6.14 Technical Data

6.14.1 Design Parameter

According to the laboratory flotation tests, pulp density and slime elimination were critical factors for the concentration design.

The following are the design parameters to reduce initial and operating costs and to facilitate the operation of the concentrator.

(1) Process will be as simple as possible.

(2) Instrumentation will be installed at principal points.

(3) Clayey ore will be eliminated by means of washing, because it has a bad influence on the flotation.

(4) The structure of the concentrator will be as simplified as possible, and the machinery is situated as efficiently as possible considering the aspect of its maintenance and control.

(5) The case of operation of the machinery and facilities will be given important consideration.

(6) Because of the water shortage, the amount of recycled water will be increased as much as possible.

Concentration Method

All slime single product phosporous flotation.

Operating Condition

Annual working days (day)	290
Shifts per day (shift)	
Primary crushing	1
Secondary, tertiary crushing	2
Grinding and flotation	3
Hours per shift (hour)	8
Operating time (hour/day)	
Primary crushing	5
Secondary, tertiary crushing	10
Grinding and flotation	24

Design capacity (T/day) 400

Physical Properties of Crude Ore

Grade of ore (% P_2O_5)	11.50
Specific gravity	3.0
Apparent density	1.8
Moisture content (%)	Ave. 5
WI (kWh/T)	12

Crushing

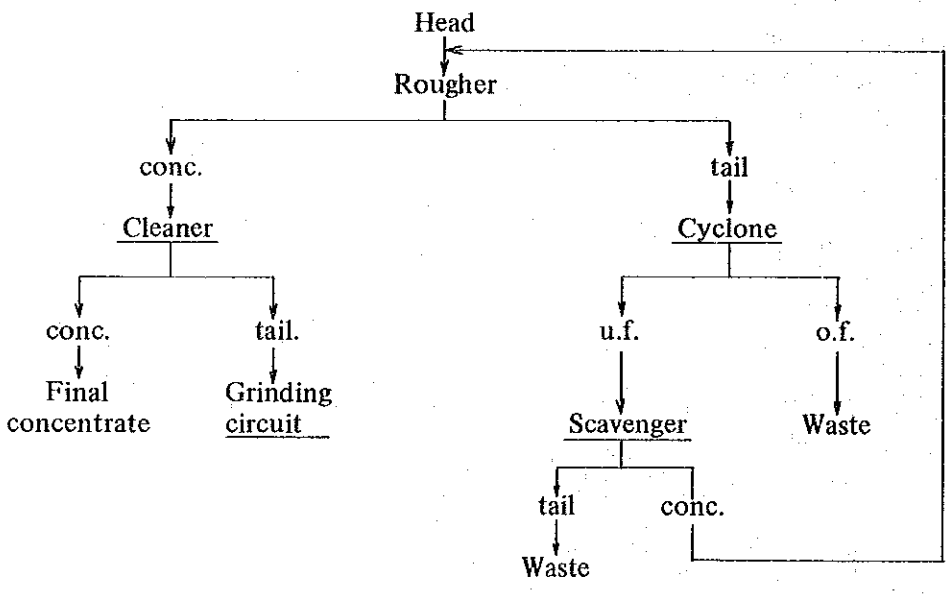
Crushing system		3-stage closed circuit
Feed maximum size (mm)		400
Product maximum size (mm)	Primary	150
	Secondary	70
	Tertiary	15
Operating capacity (T/hour)	Primary	80
	2nd and 3rd	40
Ore bin capacity (T)		
Crude ore – stock pile		26,000
Crude ore – ore bin		50
Primary product		350

Grinding

Grinding circuit	Ball mill – closed circuit
Classification	Spiral classifier
Feed, 80% size (mm)	10
Product, 80% size (mm)	0.300
WI (kWh/T)	12
Operating capacity (T/hour)	15
Classifier circulating load (%)	200
Classifier overflow pulp density (%)	50
Ore bin capacity (T)	400

Flotation

Flotation method	P_2O_5 plain flotation
Cleaning circuit	1-stage cleaning



	Pulp density (%)	Conditioning and floating time (min)
Conditioner	45	8
Rougher	45	17
Scavenger	50	23
Cleaner	30	30
Slime flotation	30	21

PH value, Rougher	10.0
Final concentrate grade (% P_2O_5)	30.07
Recovery (%)	88.4

Concentrate Thickening

Feed pulp density (%)	22
Spigot pulp density (%)	65
Settling speed (ft/hr)	4.5

Concentrate Filtration

Concentrate size (%)	−200 mesh	20
Concentrate moisture content (%)		10
Concentrate bulk density		1.9

6.14.2 Product balance

Product	Weight (T/year)	Grade (P_2O_5 %)	P_2O_5 weight (T/year)	Distribution	
				Weight	P_2O_5
Feed	104,000	11.50	11,960	100.0	100.0
Concentrate	35,181	30.07	10,578	33.8	88.4
Tailing	68,819	2.01	1,382	66.2	11.6

6.14.3 Principal unit consumption

Grinding

Ball mill	ball (g/T ore)	800
"	liner (")	77

Reagents

Caustic soda	(g/T ore)	400
Lilaflot	(")	400
Water glass	(")	2,000

Power (kWh/T ore)		36.9
Water		
Fresh water	(m^3/T ore)	2.00
Recycled water	(")	2.68
Total water	(")	4.68

6.14.4 Instrumentation

Crushing	
Weightometer	2
Flow meter	1
Grinding, flotation	
Weightometer	1
PH meter	2
Densitometer	1
Flow meter	1

6.14.5 Building

Construction Steel frame, slate roofing

Size

Building	Size (m)	Height (m)	Area (m^2)
Primary crushing	7.5 X 5.0 9.0 X 8.0 5.0 X 3.0	9.5	124.5
2nd · 3rd crushing	30.0 X 15.0 15.0 X 13.0	15.25	645.0
Grinding · flotation	65.0 X 14.0	14.0	910.0

6.14.6 Facilities

Refer to Fig. 6.1 & Table 6.

Table 6 Legend for Flow Sheet

No.	Equipment	Size & Spec.	Number	Power (kW)	Remarks
1	HOPPER	50t	1		
2	GRIZZRY FEEDER	900 x 2,400	1	7.5	100mm
3	PRIMARY CRUSHER	900 x 600	1	55	Single toggle
4	B.C.	600	1	11	Belt conveyor
5	ORE BIN	300t	1		
6	APRON FEEDER	900 x 3,000	1	2.2	
7	B.C.	400	1	3.7	
8	2ND SCREEN	900 x 1,800	1	5.5	60mm
9	2ND CRUSHER	760 x 300	1	37	Single toggle
10	B.C.	400	3	7.4	
11	3RD SCREEN	1,200 x 2,400	1	7.5	15mm
12	3RD CRUSHER	900ϕ	1	55	Cone crusher
13	B.C.	400	2	3.7	
14	B.C.	400	3	5.2	
15	WASHING SCREEN	1,200 x 2,400	1	7.5	15mm, 5mm Double
16	SPIRAL CLASSIFIER	600ϕ x 4,500	1	2.2	
17	B.C.	400	1	1.5	
18	B.C.	400	1	1.5	
19	B.C.	400	1	5.5	
20	ORE BIN	400t	1		
21	BELT FEEDER	400	1	1.5	
22	B.C.	400	1	2.2	
23	BALL MILL	2,400 x 1,800	1	150	
24	SPIRAL CLASSIFIER	1,050ϕ x 6,800	1	3.7	

No.	Equipment	Size & Spec.	Num-ber	Power (kW)	Remarks
25	PUMP	3/2 WP	2	3.7 x 2	
26	CONDITIONER	2,000ϕ x 2,000	2	5.5 x 2	
27	ROUGHER	#24 FW	8	11 x 8	
28	PUMP	3/2 WP	2	5.5 x 2	
29	CYCLONE	200ϕ	2		
30	SCAVENGER	#24 FW	6	11 x 6	
31	PUMP	3/2 WP	2	2.2 x 2	
32	CLEANER	#24 FW	8	11 x 8	
33	PUMP	3/2 WP	2	3.7 x 2	
34	PUMP	1 WP	2	2.2 x 2	
35	THICKNER	10mϕ	1	1.5 + 0.4	
36	PUMP	3/2 WP	2	5.5 x 2	
37	CYCLONE	200ϕ	2		
38	CONDITIONER	2,000ϕ x 2,000	1	3.7	
39	SLIME FLOTATOR	#21 FW	6	3.7 x 6	
40	PUMP	3/2 WP	2	3.7 x 2	
41	FILTER	2,400ϕ x 3,600	1	2.2 + 5.5	
42	STOCK YARD	600t	1		
43	PUMP	3/2 WP x 2	4	22 x 4	
44	PUMP	3/2 WP	2	15 x 2	

Fig. 6.1(1) FLOW SHEET(Crushing)

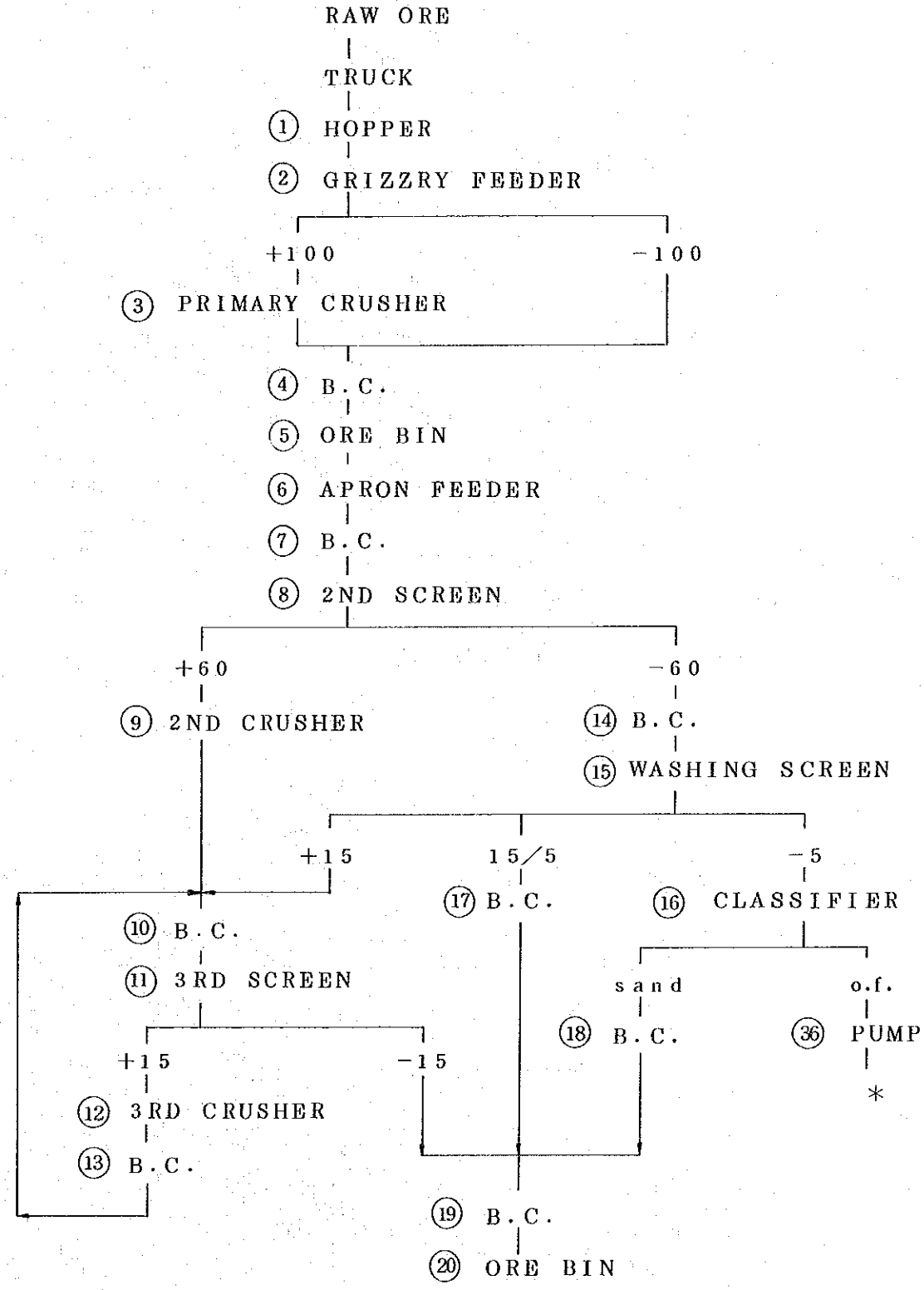
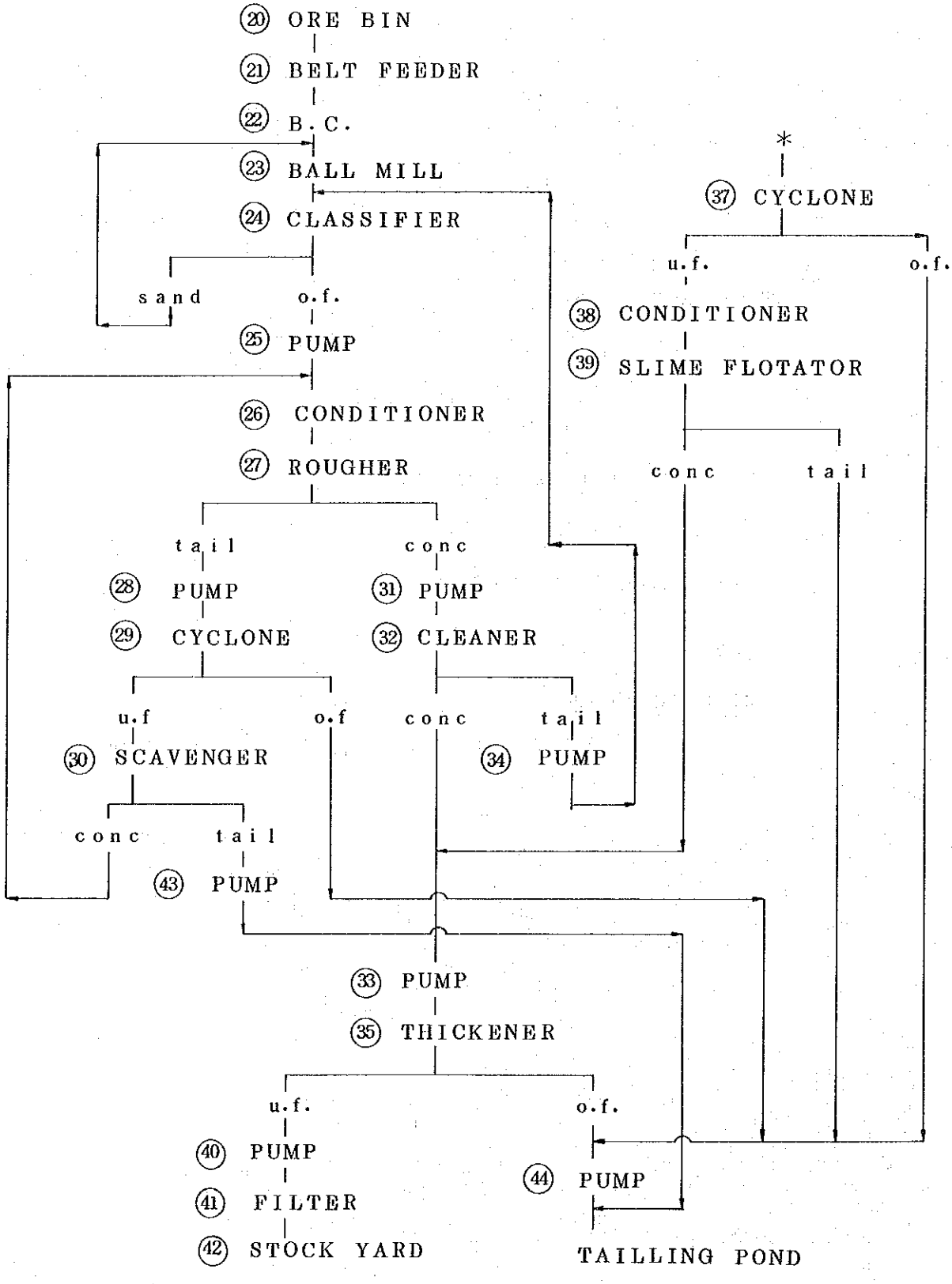


Fig. 6.1(2) FLOW SHEET (Grinding and Flotation)



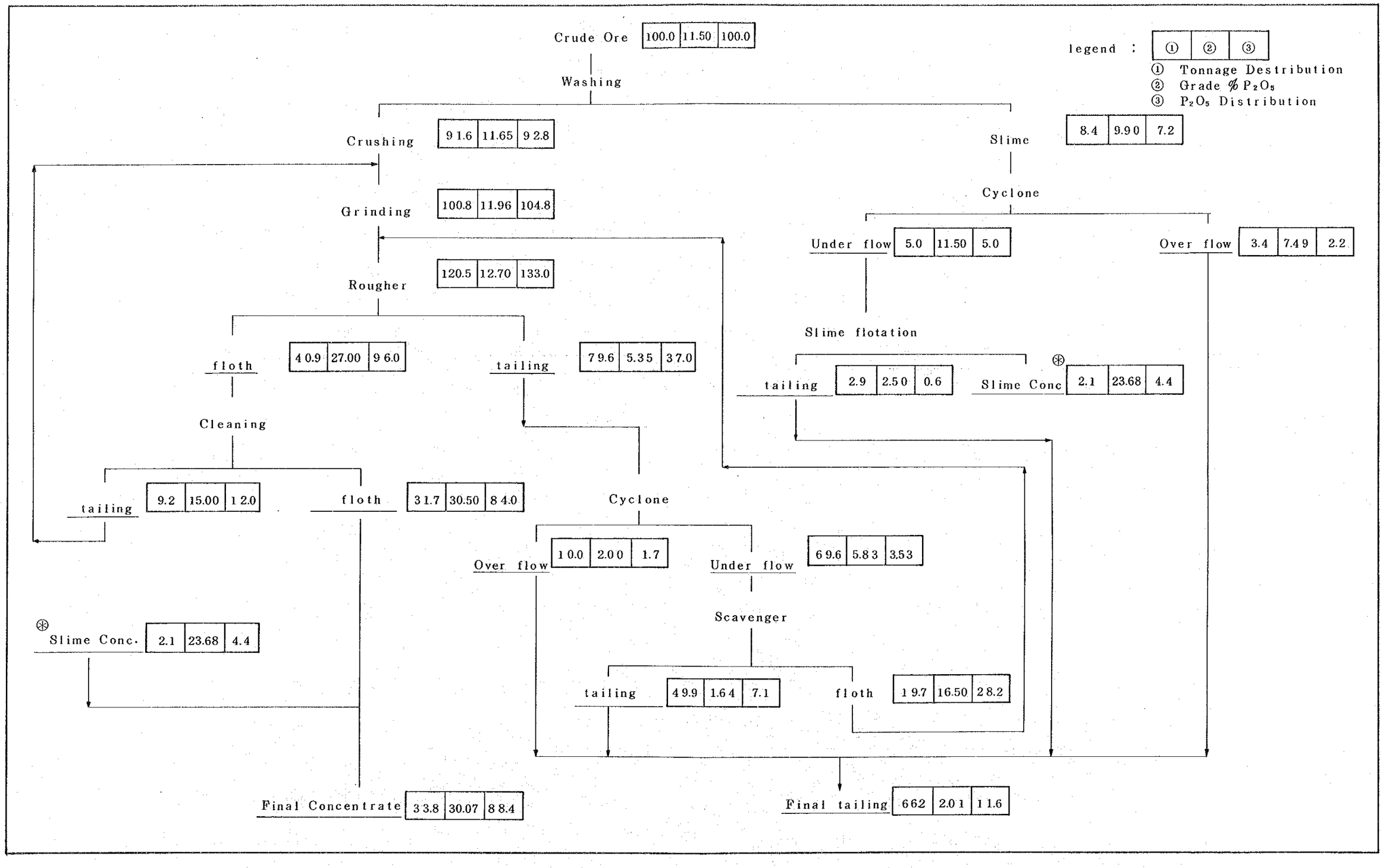
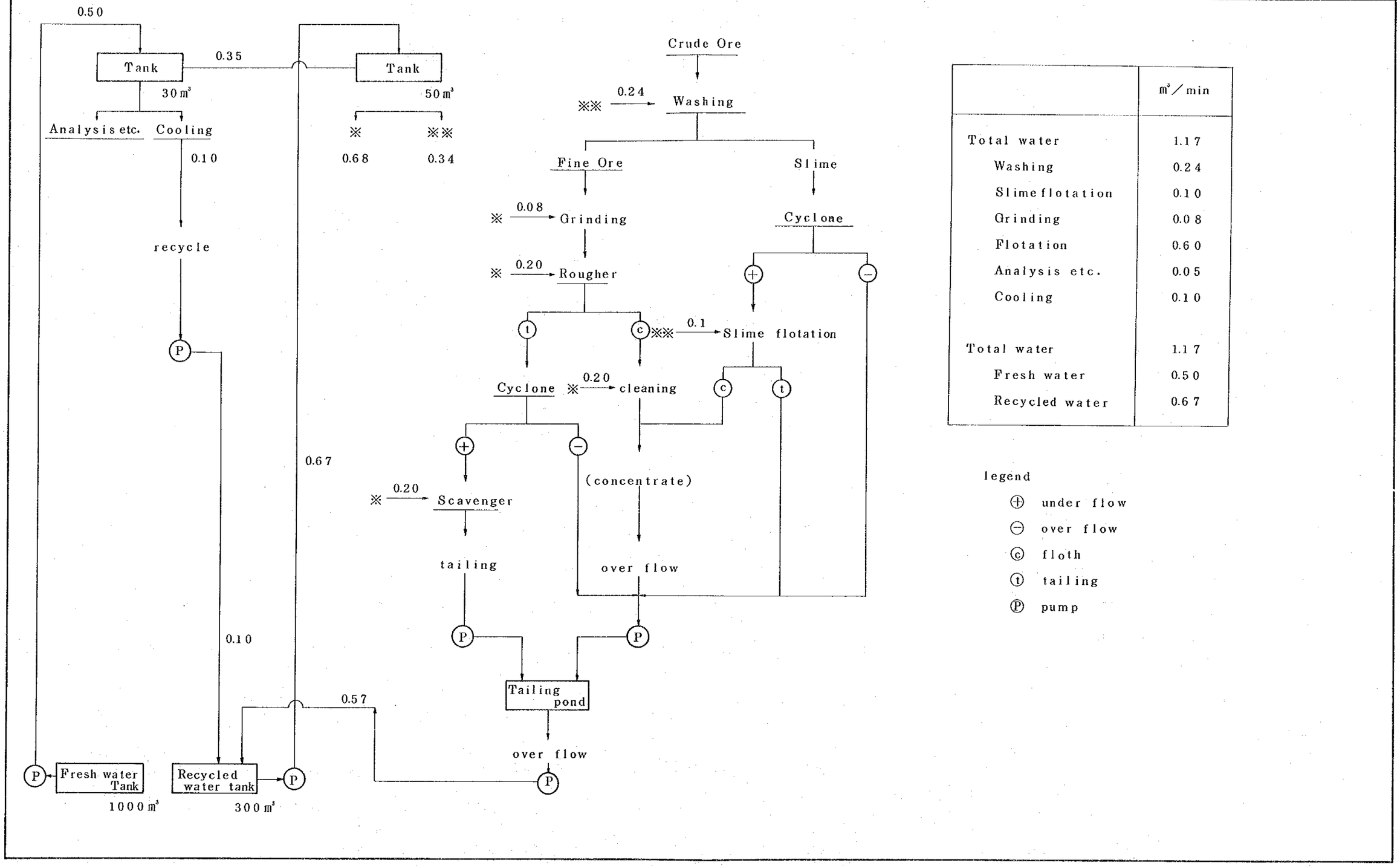


Fig. 6.2 Material Balance Sheet

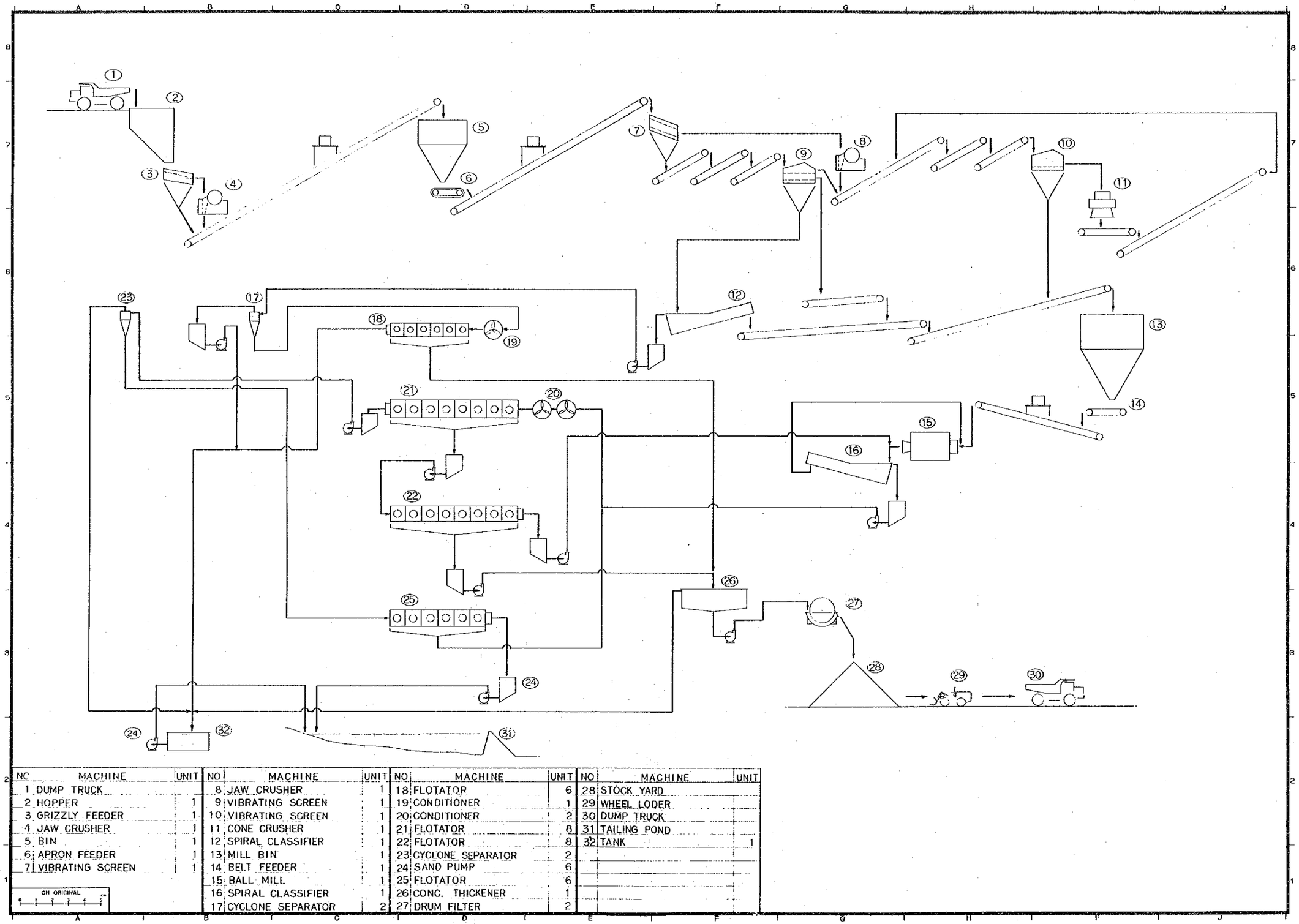


	m³／min
Total water	1.17
Washing	0.24
Slime flotation	0.10
Grinding	0.08
Flotation	0.60
Analysis etc.	0.05
Cooling	0.10
Total water	1.17
Fresh water	0.50
Recycled water	0.67

legend

- ⊕ under flow
- ⊖ over flow
- ⓒ floth
- ⓣ tailing
- Ⓟ pump

Fig. 6.3 Water Balance Sheet (m³／min)



NO	MACHINE	UNIT
1	DUMP TRUCK	
2	HOPPER	1
3	GRIZZLY FEEDER	1
4	JAW CRUSHER	1
5	BIN	1
6	APRON FEEDER	1
7	VIBRATING SCREEN	1
8	JAW CRUSHER	1
9	VIBRATING SCREEN	1
10	VIBRATING SCREEN	1
11	CONE CRUSHER	1
12	SPIRAL CLASSIFIER	1
13	MILL BIN	1
14	BELT FEEDER	1
15	BALL MILL	1
16	SPIRAL CLASSIFIER	1
17	CYCLONE SEPARATOR	2
18	FLOTATOR	6
19	CONDITIONER	1
20	CONDITIONER	2
21	FLOTATOR	8
22	FLOTATOR	8
23	CYCLONE SEPARATOR	2
24	SAND PUMP	6
25	FLOTATOR	6
26	CONC. THICKENER	1
27	DRUM FILTER	2
28	STOCK YARD	
29	WHEEL LODER	
30	DUMP TRUCK	
31	TAILING POND	
32	TANK	1

ON ORIGINAL

Fig. 6.4 Flow sheet

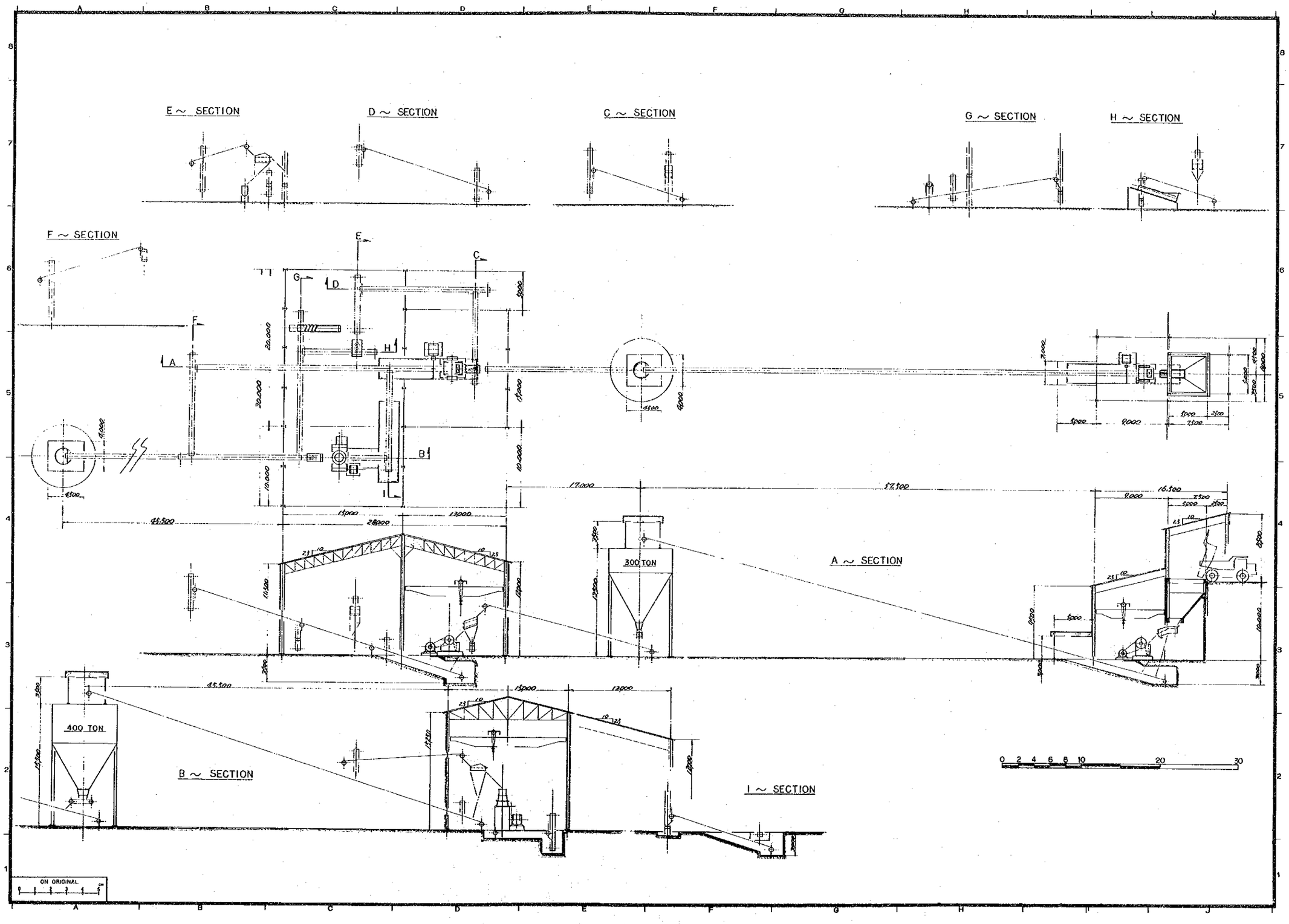


Fig. 6.5 Unit Prot Plan (1)

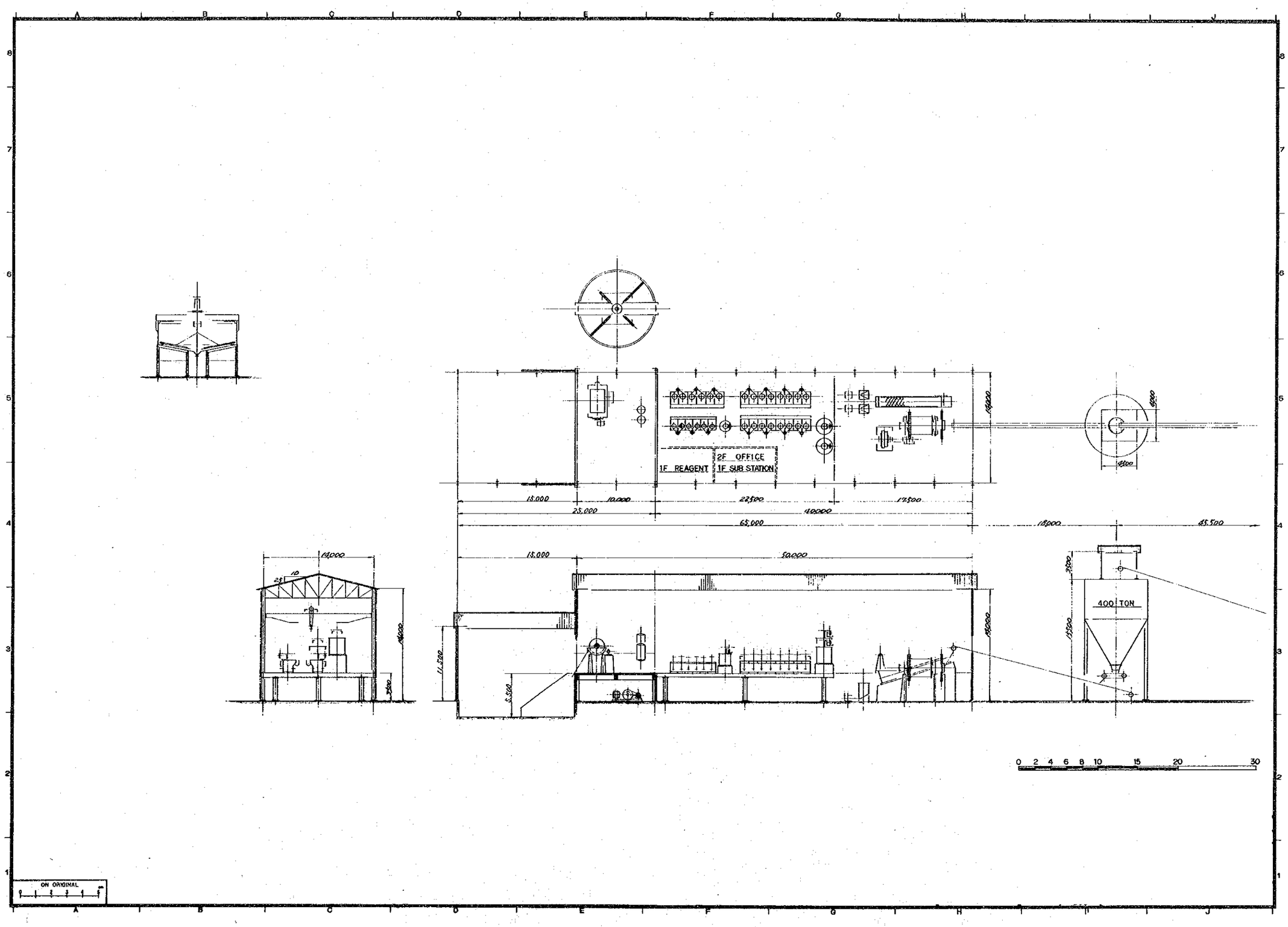
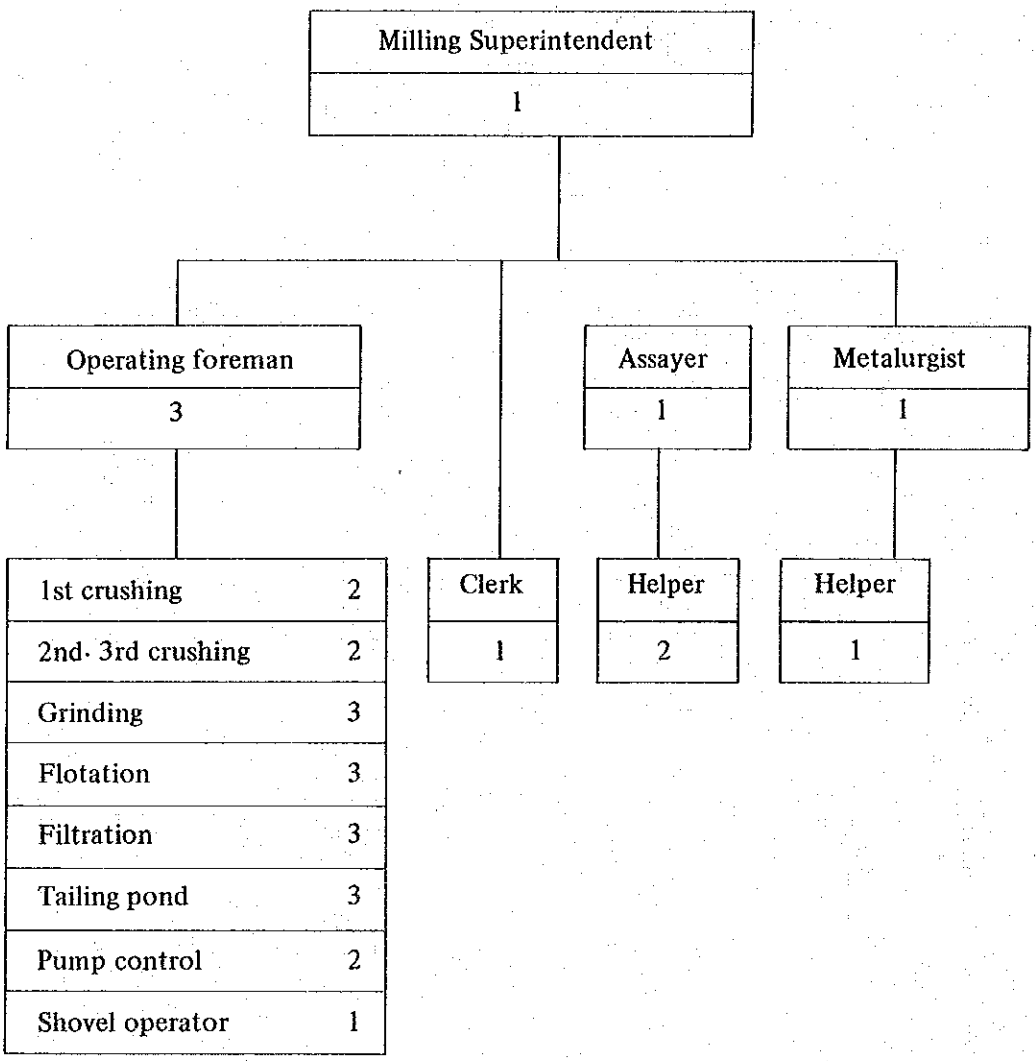


Fig. 6.6 Unit Prot Plan (2)

6.15 Operating Cost

Item	Unit	Unit Price	Crushing		Grinding		Flotation		Filtration		Tailing pond		Others		Total	
Material Cost		US$														
Ball	T	750			83.2	62,400									83.2	62,400
Caustic soda	Kg	0.5					41,600	20,800							41,600	20,800
Water glass	Kg	0.33					208,000	68,640							208,000	68,640
Lila flot	Kg	0.275					41,600	114,200							41,600	114,200
Settling promoter	Kg	5.3					2,000	10,600							2,000	10,600
Liner	T		4.315	7,560	8.0	12,480									12,315	20,400
Spare	lot			4,500		4,075		9,075		2,450		2,850		2,050		25,000
Fuel	ℓ	0.56											32,370	18,127	32,370	18,127
Oil	lot			2,049		1,281		768		461		512		1,864		6,935
Reagent	lot													4,878		4,878
Others	lot			2,553		2,704		3,755		2,253		2,253		13,882		27,400
Total				16,662		82,940		227,838		5,164		5,615		39,721		337,940
(US$/T)				(0.16)		(0.80)		(2.19)		(0.05)		(0.05)		(0.38)		(3.58)
Labor Cost																
Total			4	8,400	3	6,300	3	6,300	3	6,300	3	6,300	13	40,500	29	74,100
(US$/T)				(0.08)		(0.06)		(0.06)		(0.06)		(0.06)		(0.39)		(0.71)
Total				25,062		89,240		234,138		11,464		11,915		80,221		452,040
(US$/T)				(0.24)		(0.86)		(2.25)		(0.11)		(0.11)		(0.77)		(4.35)

Organization



7. ANCILLARIES

7.1 Power Supply

7.1.1 Outline

There will be two power distribution systems, one for mine area where the pit, concentrator, and various facilities will be located and the other for Mankwala Dam where the pump station for the water supply will be located. The power line to Mankwala Dam will be diverged from the substation at the mine site.

A cost of generating electricity in a private sector exceeds a cost of power purchased from an electric company. The power is deemed to be introduced from outside.

(1) Power source

Power will be purchased from Zambia Electricity Supply Corporation Limited (ZESCO) at the prevailing rates.

Between the mine site and Katete substation, the power line with 33 kV will be constructed, and maintained by ZESCO.

The mine site substation will be located near the concentrator and power will be stepped down to 6,600, then 440 and 220 V to be supplied to various equipments.

(2) Power distribution

Power Requirement:

The maximum power required for the production and resident facilities will be 790 kW and the total annual requirement will be 3,317,800 kWh as follows:

Mining	161,900 kWh
Concentration	2,830,100
Water supply	201,800
Resident use	124,000
Total	3,317,800 kWh

Voltage Used:

The power line from Katete to the mine site substation will be of 33 kV. At the mine site substation, the voltage will be stepped down to 6,600, then 440 and 220 V.

To the Mankwala Dam and residence area, 6,600 kV will be used and then stepped down to 440 and 220 V.

Emergency Power Supply:

Emergency power facilities will not be constructed, because the demand of electric power is not so great as to disturb production.

7.1.2 Power distribution facilities

(1) Basis for power distribution

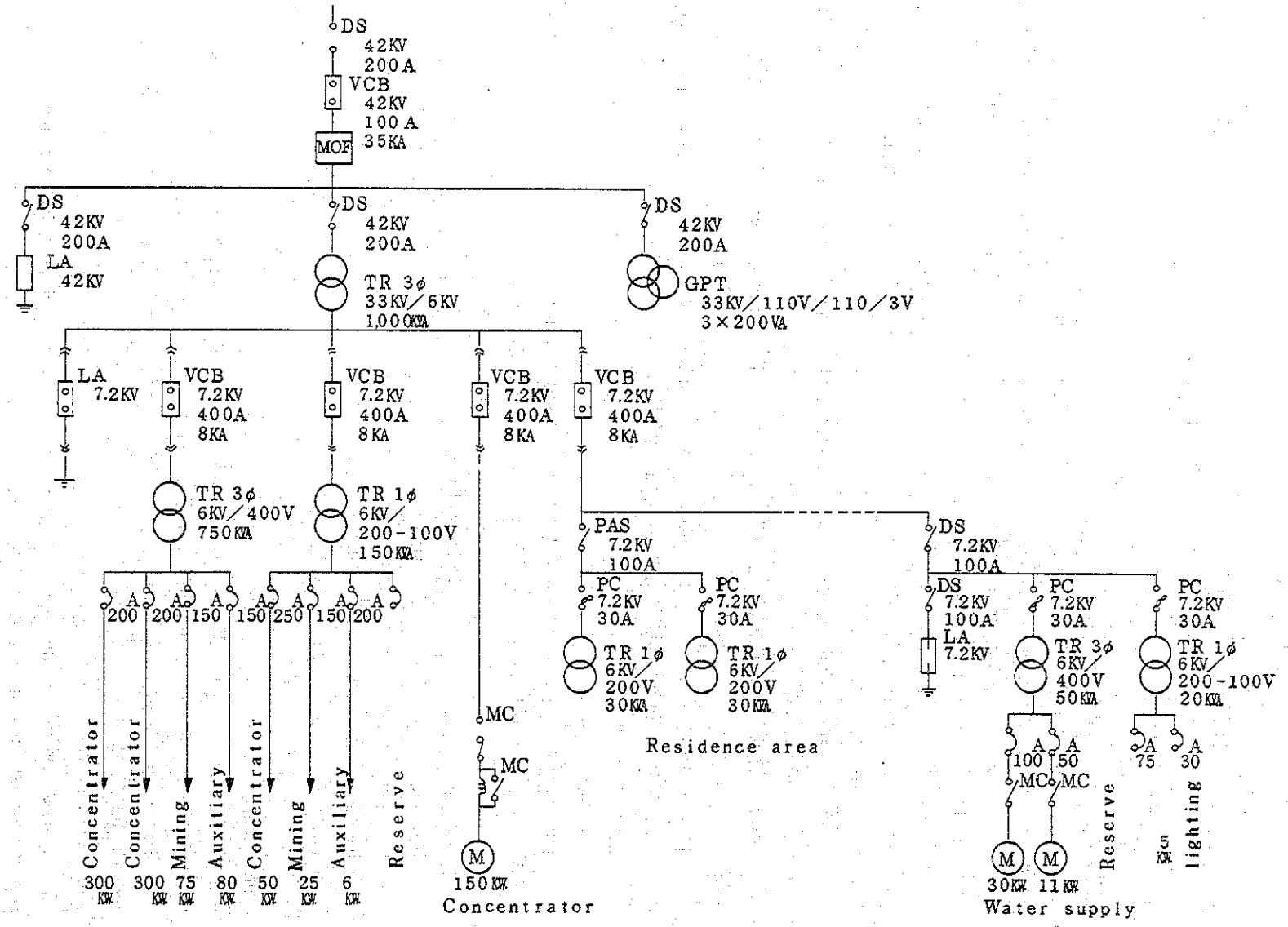


Fig. 7.1 Single—line Diagram Showing Power Distribution System

Power requirement 3,317,800 kWh/year
Max. demand 900 kVA
where; power factor 80%
load factor 80%
diversity factor 1.1
Power source: Power will be purchased from ZESCO.
Power supply point will be at the mine site substation.

(2) Main electrical equipment

Substation

42 kV three pole disconnecting switch	4
42 kV 100 A air circuit breaker	1
1000 kVA transformer 33/6.6 kV	1
42 kV lightening arrester	1

Transmission line

33 kV aerial lines, total length (km)	40
Cable	25 mm^2 ACSR
Pole	9 m-long wooden post

(3) Cost of purchased power

Applicable code:

Section 12 of Electricity Act. Chapter 811 of the Laws of Zambia. Tariff D2. (Effective 1st May, 1983)

Estimated unit cost 0.015 US$/kWh
Annual power cost 50,900 US$/year

7.2 Water Supply

7.2.1 Outline

The facilities will supply water both for the process and the domestic use, comprising of intake, heading-water, purification and distribution.

The process water will be used for the dressing plant, repair-shop, car-washing and sprinkling, while the domestic water will be filtrated, sterilized, and then distributed to the residence and office area.

7.2.2 Water requirement

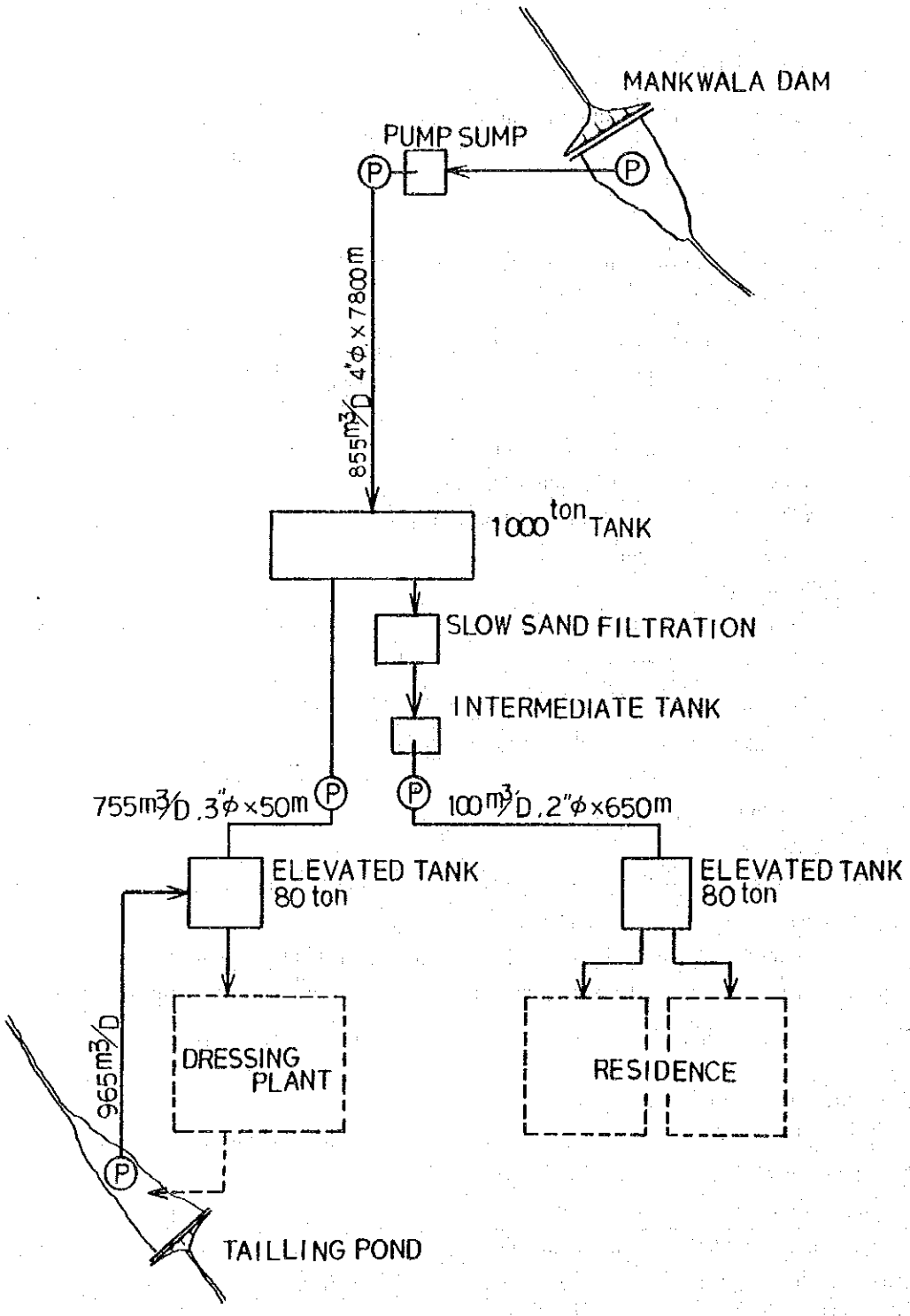
Required quantity is 1,820 m^3 per day for all purposes. But the necessary amount of intake water is 855 m^3 per day. (Refer to Fig. 7.2.1)

(1) Process water

During the dry season when 360 T/day of crude ore will be treated, the total process water requirement will amount to 1,700 m^3, out of which about 99% will be used for the concentration alone.

About 57% of the required amount will be recycled in the plant, because the Mankwala source has not enough capacity.

FLOW SHEET OF WATER SUPPLY



Therefore, required amount of fresh water is 735 m^3/day.

Details are as follows:

	Fresh	Recycled	(m^3/day) Total
Dressing plant	720	965	1,685
Other	15	–	15
Total	735	965	1,700

(2) Water for domestic use

Required quantity is 120 m^3/day.

And 83% of it will be used at the resident area.

The proposed population of the resident area will be 500 including families and its daily consumption is set at max. 200 ℓ per head.

The daily required quantity in each district is as follows:

	(m^3/day)	
District of staff	35	Including service equipment
District of workers	65	Ditto
Plant, administration	20	
Total	120	

7.2.3 A method of supply and installation

(1) Source of water (Refer to Fig. 7.2.2)

The following two places were investigated for the proposed source of water.

a. The Chitawe (The Luwanda River area)

b. The Mankwala (The Kasangazi River area)

The Mankawala is selected because of its great advantage of a large capacity.

However, the capacity of the Mankwala Dam at the end of the dry season, the Kasangazi River being a dry swamp during dry season, is less than the necessary amount of water for the operation and there is no water supply except precipitation.

Therefore, the process water will be recycled in the plant.

The required amount of process water will coordinate with the maximum capacity of Mankwala Dam using the recycled water.

Besides, a water quality of the source has no problem for the process water because of its softness on hardness 75.

(Commentary) The source in the wet season: (Refer to Table 7.1)

The Mankwala source, where there is a lot of rainfall (about 1,000 mm/year) in the wet season, has a great catchment area of 177.6 km^2. The

80

Table 7-1. Rain-fall Data at CHIPATA

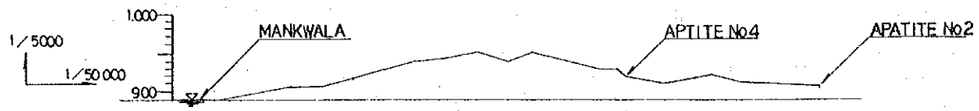
Unit: mm

			1940 ~ 1970	1981 ~ 1982	1982 ~ 1983
Oct.	Total		0	14	19
Nov.	Total		92	17	122
		I	18	0	1
	Decade	II	30	0	32
		III	44	17	89
Dec.	Total		215	93	264
		I	59	40	71
	Decade	II	75	0	166
		III	81	53	27
Jan.	Total		257	197	208
		I	83	34	73
	Decade	II	89	104	74
		III	85	59	61
Feb.	Total		231	178	116
		I	83	103	65
	Decade	II	79	42	51
		III	63	33	0
Mar.	Total		153	67	36
		I	62	26	24
	Decade	II	52	11	0
		III	39	30	12
Apr.	Total		49	60	97
		I	26	31	88
	Decade	II	14	26	0
		III	9	3	9
Total			997	626	862

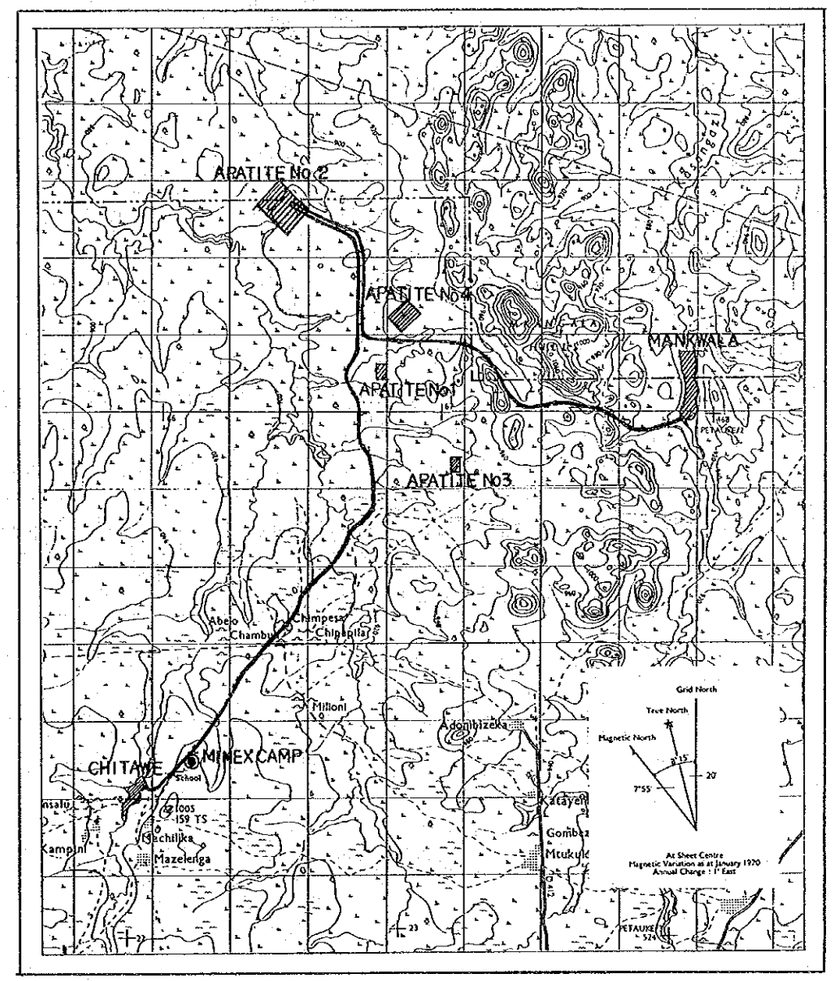
Source: Ministry of Power, Transport and Communications – Meteorological Department

NO.	REVISIONS	DATE	DRAFT	CHK'D	APP'D
1					
2					
3					

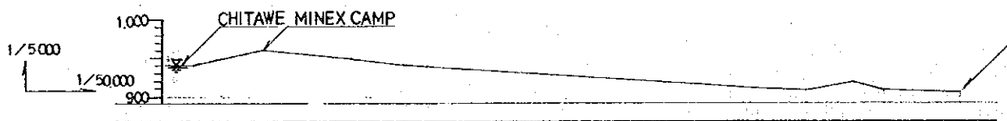
MANKWALA – APATITE No 2



No	DISTANCE (m)	CUMULATIVE DISTANCE (m)	ELEVATION (m)
0	000.0	000.0	890.0
1	200.0	200.0	
2	200.0	400.0	
3	600.0	1000.0	905.0
4	400.0	1400.0	
5	400.0	1800.0	915.0
6	400.0	2200.0	928.0
7	400.0	2600.0	938.0
8	300.0	2900.0	941.0
9	500.0	3400.0	952.0
10	400.0	3800.0	940.0
11	300.0	4100.0	952.0
12	900.0	5000.0	928.0
13	200.0	5200.0	928.0
14	100.0	5300.0	920.0
15	500.0	5800.0	910.0
16	600.0	6400.0	921.0
17	400.0	6800.0	910.0
18	1000.0	7800.0	905.0



CHITAWE – APATITE No 2



No	DISTANCE (m)	CUMULATIVE DISTANCE (m)	ELEVATION (m)
0	000.0	000.0	942.0
1	900.0	900.0	960.0
2	500.0	1400.0	
3	600.0	2000.0	950.0
4	700.0	2700.0	942.0
5	2000.0	4700.0	
6	700.0	5400.0	
7	500.0	5900.0	
8	200.0	6100.0	
9	800.0	6900.0	913.0
10	200.0	7100.0	
11	1000.0	8100.0	
12	700.0	7900.0	910.0
13	600.0	8500.0	921.0
14	400.0	8900.0	910.0
	1000.0	9900.0	905.0

(N.B) TEMPORARY ELEVATION : THE CHITAWE DAMCREST EL = 945.000 ML

HAPPY

Fig. 7.2.2 Route Map of Pipe Line

spill way on the left side of the Mankwala shows traces of spill, indicating that the dam is filled with water in the rainy season.

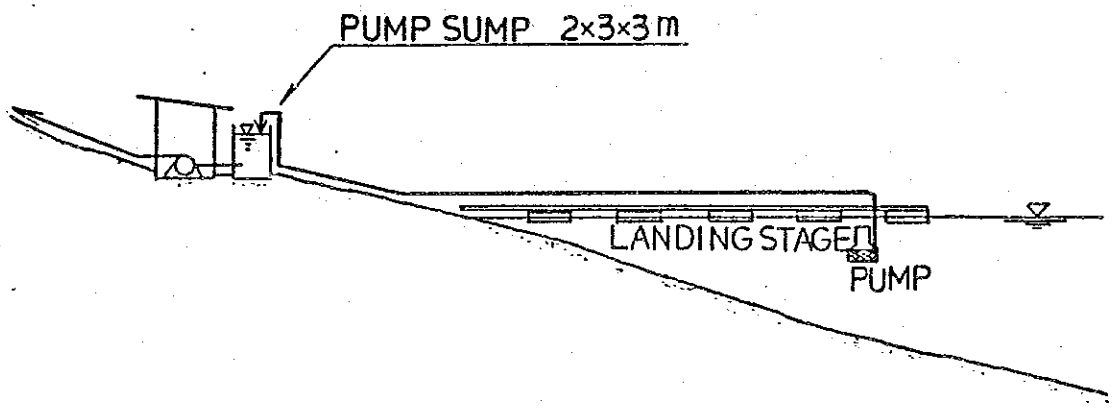
(2) Intake of water

The water will be taken in by the diver pump at the upper reaches of the pond, and sent to a pump sump near the pond.

The pump is mounted on a landing stage of a float type which rises and falls according to the water level.

The specifications of equipment are as follows:

Equipment	Number	Specification
Diver pump	2	Q = 0.6 m^3/min., H = 10 m, 11 kW
		Diameter of pump 3"ϕ
		Reserve 1
Pump sump	1	Concreted 2 × 2 × 3 m (3 m in height)



(3) Heading of water

The water will be sent through a 4"ϕ steel pipe for a distance of 7,800 m from the pump station to the 1,000 ton tank in the plant.

After purification, the process water will be pumped up to an adjacent 80 ton elevated tank and also the water for domestic use will be pumped up to an 80 ton elevated tank in the resident area which is 650 m from the purifier after being sterilized.

The specification of the equipment for the elevated tank is as follows:

Equipment	Number	Specification
Pump	2	*Q = 0.52 m^3/min., Head = 210 m, 30 kW
		Turbine type (7 stages)
		Diameter 3"ϕ
		Reserve 1

Piping	1	Diameter 4″ϕ, length 7,800 m Seamless steel pipe for high-pressure
Tank	1	Concreted, capacity 1,000 m^3, 10 X 25 X 4 m
Pump, for process	2	Q = 0.5 m^3/min., Head = 20 m, 3.7 kW Turbine type (single) Diameter 1.5″ϕ Reserve 1
Pump, for domestic	2	Q = 0.2 m^3/min., Head 85 m, 7.5 kW Turbine type (4 stages) Diameter 2″ϕ Reserve 1
Piping	1	Diameter 2″ϕ, length 650 m, steel pipe

(N.B.) Piping is to be laid on the surface

* [(735 m^3 + 20 m^3) X 6 days + 100 m^3 X 7 days] /(7 days X 1,440 min.)
= 0.52 m^3/min.

(4) Purification of water

The object of this installation is to remove foreign and fine impurities. This installation will be furnished with an 1,000 ton concrete tank. The filter medium will be sand and gravel, and the thickness will be about 1.0 m. After filtration, moreover, the water will be treated by calcium hypochlorite sterilization.

The specification of equipment is as follows:

Equipment	Number	Specification
Filtration	1	Concreted, * 855 m^3/day Filter speed 5 m/day
Intake tank	1	Concreted, 5 X 5 X 4 m
Sterilization	1	Automatic type, for 500 persons An amount of calcium hypochlorite = 1.2 kg/day

* Amount of water = 735 m^3 (process) + 120 m^3 (domestic)

(5) Distribution of water

A distribution is accomplished by 2 systems for the process and domestic water. The water will be distributed from each elevated exclusive tank by natural head. The specification of equipment is as follows:

Equipment	Number	Specification
(For industrial)		
Elevated tank	1	Steel, 20 mH, capacity 80 m^3
Pipe line	1	Diameter 3"ϕ, steel pipe length 1,000 m
(For residence)		
Elevated tank	1	Steel, 20 mH, capacity 80 m^3
Pipe line	1	Diameter 3"ϕ, steel pipe length 1,400 m
		Others, 2"ϕ, 1"ϕ, length 2,800 m

Table 7.2 List of Pumps

	Catch	Supply	Industrial use	Residents use
Quantity	0.6 m^3/min	0.52 m^3/min	0.51 m^3/min	0.2 m^3/min
Head	10 m	210 m	20 m	85 m
Power	11 kW	30 kW	3.7 kW	7.5 kW
Diameter	65 mm	80 mm	65 mm	50 mm
Stage	1	7	1	4
Type	Diver pump	Turbine pump	Turbine pump	Turbine pump
Number	2 (Inc. reserve)	2 (Inc. reserve)	2 (Inc. reserve)	2 (Inc. reserve)

7.3 Road Construction

The work is composed of constructing a main access road from the Great-East Road to the mine-site and the inside roads being mainly one to the plant and an approach road to the Mankwala Dam.

7.3.1 Main access road (Refer to Fig. 7.3)

The established road (width 3.2 m, length 35 km) is to run through at about the ridge line from the Great-East Road to the mine site.

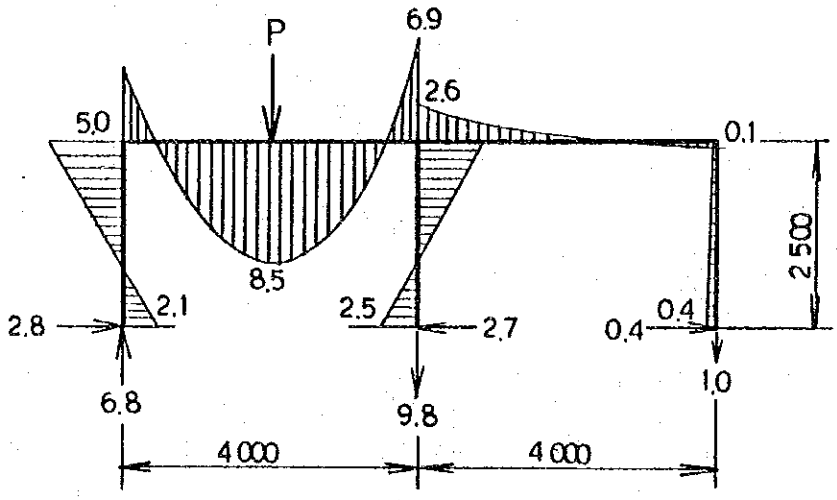
The maximum grade is about 1.2%. Therefore, the work will be to widen and improve the established road except for a 2 km section close to the mine site which will have to be of new construction.

Standard of the road

Width	5 m
Length	35 km
A gravel road	

A two lane zone will be provided every 200 m. Concrete-culverts will be constructed at the 13 points where the creek intersects the road and the existing No. 9 concrete bridge will be reinforced.

(Commentary) Moment of No. 9 bridge [Moment: T.m]
[Reaction force: T]



P = 13.5 T
(Load on each wheel of gross truck weight)

7.3.2 The inside roads

The roads will be constructed with a gravel surface and will connect the office, the pit, the concentrator, the magazine, and the tailing-pond.

Total length: · 2,500 m

7.3.3 Approach for the water supply

This approach will be constructed with a gravel surface, and will connect the plant to the Mankwala Dam which will be an important source of water supply.

This will facilitate dam patrol during operation.

Total length: 4,500 m

7.4 Tailing Pond

The purpose of the tailing pond is to allow the solids to settle out of the tailing discharge of the plant, and because of the shortage of dressing water, to recycle the separated water to the plant.

7.4.1 Site selection

As the result of the investigation, the valley of the Luwanda River, 600 m south from

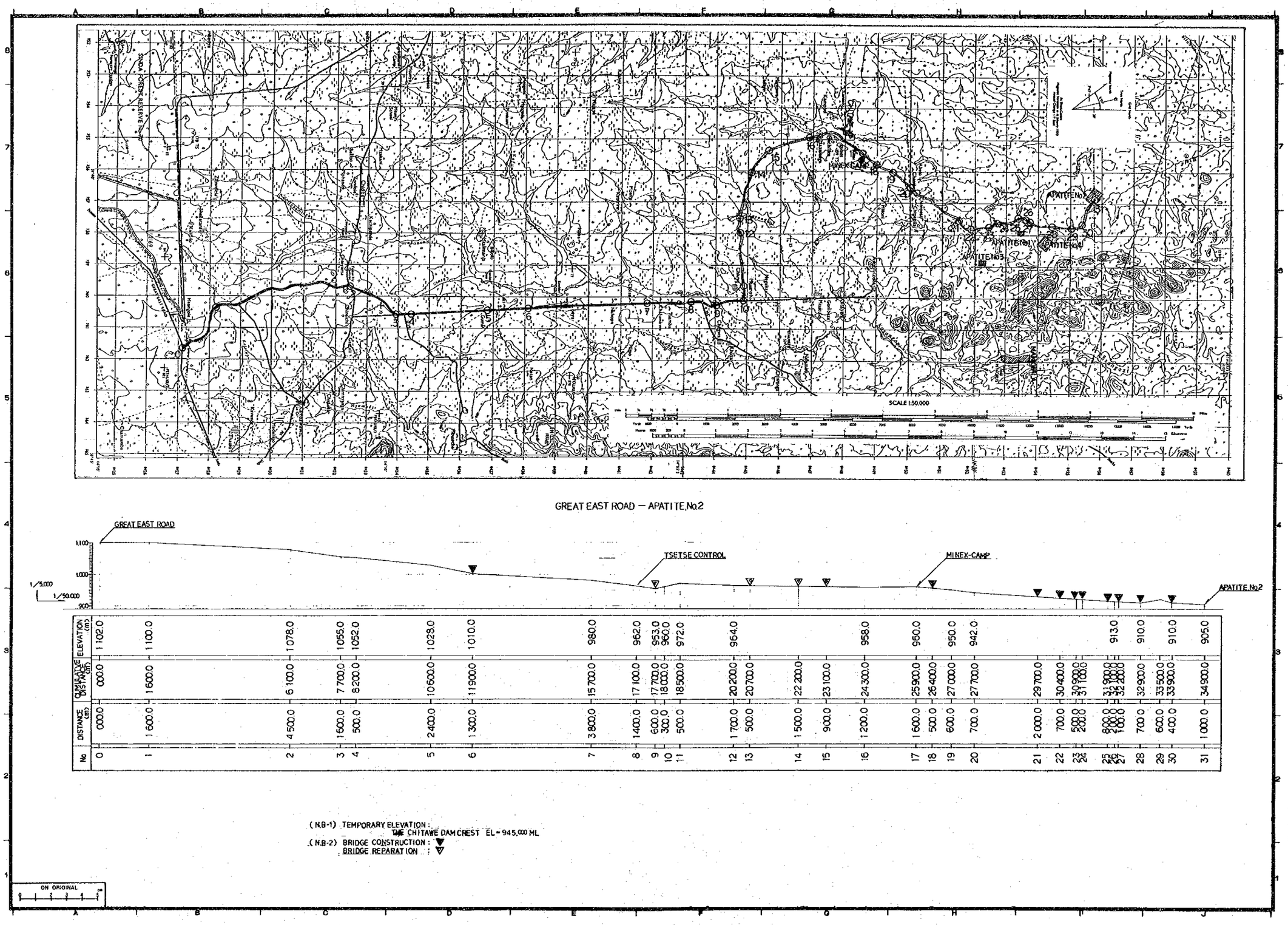


Fig. 7.3 Road Profile

the proposed site of the concentrator is selected for the following reasons:

(1) The capacity of the pond is great enough for use during the production period.

(2) It is a short distance over the level ground making it easy to pump the tailing to the pond and then return the separated water to the plant.

(3) Suitable construction materials are available nearby.

(4) The ground condition is such enough that stability and storage capacity can be expected.

7.4.2 Topography

The site is of a comparatively deep valley forming a distinct basin and a big tributary. Accordingly, it will have an advantageous pocket.

7.4.3 Catchment area (Refer to Fig. 7.5)

The catchment area of the site is 80.6 km^2, reaching 15 km south and extending 7 km in an east-west direction.

In the dry season it has a dry river bed.

7.4.4 Type of tailing pond

The pond will be formed by closing the opening on the north-west side. The tailing transported by the pipe line from the concentrator to the pond will be discharged on the upper side without any treatment and will be piled up to an elevation of 890 m above sea level.

The capacity of pond: 1,033,000 m^3

7.4.5 Embankment

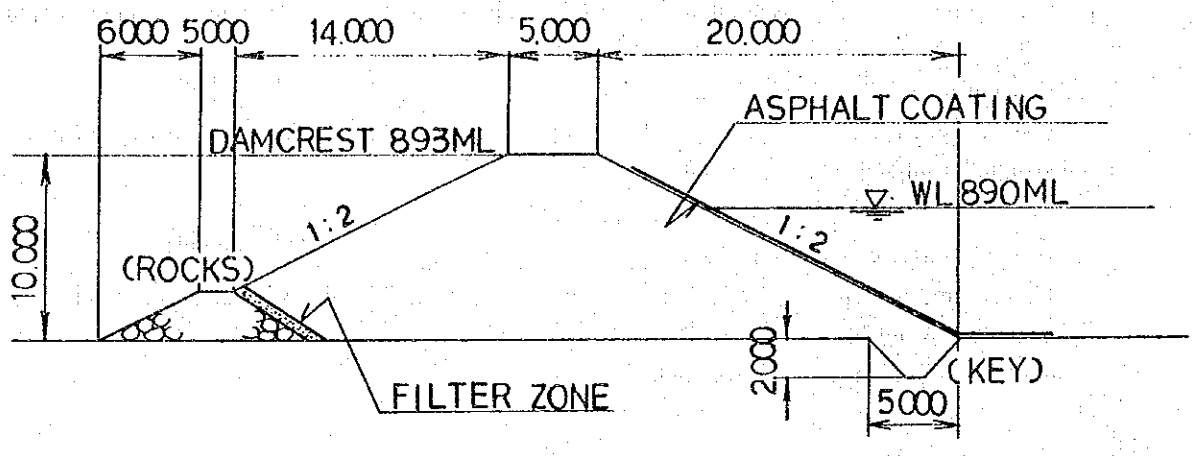
The dam will be an earth-filled dam with asphalt coating on the inner slope to store water coming from the upper stream. At the dam toe, a drain which has good permeability will be constructed to lower the seapage line.

Specification:

Face of slope	Inner slope 1 : 2
	Outer slope 1 : 2
Final level	893 m (above sea level)
Embankment height	10 m (effective)
Embankment width	5 m
Embankment length	610 m
Volume of embankment	70,000 m^3

Design of Embankment

Scale 1/400



7.4.6 Construction

(1) A rock filled embankment will be built at the toe of the outer slope using mining waste.

(2) Nearby topsoil will be used for construction material. Each layer of 30 cm will be tamped 5 to 7 times by a Tamping Roller or Macadam Roller.

(3) Between the rock-filled embankment and the earth dam, a filter zone 60 cm thick will be constructed to prevent piping phenomenon.

7.4.7 Construction plan

(1) Volume balance of tailing

Annual production of crude ore	104,000 T
Tailing ratio	66.2%
Tailing volume	68,848 T/year (specific gravity 1.0)
Total tailing volume	68,848 T × 15 year = 1,033,000 m^3

(2) Dam volume

Elevation (mL)	Area (m^2)	Height (m)	Volume (m^3)	Cumulative volume (m^3)
883	0	–	–	–
884	27,000	1	13,500	13,500
885	66,400	1	46,700	60,200
886	104,400	1	85,400	145,600
887	146,000	1	125,200	270,800
888	201,400	1	173,700	444,500
889	286,000	1	243,700	688,200
890	403,800	1	344,900	1,033,100

(3) Construction plan

To minimize the initial investment the dam construction is separated into three 5 year periods. By the cumulative curve, dam heights are as follows:

Year	Dam height (mL)	Dam capacity (m^3)
1	890.5	348,000
7	892	688,200
12	893	1,033,100

Note: Height of extrabanking between the top of the dam and water level is 3 m.

7.4.8 Drainage

The catchment area of 80.6 km^2 is very spacious in comparison with the dam area. As this dam is utilized for an impounding reservoir, storm sewage is gathered and impounded.

For the purpose of water level adjustment, an open channel at the left side of dam (3.5 m wide, 1.8 m high, 150 m long) will be constructed with concrete to discharge downstream.

(1) Condition

a. Intensity of rain fall

Probability in 200 years: 100 mm/day

According to the maximum daily precipitation record at Petauke and Chipata near the mine site, the daily rain-fall is calculated with the "log normal curve paper".

b. Catchment area ..... 80.6 km^2 (Refer to Fig. 7.5)

c. Coefficient runoff ..... f = 0.05

90

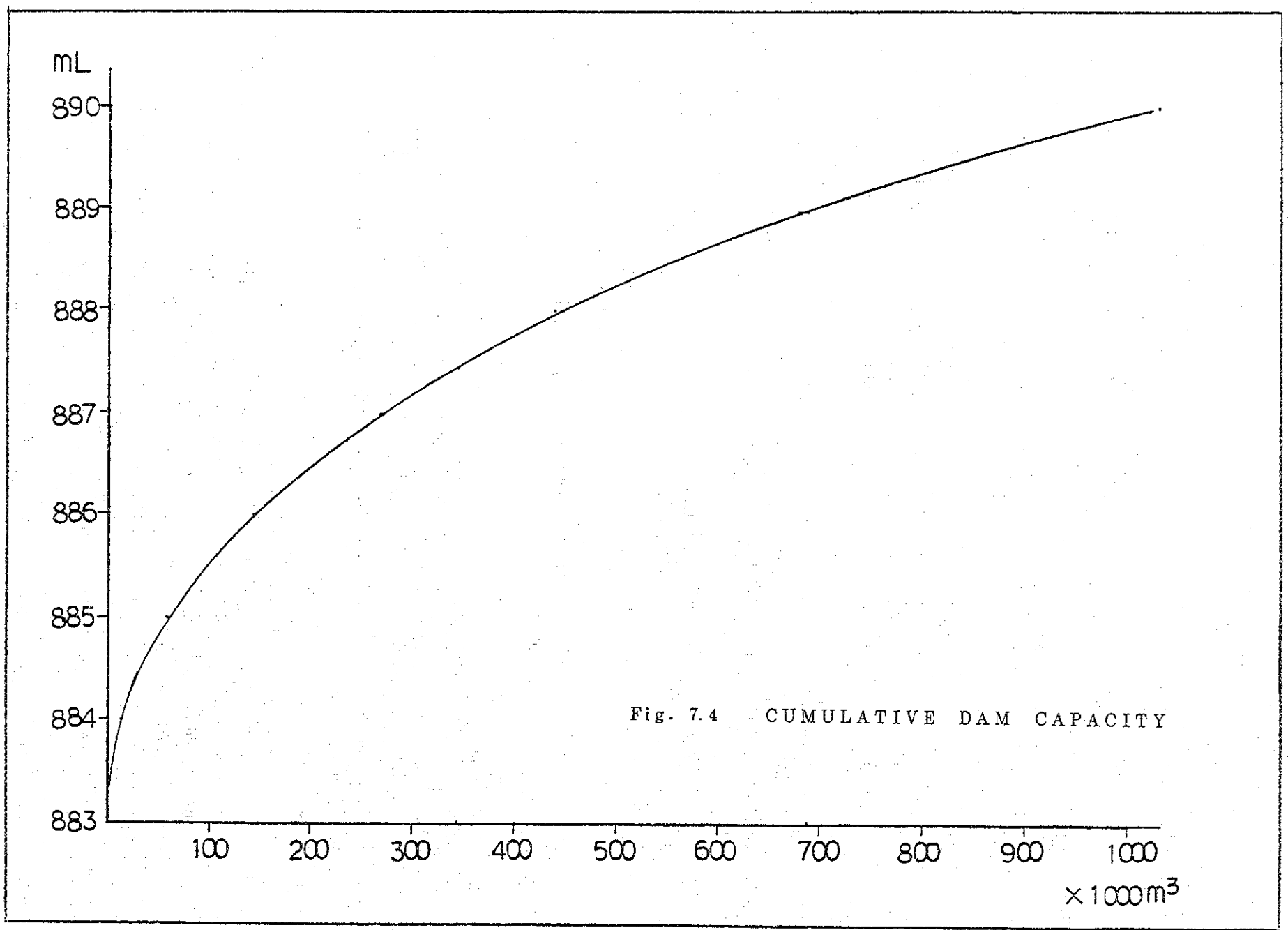
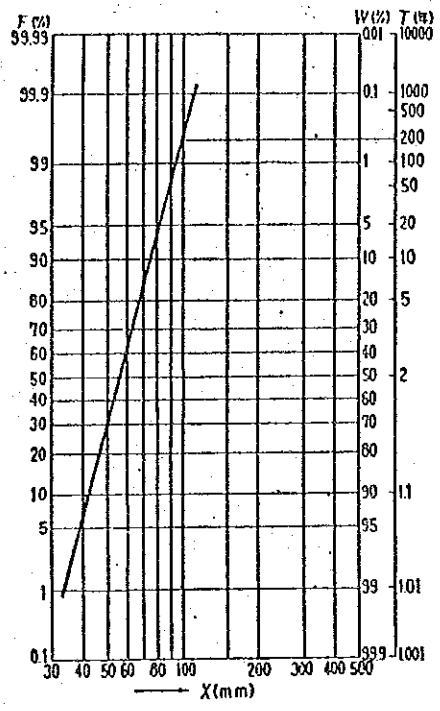


Fig. 7.4 CUMULATIVE DAM CAPACITY

Probable value by log normal curve paper



(mm/day)

	'79 1	2	3	4	5	6	7	8	9	10	11	12	'80 1	2	3	4	5
Chipata	43	48	25	1	0	0	0	0	0	15	42	32	43	29	41	38	0
Petauke	19	50	23	15	0	2	0	0	0	3	47	25	35	64	27	33	0

* Zambian climatological summary, surface and upper air date, Meteorological Department, Lusaka, Jan/1979 ~ May/1980.

(2) Spillway

a. Height

Spillway elevation is three meters below the dam crest.

b. Maximum design outflow 40 m^3/sec

c. Overflow depth 1.5 m

d. Section of overflow 3.5 m × 1.5 m

e. Spillway gradient 1.5%

92

Values of runoff coefficient C

after "HANDBOOK OF APPLIED HYDROLOGY", VEN TE CHOW (1964)

Type of drainage area	Runoff coefficient, C
Lawns:	
Sandy soil, flat, 2%	0.05 ~ 0.10
Sandy soil, average, 2 ~ 7%	0.10 ~ 0.15
Sandy soil, steep, 7%	0.15 ~ 0.20
Heavy soil, flat, 2%	0.13 ~ 0.17
Heavy soil, average, 2 ~ 7%	0.18 ~ 0.22
Heavy soil, steep, 7%	0.25 ~ 0.35
Business:	
Downtown areas	0.70 ~ 0.95
Nieghborhood areas	0.50 ~ 0.70
Residential:	
Single-family areas	0.30 ~ 0.50
Multi units, detached	0.40 ~ 0.60
Multi units, attached	0.60 ~ 0.75
Suburban	0.25 ~ 0.40
Apartment dwelling areas	0.50 ~ 0.70
Industrial:	
Light areas	0.50 ~ 0.80
Heavy areas	0.60 ~ 0.90
Parks, cemeteries	0.10 ~ 0.25
Playgrounds	0.20 ~ 0.35
Railroad yard areas	0.20 ~ 0.40
Unimproved areas	0.10 ~ 0.30
Streeets:	
Asphaltic	0.70 ~ 0.95
Concrete	0.80 ~ 0.95
Brick	0.70 ~ 0.85
Drives and walks	0.75 ~ 0.85
Roofs	0.75 ~ 0.95

93

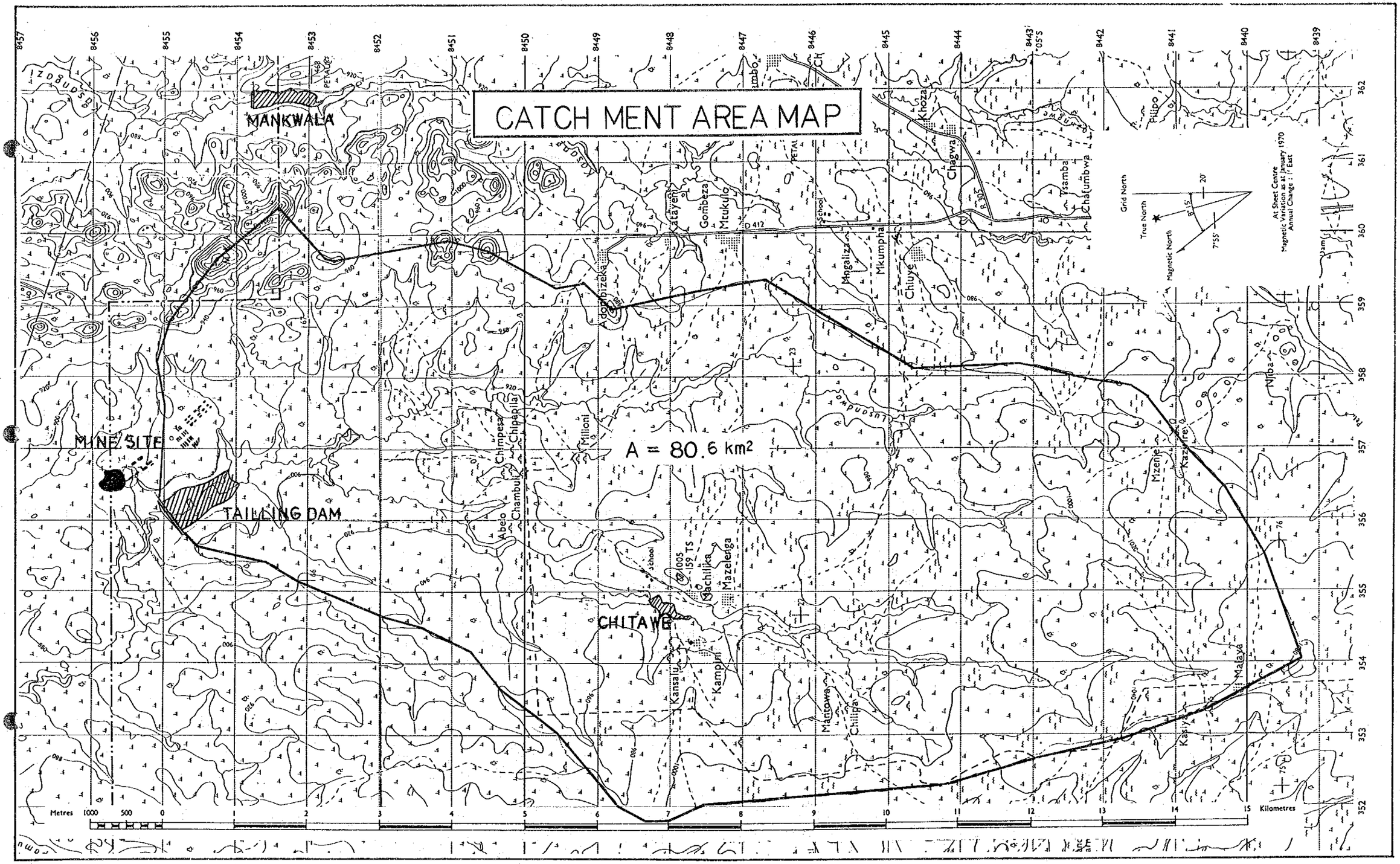
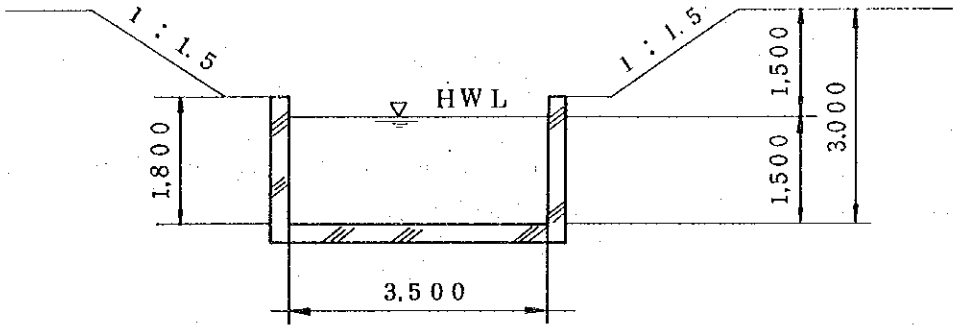


Fig. 7.5 Catchment Area Map



Note: An inlet is of a bell-mouth type for preventing the approach head.

7.5 Auxiliary Facilities (Refer to Fig. 7.6)

These facilities are composed of a repair shop, office, warehouse and other facilities.

7.5.1 Repair shop

The repair shop is a facility to repair and maintain equipments.

This will be composed of a combined machine, electric and wood-work shop.

The shop will be built near the Milling Plant and the warehouse in consideration of convenience of conveyance, and will have a complete set of machine, electric, and other tools.

Const: Concrete-block

Floor: 150 m^2

7.5.2 Pit shop

The pit shop will be composed of a repair shop (const: steel frame and slate type) that will be able to house 3 dump tracks at one time, and a shop for tires, machine parts, and a service office (const: concrete-block).

Total: 216 m^2

7.5.3 Magazine

This facility is a magazine that will be able to store 43 tons of AN-FO and dyamite for a half year.

The magazine will be built 350 m to the north of the plant.

A built-up bank will surround the magazine, and the roof of the magazine will be designed to direct any explosion in an upward direction.

7.5.4 Warehouse

It will have a service office and a shop for equipment spare parts and general goods.

Const: Concrete-block

Floor: 150 m^2

7.5.5 Office

The office will be constructed as the Mine Management Center and will provide offices for the managers, office staff and a part of the technical staff.

Total personnel to be accommodated will be about 120.

7.5.6 Canteen

This facility will be used for meals during working hours and for entertaining guests.

Capacity: 120 persons

Const: Concrete-block

Floor: 250 m^2

7.5.7 Other

(1) A total of 4 buildings will be constructed which include a changing-house with individual lockers, an oil shop, and 2 security-offices.

Note: On the supposition that the fuel tank will be built and financed by the oil company.

(2) Spreading gravel (thickness 15 cm)

Around the milling plant	2,700 m^2
Front of the office and warehouse	1,000 m^2
Front of the repair shop	500 m^2
Pit shop	300 m^2
Fuel tank-station	1,500 m^2
Motor pool	500 m^2
Total	6,000 m^2

(3) Fence

It will be 2,800 m in length and will surround the plant including the pit and the magazine.

(4) Lighting

There will be lights at 20 points at the office and around the milling plant. The lights will be equipped with auto-switches.

(5) Telephone

A 50 line system will provide service at strategic points in the plant.

Table 7.3 List of Auxiliary Facilities

Item	Nos.	Dimension	Units	Specification
Repair shop	1	5 m × 30 m	150 m	Mechanic, electric
Pit shop	1	9 × 24	216	Tire parts, office
Magazine	2	4 × 5	20	Dynamite 43 t for 6 months
		3 × 4	12	
Warehouse	1	5 × 30	150	Spare parts, general goods
Office	1	10 × 20	200	Office, technical staff; capacity 120
Canteen	1	10 × 25	250	Capacity 120 persons
Change house	1	3 × 6	18	Personnel locker 45
Fuel station	1	3 × 4	12	For dump truck, machine
Security office	2	3 × 4	12	South gate, East gate

7.6 Welfare Facilities

7.6.1 Outline

An entirely new mine town will be built to accommodate all the mine personnel and their families and to provide necessary services for their daily needs.

The main part of the town will be the residential area with service facilities such as a school, a clinic, recreational and sanitary facilities and a church.

The estimated population of the mine town belonging to the company is 500 including the families.

7.6.2 Estimate of resident personnel

In this estimate the percentage of unmarried personnel among the workers is to be 50%. Each family consists of 5 members; a wife and 4 children.

	Staff and worker	Family	Total
Staff	27 (–)	135	162
Worker	90 (45)	225	315
Total	117 (45)	360	477

( ) : single

7.6.3 Location and development

The mine town will be built 300 m east from the gate of mine. The staff area and worker's area will be separated.

Development area is 6.6 hectares. In roder to leave as many trees as possible only 70% of the area will be cleared.

7.6.4 Residence

Housig to be built will be 5 single units (116 m^2/unit) for the mine manager and super intendents, and 22 single units (35.25 m^2/unit) for the other staff.

Housing for the married personnel among the workers will be 12 quadruple units (4 X 26.25 m^2/unit).

Housing for bachelor workers will be 6 octuple units.

Total: 45 units

Const: Concrete block

		Areas (m^2)	Units	Spec.	Others
Staff	Mine manager Superintendent	116	5	5 rooms kitchen bathroom lavatory	Garden
	Other	35.25	22	2 rooms kitchen bathroom lavatory	Garden
Worker	Family	26.25	12	2 rooms	*
	Bachelor	13.5	6	1 room	*

* There will be a communal toilet and water supply for each five units.

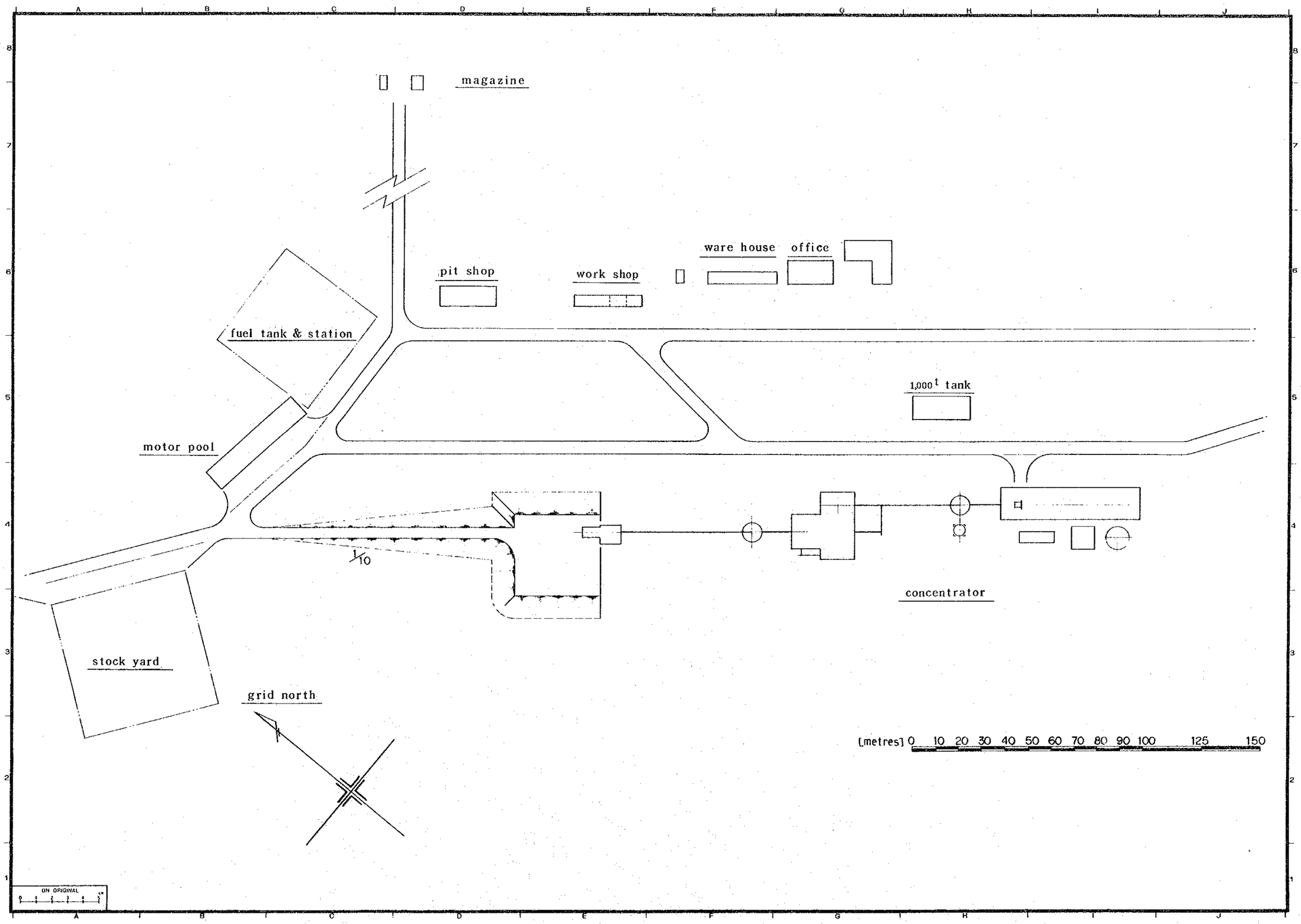


Fig. 7.6 Layout of Concentrator

7.6.5 Service facilities

The service facilities will be built as follows:

Cost: Concrete-block for all

Facilities	Unit	Area (m^2)	Specification
Church	1	96	Capacity 120 persons
School	3	96	Capacity 100 students
Clinic	1	96	
Guest house	1	100	Reception and accommodation
Warehouse & store	1	300	Supply of maize and daily needs
Meet	1	200	Meeting, amusement, bachelor's dining room

7.6.6 Domestic water supply and sewage disposal

Domestic water will be filtered, sterilized and supplied to each place by steel pipes from an elevated tank.

The sewage that drains from each family unit will be discharged in a channel at the edge of the road which also serves for rain drainage.

The sewage water will be sent by a polyethylene pipe to the purification tank which will be built at the south of the residence area, and discharged into the Luwanda River.

The design standard of each facility is as follows:

(1) Water supply

Population to be supplied (person)	500
Maximum amount of supply per person	200 ℓ/day
Purification type	Slow sand filtration sterilization by chlorine
Sending type	Pump
Distribution	Natural head by elevated tank
Out pressure	1.5 kg/cm^2 <

(2) Sewage

Population to be served (person)	500
Maximum amount of sewage per person	300 ℓ/day
Disposition type	Filtration
Disposition of rain	Separation

7.7 Maintenance and Repair Section

This section has the pit shop, the machine repair shop, the electrical repair shop and the carpentry work shop which have all the necessary facilities to undertake mechanical and electrical repairs, including major overhauls.

Equipment and Tools

(1) Heavy equipment and vehicles

Item	Nos.	Specification
Water cart	1 pcs	Capacity 6 kℓ
Motor grader	1	Blade width 3,100 mm
Truck crane	1	Capacity 20 T
2 T truck	1	
Total	4	

(2) Repair equipment

Machine tools	Lathe, Shaping machine, Drilling machine
Electric tools	Drill, Grind, Welder, Air compressor
Construction machinery	Hydrolic jack, Hoist crane etc.
Hand tools	
Measuring tools	
Cutting tools	

7.8 Administration

This section consists of the purchasing, personnel, accounting, general affairs, training and security control.

101

8. PRODUCTION PLAN AND MANPOWER REQUIREMENT

8.1 Production Plan

The concentrator will treat 104,000 T of crude ore to produce P_2O_5 concentrate.

Annual average grade of ore treated will be 11.5%.

Therefore, the concentrate will average 35,181 T/year (30.07% P_2O_5) and the P_2O_5 recovered will average 10,578 T/year.

8.1.1 Production in year 3

After the construction work, start up operation and test-run for 3 months will be completed according to the project schedule, and commerical production will start.

A 6 month supply of ore will be produced during the pre-stripping period and the test-run operation at concentrator.

The new equipment can be expected to operate smoothly and normally from the beginning. Therefore, it will operate at a full capacity of 104,000 T/year from the beginning.

8.1.2 Operation

Annual working days will be 260 days for mining, 290 days for other departments.

Mining will be operated in one shift, milling in three shifts.

Item	Mining	Milling	
Annual crude ore	104,000 (11.5%)	104,000 T (11.5%)	
Daily crude ore	400 T	360 T	
Annual concentrates		35,181 T (30.07%)	
Annual waste or tailing	218,400 T	68,819 T	
Annual working days	260	290	
Shift per day	1	Primary crushing	1
		Secondary, tertiary crushing	2
		Grinding, flotation	3
Working hours per shift	8	8	

8.2 Manpower Requirement

The proposed organization and manpower distribution are shown in Table 8. and Fig. 8.

All production departments will be directly under the administration of the company management.

102

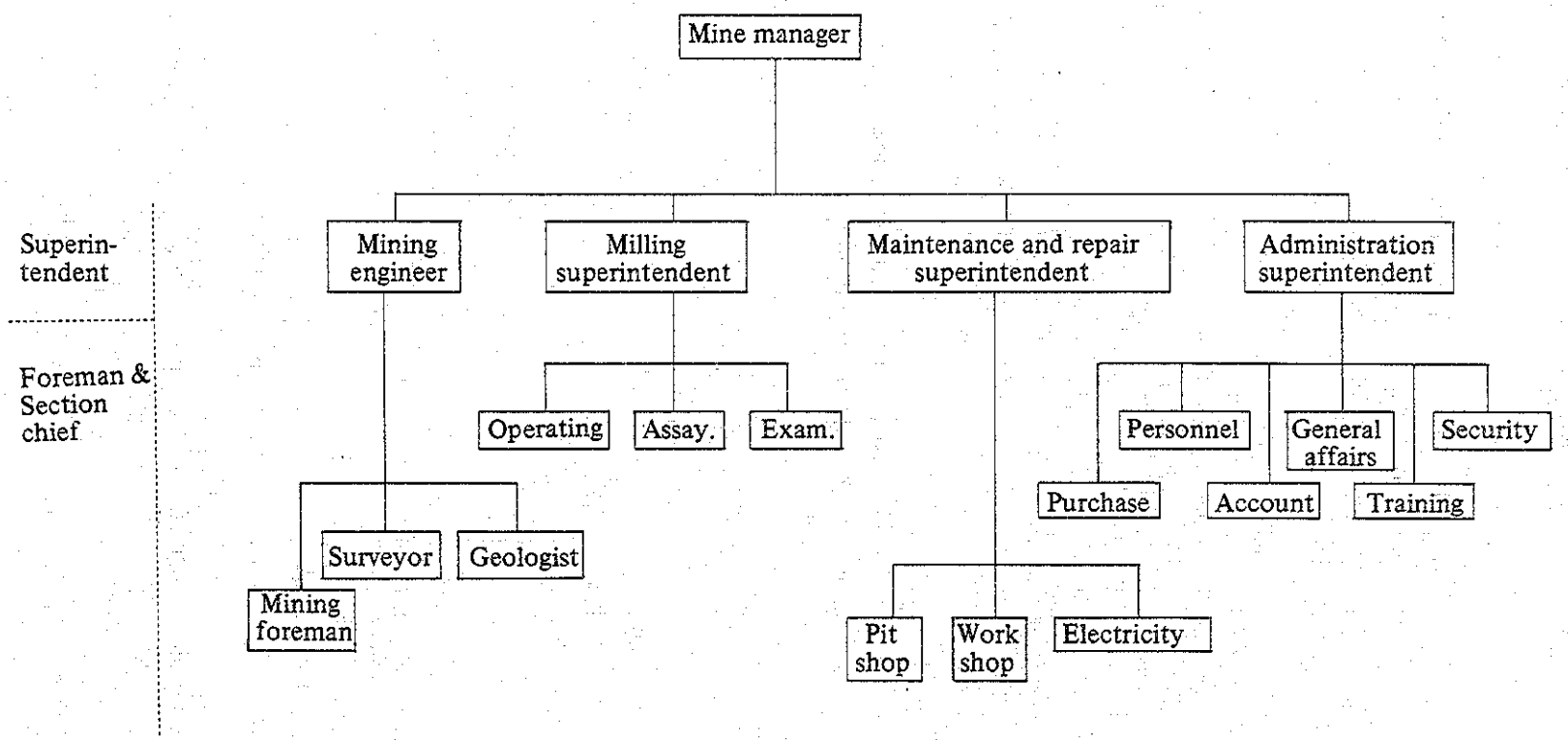


Fig. 8. Organization Chart

Table 8. Manpower

	Mining		Milling		Maintenance & repair		Administration		Total
	Item	Nos.	Item	Nos.	Item	Nos.	Item	Nos.	Nos.
Staff	Mining engineer	1	Superintendent	1	Superintendent	1	Mine manager	1	
	Mining foreman	1	Operating foreman	3	Pit shop foreman	1	Superintendent	1	
	Surveyor	1	Assayer	1	Plant maintenance foreman	1	Purchase section chief	2	
	Geologist	1	Metallurgist	1			Personnel "	1	
	Clerk	1	Clerk	1	Electrical foreman	1	Account "	1	
							General affair "	1	
							Training "	1	
							Security "	3	
Staff Total		5		7		4		11	27
Worker	Driller	4	Operator	16	Pit shop mechanics	2	Purchase section	6	
	Blasting crew	3	Assayer	2	Plant maintenance	2	Personnel "	4	
	Shovel operator	4	Metallurgical test	1	Electrician	3	Account "	2	
	Truck operator	5	Loader operator	1	Operator	2	General affair "	9	
	Bulldozer operator	2	Pump control	2	Civil work	2	Training "	2	
	Driver	2					Security "	9	
	Helper of surveyor	3							
	Helper of geologist	2							
Worker Total		25		22		11		32	90
Grand Total		30		29		15		43	117

Classification of staff and workers by department is as follows:

Classification by department	Staff	Worker	Total
Mining	5	25	30
Concentrator	7	22	29
Maintenance and repair	4	11	15
Administration	11	32	43
Total	27	90	117

Note: Including the mine manager in Administration department.

The number on the table above shows only operating staff on the mine site, and does not include managing staff in Lusaka, because they should be considered in connection with the fertilizer plant.

105

9. PROJECT SCHEDULE

The project schedule allows three years to bring the mine into the production, which is shown in Table 9.

The work in year (0) is only preparatory work such as engineering, ordering equipment and machinery, etc. The main construction work will commence in year (1) and will last for two years.

Civil work will stop during rain season.

Key dates of the project schedule are:

Year 1	April	Civil work starts
Year 1	September	Pre-stripping starts
Year 2	August	No-load test run starts
Year 2	October	Test run with load starts
Year 3	January	Production commences

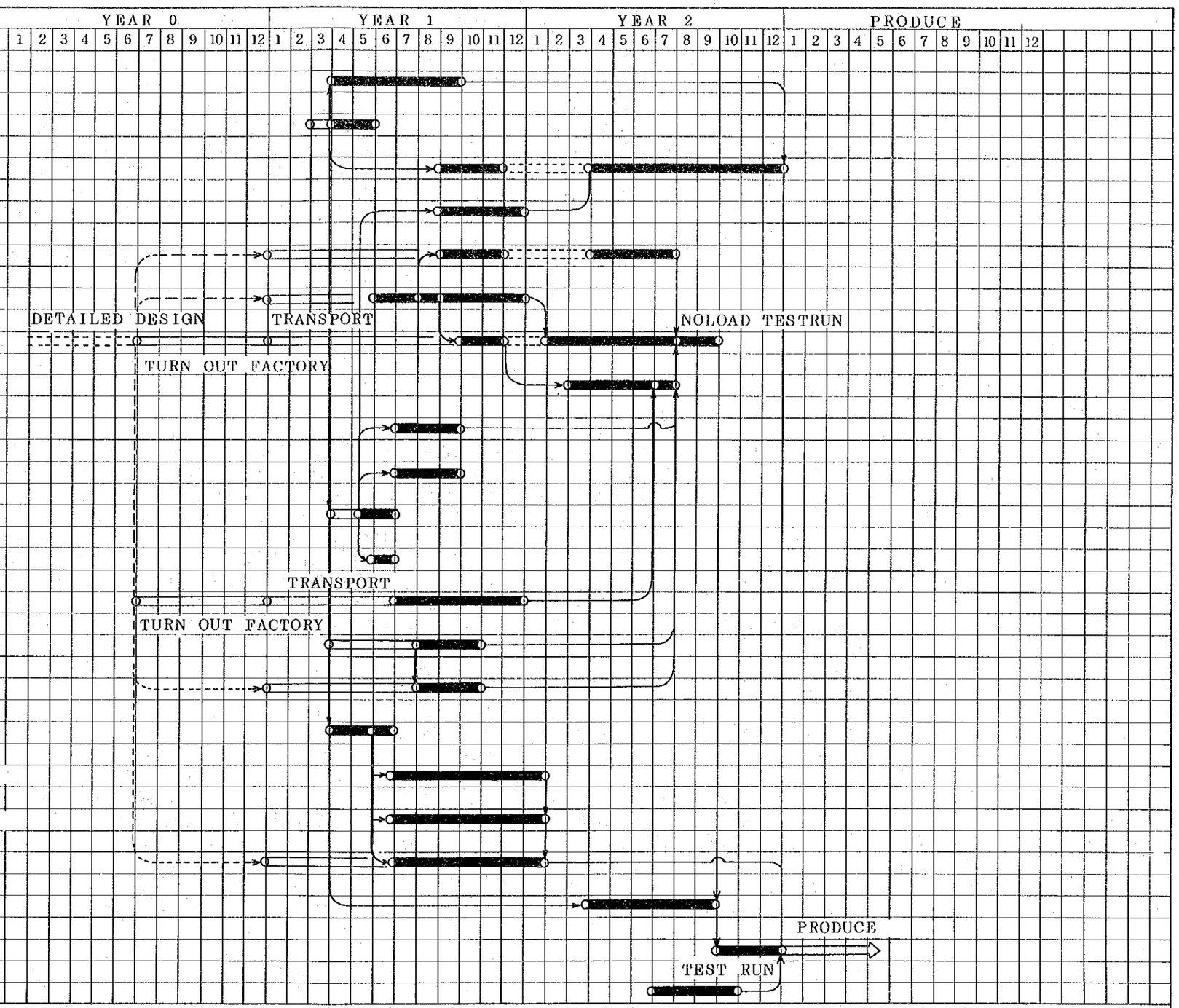
Test run without load will commence from August of year (2), while a test with load from October will end by December, treating 26,000 T.

Production will commence in January, so that Mankwala Dam and the tailing pond will be full of water, to avoid initial trouble.

106

Table 9.1 CONSTRCTION SCHEDULE

	ITEM
1	MAINROAD (35,000 m)
2	TEMPORARY WORKS (RESIDENCES, FENCE…)
3	MINNING (PRESTRIRPING, 124,000 m³)
	(MAGAZIN, FUEL-TANK, PIT-SHOP)
4	MILLING (BUILDINGS 1680 m²)
	(FOUNDATION, STRUCTURE, BIN…)
	(SETTING-MACHINE, ERECTION, PIPING)
	(ELECTRIC)
5	INCIDENTAL EQUIPMENT
	(BUILD WORKSHOP, OFFICE, WAREHOUSE)
	(SETTING MACHINE, ELECTRIC)
6	CLEARING (260,000 m²)
7	PRECINCT ROAD (2500 m)
8	POWER LINE (40km, 33 kv, INC. S/S)
9	WATER SUPPLY (ROAD, PIPING 7800 m, TANK)
	(ELECTRIC, S/S)
10	WELFARE (CLEARING, ROAD)
	(RESIDENCE, SCHOOL, CHURCH, CLINIC…)
	(WATER SUPPLY, TANK, PURIFICATION…)
	(ELECTRIC)
11	TAILLING POND (APORTION5YEARS)
12	TRIAL-RUN, ADJUST
	TEST-
13	SECURITY STRUCTURE (FENCE 2800 m)



NOTE

REV	DATE	NAME	DISTRIBUTION
①			
②			
③			

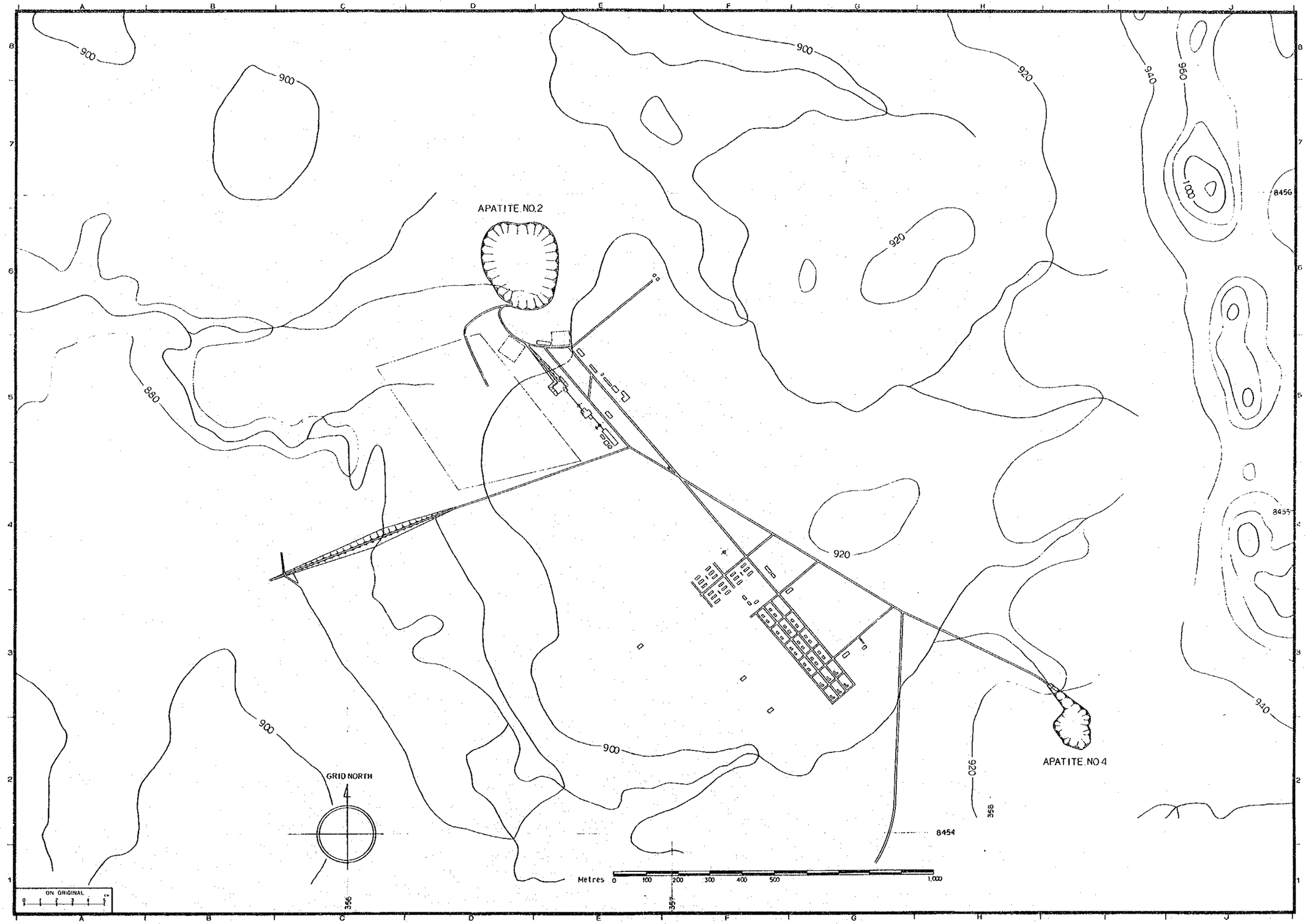


Fig. 9 General Layout

10. CAPITAL COST AND OPERATING COST

10.1 Capital Cost Estimates

10.1.1 General

The following items are the capital cost estimates at the start of production.

		Amount (1,000 US$)
(1)	Production and auxiliary facilities (Mining, concentrator, tailing pond, water supply, power distribution, main road etc.)	9,180.0
(2)	Welfare facilities	722.8
(3)	Common construction (Temporary facilities etc.)	51.1
(4)	Management cost and engineering fee	858.7
(5)	Inventories (General stocks and spare parts)	780.6
(6)	Working capital	86.2
(7)	Contingency	1,119.8
	Total	12,799.2

Working capital is based on a 3 month operation cost of labour and electricity.
Inventories are estimated;

Imported materials – 6 month supply
Local materials – 1 month supply

10.1.2 Basis for capital cost estimates

Applicable laws, working condition, salary, wage, equipment purchase cost, commodities prices, etc. are those on September ~ November, 1984.
Currency conversion rate: The rates used are;

US$ = K1.8
US$ = ¥245 (Sept. 1984)

All amounts in the estimate are expressed in US dollar.

Construction work: Pre-stripping work except clearing of the top soil is to be done by the company. All the rest of the construction work is to be done by constractors.

The average number of construction workers is estimated to be 150 per day.

Imported equipment: A transportation charge in marine and inland with an insurance is estimated at 30% of an equipment cost.

109

Prices of principal construction materials at the mine:

Diesel fuel	US$ 0.56/ℓ
Gasoline	US$ 0.75/ℓ
Cement	US$ 72/T
Dynamite	US$ 500/T
AN-FO	US$ 460/T
Wooden	US$ 417/m^3

10.2 Additional Investment and Replacement Cost

Additional investment and replacement cost after the start of production are;

(1) Drainage pump set at the bottom of open pit

(2) Additional work on tailing pond

(3) Replacement cost including mining and other equipments

Table 10.2 shows the estimated additional investment and replacement cost by year up to year 17 of production stage.

10.3 Operating Cost Estimates

The operating cost consist of the direct operating cost of each department; mining, milling and maintenance.

10.3.1 Average annual operating cost of each department

(1) Mining Refer to Chapter 5.7

(2) Milling Refer to Chapter 6.15

(3) Maintenance and repair section

Material cost

Workshop: US$26,000/year
Including oil, lubricant, steel, electrical material, etc.

Heavy equipment and vehicle: US$8,370
Including fuel, lubricant, tire and repair and maintenance

Road maintenance: US$20,350
Including fuel, lubricant, tire, etc.

Total material cost: US$54,720/year

Note: Material costs for maintenance and repairs of other sections are not included.

Labour Cost

	Unit cost	Nos.	Amount
Superintendent	5,400 US$/year	1	5,400 US$/year
Foreman	3,960	3	11,880
Mechanic	2,400	4	9,600
Electrician	2,400	3	7,200
Heavy equipment operator	2,400	2	4,800
Civil work	1,500	2	3,000
Total labour cost		15	41,880 US$/year
Total			96,600 US$/year

(4) Administration

Material cost: 55,500 US$/year
Including stationary, communication, welfare, etc.

Labour Cost:

	Unit cost	Nos.	Amount
Mine manager	7,200 US$/year	1	7,200 US$/year
Superintendent	5,400	1	5,400
Section chief	3,960	9	35,640
Worker	1,700	32	54,400
Total labour cost		43	102,640
Total			158,140 US$/year

(5) Power cost: Refer to 7.1.2 (3)

(6) Annual operating cost of each department

	Year 3 ~ 15	Year 16	Year 17
Ore treated/year	104,000 T	104,000 T	69,000 T
Operating cost ($)	1,148,100	1,120,460	638,300
Mining	390,420	362,780	135,610
Concentrator	452,040	452,040	299,910
Maintenance	96,600	96,600	64,090
Administration	158,140	158,140	104,920
Electricity	50,900	50,900	33,770
(US$/T ore)	(11.04)	(10.77)	(9.25)
By foreign currency	44.84%	44.84	46.50
By domestic currency	55.16%	55.16	53.50

The material costs of maintenance and repair for equipment and vehicle are included in each department.

10.3.2 Basis for operating cost estimates

The cost is estimated taking into account the variations in mine operation and the price level on September ~ Nobember, 1984.

Currency conversion rate:

US$1.0 = K1.8
US$1.0 = ¥245

All amounts in the estimate are expressed in US dollar.

Salary and Wage

Salary and wage including the basic pays, social security, bonus, retirement allowance, etc. are as follows:

Staff	
Mine manager	7,200 US$/year
Mining engineer and superintendent	5,400
Foreman	3,960
Surveyor and geologist	4,320
Worker	
Operator, mechanician and electrician	2,400 US$/year
Technical worker	2,100
Non-technical worker	1,700
Helper	1,500

Table 10.1. Breakdown of Capital Cost

(Units: 1,000 US$)

Item	Total			Year 1			Year 2			Remarks
	Total	K	$	Total	K	$	Total	K	$	
MINING	2314.8	290.5	2024.3	1637.1	58.3	1578.8	677.7	232.2	445.5	
Pit equipment	*1914.7		1914.7	1577.9		1577.9	336.8		336.8	Preproduction stripping
Preproduction stripping	383.2	274.5	108.7	42.3	42.3		340.9	232.2	108.7	350,670 t
Magazine	16.9	16.0	0.9	16.9	16.0	0.9				
MILLING	4029.7	1105.5	2924.2	3612.5	817.2	2795.3	417.2	288.3	128.9	
Loader	* 128.9		128.9				128.9		128.9	
Equipment	2181.3		2181.3	2181.3		2181.3				
Installation	990.5	785.2	205.3	920.9	715.6	205.3	69.6	69.6		
Building construction	422.4	312.8	109.6	211.2	101.6	109.6	211.2	211.2		
Electric work	306.6	7.5	299.1	299.1		299.1	7.5	7.5		
WATER SUPPLY	465.6	219.9	245.7	465.6	219.9	245.7				4" pipe line 7.8 km
Equipment	15.5		15.5	15.5		15.5				
Pipe line & building	250.2	127.9	122.3	250.2	127.9	122.3				
Road	70.2	70.2		70.2	70.2					
Electric work	129.7	21.8	107.9	129.7	21.8	107.9				
MAIN ROAD	503.9	502.1	1.8	503.9	502.1	1.8				
G.E.R-Minesite	471.9	471.9		471.9	471.9					Great East Road-minesite 35km
Bridge	32.0	30.2	1.8	32.0	30.2	1.8				No. of bridge 14
POWER LINE & DISTRIBUTION	831.5	389.3	442.2	767.1	383.5	383.6	64.4	5.8	58.6	
Power line (Sinda-Minesite)	361.1	361.1		361.1	361.1					Power line 40 km 33 kV
Sub-station	364.1	13.1	351.0	364.1	13.1	351.0				Capacity 900 kVA
Auxiliary facilities	83.3	14.1	69.2	41.9	9.3	32.6	41.4	4.8	36.6	
Communication	23.0	1.0	22.0				23.0	1.0	22.0	
TAILING POND	180.3	175.7	4.6				180.3	175.7	4.6	1st stage (life 5 years)
MAINTENANCE & REPAIR	652.1	187.9	464.2	536.4	187.9	348.5	115.7		115.7	
Maintenance equipment	224.6		224.6	224.6		224.6				
Building construction	72.1	64.9	7.2	72.1	64.9	7.2				
Vehicle	* 232.4		232.4	116.7		116.7	115.7		115.7	
Civil work	123.0	123.0		123.0	123.0					Including clearing & road construction in minesite
SUB TOTAL	8977.9	2870.9	6107.0	7522.6	2168.9	5353.7	1455.3	702.0	753.3	

(Units: 1,000 US$)

Item	Total			Year 1			Year 2			Remarks
	Total	K	$	Total	K	$	Total	K	$	
AUXILIARY FACILITIES	109.7	70.6	39.1	96.9	70.6	26.3	12.8		12.8	
Vehicle	* 36.1		36.1	23.3		23.3	12.8		12.8	
Building construction	53.2	50.2	3.0	53.2	50.2	3.0				
Furnitures & fixtures	20.4	20.4		20.4	20.4					
MINE WELFARE FACILITIES	722.8	660.1	62.7	616.5	553.8	62.7	106.3	106.3		Population 500
Site preparation	9.2	9.2		9.2	9.2					
House & quarters	515.0	485.9	29.1	432.6	403.5	29.1	82.4	82.4		
Road	52.5	52.5		52.5	52.5					
Water supply & sewage	129.5	108.9	20.6	105.6	85.0	20.6	23.9	23.9		
Power distribution	16.6	3.6	13.0	16.6	3.6	16.6				
SECURITY FACILITIES	92.4	28.0	64.4				92.4	28.0	64.4	Fencing around the mine site
TEMPORARY FACILITIES	51.1	19.4	31.7	51.1	19.4	31.7				
Portable generator	26.5		26.5	26.5		26.5				
Temporary housing	5.6	5.6		5.6	5.6					
Warehouse stockyard	12.4	11.8	0.6	12.4	11.8	0.6				
Fence	6.6	2.0	4.6	6.6	2.0	4.6				
CONSTRUCTION MANAGEMENT	152.7	152.7		60.8	60.8		91.9	91.9		
EDUCATION AND TRAINING	111.1	111.1					111.1	111.1		
INVENTORY	* 780.6	24.0	756.6	327.3		327.3	453.3	24.0	429.3	Import material 6 months Local material 1 month
TEST-RUN	113.7	42.2	71.5				113.7	42.2	71.5	
WORKING CAPITAL	* 86.2	86.2					86.2	86.2		
SUB TOTAL P.1 + P.2	11198.2	4065.2	7133.0	8675.2	2873.5	5801.7	2523.0	1191.7	1331.3	
CONTINGENCY (p.1 + p.2) *10%	1119.8	406.5	713.3	867.5	287.4	580.2	252.3	119.2	133.1	
ENGINEERING FEE	481.2		481.2	397.8		397.8	83.4		83.4	6% of capital cost without * mark
TOTAL	12799.2	4471.7	8327.5	9940.5	3160.9	6779.7	2858.7	1310.9	1547.8	
INTEREST DURING CONST.										

Amount Subject to Depreciation

Unit: 1,000$

Half Term	1st	2nd	3rd	4th
Mining	0.9	1,636.2	108.7	569.0
Concentrator	2,347.6	1,264.9	128.9	288.3
Water supply	245.7	219.9		
Road	1.8	502.1		
Power supply	383.6	383.5	58.6	5.8
Tailing pond			4.6	175.7
Maintenance & repair	123.9	412.5		115.7
Auxiliary facilities	3.0	93.9	12.8	
Welfare facilities	62.7	553.8		106.3
Security facilities			64.4	28.0
Temporary facilities	31.7	19.4		
Construction management		60.8		91.9
Education & training				111.1
Sub-total	3,200.9	5,147.0	378.0	1,491.8
Contingency	320.1	514.7	37.8	149.2
Engineering fee	397.8		83.4	
Total	3,918.8	5,661.7	499.2	1,641.0

Table 10-2. Additional Investment and Replacement Cost

(US$1,000)

Year	Additional Investment			Replacement Cost			Grand total
	Tailing pond	Mining equipment	Total	Heavy equipment	Vehicles	Total	
3	–	13.5	13.5	–	–	–	13.5
4	–	–	–	–	–	–	–
5	–	–	–	–	14.6	14.6	14.6
6	–	–	–	–	–	–	–
7	113.8	–	113.8	190.8	41.6	232.4	346.2
8	–	–	–	162.8	14.6	177.4	177.4
9	–	–	–	171.6	–	171.6	171.6
10	–	–	–	347.4	–	347.4	347.4
11	–	–	–	162.8	14.6	177.4	177.4
12	70.7	–	70.7	663.0	32.6	695.8	766.5
13	–	–	–	–	–	–	–
14	–	–	–	–	14.6	14.6	14.6
15	–	–	–	–	–	–	–
16	–	–	–	–	–	–	–
17	–	–	–	–	–	–	–
Total	184.5	13.5	198.0	1,698.4	132.8	1,831.2	2,029.2

Table 10-3. Replacement (Heavy Equipment and Vehicle)

Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
Crawler drill										1						1
Dozer shovel										1						1
20 T dump truck					1	1	1	1	1	1						6
Bulldozer								1								1
Wheel loader										1						1
Water cart					1					1						2
Pick-up					1					1						2
2 T truck					1		1			1						3
Light van					1					1						2
Ambulance			1			1			1			1				4
Vehicle for manager					1					1						2

Table 10-4. Operating Cost per Year

(US$)

Year	Mining	Concentrator	Maintenance	Administration	Electricity	Total	Foreign currency	Domestic currency
3	390,420	452,040	96,600	158,140	50,900	1,148,100	514,800	633,300
4	"	"	"	"	"	"	"	"
5	"	"	"	"	"	"	"	"
6	"	"	"	"	"	"	"	"
7	"	"	"	"	"	"	"	"
8	"	"	"	"	"	"	"	"
9	"	"	"	"	"	"	"	"
10	"	"	"	"	"	"	"	"
11	"	"	"	"	"	"	"	"
12	"	"	"	"	"	"	"	"
13	"	"	"	"	"	"	"	"
14	"	"	"	"	"	"	"	"
15	"	"	"	"	"	"	"	"
16	362,780	"	"	"	"	1,120,460	502,420	618,040
17	135,610	299,910	64,090	104,920	33,770	638,300	296,810	341,490
Total	5,573,850	6,628,470	1,410,490	2,318,880	746,370	16,684,060	7,491,630	9,192,430

Purchased power cost:

Computed in accordance with the section 12 of Electricity Act, Chapter 811.

From Tariff D 2	US$0.015/kWh

Commodity Price

Fuel oil (diesel oil)	US$0.56/ℓ
(gasoline)	US$0.75/ℓ
Dynamite	US$500/T
AN-FO	US$460/T
4 inch cross bit	US$200/pc
Tire for 20 T truck	US$1,172/pc
Ball for ball mill	US$750/T
Caustic soda	US$0.33/kg
Sodium silicate (water glass)	US$0.22/kg
Lila flot	US$2.33/kg

119

SUPPLEMENT

SUPPLEMENT

1. FINANCIAL EVALUATION

1.1 Evaluation Method

Mining differs from an ordinary industry that has an indeterminate life. The original capital investment must be returned to the investor before the profitable life of the enterprise is ended. In mining evaluation, the most prevailing method involves two rates of interest: one being a speculative rate on capital and the other being provided for the redemption of capital at the expiration of the annuity life by annual reinvestment of the balance of the early earnings at a safe rate of interest. When the dividend overplus is put back into the business, it is justifiable to assume the same rate of interest on redemption of capital as on capital investment. This makes the two rates identical.

For the convenience of comparison of the project with projects in other fields, a single rate, which is known as the internal rate of return, is used in the present evaluation. The internal rate of return is a discount rate that makes the sum of present values of annual inflow zero.

In general, the price of non-metallic mineral is low and especially in inland areas, the delivery costs often exceed production costs. Profitable mining of such minerals cannot be realized if a market is not situated within an accessible range of distance. Production of phosphatic fertilizer is quite new and no plant is available in the country, but the mining project should, as a prerequisite, demand that a phosphatic manure plant be constructed. Without the existence of the plant, the project may be of no value. Selection of a site for a fertilizer plant and determination of its production scale are beyond the scope of the present study. Therefore, a delivery cost of apatite concentrates is excluded from the calculation. The evaluation of the mining project is based on the mine-site realization derived from a sale of concentrates.

1.2 Assumed Parameters

(1) Capital

Initial expenses have been estimated to be in the sum of $12.8 million, excluding interest yielded during a construction period. Furthermore, an amount of $8.328 million is payable in foreign currencies and the rest is payable in the national currency. To calculate the profit-and-loss account, about eighty per cent of $4.472 million, payable in Kwacha, is assumed to be provided by a capital fund. Thus, the amount of the capital is equivalent to $3.5 million, some 27% of the total funds employed.

(2) Loan

The balance of the funds is financed by the borrowing of a long-term loan from a bank. The debt is deferred at compound interest to the end of the construction period and returned uniformly for the next fifteen years. The rate of interest is set at 4% per annum on the ex-

change value of the U.S. dollar. Borrowings are made at the middle of each year, except in the case when a loan is needed at the beginning of a year for settlement of imported machineries and commodities. A flow of a bank loan is shown in Table 1-1.

Table 1-1 Flow of Bank Loan

US$1,000

Year	Amount borrowed	Debt at the beginning	Payable Interest	Retirement
1st, initial	779			
middle	5,662			
2nd, initial	578			
middle	1,778			
3rd		9,262	370	618
4th		8,644	346	618
5th		8,262	321	618
6th		7,408	296	618
7th		6,790	272	618
8th		6,172	247	618
9th		5,554	222	618
10th		4,936	197	618
11th		4,318	173	618
12th		3,700	148	618
13th		3,082	123	618
14th		2,464	99	618
15th		1,846	74	618
16th		1,228	49	618
17th		610	24	610

(3) Depreciation

After the completion of the construction period, an accelerated depreciation method is applied as stipulated in the Income Tax Act. An unredeemed amount of investment in plant and equipment at the end of a previous year is the subject of depreciation in a relevant year.

(4) Taxation

A tax is exempted during the construction period. A rate of 45% of tax is imposed on a taxable income.

(5) Production and Sale

The minable ore reserves have been estimated at 1,551,000 tonnes. During the construction period, some 26,000 tonnes of ore are fed in to the dressing plant for a test run, with an

expected effectiveness of 75% of the normal recovery rate. From the third year on, a sum of 104,000 tonnes of ore is treated annually to produce 35,000 tonnes of apatite concentrates for fourteen years. On the 17th year, 69,000 tonnes of ore are treated and 23,000 tonnes of concentrates are recovered. A running cost of a normal year has been estimated at $11.0 per tonne of ore treated or at $32.8 per tonne of concentrates produced. All products are acceptable to a fertilizer plant.

(6) Price

Most of the non-ferrous metals have international markets such as the metal exchange or the commodity exchange. The price of metal in these markets is often quoted as a basis of transactions. Apatite concentrates differ from these metals and the pricing of concentrates is rather local. References are usually made to a possible price of imported raw materials and a producer enters into a negotiation with a user. A comparison of the price of domestic materials with a price of foreign materials on arrival involves transportation costs which depend on the locality of a fertilizer plant. In this report, a price of apatite concentrates at the mine-site is calculated with the basis of cost-and-fee.

The total cost consists of a capital cost and an operation cost. The investment in fixed assets, working capital and commodity inventories, is provided by the capital fund and the bank loan. The present value of the initial investment at the end of the second year is calculated at 4% of the interest rate. The amounts of additional investment scheduled in the future are similarly converted to the present value at the end of the second year and added to the present value of the initial investment. As shown in Table 1-2, the total funds utilized add up to $14,920,000 at the end of the second year. The amount is then multiplied by the factor of amortization at 4% for 15 years (0.08994).

The amount needed in the amortization of the capital funds is $1,342,000 per annum. Therefore, a cost at the mine-site would be,

	in US$ 1,000
Capital cost	1,342
Operation cost	1,148
Total	$2,490

Since devaluation of the national currency in 1983, the mining and manufacturing sectors showed a slight improvement over the previous year. However, many enterprises are still not able to eliminate deficits and an adequate rate of profit in the country cannot be shown. During the first six months in 1983, the parastatal mining sector gave an average rate of profit at 6.47% against the turnover before tax.

Table 1-2 The Present Value of Investments at the end of the 2nd Year

Unit: $1,000

Year	Investment	Present Value		
1st initial	4,279	4,628		
middle	5,662	6,006		
2nd initial	578	601		
middle	2,156	2,199	Initial Investment	13,434
3rd	14	13		
4th	0	0		
5th	15	13		
6th	0	0		
7th	346	284		
8th	177	140		
9th	172	131		
10th	347	254		
11th	177	124		
12th	767	518		
13th	0	0		
14th	15	9		
15th	0	0		
16th	0	0		
17th	0	0	Additional Investment	1,486
Total				14,920

Taking this into account, the 8% is applied as the rate of fee against the total cost. In the mining business, the speculative rate at 8% on the investment may be too low in comparison with the safe rate at 4% on the sinking fund. The rate at 8% is introduced to compare the project with projects in other industries. If the rate is raised to a high level, the resulting price makes the products to be insufficiently competitive with foreign materials.

In accordance with this assumption, a price of concentrates is calculated as follows:

Cost	($) 2,490,000	÷ 35,000 (tonnes)	=	$71.14
Fee	($) 71.14	× 0.08	=	$5.69
Total				$76.83

Consequently, the mine-site realization is set at $77 per tonne of apatite concentrates.

(7) Exclusion

No provisions have been provided for exploration, lease purchase or mineral tax.

Escalation clauses are not introduced with the assumption that as an operation cost accounts for 46% of the total cost, or 47% if the additional investments are added, an increase of cost may be absorbed by an increase of the selling price.

Salvage values are deemed to be nil. There exists a possibility that a similar ore deposit may be found nearby, and in that case the ore can be treated in the remaining plant. But this is not certain and on the contrary, if no deposit is found, it will not be feasible to carry out materials from the site due to remoteness of the area.

1.3 Internal Rate of Return

In accordance with these premises, a statement of profit and loss account and the calculation of the internal rate of return is shown in Table 1-3. The results are summarized as follows:

The internal rate of return before tax	7.1%
The internal rate of return after tax	5.9%

If the owned capital stands at $3.5 million, the implementation of the project will yield an interest at 9.3% on the capital.

1.4 Sensibility of Internal Rate

When the unit price of the concentrates is changed, the internal rate of return varies as follows:

$65	2.6%
$70	4.0%
$77	5.9%
$85	7.9%
$100	11.7%

The unit price of $65 per tonne indicates the lower limitation in which depreciation and loan retirement will be completed without yielding interest on the owned capital.

The 4.0% of the financial rate at the price of $70 is equivalent to the rate of interest on redemption of capital as well as on capital investment. This situation indicates that an enterprise stands at the break-even-point.

Among the initial investment, if the cost of fixed assets together with the price of commodity inventories are changed either up or down to 20%, the financial internal rate varies as follows:

125

+20%	4.0%
Model	5.9%
−20%	8.5%

If the fuel cost increases by 20%, the internal rate becomes 5.5% and if the fuel cost decreases by 20%, the rate will stand at 6.2%.

1.5 Discussion

In regard to the Chilembwe project, the operation cost remains within the range of an acceptable standard in open pit mining. Due to the scale of ore deposits and geographical condition of location, the cost of construction, or depreciation cost per tonne of ore, is somewhat higher. Yet, the annual cost for amortization of the capital funds remains within the ratio of 117% against the operation cost. Enlargement of the rate of production is confined by the volumes of both ore reserves and available water.

If the mine-site realization is assumed to be $77 per tonne of the apatite concentrates as a cost with a fee at the rate of 8%, the financial internal rate of return stands at 5.9%. The rate depends mainly on the value of the products at the mine-site. An effect on the internal rate by fluctuation in fuel cost is rather moderate.

In this evaluation, the delivery cost of the products has been excluded from the calculation. Depending on the locality of the fertilizer plant, the products are requested to be competitive in price with foreign materials. For example, the by-products of copper mining in South Africa will be able to stand up against a low price, because the apatite concentrates of the by-products probably do not carry a mining cost or, at the most, do not have a depreciation cost.

But import of apatite from abroad conflicts with the national policy to save foreign currencies and much effort should be made to compromise on the terms of pricing the domestic apatite concentrates, enabling both the mine and the fertilizer plant to come into existence.

In cast that an additional ore deposit is found nearby, such a deposit can be exploited without raising funds for a capital investment, although heavy duty vehicles will be renewed.

Table 1-3. Profit and Loss Account and the Internal Rate of Return

in US$1,000

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	T
Tonnes, milled (x 10^3)		26	104	104	104	104	104	104	104	104	104	104	104	104	104	104	69	1,551
Tonnes of Conc. (x 10^3)		6.[56]	35	35	35	35	35	35	35	35	35	35	35	35	35	35	23	519.[56]
Capital Funds & Bank Loan	9,941	2,354																12,295
Sale of Products at $77/t		505	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	1,771	40,006
Total Available	9,941	2,859	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	2,695	1,771	52,301
Operation Expenses		125	1,148	1,148	1,148	1,148	1,148	1,148	1,148	1,148	1,148	1,148	1,148	1,148	1,148	1,120	638	16,807
Interest of Financing			370	346	321	296	272	247	222	197	173	148	123	99	74	49	24	2,961
Depreciation			1,177	1,201	1,226	1,251	1,275	1,300	1,325	1,350	1,374	1,399	858	–	15	–	–	13,751
Taxable Income													566	1,448	1,458	1,526	1,109	6,107
Tax at 45% Net													255	652	656	687	499	2,749
Net Profit													311	796	802	839	610	3,358
Taxable Income + Depreciation			1,177	1,201	1,226	1,251	1,275	1,300	1,325	1,350	1,374	1,399	1,424	1,448	1,473	1,526	1,109	19,858
Investment to be written-off	9,581	2,140	14		15		346	177	172	347	177	767		15				13,751
Working Capital & Inventories	360	594															–954	0
Total Investment	9,941	2,743	14		15		346	177	172	347	177	767		15			–954	13,751
Tax at a Payable Year														255	652	656	1,186	2,749
Total Required	9,941	2,859	1,532	1,494	1,484	1,444	1,766	1,572	1,542	1,692	1,498	2,063	1,271	1,517	1,874	1,825	894	36,268
Net Inflow	–9,941	–2,354	1,163	1,201	1,211	1,251	929	1,123	1,153	1,003	1,197	632	1,424	1,178	821	870	877	3,738
Add Interest on Financing			1,533	1,547	1,532	1,547	1,201	1,370	1,375	1,200	1,370	780	1,547	1,277	895	919	901	18,994
Discount Rate at 5.864%																		
Present Value	–9,390	–2,100	1,293	1,233	1,153	1,100	806	869	824	679	732	394	738	576	381	370	342	0
Capital Funds	3,500																	
Bank Loan, 1st half term	779																	
2nd half term	5,662																	
3rd half term		578																
4th half term		1,776																
Total Carried			9,262	8,644	8,026	7,408	6,790	6,172	5,554	4,936	4,318	3,700	3,082	2,464	1,846	1,228	610	0
Retirement			618	618	618	618	618	618	618	618	618	618	618	618	618	618	610	9,262

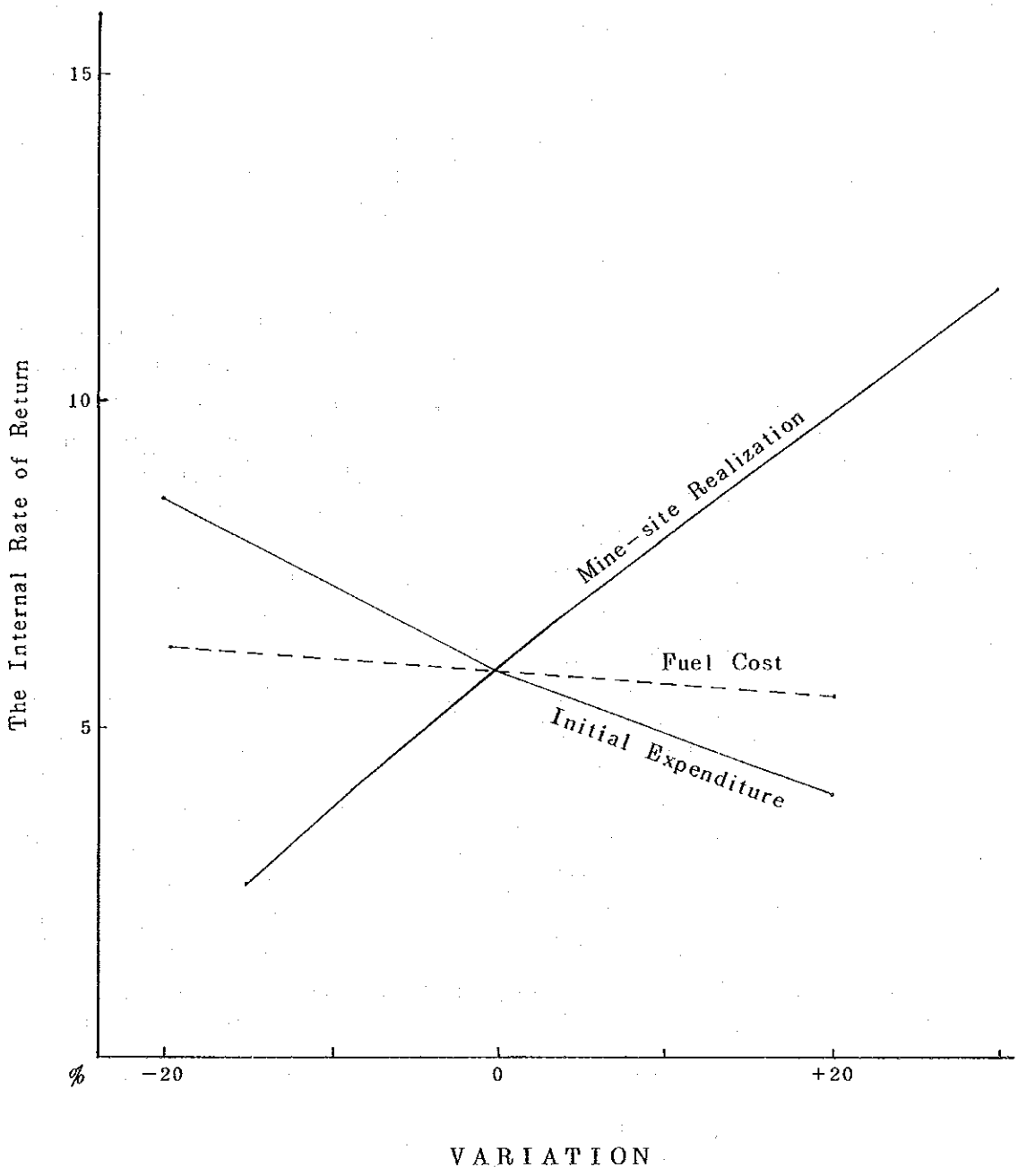


Fig. 1 Sensibility of the Financial Internal Rate of Return

2. ECONOMIC EVALUATION

2.1 Evaluation Method

Whereas the object of the financial evaluation is to assess a private enterprise or an individual project, the economic evaluation aims at evaluating a project from the viewpoint of national economy. For example, taxes are excluded from a cost in the economic evaluation, since taxes represent only a transfer within a country and no consumption of resources is involved.

The existence of a fertilizer plant in the country is presupposed in the financial evaluation, since the mining of phosphate ore cannot be feasible without a manufacturer of artificial manure in an accessible range of distance. The same assumption is set forth for the present economic evaluation and the method of internal rate of return is similarly utilized.

The benefit is measured by a value at the fertilizer plant, yielded from the consumption of domestic resources and is compared with the economic cost at the mine-site derived from the production of apatite concentrates.

2.2 Assumed Parameters

(1) Benefit

When the domestic raw materials are not available, the fertilizer plant has to import the apatite concentrates from abroad. The benefit originated from implementation of the mining is calculated with the economic cost of importation.

The price of apatite concentrates of 36.4% P_2O_5 produced as the by-products of copper mining, has been indicated to be of US$40 per tonne on the term of f.o.r. Phalaborwa, South Africa. If the unit tariff of South African Railway is given to be of 2.5 cents per tonne-kilometer, the tariff sums up to $17.5 per tonne of concentrate over a distance of 1,170 km. Similarly, the tariff of the Zimbabwe Railway is estimated to be $51.66 per tonne over a distance of some 1,230 km at a rate of 4.2 cents per tonne-kilometer. The total railway tariff amounts to $69.16 per tonne and the price of concentrates at the Zambian border would be,

$$\$40.0 + \$69.2 = \$109.2$$

The grade of contents is then changed from 36.4% to 30%, and the price comes to:

$$\$109.2 \times \frac{30.0}{36.4} = \$90.0$$

Consequently, the utilization of domestic raw materials of 30% P_2O_5 can be deemed to bring the benefit at the rate of $90 per tonne of concentrates.

Due to uncertainty of estimation, the social benefit accompanied by the implementation of mining operation is excluded from the calculation. For example, a dam to be built is deemed to bring no benefit of other than the mining purpose, because even an existing dam was provided for birds and animals and is not in use for the agricultural purpose.

(2) Cost

Sunk Cost: The economic analysis compares a benefit created, with a cost newly added. The amount spent in the past is dealt with as a sunk cost and is excluded from the calculation. Thus, for example, a cost required for a construction of the existing dam is not included in the evaluation.

Commodity Price: Commodity prices in the domestic market is rather expensive compared with the international standard. In the financial analysis, the most of machineries and commodities were assumed to be directly imported from abroad, and the prices of domestic supplies remained unchanged. In the economic analysis, the prices of domestic supplies are provisionally reduced by a 10% to eliminate an effect of the sales tax.

Labour Cost: For skilled labourers, the market theory functions and the same amount of salaries used in the financial evaluation can be applicable for the economic evaluation. During the production period, a number of unskilled labourers are limited to be small and most of the labourers are deemed to be the skilled labourers after an education and training. The expenses in the education and training, which are spent to increase productivity of unskilled labourers, shall be excluded from the initial investment of the economic evaluation to make an adjustment of labour cost.

As for the construction period, an amount of labour charge forms a part of basis of the calculation for an estimation of payments for contractors. The latest statistics show that, in 1980, an average cash earning of employees in the field of agriculture, forestry and fisheries was K688 per annum in the private sector. It would be possible to assume that the amount reflected employer's willingness to pay in that time, and the market theory functioned. But if the exchange rate against foreign currencies in that year is applied, the amount exceeds the minimum wage in force. To estimate the labour cost of unskilled labourers, the average cash earning was fixed and converted into U.S. dollars using the exchange rate at the time of the study. The result was used in the calculation of payments to contractors, being at $1.274 per day for an unskilled worker over 300 days a year.

Among the construction expenses of a power line, the wiring fee has been given by an electric company in a form of contract basis. The price probably involves a surplus deductable in the economic evaluation but the amount of it is not known. Provisionally, a 5% of the total wiring fee is assumed to be reduced.

130

Power Cost: Revenue and expenses of electric companies are well balanced. A sales tax, being at 12.5% of a power charge, is excluded from the cost.

Currency: The national currency was devaluated several times and then allowed to float in 1983. Allotment of foreign currencies for imports is still being enforced and the officially announced exchange rate is deemed not necessarily to represent the practical rate. Some adjustment of the announced exchange rate might be required to reflect the real rate in a market. A conversion factor is designated by R and is expressed by a formula,

$$R = \frac{(I + D) + (E + M - S)}{I + E}$$

where, I ..... the total amounts of imports
E ..... the total amounts of exports
D ..... the total amounts of import duties
M ..... the governmental mineral revenues
S ..... the subsidies

When the amounts for 1983 are applied,

I = K 1,382.2 million (provisional)
E = K 1,300.8 ditto
D = K 175.3 ditto
M = K 56.5 ditto
S = K 82.6 ditto

then, the factor would be,

R = 1.056

The amounts payable in the national currencies in the cost of the economical evaluation are discounted by this factor and then expressed in dollar using the exchange rate at the time of the study.

2.3 The Economic Internal Rate of Return

The economic internal rate of return stands at 12.8% as follows:

Year	Benefit	Cost	Flow	in $1,000 Present Value
1st		9,533	–9,533	–8,451
2nd	590	2,607	–2,017	–1,585
3rd	3,150	1,095	2,055	1,432
4th	3,150	1,081	2,069	1,278
5th	3,150	1,096	2,054	1,124
6th	3,150	1,081	2,069	1,004
7th	3,150	1,427	1,723	741
8th	3,150	1,258	1,892	723
9th	3,150	1,253	1,897	641
10th	3,150	1,428	1,722	516
11th	3,150	1,258	1,892	503
12th	3,150	1,848	1,302	307
13th	3,150	1,081	2,069	432
14th	3,150	1,096	2,054	380
15th	3,150	1,081	2,069	339
16th	3,150	1,056	2,094	305
17th	2,070	–342	2,412	311

EIRR = 12.8%

2.4 Sensibility

When the value per tonne of the concentrates of 30% P_2O_5 at the national border is changed, the economic internal rate varies as follows:

+20%	($108)	18.2%
Model	($90)	12.8%
–20%	($72)	6.8%

Variation of the rate in fluctuation of the costs for the fixed assets and the commodity inventories is:

+20%	10.0%
Model	12.8%
–20%	16.9%

137

The economic internal rate is effected mainly by a change of the import value, similarly in the case of the financial internal rate.

2.5 Discussion

Even if several enterprises are earning the same profits, the contribution of each enterprise to the national economy differs automatically. The economic evaluation is employed as a measure to give a preference to an individual project for the purpose of utilizing effectively the national resources and the national funds.

In general, economic activity is closely related to overall social circumstances, and independent evaluation of an individual project is not always possible. Variation in premises often requests directly a revision of evaluation.

In the evaluation of apatite mining, a comparison has been made on the premises that there is a fertilizer plant in the country and that the delivery cost of products is equivalent to a cost, with which imported materials are brought into a plant from the border.

If the delivery cost, in the meaning of economic evaluation, of the domestic products exceeds the transportation cost of imported materials from the border, the difference between two costs pushes the internal rate downward.

Whereas the financial internal rate stands at 5.9%, the economic internal rate stands at 12.8%. The results indicate that a profit of the private enterprise would be marginal and that, at the same time, somewhat a high benefit can be expected in point of view of the national economy.

If a situation develops where the domestic products meet difficulty in competition in price with foreign materials, a possibility, which requires an introduction of the national policies, will arise. That is, an imposition of import duties or a grant of subsidy to protect the domestic industry must be considered.

The mining of apatite forms a part of the domestic production of phosphatic fertilizer and a resulting benefit, which arises from a home production of phosphatic manure, has not been woven into the present evaluation. The economic benefit that is brought in from fertilizer itself should be reviewed from the point of view of the phosphatic industry.

In this case, an overall revision is warranted with re-examination of the premises and the provisions excluded.

133

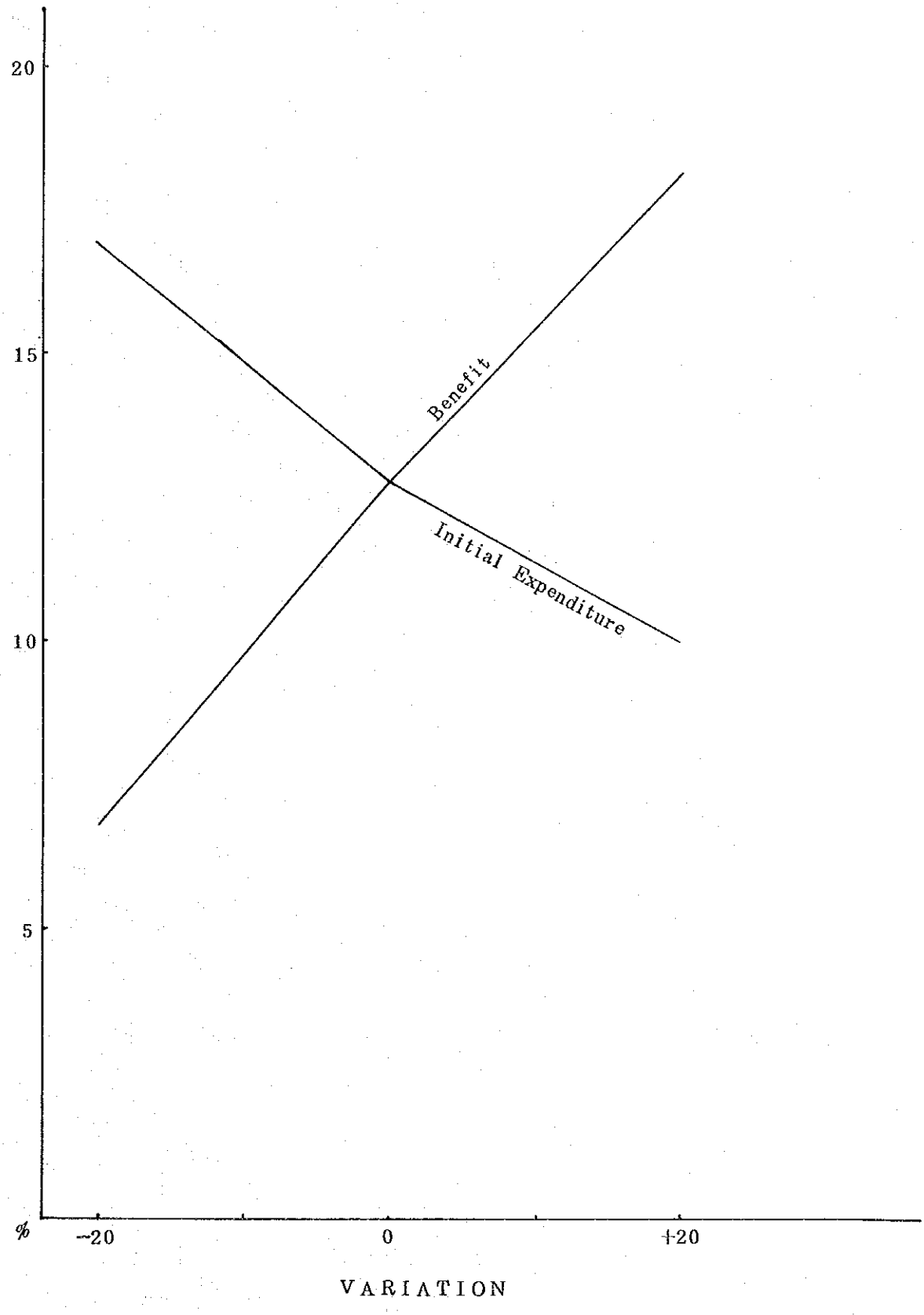


Fig. 2 Sensibility of the Economic Internal Rate of Return

APPENDIX

APPENDIX

1. COMPRESSION TEST

	Ore No. 1	Ore No. 2	Ore No. 3
Compressive strength (kgf/cm^2)	896	665	780
Static Young's modulus ($\times 10^5$ kgf/cm^2)	5.12	4.10	3.90
Static Poisson's ratio	0.19	0.22	0.32
	Waste No. 1	Waste No. 2	Waste No. 3
Compressive strength (kgf/cm^2)	865	948	1,020
Static Young's modulus ($\times 10^5$ kgf/cm^2)	4.28	4.18	3.89
Static Poisson's ratio	0.17	0.10	0.26

136

2. BEARING POWER TEST

The bearing power is measured with a cone-penetrometer at three points around the proposed construction area for the concentrator.

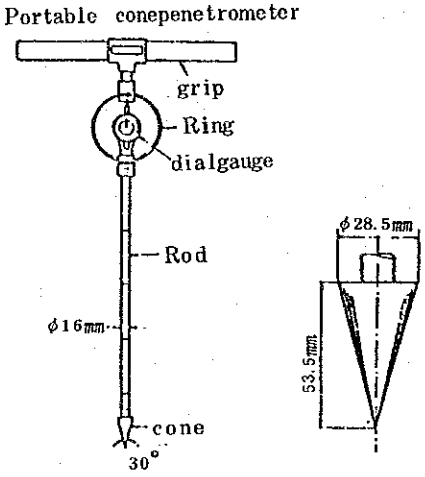
(1) Test Tool

Cone-penetrometer

KYODOSEIKI MFG. CO., LTD.

Maximum load: 100 kg

Cone-area: 6.45 cm^2



(2) Depth of testing

One time for each point and 35 ~ 50 cm deep from the surface.

(3) Test result

Point	Depth (cm)	Dial gauge (kg)	Cone bearing value (kg/cm^2)	Converted uniaxial compressive strength qu (kg/cm^2)
A	−35	240<	15.3<	3.1<
B	−50	240<	15.3<	3.1<
C	−45	250<	15.9<	3.2<

(4) Bearing power

The result shows that it seems to be fairly good bearing ground, having uniaxial compressive strength over 3.0 kg/cm^2, N-value over 30 and cohesion over 1.5 kg/cm^2.

137

3. TRANSPORTATION OF CONCENTRATES

1. Outline

As the detailed plan of the fertilizer plant has not been determined, we calculate four cases (200, 400, 540, 600 km) for reference.

It is proposed to transport concentrates from the mine site to the fertilizer plant by trailer type trucks.

2. Conditions

(1)	Transporting distance	200, 400, 540, 600 km
(2)	Truck	Trailer truck
(3)	Price of truck	US$72,408 Tire US$3,168/set
(4)	Payload	20 T (Tare 30 T, gross 50 T): weight limitation at Luangwa bridge is 50 T.
(5)	Average speed	40 km/hr
(6)	Amount transported	135 WT/day 39,150 WT/year (35,181 DT/year)
(7)	Repair factor	0.85
(8)	Depreciation	90% of truck price, straight line method
(9)	Truck life	300,000 km
(10)	Driving hour	Daytime only. Max. 10 hours/driver

3. Investment and Operating Costs

(1) Investments

Unit: US$

	200 km		400 km		540 km		600 km	
Truck	9	651,672	18	1,303,344	18	1,303,344	18	1,303,344
Housing	20	27,576	38	64,665	68	109,215	68	109,215
Total		679,248		1,368,009		1,412,559		1,412,559

138

(2) Additional Investment

Unit: 1,000US$

Year	200 km		400 km		540 km		600 km	
3								
4								
5					18	1,303	18	1,303
6	9	652	18	1,303				
7					18	1,303	18	1,303
8								
9	9	652	18	1,303			18	1,303
10					18	1,303		
11								
12					18	1,303	18	1,303
13	9	652	18	1,303				
14							18	1,303
15					18	1,303		
16	9	652	18	1,303			18	1,303
Total	36	2,608	72	5,212	90	6,515	108	7,818

(3) Operating costs

Unit: US$

	200 km	400 km	540 km	600 km
Material cost	529,491	1,058,982	1,429,624	1,588,473
Labour cost	64,560	146,760	214,380	214,380
Sub total	594,051	1,205,742	1,644,004	1,802,853
Direct cost/WT	15.17	30.80	41.99	46.05
Direct cost/DT	16.89	34.27	46.73	51.25
Depreciation (truck only)	170,001	340,003	460,004	510,004
Total	764,052	1,545,745	2,104,008	2,312,857
Operating cost/WT	19.51	39.48	53.74	59.08
Operating cost/DT	21.72	43.93	59.81	65.75
Operating cost/T.km/WT	0.098	0.099	0.100	0.098

139

Transportation Cost

Item	Haulage distance 200 km (1 way)	400 km	540 km	600 km
Type of trip Driving form	One trip within a day (1 driver)	One trip in two days (1 driver)	One trip in two days (2 drivers) (The driver will be changed en route)	One trip in two days (2 drivers) (The driver will be changed on the way)
Required number of trucks	$\frac{39{,}150\ T}{290 \times 20 \times 0.75} = 9$	$\frac{39{,}150 \times 2}{290 \times 20 \times 0.75} = 18$	18	18
Annual mileage	$\frac{39{,}150\ T}{20} \times 400\ km = 783{,}000\ km$	$\frac{39{,}150}{20} \times 800 = 1{,}566{,}000\ km$	$\frac{39{,}150}{20} \times 1{,}080 = 2{,}114{,}100\ km$	$\frac{39{,}150}{20} \times 1{,}200 = 2{,}349{,}000\ km$
Truck life	Annual mileage per truck 87,000 km $\frac{300{,}000}{87{,}000} = 3.45$ years	87,000 km $\frac{300{,}000}{87{,}000} = 3.45$ years	117,450 km $\frac{300{,}000}{117{,}450} = 2.55$ years	170,500 km $\frac{300{,}000}{170{,}500} = 2.30$ years
Material cost	Diesel oil 24.5ℓ/Hr x 19,575Hr x 0.56$/ℓ = 268,569($) Lubrication (20% of diesel) $53,714 Tire 3,168$/27,500 x 783,000 = 90,202($) Miscellaneous $20,624 Total $433,109	24.5 x 39,150 x 0.56 = 537,138($) $107,428 3,168/27,500 x 1,566,000 = 180,403($) $41,248 Total $866,217	24.5 x 52,852.5 x 0.56 = 725,136($) $145,027 3,168/27,500 x 2,114,100 = 243,544($) $55,685 Total $1,169,392	24.5 x 58,725 x 0.56 = 805,707($) $161,141 3,168/27,500 x 2,349,000 = 270,605($) $61,873 Total $1,299,326
Material cost of maintenance and repair	$\frac{72{,}408 \times 0.85}{300{,}000} \times 783{,}000 \times 0.6$ = 96,382$/year	$\frac{72{,}408 \times 0.85}{300{,}000} \times 1{,}566{,}000 \times 0.6$ = 192,765$/year	$\frac{72{,}408 \times 0.85}{300{,}000} \times 2{,}144{,}100 \times 0.6$ = 260,232$/year	$\frac{72{,}408 \times 0.85}{300{,}000} \times 2{,}349{,}000 \times 0.6$ = 289,147$/year

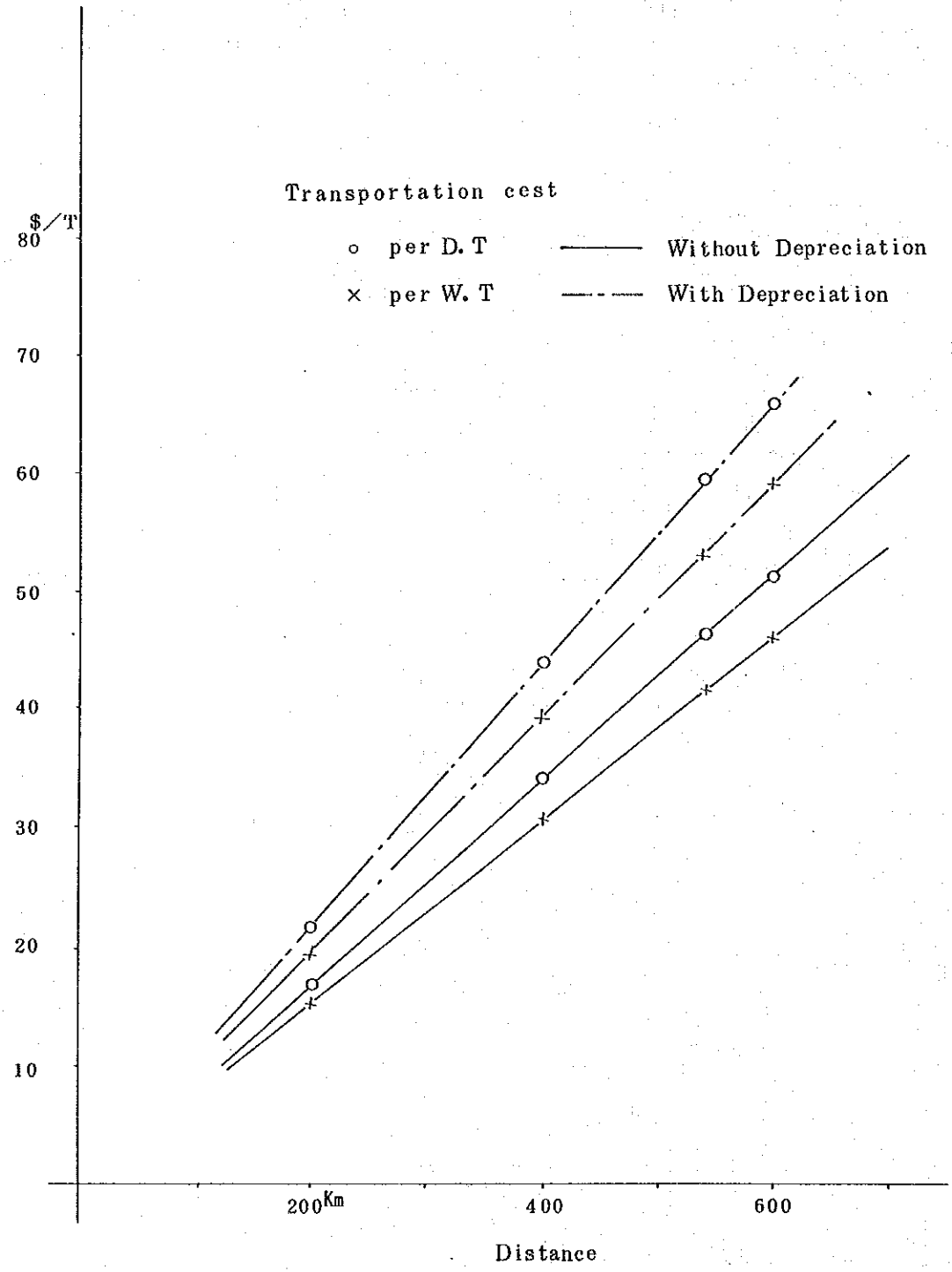
(Continued)

Item	Haulage distance 200 km	400 km	540 km	600 km
Labour cost	(Including 66% premium for 2 hours' overtime) Unit cost 10.8$/person. day (3,240$/year) Driver 7 x 2/0.9 = 16 person 16 X 3,240 = 51,840 Foreman 2 X 3,960 = 7,920 Maintenance & repair cost 2 x 2,400 = 4,800 Total 20 persons 64,560$/year	(Including 66% premium for 2 hours' overtime plus lodging allowance 5$/person. day) Unit cost 13.3$/person. day (3,990$/year) Driver 14 x 2/0.9 = 32 persons 32 X 3,990 = 127,680 Foreman 3 X 3,960 = 11,880 Maintenance & repair cost 3 x 2,400 = 7,200 Total 38 persons 146,760$/year	The driver will be changed on the way (accommodation charge lodging allowance 5$/person. day) Unit cost 10.5$/person. day (3,150$/year) Driver 14 x 4/0.9 = 62 persons 62 X 3,150 = 195,300 Foreman 3 X 3,960 = 11,880 Maintenance & repair cost 3 x 2,400 = 7,200 Total 68 persons 214,380$/year	The driver will be changed on the way (including accommodation charge lodging allowance 5$/person. day) Unit cost 10.5$/person. day (3,150$/year) Driver 14 x 4/0.9 = 62 persons 62 X 3,150 = 195,300 Foreman 3 X 3,960 = 11,880 Maintenance & repair cost 3 x 2,400 = 7,200 Total 68 persons 214,380$/year (persons)
Total	594,051$/year Unit cost per wet-T 15.17 Unit cost per dry-T 16.89	1,205,742$/year Unit cost per wet-T 30.08 Unit cost per dry-T 34.27	1,644,004$/year Unit cost per wet-T 41.99 Unit cost per dry-T 46.73	1,802,853$/year Unit cost per wet-T 46.05 Unit cost per dry-T 51.25
Depreciation (Vehicle only)	$\frac{9 \times 72,408}{3.45} \times 0.9 = 170,001$/year Unit cost per wet-T 4.34$/T Unit cost per dry-T 4.83$/T	$\frac{18 \times 72,408}{3.45} \times 0.9 = 340,003$/year Unit cost per wet-T 8.68$/T Unit cost per dry-T 9.66$/T	$\frac{18 \times 72,408}{2.55} \times 0.9 = 460,004$/year Unit cost per wet-T 11.75$/T Unit cost per dry-T 13.08$/T	$\frac{18 \times 72,408}{2.30} \times 0.9 = 510,004$/year Unit cost per wet-T 13.03$/T Unit cost per dry-T 14.50$/T
Grand total	764,052$/year Unit cost per wet-T 19.51 Unit cost per dry-T 21.72	1,545,745$/year Unit cost per wet-T 39.48 Unit cost per dry-T 43.93	2,104,008$/year Unit cost per wet-T 53.74 Unit cost per dry-T 59.81	2,312,857$/year Unit cost per wet-T 59.08 Unit cost per dry-T 65.75
Housing	20 houses at the mine site (foreman 2, worker 18) Investment $27,576	38 houses at the mine site (foreman 3, worker 35) Investment $64,665	36 houses at the mine site 32 houses in the destination town (foreman 2, foreman 1) (worker 34, worker 31) Investment $109,215	36 houses at the mine site 32 houses in the destination town (foreman 2, foreman 1) (worker 34, worker 31) $109,215

Upon investigation, the unit transportation charge in Zambia was 0.11 US$/T.km, but it seems to vary depending on the round-trip distance.

However, in the case of continuous transportation of concentrates by the mine employees, it will be possible to keep the estimated unit cost nearly the same as the investigated one. (Considering the benefits of the contractor.)

142


Transportation cost
$/T
80
70
60
50
40
30
20
10
o per D. T
× per W. T
Without Depreciation
With Depreciation
200Km
400
600
Distance