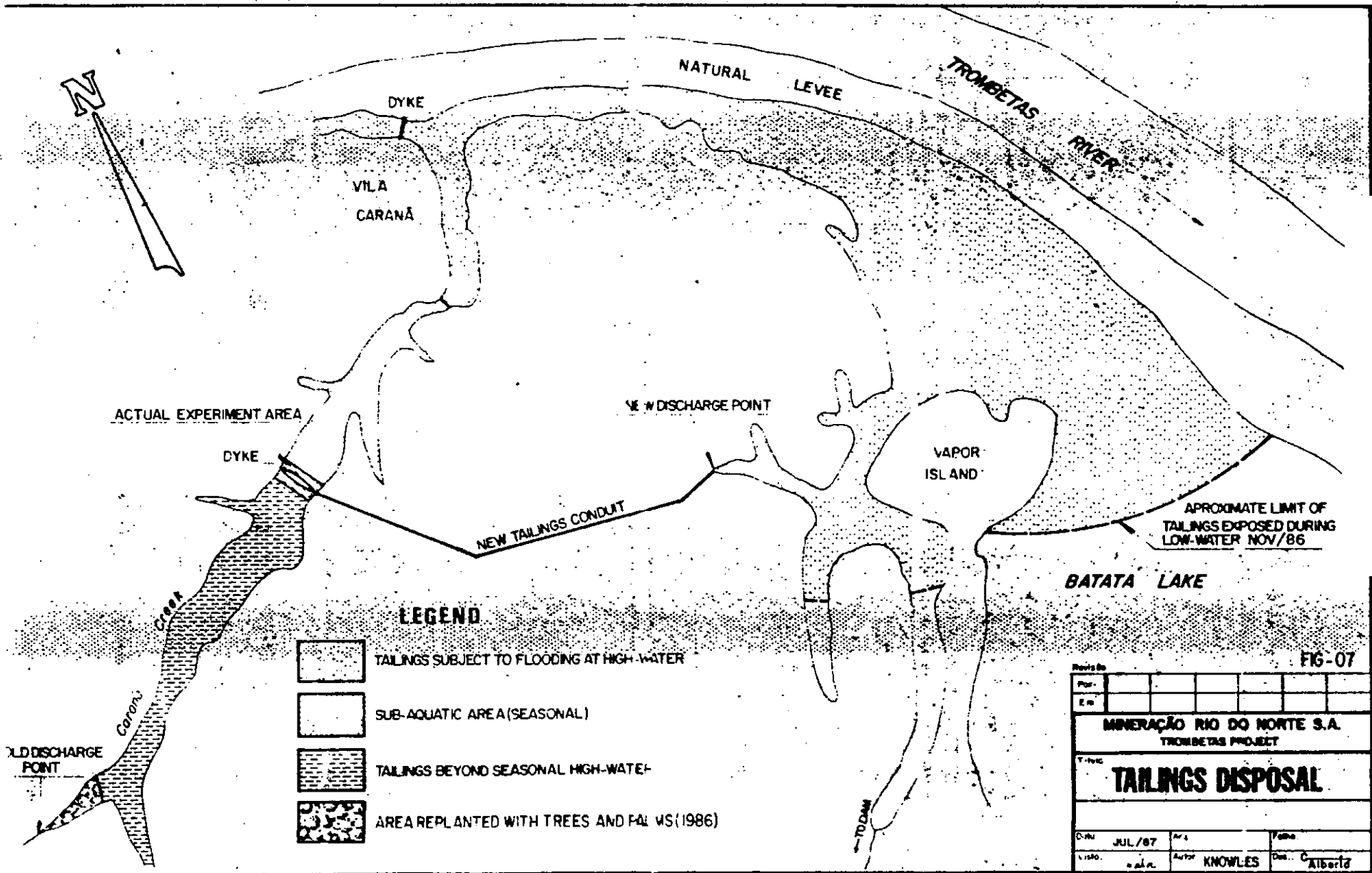
MINERAÇÃO RIO DO NORTE S.A.  
TRONHEITAS PROJECT

GRAIN SIZE DISTRIBUTION

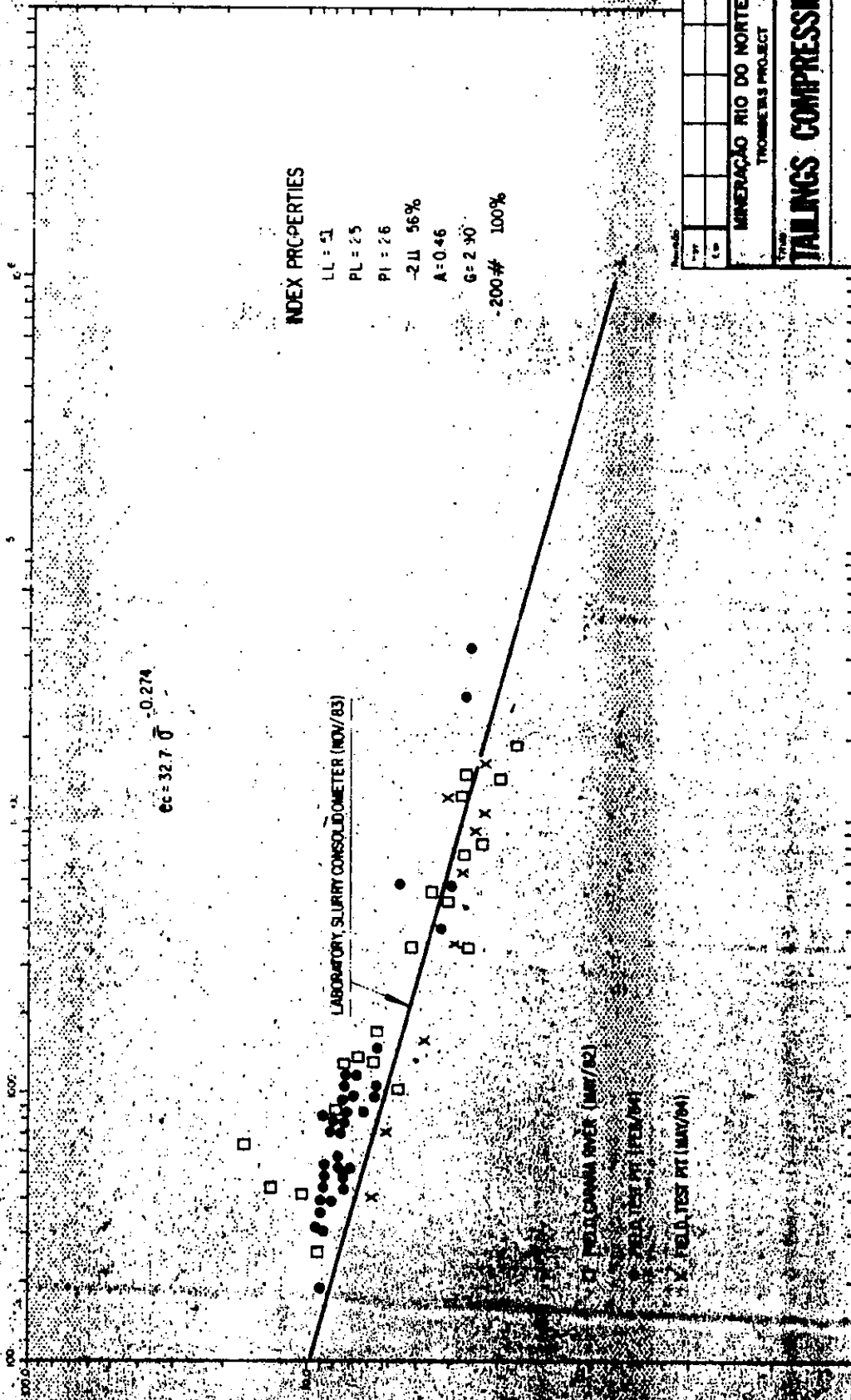
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GRAIN SIZE (mm)

PERCENT FINER THAN



VERTICAL EFFECTIVE STRESS,  $\bar{\sigma}_v$  (Pa)



INDEX PROPERTIES

- LL = 51
- PL = 25
- PI = 26
- 2U 56%
- A = 0.46
- G = 2.90
- 200# 100%

FIG-08

MINERAÇÃO RIO DO NORTE S.A.		TROMBETA PROJECT	
<b>TAILINGS COMPRESSIBILITY</b>			
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TEST NO.	144	TEST NO.	BC1
TESTER	ALBERTO	DATE	8/1/87

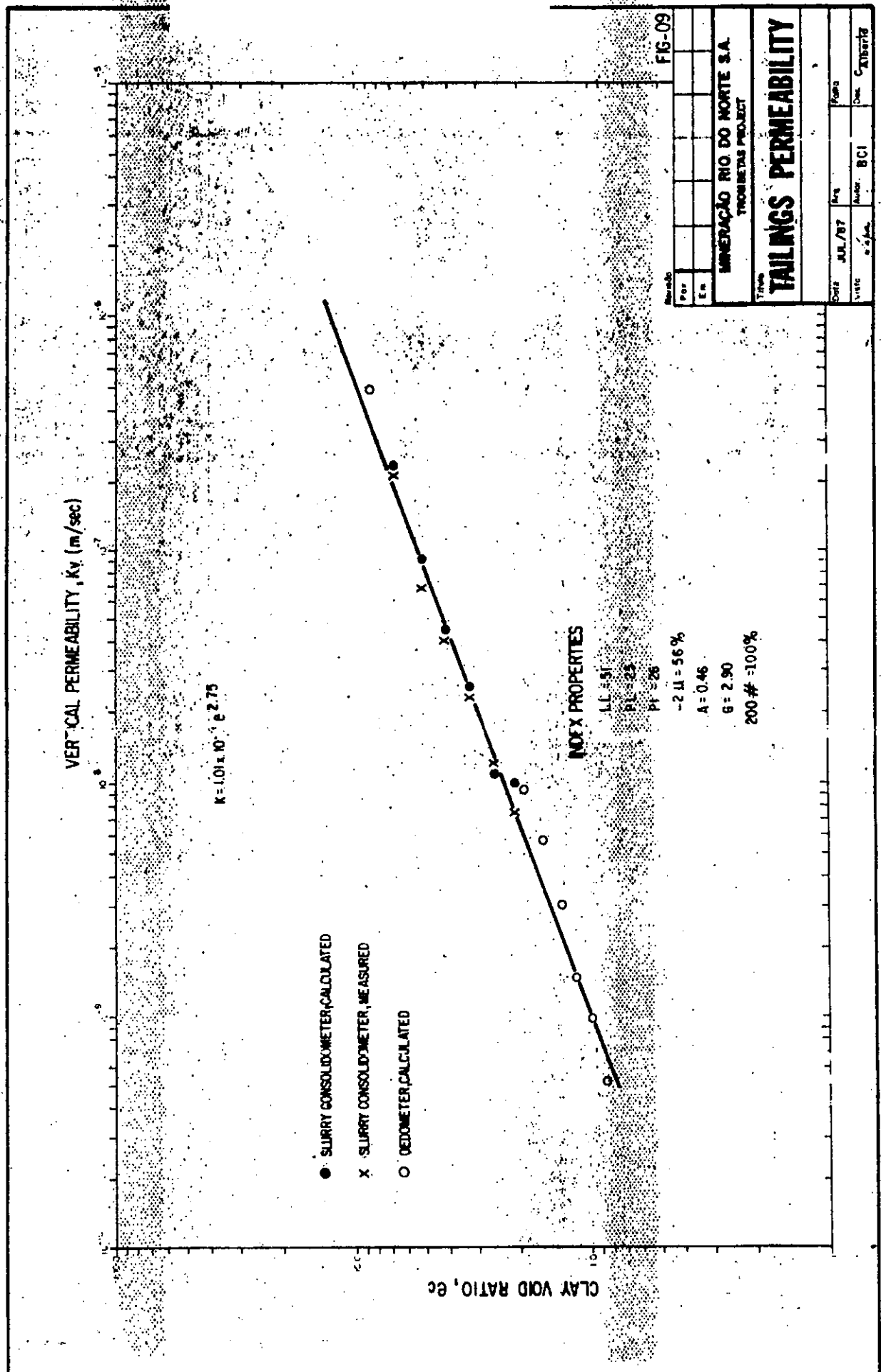


FIG-09

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<b>MINERAÇÃO RIO DO NORTE S.A.</b>					
PROJETOS PROJECT					
<b>TAILINGS PERMEABILITY</b>					
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v. teste		v. Anál.		v. Calc.	
BCI		BCI		C. Control	

S = 30% Q = 5000 gpm = 1136 m<sup>3</sup>/hr  
 L = 1 mi = 5280 ft = 1609 m

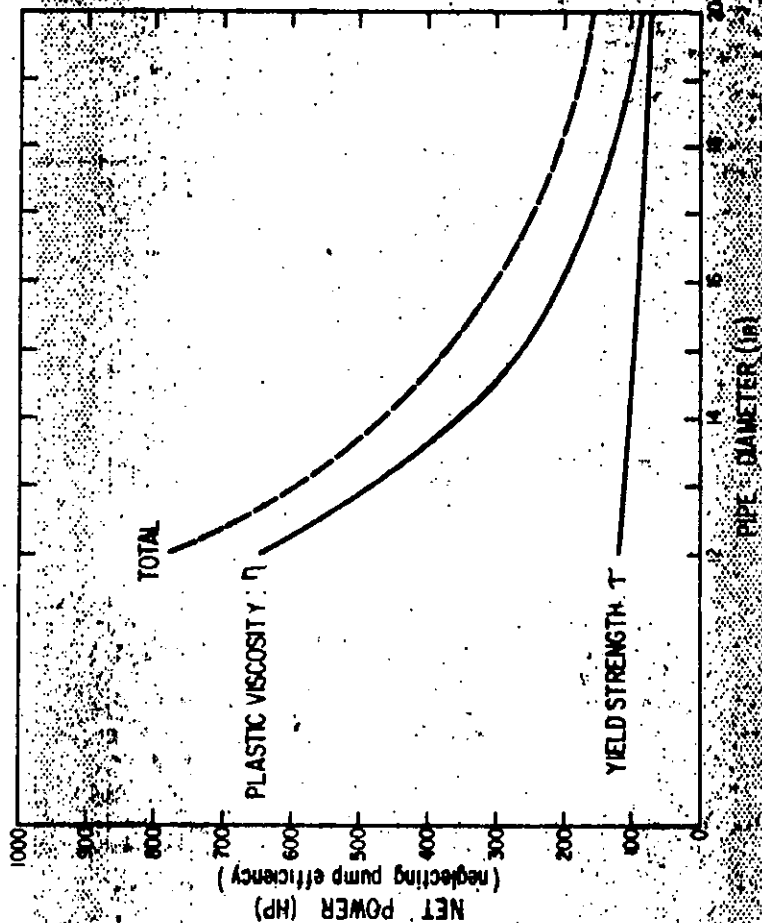
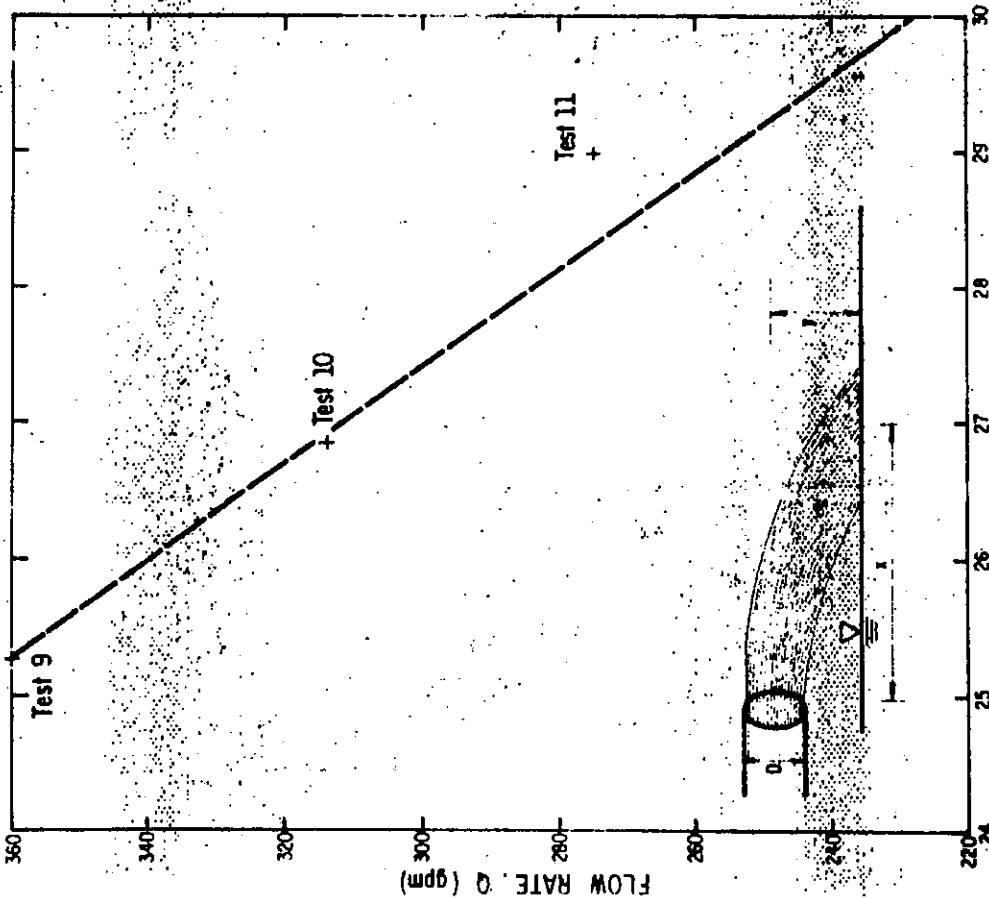


FIG -10

Project					
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MINERAÇÃO RIO DO NORTE S.A.					
TRONHEITAS PROJECT					
<b>PUMPING TESTS</b>					
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$D = 1.0416 \text{ inches} = 0.318 \text{ feet}$   
 $A = \frac{\pi D^2}{4} = 0.0793 \text{ feet}^2$   
 $Q = VA$   
 $V = \frac{Q}{A} = \frac{5000 \text{ gpm}}{0.0793 \text{ feet}^2}$

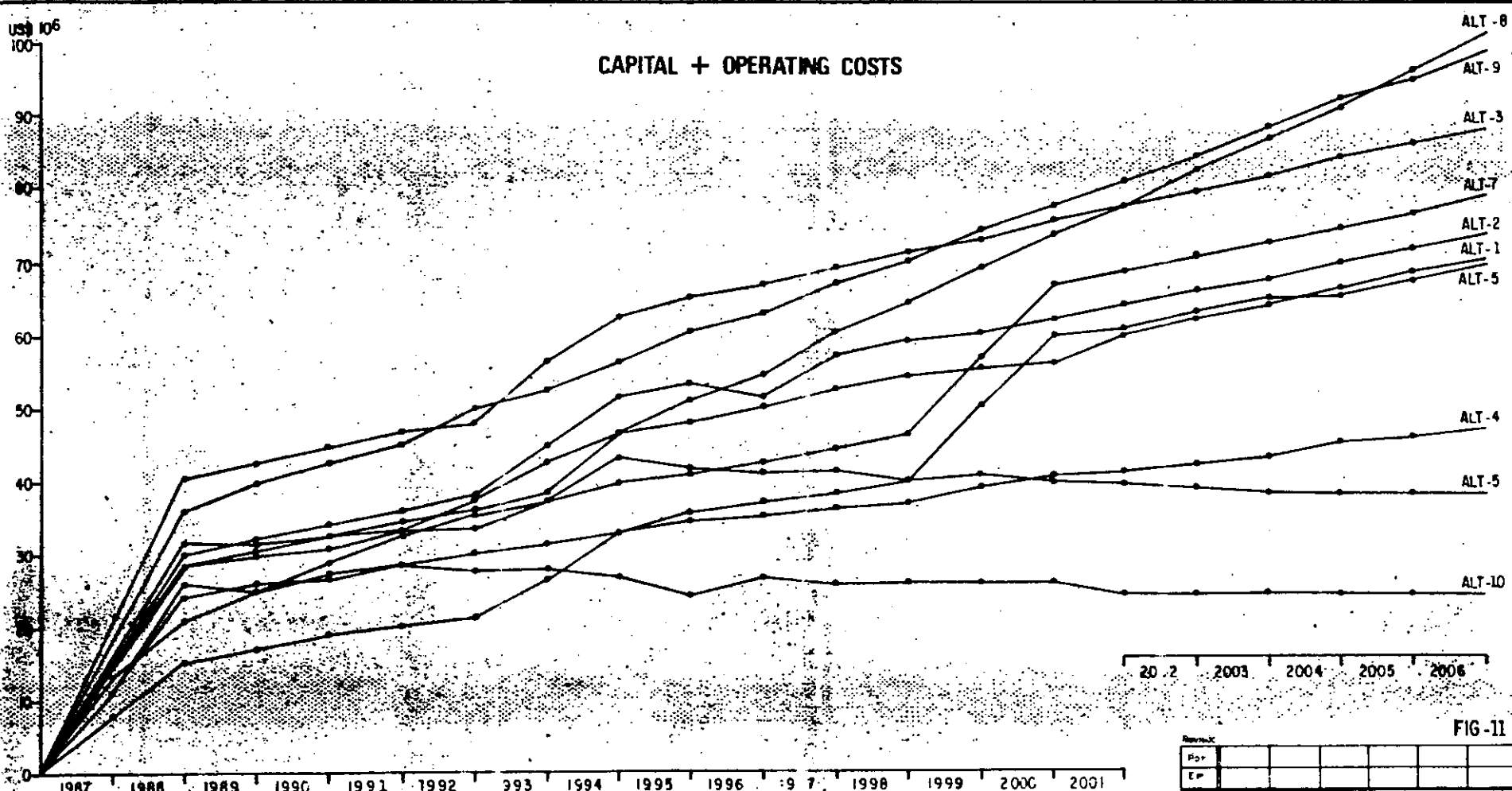


FIG-11

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<b>MINERAÇÃO RIO DO NORTE S.A.</b>					
<b>TROMBETAS PROJECT</b>					
<b>TAILINGS DISPOSAL ALTERNATIVES</b>					
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disposing of the tailings in the mined out areas.

The disposal of the tailings in the mined out areas also represents the best ecological alternative. The tailings are returned to their original source and revegetation will obliterate any signs of mining.

#### Tailings Disposal Project

The solution chosen diminishes to a great degree the environmental impact caused by the tailings.

The tailings coming from the washing plant at a solids content of 7 to 9%, will be pumped to an artificial pond. Over a certain period of time, settling of the tailings in this pond will result in a high solids content. A specially designed dredge, in which the pump is installed submerged next to the suction head, will enable the tailings to be pumped at a solids content of 25 to 30% to cells built in the mined out areas. The cells are just simple ponds formed by dykes built with the overburden material. In these cells the tailings will continue to settle to a higher density (Figure 12). The tailings will fill the cells in two stages, separated by an interval in order to permit good consolidation (Figure 13).

Roughly two years after the second filling of the cells the rehabilitation activities will start and the solids content expected at this time is around 59% (Figure 13).

The rehabilitation will be similar to the present day practice. The tailings and the tops of the dykes will be graded by bulldozer. Thereafter, the topsoil will be spread over the area to a thickness of 0.50 m to allow fast vegetation growth (Figure 14) and the ground will reflect a topography similar to that

now obtained.

The dykes will be built by the existing draglines as part of the normal stripping operation. As a consequence, no significant increase in operating costs due to the cell construction is foreseen.

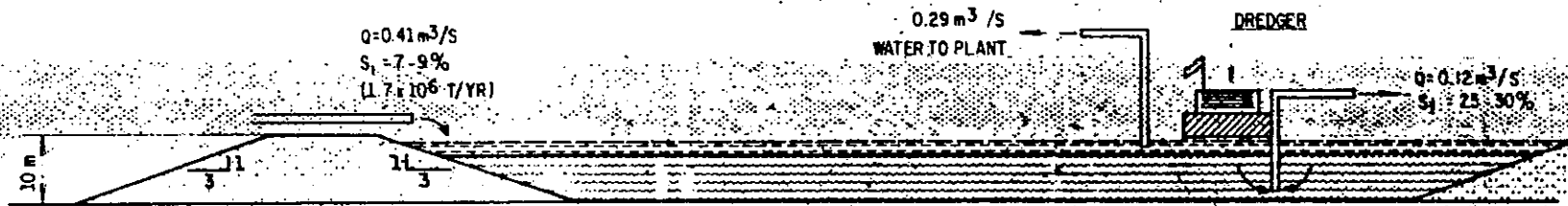
The implementation of this project started in September 1986. The new tailings disposal system will become operational during the second half of 1989.

Simultaneously, efforts are being dedicated to reclaim the silted areas of Batata Lake. Studies have already started to find out the best way to reclaim these areas when the discharge of the tailings into the lake is phased out.

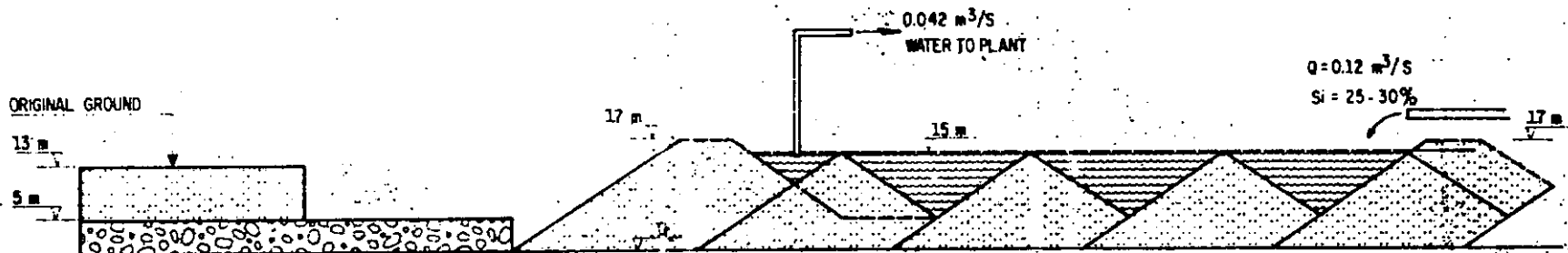
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### TAILINGS THICKENING POND



### CROSS SECTION OF MINE CELL



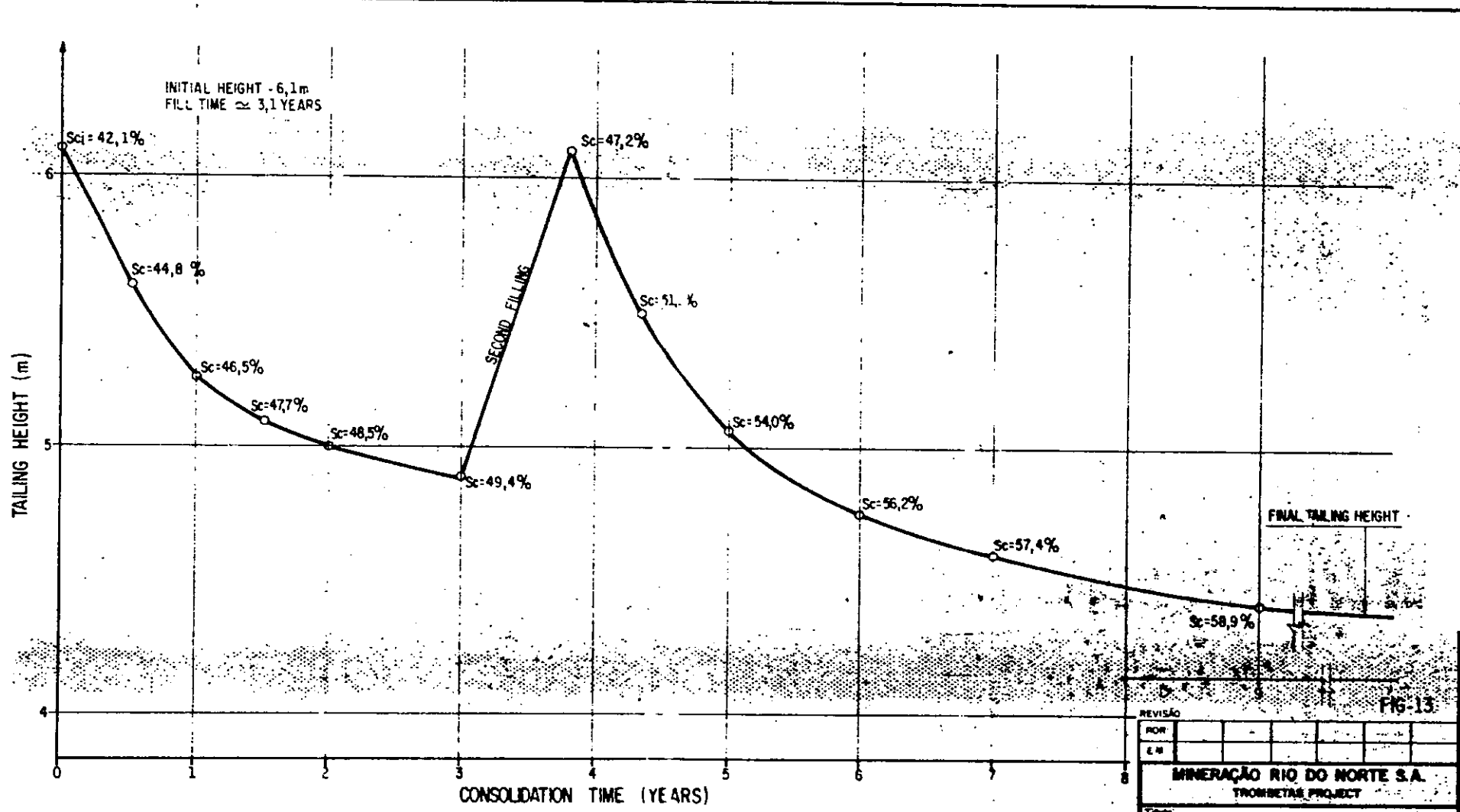
#### LEGEND



FIG-12

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TROMBETAS PROJECT				
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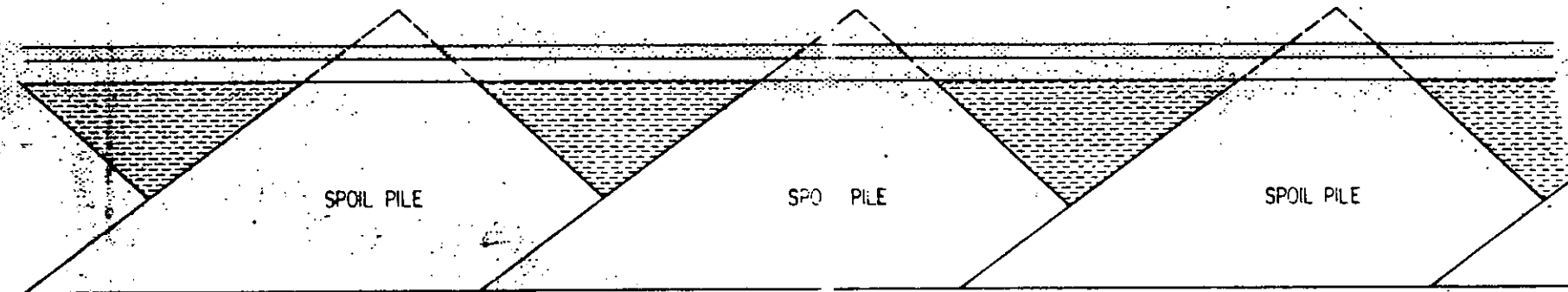


OBS.: CONSOLIDATION RATE IS VARIABLE FOR EACH MINE CELL AND DEPENDS ON ITS GEOMETRY

REVISÃO			
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TRONHEIAS PROJECT			
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<b>TAILINGS CONSOLIDATION</b>			
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FIG-13

**RECLAIMED SOIL PROFILE**



SPOIL PILE

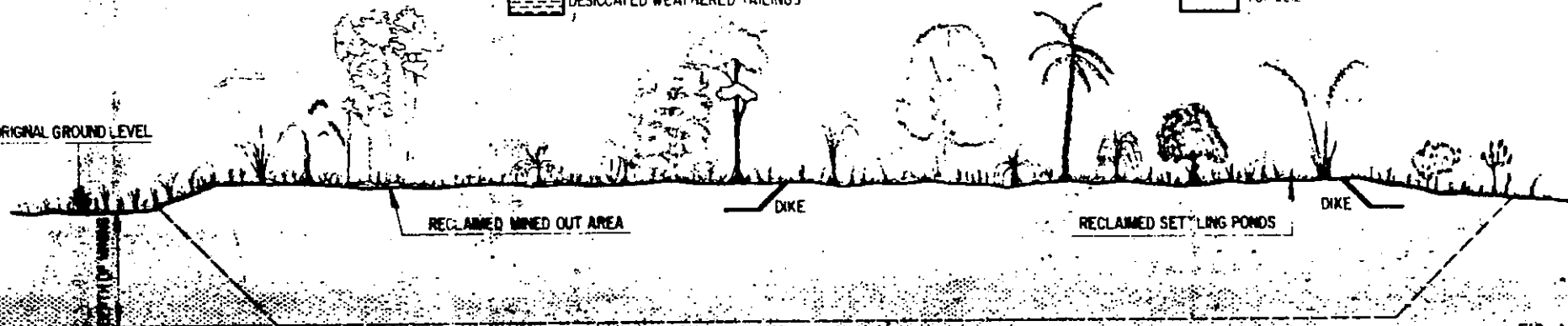
SPO PILE

SPOIL PILE

DESICCATED WEATHERED TAILINGS

TOPSOIL

ORIGINAL GROUND LEVEL



RECLAIMED MINED OUT AREA

DIKE

RECLAIMED SETTLING PONDS

DIKE

**FINAL LAND FORMS**

FIG.-14

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MINERAÇÃO RIO DO NORTE S.A. TROMBETAS PROJECT					
Título <b>RECLAMATION SCHEME</b>					
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Visto	BBP	Autor	BCI	Esc.	Aiberlô

Greig, E.W. 1977. Trombetas and other Amazon bauxites, Brazil, AIME preprints - 77/H/92. pp 34.

Lapa, R.P. and C.M. Hernalsteens. 1985. The Trombetas bauxite, Mining in Brazil, DNPM.

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