# CHAPTER 4

# CONDITIONS OF LOCATION OF TLPS SYSTEM

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## 4.1 TOPOGRAPHY AND GEOLOGY

### 4.1.1 Topography

(1) Topography

The Cordillera Central on the eastern part and the plain on the western part constitute the topographic features of the area.

The topography of the mountain part, 400 ~ 1,800 meters high above sea level, is very steep due to the rise of the earth crust which still continues now, making the canyon of the Bued River and about 20 valleys crossing it deeply V-shaped.

The plain part consists of an alluvial fan formed at the area where the Bued River departs from the mountain and the hill along the Lingayen Gulf with the ridges 100 ~ 200 meters high above sea level.

The topography of either the mountain or the plain part is characterized by hard strata of conglomerate beds forming the ridges while the sandstone, siltstone beds and faults form the valleys. This could be clearly seen from aerial photos and geological survey maps.

(2) River (See table 4-1)

There are two groups of rivers which flow through this mining area - the Agno River and its tributaries and the Bued River and its tributaries. Both rivers rise from the Cordillera Central, run through the mountains forming deep valleys, slowly wind their ways through the farming areas and empty into the Lingayen Gulf.

The mines surveyed during this time were:
Along the Agno River: Philex, BCI, Itogon and Atok, and along the Bued River: B.X. and B.M.I.

Each mill site of the mines is facing one of the rivers.

The amount of waterflow increases during the rainy season from May to October, particularly during the typhoon season from July to September.

The all-time high record is 15,000 $m^3$/sec in the Agno River in September 1968 and 222 $m^3$/sec in the Bued River in August 1967.

The total water catchment area is 1,130 $km^2$ for the Agno River and its branches and is about 8 times larger than the Bued River (141 $km^2$).

4.1.2 General Geology (See Fig. 4-1)

The geological formations in the west Camp 4 located along the Kennon Road become younger towards the west. Namely, from east to west, the Pugo Formation, the oldest stratum in the area consisted mainly of volcanic rocks of Cretaceous to Palaeogene age; the Zigzag Series made up of mostly of the conglomerate of Lower to Middle Miocene age; the Kennon Limestone, Klondyke Conglomerate of Upper Miocene age; and the Rosario Formation made up of conglomerate, sandstone and siltstone of Upper Miocene to Pliocene age.

These formations generally trend from NW to SE, and has a simple structure gradually dipping toward the west at 10 ~ 30° except the Rosario Formation along the Lingayen Gulf. This Formation along the Gulf is steeply dipping.

The intrusive rocks consist of the diorite complex intruded during the Cordillera Central oroganic movements in Miocene age and the dykes of andesite and dacite related with the complex. The quart diorite, one of the diorite complex members, intrudes into the Pugo Formation at the valleys upstream of the Bued River and also in the east of Camp 4, and copper mineralization is present. Less than several meters wide, the dykes penetrate through the Pugo Formation and the Zigzag Series.

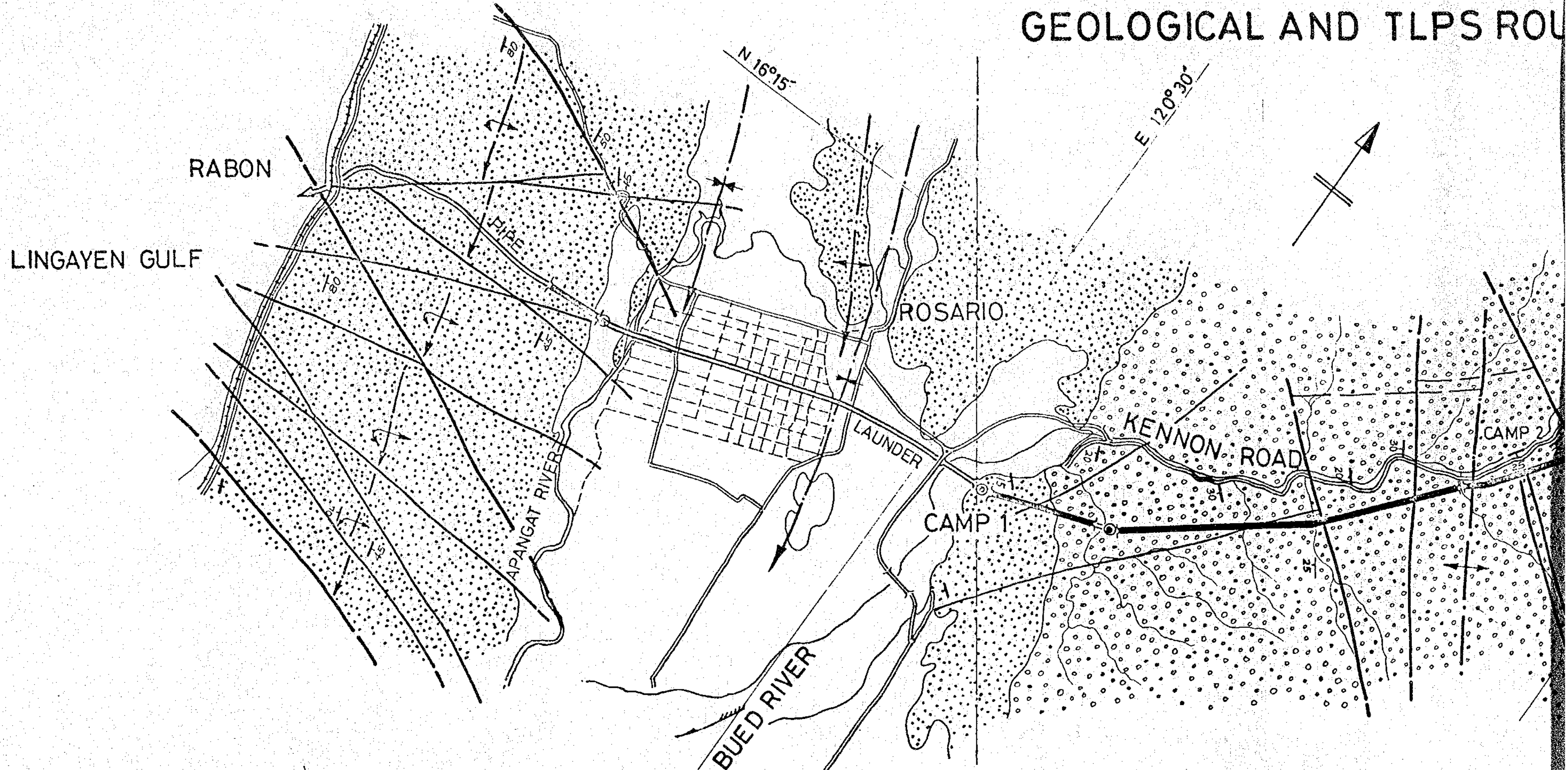
Further, Quanternary volcanic rocks such as cone-shaped plugs, dykes and sills of basalt, andesite and dacite have intrude older rocks, generally along structural lines.

4.1.3 Petrography (See Fig. 4-1 and Table 4-2)

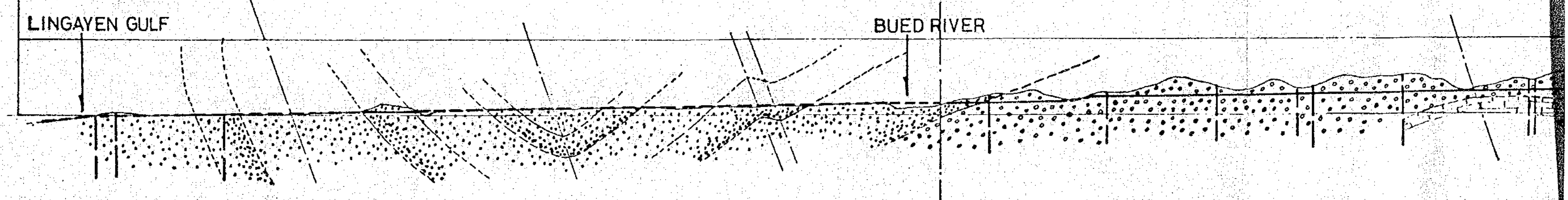
(1) Pugo Formation

The Pugo Formation is the oldest stratum surveyed and lines east of the Thirty Minutes Creek across the Kennon Road.

# GEOLOGICAL AND TLPS ROU




## PROFILE : LINGAYEN GULF – CAMP 4



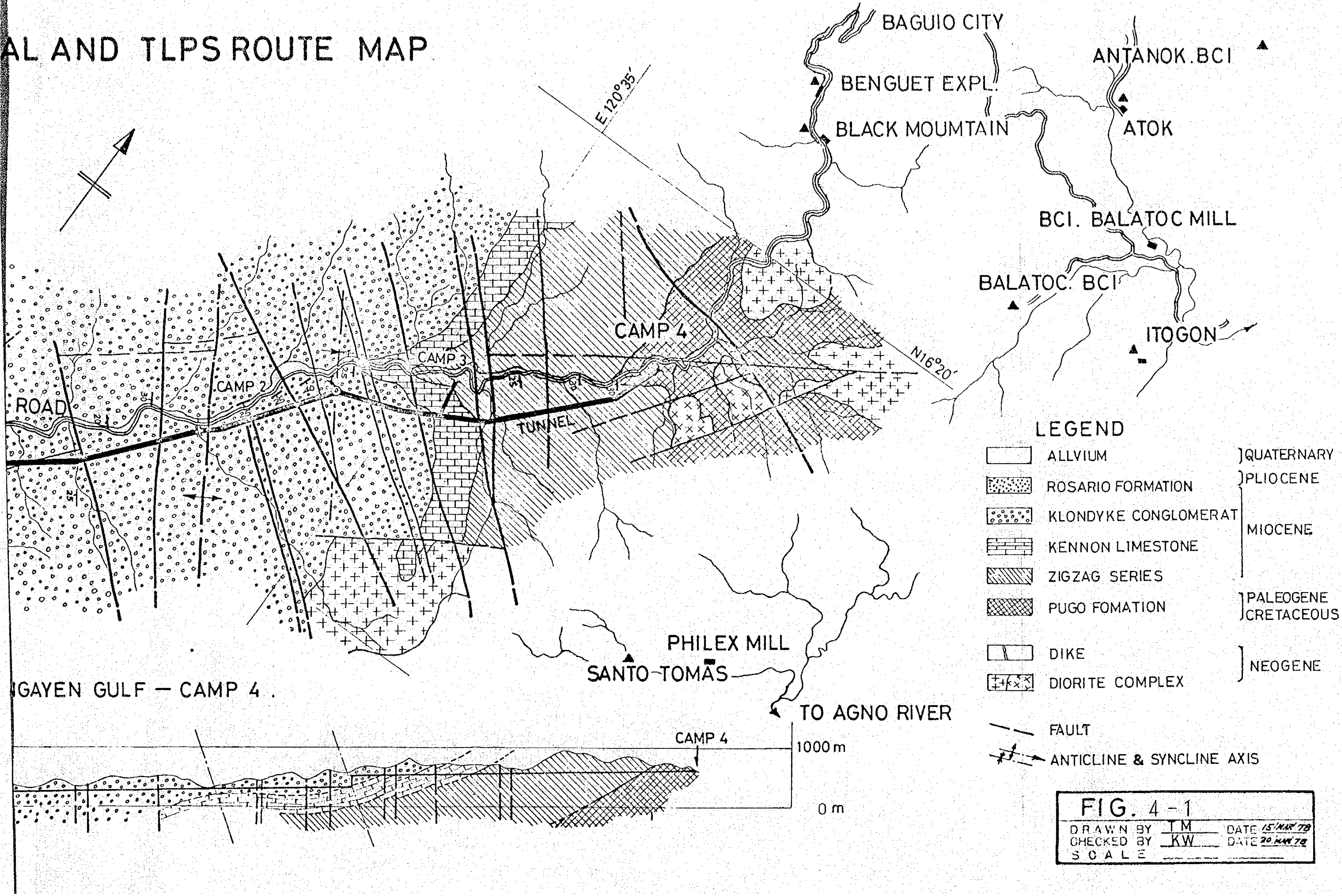



FIG. 4-1

DRAWN BY TM DATE 15 MAR 78
CHECKED BY KW DATE 20 MAR 78
SCALE

Table 4-1 Flow rate of Agno River and Bued River

| Name of River | Agno River | | | Bued River | | |
|---|---|---|---|---|---|---|
| Catchment area | 1,130 $KM^2$ | | | 141 $KM^2$ | | |
| Period of survey | 1966 ~ 1974 | | | 1960 ~ 1969 | | |
| Month \ Flow amount | $m^3$/sec Average | $m^3$/sec Maximum | $m^3$/sec Minimum | $m^3$/sec Average | $m^3$/sec Maximum | $m^3$/sec Minimum |
| January | 25.0 | 45.0 | 3.0 | 2.0 | 6.9 | 0.4 |
| February | 18.9 | 31.6 | 1.6 | 1.7 | 5.9 | 0.2 |
| March | 18.0 | 41.9 | 1.7 | 1.5 | 5.1 | 0.4 |
| April | 16.7 | 29.9 | 1.5 | 1.4 | 3.8 | 0.5 |
| May | 31.1 | 2,100.0 | 1.5 | 6.8 | 218.6 | 0.5 |
| June | 45.9 | 370.0 | 1.7 | 5.6 | 93.0 | 0.03 |
| July | 144.3 | 3,200.0 | 8.2 | 8.9 | 156.0 | 0.1 |
| August | 546.9 | 13,000.0 | 20.7 | 30.8 | 222.3 | 1.4 |
| September | 471.1 | 15,000.0 | 44.3 | 31.7 | 215.9 | 1.1 |
| October | 103.8 | 1,900.0 | 25.9 | 7.7 | 102.8 | 1.2 |
| November | 56.7 | 880.0 | 5.9 | 6.1 | 40.6 | 1.8 |
| December | 31.4 | 143.0 | 3.7 | 2.4 | 8.1 | 0.5 |
| Average | 151.0 | | | 11.7 | | |

The rocks consists mostly of basalt flows, andesite and dacite - so called "metavolcanics".

These rocks have undergone metamorphism by the diorite complex of the later age, producing partial hydrothermal alteration and copper mineralization. In the vicinity of Camp 4, the mineralized areas have many fractures and there are gossans seen due to oxidation of pyrites and bleaching by hydrothermal alteration and weathering on the surface. Generally speaking, they are massive, green-colored, highly dense and hard rocks.

(2) Zigzag series

The Zigzag Series as seen between Km. 228 on the Kennon Road and the Thirty Minutes Creek is mainly of conglomerate with interbeds of volcanic flows, volcanic greywacke and sandstone.

The series consists of ZVl - 1,2 mostly volcanic flows, the conglome rate members-rich ZCg-1,2 and ZSs-1 containing much sandstone and greywacke members.

The conglomerate members contain altered basic to intermediate rock fragments ranging in size from pebbles to boulders in a chloritized tuffaceous sandy matrix. Roundness of the fragments is low from angular to sub-angular. ZSs-1 is tuffaceous greywackes and ZVl-1,2 is andesitic lava and pyroclastics. All the rocks are massive green-colored, highly dense and hard ones.

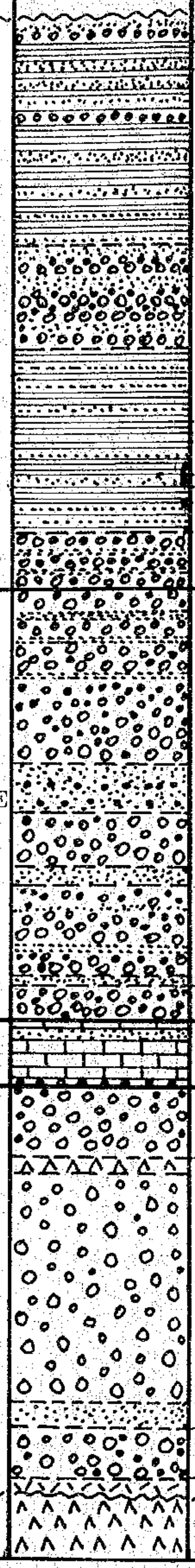
Kennon limestone

The massive limestone is exposed between Km. 225.6 and Km. 228 on the Kennon Road. The lower formation is made up of limestone containing fossil pieces of 1 ~ 2 cm in size and the upper formation consist of the limestone conglomerate having limestone gravels from several centimeters to 30 cm in diameter. At the lowermost part is several meters thick of basal conglomerate beds with well rounded gravels.

(3) Klondyke conglomerate

The Klondyke conglomerate is well exposed between Camp 1 and the Km. 225.6 of the Kennon Road. This formation consists of KCg-1,2,3,4 of conglomerate members and KSs-1,2,3 of sandstone members.

GEOLOGICAL COLUMN : BETWEEN CAMP 4 AND LINGAYEN GUIF    Tab. 4-2



| AGE | | FORMATION | GEOLOGICAL COLUMN | | REMARKS |
|---|---|---|---|---|---|
| QUATERNARY | | | | | ALLUVIUM, TERRACE |
| PLIOCENE | | ROSARIO FORMATION | RSil-2 | 1000m | alteration: siltstone and sandstone with interbedded thin conglomerate beds. |
| PLIOCENE | | ROSARIO FORMATION | RCg-2 | 450m | pebble-boulder conglomerate beds with sandstone beds. gravel: rounded-well rounded. |
| MIOCENE | UPPER | ROSARIO FORMATION | RSil-1 | 750m | alteration, siltston and sandstone beds. |
| MIOCENE | UPPER | ROSARIO FORMATION | RCg-1 | 250m | conglomerate beds with sandstone thin beds. |
| MIOCENE | UPPER | KLONDYKE CONGLOMERATE | KCg-4 | 700m | conglomerate<br>matrix : gray arkose sandstone<br>gravel : rounded metavolcanics (much), diorite, limestone. |
| MIOCENE | UPPER | KLONDYKE CONGLOMERATE | KSs-3 | 200m | alteration, siltstone and sandstone. |
| MIOCENE | UPPER | KLONDYKE CONGLOMERATE | KCg-3 | 200m | conglomerate |
| MIOCENE | UPPER | KLONDYKE CONGLOMERATE | KSs-2 | 50m | same as KCg-4 |
| MIOCENE | UPPER | KLONDYKE CONGLOMERATE | KCg-2 | 400m | same as KCg-4 |
| MIOCENE | UPPER | KLONDYKE CONGLOMERATE | KSs-1 | 50m | thin sandstone |
| MIOCENE | UPPER | KLONDYKE CONGLOMERATE | KCg-1 | 150m | conglomerate same as KG-4 |
| MIOCENE | LOWER~MIDDLE | KENNON LIMESTONE | KLs | 600m | upper: limestone conglomerate<br>lower: limestone |
| MIOCENE | LOWER~MIDDLE | ZIGZAG SERIES | ZCg-3 | 300m | conglomerate, green, gravel: subangular |
| MIOCENE | LOWER~MIDDLE | ZIGZAG SERIES | ZVl-2 | 50m | andesite lava flow. |
| MIOCENE | LOWER~MIDDLE | ZIGZAG SERIES | ZCg-2 | 950m | conglomerate<br>matorix: gray - greenish gray, tuffuceous sandstone.<br>gravel : subangular metavolcanics, green. |
| MIOCENE | LOWER~MIDDLE | ZIGZAG SERIES | ZSs-1 | 100m | tnffuceous greywacke |
| MIOCENE | LOWER~MIDDLE | ZIGZAG SERIES | ZCg-1 | 200m | conglomerate same as ZCg-2 |
| MIOCENE | LOWER~MIDDLE | ZIGZAG SERIES | ZVl-1 | 50m | tuff uceous greywacke, conglomerate. |
| PALEOGENE CRETACEOUS | | PUGO FORMATION | PMV | | massive hard andesite and basalte lava flows. |

The gravel in the Klondyke Conglomerate is more rounded than those of the Zigzag Series. Pebbles and boulders are of diorite, andesite, limestone, and altered volcanic rocks in an arkosic sandy matorix.

(4) Rosario formation

This formation is observed from Camp 1 up to the Lingayen Gulf in the west, and is largely a siltstone-sandstone-conglomerate sequence. It is divided into RCg-1,2 containing much conglomerate and sandstone members and RSil-1,2 having much sandstone and siltstone members.

The conglomerate of this formation is similar to those of the Klondyke Conglomerate in shape and quality but with thinner beds than the latter (under 10 m).

(5) Miocene intrusive rocks

Quartz diorite, one of the diorite complex members, intrudes the Pugo Formation at the valleys upstream of the Bued River and at the east side of Camp 4.

This diorite complex intruded the Pugo Formation during the Central Cordillera orogenic movement. The Agno batholith (Itogon quartz diorite) also among the complex, is widely exposed from north to south along the Agno River west of the survey area. Further, the andesite and dacite dykes related with the diorite complex have intruded into the Pugo Formation and the Zigzag Series around the stocks.

(6) Quaternary volcanic rocks

Although hardly recognized within the survey area, there are intrusions of cone-shaped plugs, stocks, dykes and sills of basalt, andesite and dacite along the structure lines of the formations east of the survey area.

4.1.4 Geological Structure and Mineralization

(1) Geological structure (See Fig. 4-1)

The formations formed in Cretaceous through Pliocene have been folded and faulted owing to the Central Cordillera orogeny, accompanied by intrusion of the diorite complex of Miocene age, and rising of the earth crust which is still under way.

The general strike of the Pugo Formation and the Zigzag Series east of Camp 3 is approximately northwest and have a gradually west-dipping structure.

Some folded structures with the axis striking N20°W, the axial plane dipping 70°E and gradually south-dipping plunge are in the Klondyke Conglomerate and the Rosario Formation west of Camp 3. The Rosario Formation along Lingayen Gulf has steeply dipping beds with intricate faulting and folding.

The rise of the land still continues, making the canyon of the Bued River very deep and the deposits on the river terrace 30 ~ 50 meters higher than the present riverbed.

The faults observed in the Pugo Formation and Klondyke Conglomerate strikes N45° ~ 60°E and N45° ~ 50°E respectively. The northeasterly strike is the structure represented by the Bued River and the northwesterly strike goes across the river forming the deep V-shaped valleys. Among the faults in the Rosario Formation, those running N70° ~ 80°W and N60° ~ 80°E are prominent. They are also forming creeks flowing across the strata.

The northwest strike faults in the Rosario Formation have large lateral displacements (up to 300 m in left lateral displacement). The other faults have smaller displacements.

(2) Mineralization

Hydrothermal alteration and copper mineralization of porphyry copper type are around the exposed quartz diorites in the valleys upstream of the Bued River and at the eastern side of Camp 4. These copper showings are green copper stains in the weathered rocks and chalcopyrite disseminations in the fresh rocks.

### 4.1.5 Civil Engineering Geology

(1) Rock tests (See Table 4-3)

Field compressive strength tests were conducted on rocks with Shmidt Hammer. Some fresh rock samples were brought to Japan and subjected to single direction compressive strength tests and elastic tests. Hereunder are the test methods and the test results.

a. Test by Shmidt hammer

Object: Since the survey area is extensive and most of the rocks belong to Tertiary, the field compressive tests were conducted with Shmidt Hammer on fresh rocks as well as slightly weathered ones.

Test place: The road cuts along the Kennon Road and the exposed rocks and boulders in the riverbed of the Bued River and other valleys.

Test Method: The tests were made more than three times on the same kind of rock of the same stratum at different sampling places. More than 24 times of hammering were made at each test places. The average value was obtained from 20 times hammerings (exepting four unusual values). The compressive strength of a rock is the average of several test results. The compressive strength above 600 kg/cm$^2$ is shown as +600 kg/cm$^2$ as the maximum measuring limit of the Shmidt Hammer is 600 kg/cm$^2$.

b. In-door rock compressive strength test and seismic test

Object: In-door tests were carried out on fresh rocks to obtain their compressive strengths and the velocity of elastic wave, these rocks having hardness beyond the compressive capacity of Shmidt Hammer (600 kg/cm$^2$).

Test place and machine: The Geological Measurement Co., Ltd.
The relay type compressive tester: Maruto PHC-20

Test method: Test piece: Dry column (2 cm dia. x 4 cm high)
Test were made three times on the same kind of rock.

As seen from Table 4-3 which shows the compressive strengths of rocks in the formation where the tunnel is to be built, the intrusive rocks of the Pugo Formation, Zigzag Series and the Kennon Limestone have high compressive strengths of 1,000 kg/cm$^2$ or above. But, rocks of the Klondyke Conglomerate and the Rosario Formation have low compressive strengths (299 ~ 568 kg/cm$^2$). Therefore, some reinforcement by concrete or timbering is necessary for rocks of soft strata and the sheared zones in the Klondyke Conglomerate and the Rosario Formation.

(2) Fault

In the area east of Camp 1 where the tunnel is to be constructed are prominent faults with N45° ~ 60°E strike which run parallel with the tunnel and N45° ~ 50°W strike which traverses it. Of the two, the NW dislocation traversing the tunnel has a large effect on the tunnel construction work.

Table 4-3 Rock compressive strength and elastic wave velocity

| Formations | Rocks | Specific Gravity | Compressive Strength $kg/cm^2$ | Compressive Str. by Schmit Hummer | | Elastic Wave Velocity | |
|---|---|---|---|---|---|---|---|
| | | | | Fresh Rock $kg/cm^2$ | Slightly weathered Rock | P. wave m/sec | S. wave m/sec |
| Diorite Complex | Quartz diorite | 2.83 | 1,790 | +600 | no test | 5,290 | 2,940 |
| | Porphyrite | 2.87 | 651 | no test | no test | 5,270 | 2,970 |
| Pugo Formation | Meta-Volcanic | 2.80 | 1,570 | +600 | 250 | 5,860 | 3,250 |
| | Meta-Volcanic | 2.87 | 2,940 | +600 | no test | 5,780 | 3,180 |
| Zigzag Series | Conglomerate | 2.77 | 1,960 | +600 | 270 | 4,950 | 2,760 |
| Kennon Limestone | Limestone | 2.69 | 1,055 | 400 | no test | 5,525 | 3,055 |
| Klondyke Conglomerate | Conglomerate | 2.56 | 299 | 370 | 230 | 2,160 | 1,180 |
| | Sandstone | 2.51 | 568 | no test | 100 | 3,240 | 1,790 |
| Rosario Formation | Sandstone | 2.33 | 341 | no test | 80 | 2,910 | 1,590 |

The fault zone of the NW dislocation which can be observed from sections along Bued River and the Kennon Road is not very large (2 ~ 3 m). Some NW dislocation (not directly observable but can be seen on air photos) which forms the valleys crossing the Bued River is estimated to be 10 to 20 m. wide. These sheared zones cause underground water to flow into the tunnel. In the case of Philex, 1 $m^3$/min of water passing thru faults and cracks is expected every 1 km of the tunnel.

All the NW and NE strike faults traversing the Rosario Formation west of Camp 1 from the creeks running across the strata. The lateral displacement of the strata is large (up to 300 m), so this fact must fully be considered when the transportation line is constructed along any creek produced by large fault.

(3) Mineralization

In the vicinity of Camp 4 where the tunnel starts, alteration and mineralization of the porphyry copper type accompanied by the Diorite Complex are observed. This will pose problems of acquiring rights of way for driving the tunnel, timbering work, tunneling thru ore deposit, etc., and the problem of tunnel maintenance due to mining regulation. It is expected that between the starting point up to 1.5 km far from it, the tunnel will pass through the mineralized area having many faults and fractures.

4.1.6 Nature of the Sea Bottom:

The sea bottom under the offing at Rabon in the Lingayen Gulf, has sand, silt and rocks distributed as follows:

Sand ground: Found in the shallow sea area (the iron sand mining area) extending southward from the sand bank west of Santo Tomas and around the beach line in the neighborhood of Rabon. The sand ground is made up of coarse-grained sand and has a sufficient compressive strength for foundation ground for a structure.

Silt ground: The silt ground is thickly accumulated in the deep sea area six km. off Rabon (the west), (thickness unknown). The silt is also accumulated around the mouths of rivers in and around Rabon. Some silt accumulation is also present at the proposed reclamation area at depths of less than 15 m. This fine silt seems to have been moved from the Bued River and is several tens of meters thick.

Rock ground: Reefs are distributed around the Rabon Station south of that station. The reef projects about 200 m toward the offing.

Topography of the sea bottom: Topography of the sea bottom in the offing of Rabon in the Lingayen Gulf is quite flat, the depth being 15 m at 2.5 km from the shore (Gradient: 6/1000). These areas are relatively flat except for occasional sand bars.

## 4.2 WEATHER CONDITIONS OF MOUNTAIN AREA

### 4.2.1 General Philippine Weather Conditions

Temperature difference throughout the year is very small, i.e. 3°C. The highest temperature (about 28.1°C) is in May and the lowest (about 25.4°C) in January.

Temperature difference between the north and south districts is also small, i.e., 25.8°C (annual average at Aparri at the northern end of Luzon Island and 26.6°C at Jolo, in the Sulu Islands (the southernmost island of the Philippines).

About 159 days a year are rainy which bring an annual average rainfall of 2,366 mm. The rainfall about 4,600 mm annually is particularly heavy at Baguio and Benguet at the northern part of the Luzon Islands.

Typhoons mostly pass from SE to NW at 10° ~ 15° north latitude. Destructive typhoons often arise in the zone from 11° to 13°30' north latitude and amount to about 30% of all the typhoons passing thru the Islands. The frequency of typhoons is very high in the northern part of Luzon Island, particularly the area northward from the Cagayan Valley, and shares about 35% of the total number.

Weather features of the Luzon Island are:

(1) Western area: Dry during November-April and rainy during May to October.

(2) Mountainous districts: Dry from February to April
No heavy rain season.

(3) Eastern and southeastern area: No distinct dry season or heavy rain season.

(4) Bicol Provinces: No district dry season.

4.2.2 Temperature and Rainfall at Baguio Mining Area (See Table 4-4)

The Weather at the mountainous district is of tropical type. Rainy seasons is from May to October and dry season is from November to April.

Temperatures at Baguio City area: The highest (25°C), the lowest (12°C) and the annual average (18°C).

Data from 1949 to 1977 shows that the maximum annual rainfall is 8,950 mm. and the minimum is 2,000 mm with an average of 3,600 mm. Most of the rainfall is concentrated during the typhoon season from July to September, and the all-time high records are 1,168 mm on July 14, 1974 and 2,419 mm/3 days on May 25, 1976 when typhoon Didang passed over the Island.

Typhoon passes over this area from SE to NW. In 1974, there were successively six (6) heavy typhoons in a span of six (6) weeks.

Table 4-4 Amount of rainfall in Baguio City & Philex Main Camp (MM/month)

| Area / Month | Baguio City (1949 ~ 1977) | | Philex Main Camp | |
|---|---|---|---|---|
| | Average | Maximum | Average | Maximum |
| January | 12.2 | 35.1 | 21.1 | 162.7 |
| February | 8.9 | 113.3 | 9.0 | 42.4 |
| March | 36.3 | 140.0 | 47.2 | 214.6 |
| April | 96.6 | 289.0 | 112.7 | 338.5 |
| May | 302.8 | 1,304.5 | 553.8 | 3,048.5 |
| June | 471.8 | 1,417.9 | 789.4 | 1,759.5 |
| July | 740.9 | 4,774.5 | 1,177.1 | 5,649.0 |
| August | 829.9 | 1,917.4 | 1,225.2 | 2,452.9 |
| September | 615.1 | 1,480.8 | 865.9 | 2,414.5 |
| October | 350.4 | 2,273.5 | 594.4 | 2,903.0 |
| November | 138.4 | 706.9 | 124.9 | 696.1 |
| December | 27.0 | 143.4 | 35.0 | 157.7 |

## 4.3 WEATHER CONDITIONS (THE SEA AREA)

### 4.3.1 General Weather Conditions

The climate of La Union and Pangasinan facing the Lingayen Gulf belongs to the Climate Zone type I and is divided into the dry season from November to April and the rainy season from May to October.

The temperature ranges from $26^{o}$ ~ $29^{o}C$ in the whole year.

Since the Lingayen Gulf is located at the western side of the Central Mountains, it is little affected by the monsoon from the east or northeast but is influenced by winds from the southwest caused by typhoons from June to September.

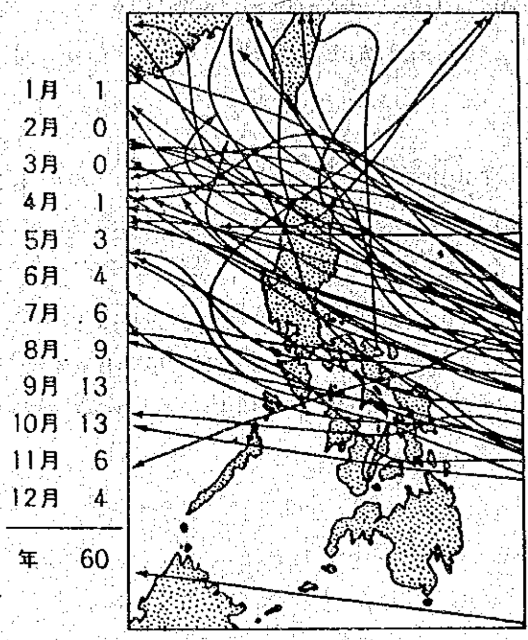
In the world, the Philippines is the most frequently attacked by typhoons. The most popular path of the typhoon lies in the north of $11^{o}$ of North Latitude. They seldom pass south of this Latitude. The word "baguio" means typhoon. Frequent typhoons pass in the central to north districts of Luzon Island.

Fig. 4-2 shows the paths of typhoon and Appendix A-4-3-1 contains records of typhoons in the past 30 years.

Table 4-5 Monthly mean temperature, $^{o}C$

| | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sept | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dagupan | 26.1 | 26.7 | 28.3 | 29.6 | 29.7 | 28.2 | 28.3 | 27.8 | 27.9 | 28.2 | 27.4 | 26.7 |

Fig. 4-2 Path and monthly frequency of typhoon (including weak tropical depressions) around the philippine islands




Courses and Times (Per Month) of Typhoons
Passing thru Philippine Islands.
(Including Weak Tropical Low Atmospheric Pressure.)

#### 4.3.2 Wind Direction and Wind Speed

Wind directions and wind speeds at Dagupan city are shown in Table 4-6.

Table 4-6 Mean monthly and annual prevailing winds and average wind speeds in knots

Dagupan City

| | | | | | | |
|---|---|---|---|---|---|---|
| (1957~1970) | Jan. | Feb. | Mar. | April | May | June |
| | SSE/5 | SSE/6 | NNW/6 | NNW/6 | SE/5 | SE/5 |
| | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
| | SE/5 | SE/4 | SE/5 | SE/5 | SE/5 | SE/5 |

Annual Average- - - - - - - - - - - - - - - - - - - - - - - SE/5

Fig. 4-3 shows the mean monthly wind direction and average wind at Iaoag City (about 250 km north of the Lingayen Gulf) which has similar weather conditions as the Gulf. Comparison with the data for Laoag City clearly shows that wind blows over Daguapn City from SE in the whole year and from NNW during March and April. The wind from the east is interrupted by the mountains.

The wind blows strongest in March to May. During this period, the wind from NNW-NW blows at maximum speed of about 10 m/sec. in the afternoon. In the morning, wind from the east blows at 5 ~ 7 m/sec and the sea remains calm. Strong winds have prevented small fishing boats from going out in the afternoon. The ways height during the period is from 1 to 1.5 m. The maximum wind speed used in the design is 30 m/sec.

### 4.3.3 Ocean Current

There always flows at the offing of the Lingayen Gulf the North Equatorial current at 0.5 to 1.0 knots. (See Figs. 4-4, 4-5 and 4-6).

The Lingayen Gulf has a countercurrent agains the North Equatorail current which flows at 0.5 to 1.0 knot from the offing of San Fernando to the innermost part of the Lingayen Gulf.

This countercurrent has formed a sand bar which beings at Agoo town and extends southward about 6 km.

The proposed reclamation area in the offing of Rabon is behind this sand bar, and the nature of the tidal current at this area is unknown. If there is another counter current against this counter current, its strength will be under 0.5 knot.

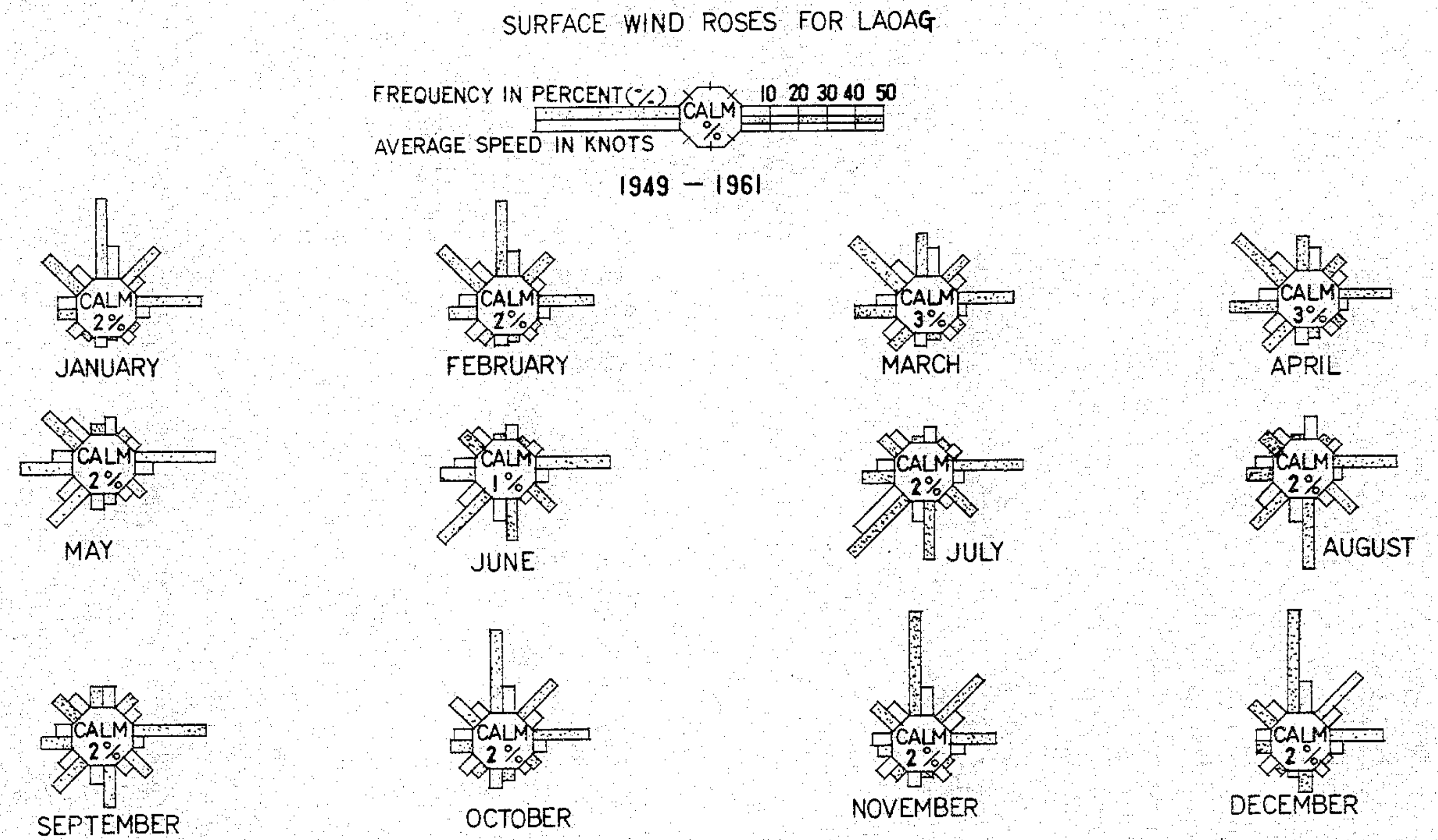
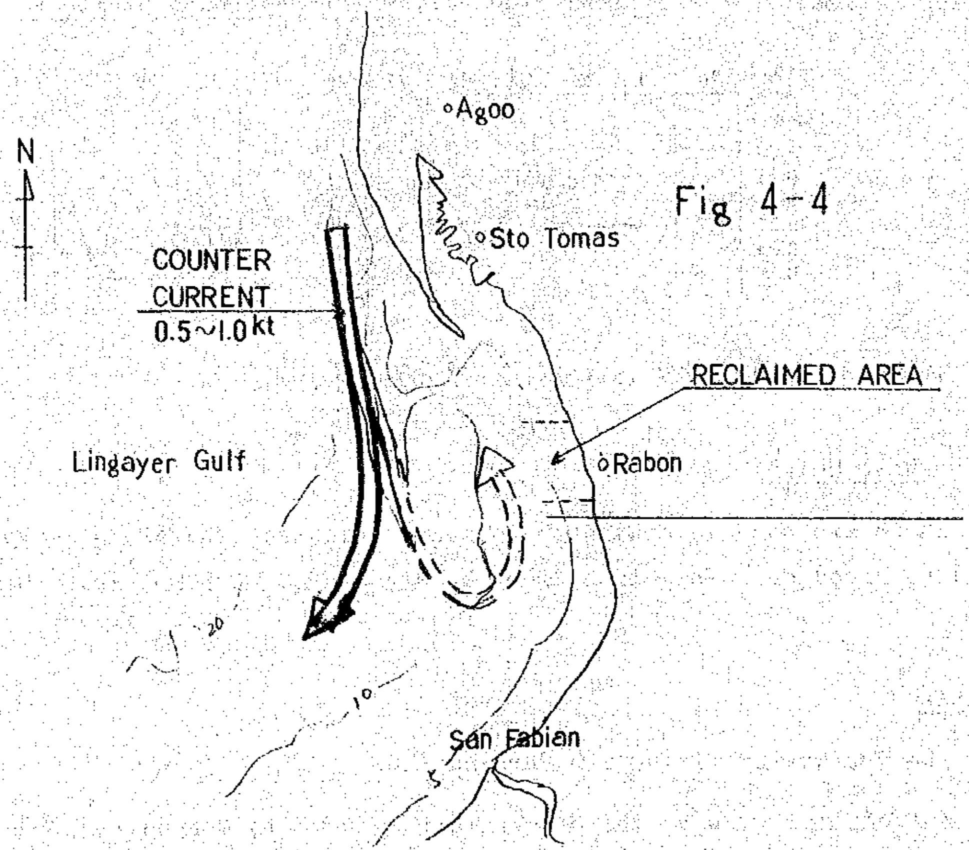

SURFACE WIND ROSES FOR LAOAG
FREQUENCY IN PERCENT(%)
CALM %
10 20 30 40 50
AVERAGE SPEED IN KNOTS
1949 — 1961
CALM 2%
JANUARY
CALM 2%
FEBRUARY
CALM 3%
MARCH
CALM 3%
APRIL
CALM 2%
MAY
CALM 1%
JUNE
CALM 2%
JULY
CALM 2%
AUGUST
CALM 2%
SEPTEMBER
CALM 2%
OCTOBER
CALM 2%
NOVEMBER
CALM 2%
DECEMBER

Fig 4-3




4.3.4 Tide Level

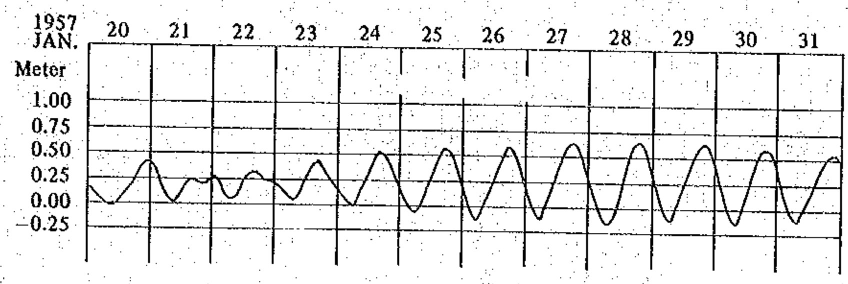
The tide level in the Lingayen Gulf is:

| | | |
|---|---|---|
| 1.20 m | HHWL | (Santo. Tomas) |
| 0.81 m | MWL | |
| 0.45 m | LLWL | |
| 0 m | ELW | |

Table 4-7 Tidal Information

| Place | Height referred to datum of soundings (MLLW) | | | | |
|---|---|---|---|---|---|
| | Mean High Water Interval | | Mean Higher High Water | Mean Tide Level | Extrame Low Water |
| | hrs. | min. | feet | feet | feet |
| Bolinao | 9 | 15 | 2.5 | 1.2 | -1.5 |
| Sual | 9 | 25 | 2.5 | 1.2 | -1.5 |
| Santo Tomas | 9 | 20 | 2.5 | 1.2 | -1.5 |
| San Fernando | 9 | 10 | 2.2 | 1.1 | -1.5 |

Table 4-8 Typical tide curves for reference stations




The tide table 1977 is shown in Appendix A-4-3-2.

### 4.3.5 Wave Height

There are no data available for wave heights. The desing wave height shall be based on information from the structures of ports near the Lingayen Gulf.

Example

i) The breakwater of the San Fernando port

A sectional view of the breakwater is shown in Appendix A-4-3-3.

From Appendix A 4.3.3, the height of the top surface ($R_c$)

= 4.0 m + MLLW

= 3.34 m + MHHW

$R_c = 1.25$ H

$R_c$ : Height of the top surface

H : Wave height in front of the breakwater (= H 1/3)

$$H = \frac{R_c}{1.25} = \frac{3.34}{1.25} = 2.7 \text{ m}$$

ii) The breakwater of the Navotas port (the Manila Gulf)

$R_c$ = 3.30 m + MLLW

= 2.8 m + MHHW

$$H = \frac{28}{1.25} = 2.3 \text{ m}$$

As the Lingayen Gulf has similar conditions of location to the San Fernando port, the desing wave height (H 1/3) shall be 2.7 m.

Fig. 4-5

# SURFACE CURRENTS SUMMER

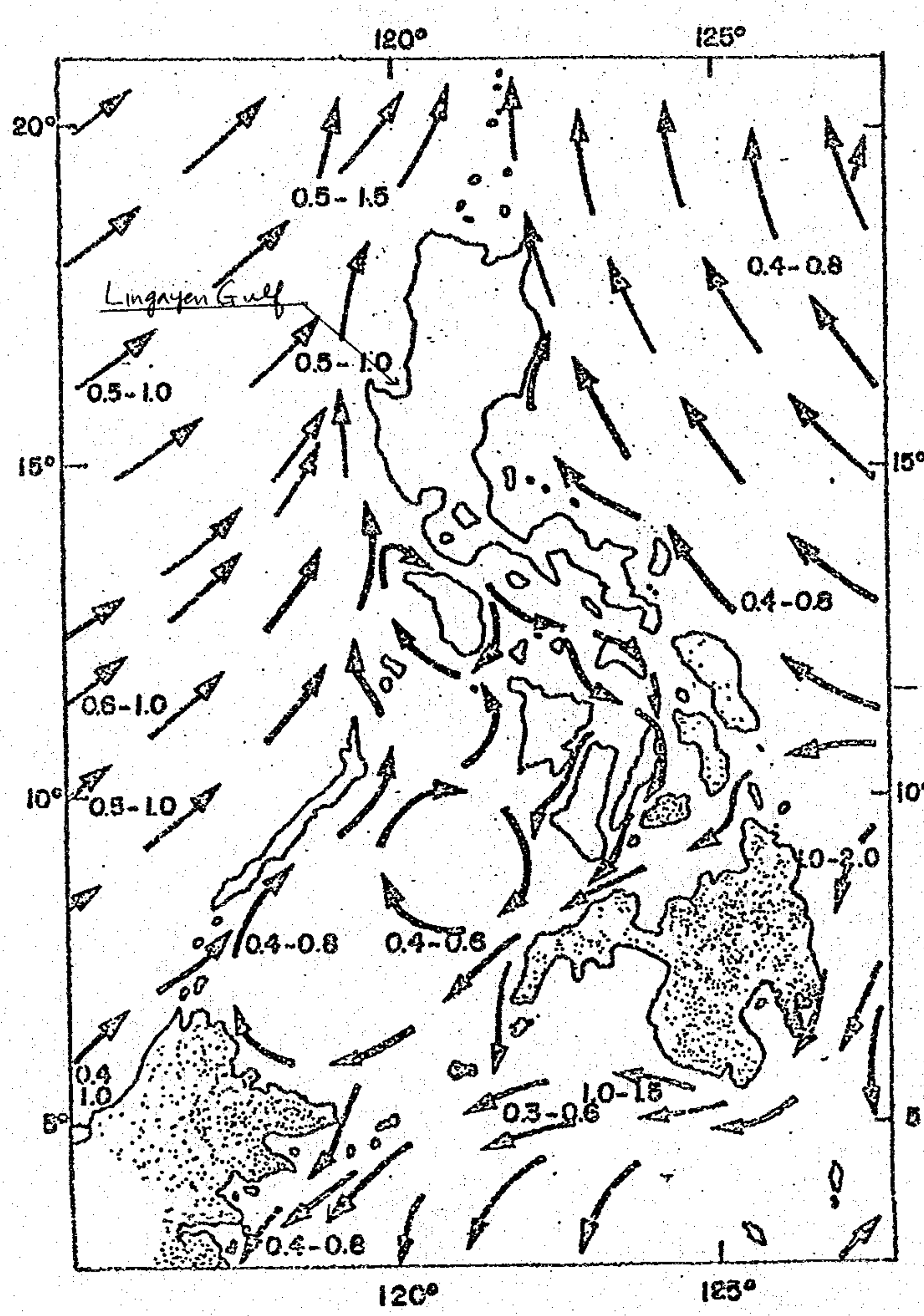
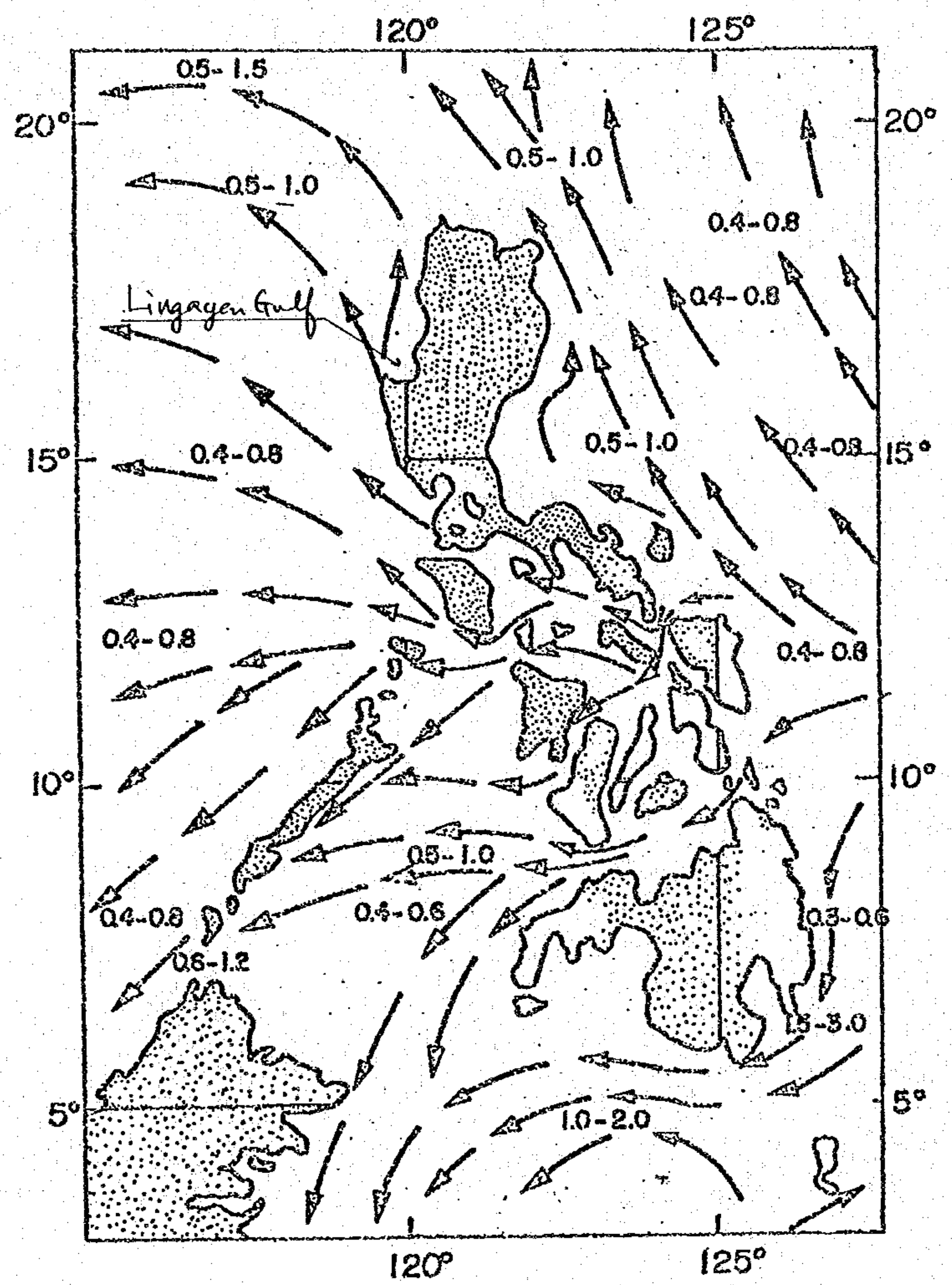


Fig. 4-6

# SURFACE CURRENTS WINTER



# CHAPTER 5

# BASIC PROJECT OF TLP SYSTEM

# CHAPTER 5

# BASIC PROJECT OF TLD SYSTEM

## 5.1 CHARACTERISTICS OF THE SYSTEM

### 5.1.1 Slurry from Several Different Mines

In this project, the flow of slurry with comparatively coarse-grained size from porphyry copper mines and the flow with comparatively fine-grained size from gold mines join together in the common line. Considerable long-term as well as short-term changes are expected in the physical properties of such mixed slurry resulting from the different properties of milled ore from several different mines.

The concentration of slurry usually varies with changes in the mine's operating conditions, seasonal and weather factors, suspension of the operation for maintenance and repair of the equipment.

Furthermore, operational conditions of a mine are often changed by transition in the metal market conditions, repair of the facilities, unexpected accidents, etc.

Since slurry from six (6) mines is considered in this Project, the above-mentioned variations may not take place when some factors compensate others. In planning the Project, however, it is necessary to consider in the meantime variations in volume and concentration of the slurry from each mine, particularly the slurry from the Philex Mine which accounts for about 80% of the total slurry produced. Changes in operation conditions, concentration and grain size of the slurry in this company therefore have a large effect on this Project.

To take care of these variations, a pretreatment plant may be installed at the starting point of the common line to adjust the slurry concentration and flow rate as well as check the abnormal slurry and remove foreign materials. However, it is impractical to adopt this method because it requires a large-scale plant and because the area where it is to be located is steep and often subjected to heavy rain. The alternative plan is to increase the inclination at different flow rates, concentrations and grain sizes, although in this method the flow passage will wear out faster.

### 5.1.2 Launder Line and Pipe Line

(1) Characteristics of the two systems

This TLP system for conveying slurry is a combination of launder line and pipe line, and these two (2) systems have different characteristics.

The launder has a free water surface and therefore, is not usually affected by changes in the slurry flow rate, while in the case of pipe, changes in the flow rate directly lead to changes in the flow speed and pressure loss producing a large effect on the natural flow transport system.

Table 5-1 shows comparison of itemized characteristics between launder line and pipe line.

Whenever the topographical conditions permit the above-mentioned merits of the launder line allows it to be adopted in the construction plan in preference to pipe lines. The pipe line must in principle be laid in pairs because the intervals of rotation and renewal are relatively short.

Fortunately, the tunnel line can be laid at a constant gradient and the 1.25% gradient can also be secured for the line at the plain part permitting the launder line system to be adopted for the entire area except for the area near the sea.

The minimum radius of curvature of the launder line will be about 100 m to facilitate the contents to flow smoothly.

(2) Gradient of the launder line

The gradient of the launder line must be determined considering two (2) points - 1) prevention of sanding, and 2) wear of the launder. The economical way to determine it is first to know the gradient for the limit flow speed where no sanding takes place, and then select a gradient above this value plus some safety allowance.

The limit flow speed varies with the composition of the transported contents, the flow characteristics, shape, material and surface roughness of the launder and can only be determined with accuracy by actual test under the same conditions as the actual slurry transportation. The present Project aims to transport the abrasive slurry over a distance of 19.7 km

Table 5-1 Characteristics of Launder Line and Pipe Line

| | | Launder line | Pipe line |
|---|---|---|---|
| Slurry volume ($m^3$/Sec) | Case of increase | Degree of freedom is large if concentration is same. | Degree of freedom is small because haed is necessary. |
| | Decrease | Degree of freedom is large. | Degree of freedom is small because water must be added. |
| Concen-tration (wt %) | Increase | Degree of freedom is large unless fluidity is r duced. | Degree of freedom is small because head is needed. |
| | Decrease | Degree of freedom is small because of increasing settling velocity in the range of coarse grain size. | Degree of freedom is large if water volume is same. |
| Transport tonnage (DMT/Sec) | Increase | Degree of freedom is large. | Small |
| | Decrease | Degree of freedom is small if water volume is same. | Large if water volume is same. |
| Average flow velocity (m/sec) | Setting allowance | Velocity must be given relatively large allowance as surface speed largely differs from bottom speed and sanding easily takes place. | Velociy can be set smaller than launder as variable head and flow velocity section prevent sanding. |
| Wear of liquid contacting part | Speed | Speed increases as velocity larger. | Relatively small. |
| | Counter-measure | Much more wear allowance can be taken. Repair is comparatively easy. | If wear allowance is large, construction cost becomes high. Rotation of the bottom and renewal of pipe are needed when used for a long time. |
| Measures in emergency | | Not necessary in principle. | Necessary |
| Ease and economy of execution | | Although main body is cheap in unit price, laying cost may become high due to conditions of location. | Unit price is high. Laid on land due to necessity of rotation. Execution is compara-tively easy. |

by means of the launder (aside from the 6.3 km transport by pipe) so that the field tests to determine the launder gradient is a must before the Project is exeuted. It will be adequate that these tests be conducted on the tailings from the Philex mine which accounts for about 80% of the total slurry to be disposed of by this system.

In the Plan, the launder gradient of 1.25% is adopted for the following reasons:

a. The Marcopper and the Atlas mines have already been disposing tailings with properties similar to those of the Baguio mining area. As shown in Table 5-1, their tailings are similar in grain size to those to be disposed of by this system. In both Marcopper and Atlas mines, the tailing slurry is concentrated to 45 ~ 50% by giant thickeners and sent through the concrete launder having a gradient of -1%. The thickener is used to recover ore dressing water and prevent sanding when the slurry in transit has low concentration.

b. Each of the six (6) mines may obtain comparatively much ore dressing water from their pits and has less need of reusing the overflow of the tailing slurry in the thickener. Furthermore, it is almost impossible to provide a large-scale thickener because of the steep slopes of the area. Therefore, the concentration of the slurry from each mine will be low i.e. 35 ~ 40%.

c. If a thickener were to be installed at Camp 4 where slurry feeder lines from the six (6) mines join together to increase the concentration to 50% or so, the gradient of the launder line in this system could also be 1% as in the Marcopper or Atlas line. But, the installation is impossible as mentioned previously due to the steep slopes around Camp 4. Accordingly, the -1.25% gradient was adopted in this plan in view of the low concentrations of the slurry. Then, the average flow speed of the slurry within the launder becomes about 10% faster than when the 1% gradient is adopted.

(3) Request to the mines concerning prevention of coarse-grained size particles entering into the system

The Philex mine which produces about 80% of the total volume to be disposed of by the system is now disposing tailings from their mill plant to the dam by means of pipe line with a gradient of -2.5%. This gradient seems to have been designed to prevent sanding caused by coarse-grained size particles and foreign substances mixed in the miscellaneous water (floor washing water, drainage from repair of ore dressing equipment, etc.). Equipment to remove such coarse-grained substances are of course necessary in this system. The common sump can remove particles larger than 5 mm, but those less than 5 mm can only be checked by equipment which are commercially impractical. For the purpose of this Project, therefore, each mine shall be required to establish measures to prevent coarse-grained size particles in the millimeter order from entering the tailings flow system within the ore dressing site.

To be concrete, the Philex mine should fully utilize their spiral classifier being used for the miscellaneous water line to remove coarse grained size particles. The miscellaneous water launder should completely be separated from the tailings launder to the earth and sand which may be brought into the site by heavy rain.

Countermeasures against floods by heavy rain are also necessary for the other mines.

(4) Request to the mines with regard to the tailings slurry concentration

The Philex Mine can obtain a sufficient volume of ore dressing water during rainy seasons and so can reduce the operation load of the thickener. But, it is expected of them to utilize the existing thickener and cyclones at all times to keep the slurry at a high, stabilized concentration. It is also expected of the other mines to fully utilize their existing concentrating facilities.

### 5.1.3 Utilization and Absorption of Altitude

In the TLP system, the distance from Camp 4 where the slurry from the six (6) mines is collected to the sea shore is about 26 km. and the elevation difference and average gradient are 610 m and 2.4% respectively.

Topographically, the route with a length of about 15 km from Camp 4 (SL 610 m) to the Bued River bank (SL 160 m) near Camp 1 passes through the mountainous area and is graded 2.9%. The remaining route about 11 km long goes through mostly plain area including the hills with a width of about 4 km located near the sea shore and has a mean gradient of 1.5%.

As mentioned previously, the optimum gradient of the launder line for natural-flow transport of slurry is 1.25%.

Therefore, the elevation difference should be utilized as much as possible for the natural-flow transport of slurry without using any artificial power, hence reducing equipment and operation costs.

The slurry conveyed to the seashore must further be carried about 6.9 km toward the offing and it is planned that the slurry will over this 6.9 km distance by elevation difference.

The gradient of the mountain area is 2.9% and that of the launder line is 1.25%, resulting in about 200 m of excess head. Some method must be employed to take care of this excess head.

The drop box system is usually employed to take care of this excess head, but it is difficult to construct or maintain several drop boxes at the mountain slopes because they are very steep and easily eroded.

The method of constructing artificial waterfall at a steep slope cannot be adopted because a considerable amount of earth, sand and water will inevitably enter the system from outside making the properties of the slurry in transit uncontrollable.

Underground Fall is proposed here which is easily constructed and maintained and does not permit the entrance of earth and sand from outside. The method is to open a vertical round hole between upper and lower tunnels to drop the slurry from the upper tunnel into the lower thru the round hole. The kinetic energy of the slurry is absorbed by the basin below the round hole.

When there is the possibility of encountering spring water in the round hole, waterproof grouting is done in advance and a base rock having a larger wear-resistance than concrete is selected as the location of the vertical round hole construction.

The excess heads at gentle slopes down the mountain and at the plain part will be absorbed by the drop boxes (or tanks).

### 5.1.5 <u>Gradient and Section of the Tunnel at Upper Mountain Part</u>

(1) Tunnel division

It is impossible to lay oaunder or pipe line as the common line facilities along the Kennon Road, because the area has steep slopes and many sharp curves. A tunnel must be driven through the mountainous area where the upstream part of the common line passes.

Camp 4 and vicinity is best suited as the starting point of the common line in view of economy in the total construction and operation costs required for feeder lines from the six (6) mines and the common line.

The tunnel outlet should be located at the eastern slope of the valley to the southeast of Dongon, cosidering the topography of the mountain area and the route at the plain under the mountain.

The length of this route division is about 13 km and its average gradient is 2.85% assuming that the inlet of the tunnel is 610 m above sea level and the outlet is 240 m above sea level.

The mountain area has quite steep slopes. The valleys are narrow and still suffering the violent erosions due to heavy rains. The nature of the rock changes from the lower metavolcanics around Camp 4 to the upper limestone and conglomerate at its downstream area. All rocks are hard and do not constitute any hindrance to the tunnel excavation. However, timbering work and measures against spring water are necessary as some fractures joints intersecting the tunnel at approximately right angles are anticipated.

(2) The gradient of tunnel

As mentioned above (Section 5.1.3), the tunnel should be graded by the same 1.25% as the launder and the excess head should be absorved by the Underground Fall provided within a rigid bed rock.

The combination of a tunnel 1.25% gradient and underground fall is not only practical for transporting the slurry but also has the following advantages:

a. Track excavation method can be adopted for either rising or falling gradient, if the gradient is 1.25%.

b. In order to shorten the term of works and reduce the ventilation equipment costs, the entire work program can be divided into several work sections provided with access tunnels. By providing the underground fall, the entrance to these tunnels may be located on a level with the Kennon Road, so that the construction cost for roads to the entrance and the facilities outside the tunnel is comparatively low.

c. To control the operation, a battery locomotive can be used for patrol and transport of maintenance materials to both upstream and downstream areas of the underground fall.

The disadvantages of the underground fall are the relatively high cost for opening the vertical cylindrical hole and the difficulty of inspecting the interior during operation. However, selection of a rigid bed rock and provision of another spare hole will be enough to overcome the latter disadvantage. This method is more advantageous than any other method in terms of total cost. No cost calculation was made concerning the other plans to make the tunnel gradient about 3%, to make the tunnel partially inclined, to provide many underground falls with small heads, etc.

(3) Section of the tunnel

The section of the tunnel should be wide enough to accommodate the launder to transport the slurry, the drainage ditch for spring water, the work space and passage for the patrol mini-locomotive, and allowances for future increase in the volume of slurry.

The dimensions of the tunnel section should also be considered view of the required work efficiency and the size of excavator employed.

The required dimensions of the tunnel section after completion are 2.8 m wide and 2.5 m high. There are two (2) methods of excavating the tunnel - track and trackless methods. The track method can achieve the work efficiency of 100 m per month imposed by the requirements of the work term. The trackless system is generally more efficient but expensive. The tunnel section excavated by this becomes wide and there are ventilation problems arising from excavation of a long tunnel. Therefore, this method cannot be adopted.

The smaller is the tunnel section, the cheaper is the cost for timbering work (steel material, shotcrete or concrete lining). Also, if the tunnel section is small, the excavation of the crushed rock in faulted zones and the waterproof grout work are relatively easy. Therefore, the recommended standard tunnel section must be 2.8 m wide by 2.5 m high.

### 5.1.5 Topography of the Plain Part (See Figs.1 and 2)

The topography of the district downstream of the Bued River after the common line has crossed it is divided by the Apangat River into the plain mainly used as paddies and farm lands and the hills leading to the seashore.

The distance from the Bued River Cross Point (SL 160 m) to the seashore is about 10 km with a gradient of about 1.6%, so that natural-flow conveyance of slurry is possible. No rising gradient is needed for the hills down the Apangat River if a tunnel is partially used and the launder line is detoured along rivers.

There is some excess head over this area which will be used as the head for the piping downstream by providing a small-scale head work and drop tank. The slurry can then be conveyed by gravity.

## 5.2 PRIOR CONDITIONS FOR THE PROJECT

### 5.2.1 Assumptions in Planning the TLP System

As is known from Section 3.1 which describes the purpose and development of the original plan, this TLP System Project is based on an Executive Order issued from the Philippine Government.

The following assumptions are made in planning the TLP System.

(1) The construction and operation of the common line will be supervised by the Philippine Government. The costs of construction and operation of the common line are likely to be paid by toll charges from the participating mines.

(2) Construction and operation of the feeder lines will be alloted to the six (6) mines now in operation at the Baguio area (Philex, BCK, BMI, Itogon, BX and Atok) according to the conditions of their respective operation.

However, the common line and the feeder line cannot be divided from each other from the standpoint of tailings disposal process. The Government and the six (6) mines will always cooperate in the design, work execution, operation and maintenance of the system, and when any problem occurs, they will individually or jointly if necessary, solve it promptly as possible.

(3) All the sites for the common line route will be acquired by the Philippine Government. The route is selected so that it may not become a direct obstacle to the houses and the activities of the local people. This rule is also applied to the site for the route in the sea area.

(4) No import taxes are calculated in the costs for this Feasibility Report, as it is supposed that all the imported materials for the construction and operation required in this Project are exempted from taxation.

5.2.2 Survey Means

(1) Means for the selection of route

A topographical map (scale: 1:5,000 or bigger) is necessary to dtermine the final route for the launder line or pipe line. A map with scale of 1:50,000 (photographed in 1947 and prepared in 1956) was enlarged to the scale of 1:25,000 and was used in the Feasibility Report. Because of the complicated topography of the area, a helicopter was employed. But it was only an auxiliary means to select the route and determine the location of the tunnel portals. Mapping based on the aerial photos should be made to prepare a detailed topographical map of 1:5,000.

A simplified land leveling was conducted in order to check the adequacy of the selected launder line route on the plain part.

(2) Geological survey

The major portion of the Project is the tunnel construction work. To clarify the nature of the rocks where the tunnel is constructed, physical and boring investigations are necessary. In this Feasibility Report, the geological survey of the ground surface, analysis of the aerial photos and leveling based on the data were conducted according to the survey schedule.

(3) Slurry transport test

When the flow characteristics of the object to be transported is not clear in a project of slurry transport over a long distance, it is usually necessary to conduct flow tests at a certain scale in order to confirm the data for the critical flow speed, concentration within the line section, grain size distribution, etc.

In this Feasibility Report, a flow transport system was planned based on the past transport records of similar slurries, the data and articles concerning various slurry transport fields in the Philippines. Due to various conditions, the adopted gradient of the launder line is slightly larger than the conventional. In view of the scale of this Project, it is desirable to carry out the flow transportation tests with gradients ranging from 1% to 1.25% in order to determine the final gradient to be adopted.

## 5.3 SPECIFICATION OF THE TAILINGS FOR TRANSPORT

The quantity and properties of the mixed tailings from the six (6) mines (specific gravity of tailings, concentration and size distribution of tailings) are shown below.

### 5.3.1 Setting the Conditions for the Project

(1) Quantity Volume of the tailings from each mine are shown according to their production plans for 5 years. (See Table 2-4).

The variation range in quantity is based on the conditions shown in Table 5-2 below.

Table 5-2 Variation Range in Quantity of Tailings

| | Maximum | Minimum |
|---|---|---|
| Philex | The supposed ore dressing capacity is 32,000 DMT/D (average capacity of 31,000 DMT/D plus an al owance of 1,000 DMT/D). | 70% of the average capacity is adopted assuming that the mill with the largest capacity become out of operation. |
| B.M.I. | Mean +10% | -10% |
| B.C.I. | The case when sand slime filling is suspended. | The case when sand slime filling rate of 35% is conducted |
| Atok | Mean +10% | -10% |
| Itogon | Mean +10% | -10% |
| B.X. | Mean +10% | -20% |

(2) Specific gravity of tailings: Same as the present conditions (See Table 2-5)

(3) Pulp density

The following values are adopted according to the present operation conditions. Each mine is requested to increase the minimum pulp density as high as possible.

| | Max. pulp density | Min. pulp density |
|---|---|---|
| Philex | 45% as the pulp density is 40 ~ 45% during dry season. | 35% as the pulp density is 35 ~ 40% during rainy season. |
| B.C.I. | 46% assuming that no sand slime filling is made. | 39% assuming that sand slime filling rate is 35%. |
| Other | Same as the present conditions (see Table 2-5) | |

(4) Grain Size: Same as the present conditions (See Table 2-5)

## Table 5-3 Data on The Characteristics of Slurry

( ) : Ratio of distribution

| | | Amount of Tailings (Ton/day) | Pulp Density P.D. % | Specific Gravity S.G. | Water Volume $m^3/D$ | Slurry Weight t/D | Slurry Volume $m^3/D$ | Slurry S.G. |
|---|---|---|---|---|---|---|---|---|
| Philex | Mean | 28,000 (80.7) | 40.0 | | 42,000 | 70,000 | 52,000 (77.7) | 1.341 |
| | Max. | 32,000 | 35.0 | 2.75 | 59,429 | 91,429 | 71,065 | 1.287 |
| | Min. | 19,600 | 45.0 | | 23,956 | 43,556 | 31,083 | 1.401 |
| B.M.I. | Mean | 3,600 (10.4) | 33.0 | | 7,309 | 10,909 | 8,694 (13.0) | 1.255 |
| | Max. | 4,000 | 28.0 | 2.60 | 10,286 | 14,286 | 11,824 | 1.208 |
| | Min. | 3,200 | 38.0 | | 5,221 | 8,421 | 6,452 | 1.305 |
| B.C.I. | Mean | 2,150 (6.2) | 41.0 | | 3,094 | 5,244 | 3,890 (5.8) | 1.348 |
| | Max. | 2,900 | 46.0 | 2.70 | 3,404 | 6,304 | 4,478 | 1.408 |
| | Min. | 1,900 | 39.0 | | 2,972 | 4,872 | 3,676 | 1.325 |
| Atok | Mean | 450 (1.3) | 37.5 | | 750 | 1,200 | 930 (1.4) | 1.290 |
| | Max. | 500 | 32.5 | 2.50 | 1,038 | 1,538 | 1,238 | 1.242 |
| | Min. | 400 | 42.5 | | 541 | 941 | 701 | 1.342 |
| Itogon | Mean | 400 (1.1) | 29.0 | | 979 | 1,379 | 1,127 (1.7) | 1.223 |
| | Max. | 440 | 24.0 | 2.70 | 1,393 | 1,833 | 1,556 | 1.178 |
| | Min. | 360 | 31.0 | | 801 | 1,161 | 934 | 1.243 |
| B.X. | Mean | 90 (0.3) | | | 263 | 353 | 294 (0.4) | |
| | Max. | 100 | 25.5 | 2.90 | 292 | 392 | 326 | 1.201 |
| | Min. | 70 | | | 205 | 275 | 229 | |
| Total of 5 mines except for Philex | Mean | 6,690 (19.3) | 35.05 | | 12,395 | 19,085 | 14,935 (22.3) | 1.278 |
| | Max. | 7,940 | 32.60 | 2.64 | 16,418 | 24,353 | 19,447 | 1.254 |
| | Min. | 5,930 | 37.84 | | | 15,670 | 11,992 | 1.307 |
| Total | Mean | 34,690 (100.0) | 38.94 | 2.71 | 54,395 | 89,085 | 67,135 (100.0) | 1.326 |
| | Max. | 39,940 | 34.50 | 2.72 | 75,842 | 115,782 | 90,487 | 1.280 |
| | Min. | 25,530 | 43.11 | 2.72 | 33,696 | 59,226 | 43,075 | 1.375 |

### 5.3.2 Specifications of Transported Slurry

(1) The tonnage and specific gravity of tailings, the pulp density, quantity and specific gravity of the slurry are tabulated in Table 5-3 based on the conditions shown in the Section 5.3.1.

(2) Maximum and minimum quantities of slurry

The maximum volume of slurry from each mine is calculated using the maximum quantity of tailings and the minimum pulp density of slurry.

The minimum volume of slurry is calculated using the minimum quantity of tailings and the maximum pulp density of slurry.

The pulp density of the slurry from BCI is as shown in Section 5.3.1 (3).

(3) Setting of quantity and pulp density of the slurry to be transported.

Based on Table 5-3, conditions of the slurry to be transported are set in Table 5-4.

Table 5-4

| | Tonnage of tailings | Volume of slurry | Velocity of slurry | Pulp density | Specific gravity |
|---|---|---|---|---|---|
| Average | 35,000 DMT/D | 67,100 $m^3$/D | 0.78 $m^3$/S | 39% Solid (wt) | 1.33 |
| Maximum | 40,000 DMT/D | 90,500 $m^3$/D | 1.05 $m^3$/S | 35% Solid (wt) | 1.38 |
| Minimum | 25,500 DMT/D | 43,000 $m^3$/D | 0.50 $m^3$/S | 43% Solid (wt) | 1.38 |

(4) Grain size distribution

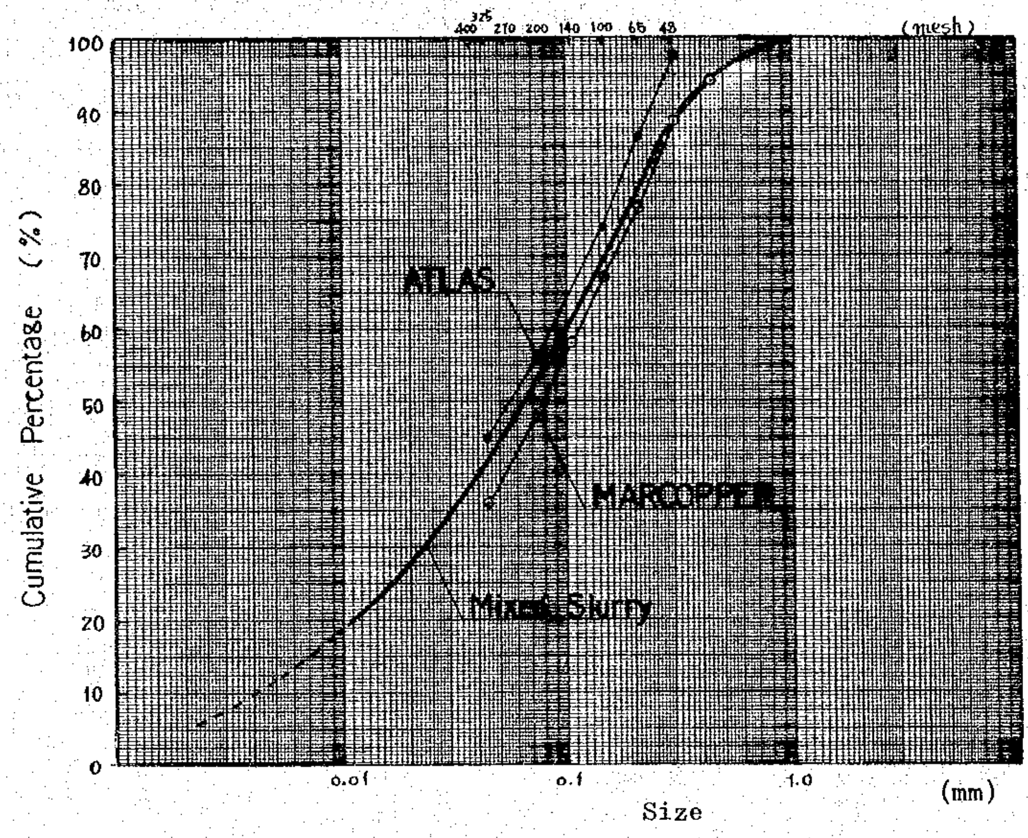
Fig. 5-1 shows grain size distribution of the mixed slurry which resulted from synthesizing the grain size distributions of tailings from the six mines. The figure includes the grain size distributions of the tailings from Atlas and Marcopper. As seen from the figure, grain size of the tailings dealt with in this Project is between those of the Atlas and the Marcopper.

Fig. 5-1 Particle Size Distribution of Mixed Tailings

| Size | | total | 48 | 65 | 100 | 140 | 200 | 270 | 325 | 400 |
|---|---|---|---|---|---|---|---|---|---|---|
| | m/m | total | 0.295 | 0.208 | 0.147 | 0.105 | 0.074 | 0.053 | 0.043 | 0.037 |
| Percentage by weight (%) | | 100.0 | 10.4 | 7.6 | 9.7 | 8.3 | 8.1 | - | 13.9 | - |
| Cumulative percentage (%) | | 100.0 | 89.6 | 82.0 | 72.3 | 64.0 | 55.9 | - | 42.0 | - |

| Size | mesh | | | | | |
|---|---|---|---|---|---|---|
| | | 30.5 | 22.7 | 15.8 | 12.4 | -12.4 |
| Percentage by weight (%) | | 7.0 | 5.6 | 4.9 | 4.3 | 20.2 |
| Cumulative percentage (%) | | 35.0 | 29.4 | 24.5 | 20.2 | |

Cumulative Size Distribution Curve



## 5.4 PLANNING OF THE SYSTEM

A flow sheet based on the basic plan of TLP System is shown in Fig. 5-2.

In this study, the quantity and quality of the tailings produced by the six mines have been determined previously (See Table 5-3). The tailings are received by the common sump and then allowed to flow continuously - in principle - to the sea area through the launder and pipe lines.

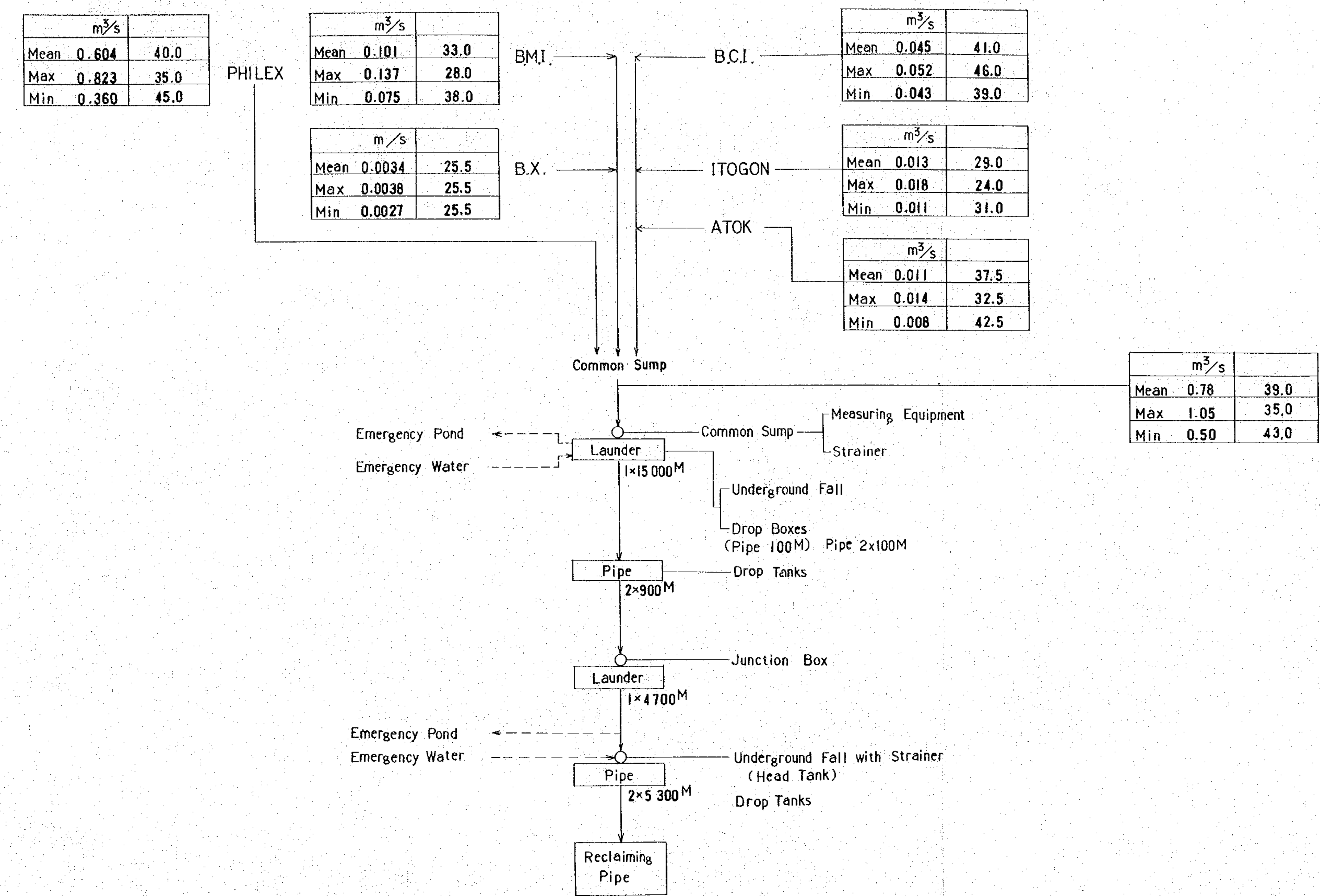
Slurry transport facilities will be designed to accommodate a certain range of variations in quantity, concentration and grain size of the slurry.

The emergency ponds will be provided to drain the slurry from the line when the common line becomes inoperational. Further, the emergency water supply equipment will be provided to wash the interior of the line when its operation stop or prevent sanding within the line when the slurry flow decreases.

The equipment to measure the flow and concentration and the strainers to remove the foreign materials mixed in the slurry are installed at the common sump.

Other provisions are a jeep or small-size truck to patrol and inspect the outside tunnel, a mini-locomotive for inspection and other use inside the tunnel, and a telephone system over the entire length of the flow line. Furthermore, telephone lines to communicate with other mines will also be provided.

Fig 5-2 Flow Sheet of System Plan



# CHAPTER 6

# THE FEEDER LINE PLAN

## CHAPTER 6

## THE FEEDER LINE PLAN

The feeder line which delivers the tailings from the mines to the starting point of the common line at Camp 4 will be constructed and maintained by each respective mine.

In this Chapter, the feeder line plan of each mine which has been disclosed in the mission's interview with the different mines is examined from the view points of technology, term of works and economy. Then, the recommendations are made as an aid for their future enforcement plan. A plan and a sectional view of the recommended system are shown in Figs. 4 and 5.

### 6.1 PHILEX

#### 6.1.1 The Mine's Plan and Its Problems

The Philex mine plans to excavate a tunnel (-3% in grade and 5 km long from their mill (SL 950 m) to Camp 4 for slurry transport by the launder passing through it. The excavation will be made by trackless method to develop the tunnel with a section 4.0 m wide and 3.5 m high within three (3) years. Designed mainly for transport of tailings, this tunnel is also intended for prospecting. The location and level of the tunnel entrance and the tunnel route are not yet determined. This plan has the following problems.

(1) Gradient

The flow speed of slurry at the gradient of -3% is supposed to be 3.9 m/s, which is about 1.34 times larger than the flow speed of 2.9 m/s at the gradient of -1.25% proposed for the common line in this Project. If the wear on the transport facilities (launder and pipe) is proportional to the square of the flow speed, the wear rate will be 1.8 times faster than if the gradient is -1.25%. This means that the life of the launder is reduced to 55%, and that maintenance cost during operation will soar up.

(2) Altitude difference at Camp 4

When the tunnel is developed at a gradient of -3% from the Philex mill (SL 950 m) toward Camp 4, it will reach the mountain slope (SL 825 m) southeast of Camp 4 where the total length is about 4,200 m. If the gradient of -1.25% is adopted, it reaches a point on the mountain slope (SL 900 m) where the total length will be about 4,000 m.

The starting point of the common line is at 610 m above sea level and the required height of the junction facilities with the feeder line is about 6 m. Therefore, the terminal of the feeder line will be at 616 m elevation.

When the gradient is -3%, the horizontal distance from the terminal of the feeder line to the tunnel exit is about 800 m, and the altitude difference between them is 209 m. The drop box system may be available to the excess head for this section. However, there are problems such as difficulties of construction and maintenance during operation, high construction cost, etc. due to the steep terrain.

(3) Term of works

Philex is now constructing a drainage tunnel at a place 745 m above sea level. The monthly excavation distance is about 80 m. It will require more than four (4) years to excavate the total length of 4,000 m at this rate. Almost five (5) years will be needed as the term of works including the preliminary work period and the period for installing the slurry transport equipment. Further, the excavation of a long distance tunnel requires special ventilation and drainage facilities.

The term of works for the common line is estimated at three (3) years. If the feeder line tunnel is excavated only from the side of the Philex mill the completion date will be far behind that of the common line. Excavating this tunnel from both sides is difficult because excavation of the tunnel entrance at the mountain slope (825 m above sea level) at Camp 4's side is difficult due to steep terrain, as mentioned previously.

### 6.1.2 Recommendations

An alternative plan is proposed to solve such problems as wear of the facilities, altitude difference and term of works.

The tunnel should be excavated from both sides - from the tunnel entrance of the common line tunnel (SL 616 m) at Camp 4's side and from the Philex mill (SL 950 m).

In this case, the total length of the tunnel will be about 5,000 m. The excavation length is 2,600 m (gradient: +1.25%) from Camp 4's side and 2,400 m (gradient: -1.25%) from the Philex mill's side. Altitudes of the terminal of each tunnel will be 648.5 m and 920 m above sea level respectively and differs 271.5 m from each other.

Two vertical holes for underground falls each 550 mm in dia. (one of them is spare) will be provided at this terminal point to take care of the excess head. The slurry will flow down the underground fall. Further, a vertical hole 250 mm in dia. will be opened along the underground fall to accommodate the drainage hole and communication cable.

The excavation method for these vertical holes is described in detail in Chapter 8. Tunnel Construction Work. No problems are anticipated in this case.

The rock where the underground fall is to be excavated is hard meta-volcanics and diorite of the Pugo Formation which have wear resistance higher than concrete. Even if the inner wall is worn off, a rock collapse to block up the vertical hole will unlikely occur.

Below are the construction cost and the term of works on the excavation of the vertical holes:

| | Construction Cost | Term of Work |
|---|---|---|
| Holes each 550 mm in dia. (270 m long x 2) | 2,300 x 1,000₱ | 3.0 month |
| Waterproof grout work | 250 | 1.0 |
| Hole 250 mm in dia. (270 m long x 1) | 500 | 1.0 |
| Total | 3,060 | 5.0 |

The above cost and the term of works do not include the cost and period required for transporting the equipment from Japan to the Philippines. In case the same type of Raise Boring Machine cannot be procured within the Philippines, the transportation cost of about ₱155,000 and a six (6) months advance order for the machine will be further required.

There are several items to be provided at the expense of the contractor, such as power supply of 150 kw, 200V, etc.

The tunnel entrance at the side of Camp 4 is adjacent to that of the common line. It will be more economical when the facilities are in common use.

## 6.2 B.C.I.

### 6.2.1 The Mine's Plan

B.C.I. concentrates the ores produced from the Acupan and Antamok mines at the Balatoc mill located midway between the two (2) mines. The B.C.I.'s feeder line project is to transport the tailings over a distance of three (3) kms from the southernmost end of level L-2000 (850 m SL), one of the main level of the Acupan mine, to Camp 4 by means of the launder and pipe line. Feeder line will pass through the tunnel route with a length of 1,800 m (not yet excavated) and the land route with a length of 1,200 m. This tunnel is also intended for prospecting the Pugo mine located on the way to Camp 4. The elevation, gradient and route of this proposed tunnel are not yet determined.

### 6.2.2 Recommendations

(1) Transportation route

According to the B.C.I.'s plan, the distance from the southernmost end of the Acupan Mine level L-2000 to Camp 4 is three (3) kilometers. However, with the starting point of the common line being located south of the Camp 4 area, the length will increase to about 4 km.

Utilization of the existing transport level as a part of the feeder line is quite reasonable as construction cost and term of works will be reduced. Therefore, a proposal for an alternative plan is not necessary.

(2) Tunnel part

The level L-2000 from the Balatoc Mill to the Acupan Mine measures about 5 kms long and +0.5% in gradient. If the starting point of L-2000 is at elevation 850 m, the southernmost end of the level will be at 875 m above sea level. The differences in elevation between the southernmost end of the level and the lowest level of the Mill (840 m SL) is 35 meters. Considering the frictional loss of 17 kg/cm$^2$ within the transport pipe, a pump with pressure, of 22 kg/cm$^2$ is required to transport the slurry.

The power cost for transporting the slurry will become a tremendous amount over a long time and it is desirable to reduce the required pressure of the pump as low as possible.

Further, the concrete launder system is more favorable than pipe line system considering the total cost, including the construction and operation costs, so that the tunnel which will be constructed should preferably be given a falling gradient, i.e. -1.25%.

In this case, the tunnel will measure about 2 km long and the tunnel entrance will be at 850 m above sea level and located at a comparatively gentle mountain slope northwest of Camp 4.

(3) Land part

The distance from the tunnel exit to the junction point with the common line is about two (2) km and the elevation difference is 234 m. At this section, it will be desirable to adopt the pipe line system where drop boxes are employed to absorb the excess head.

The slope is comparatively gentle although there are three (3) valleys to be crossed. The construction method to be adopted should be cheap and practical and should provide preventive measures against flood, rolling stones and driftwood in order to eliminate troubles in the maintenance of the system.

In view of these requirements, it may be more expedient to shift the location of the tunnel exit south to reduce the number of the valleys to cut across, although it will increase the length of the tunnel. Anyway, the problem requires further detailed studies.

## 6.3 <u>ITOGON</u>

### 6.3.1 <u>The Mine's Plan and Its Problems</u>

Itogon desires to join their feeder line including a tunnel and the line on the slope, which connect the Itogon Mill to B.C.I.'s Balatoc Mill, with the B.C.I.'s feeder line. However, no discussions about the altitude, route, etc. of the feeder line have yet been made.

This idea has the following difficulties:

The distance betwen Itogon Mill and B.C.I.'s Balatoc Mill is about three (3) km, and the elevation difference is 310 m between the thickener of the Itogon mill (1,150 m SL) and that of the Balatoc mill (840 m SL).

If the tunnel is excavated from the side of the Itogon mill, the tunnel part will become shorter and the land part will increase beyond two (2) kilometers. The land section has slopes making it difficult to construct drop boxed and pipe line.

If the tunnel is excavated from the side of the Balatoc Mill towards, it will reach an underground point about 370 m below the Itogon Mill. Therefore, the slurry has to be dropped first through a shaft or boring hole before it is sent through the tunnel to the Baltoc Mill. Furthermore, the excavation of a tunnel with a length of three (3) km only from the side of the Balatoc Mill is problematic regarding the term of works.

Another question is that the equipment investment on a slurry transport system three (3) kms long might be too big for Itogon whose income in recent years have not always met the expenses. In view of the present conditions of their deposits and production, their income will not satisfactorily increase unless the gold price is much improved.

### 6.3.2 Recommendations

As mentioned previously, the Itogon Mine is adjacent to the B.C.I. Acupan mine and B.C.I. is planning to utilize the level L-2000 of the Acupan mine as a part of their feeder line. The Itogon mine's main shaft, is located 1,500 m from the Acupan mine's L-2000 and is deeper than the latter. Further, the Taka Shaft is located 250 m from the thickener of the Itogon Mill. Therefore, it seems that the most realistic approach is to develop a tunnel with a length of 1,500 m which will connect the Itogon's Taka Shaft and the Acupan mine's L-2000 (the tunnel length will be shortened if the old level on the way can be utilized) and join it with the B.C.I.'s feeder line.

It is desirable to join the Itogon's feeder line with the downstream launder part of the B.C.I.'s feeder line, as joining it with the pipe section of the latter may cause troubles in maintenance and control of the system.

On principle of mutual cooperation among the six (6) mining companies which is the basic idea of the TLP System Project, Itogon and B.C.I. should agree that the two mining companies have the same slurry transport system for common use and connect the two mining areas under differenct ownership by linking their levels together.

## 6.4 ATOK

### 6.4.1 The Mine's Plan

Atok desires to connect their feeder line with the B.C.I. line.

The B.C.I.'s Antamok mine is adjacent to the east side of the Atok mine and B.C.I.'s Kelly Group is on the west. B.C.I. is requesting Atok for their permission to construct a tunnel to prospect their Kelly Group. The tunnel will pass thru Atok mine to the Kelley Group on a level with Atok's L-4 (856 m SL). Atok thinks that if they accept B.C.I.'s proposal, they will be able to utilize the B.C.I.'s feeder line.

### 6.4.2 Recommendations

Atok's L-4 (856 m SL) is located substantially on the same level as the main transport level 400 L (850 m SL) which connects the Antamok mine with the Balatoc mill. A slurry transport line can be formed by utilizing this route - Atok mill - Atok Mine's vertical shaft and adit - Atok's L-4 (the prospecting drift for the Kelly) - Antamok's 400 L - Balatoc Mill.

In this case, the transport line with a length of 2,000 m from the Atok Mill (945 m SL) to the entrance of the vertical shaft (997 m SL) has a rising gradient and necessitates power to transport the slurry to a higher level. However, the transport level - 400 L - to the Balatoc Mill is downward with a falling gradient of 0.5%. Therefore, no power will be needed for slurry transport for a line about five (5) km from Atok mine's vertical shaft to the Balatok mill if the head within the vertical shaft (140 m) is used.

The B.C.I.'s feeder line starts from Balatok mill, and the slurry from Atok's joints at the Balatok's mill. Atok has to make arrangements with B.C.I. concerning the volume, the pulp density, the size distribution and operating time to transport their slurry.

## 6.5 B.M.I. AND B.X.

### 6.5.1 Mine's Plan

B.M.I. and B.X. will cooperate in constructing a drainage tunnel from the north side of the Bued River north of Camp 4 to the bottom of B.M.I.'s No. 2 shaft.

This drainage tunnel is about four (4) kms long and graded 0.25%. The tunnel exit is 625 m above sea level and located about 1.2 km north of the junction point with the common line. They have already excavated about 900 m, but have stopped operation.

### 6.5.2 Recommendations

As the tunnel has a low gradient of 0.25%, it is impossible to transport the slurry by gravity through the launder. The B.M.I. mill is at 783 m SL and connected with the bottom of the No. 2 Shaft via an inclined shaft. Further, since the B.X. mill is at 800 m SL and located adjacent to the B.M.I.'s No. 2 shaft, it is easy to transport the slurry from the mill to the shaft bottom via the No. 2 shaft. Therefore, the slurry from the two mills can be transported down via their respective pipes and join together at the shaft bottom (675 m SL) and then through the pipe in the drainage tunnel by gravity.

The exit of the drainage tunnel is located at the middle of the bluff bank of the Bued River. The most economical piping layout from this place to the common sump, which is joined with the common line, will be to corss the river passing the river side of the Kennon Road (the back side of the stone-wall guard for automobile), then under the second downstream bridge and goes in parallel with the feeder line from B.C.I. This route has partially a rising gradient part but the head in the shaft will be enough to transport the slurry. Further detailed discussions are necessary on whether or not this head can accommodate variations in the flow volume and pulp density and grain size of slurry.

The drainage tunnel should be excavated from two sides - from the downstream tunnel entrance and from the shaft bottom. The required legnth to be excavated is about 3.1 km but a fully mechanized excavation from the downstream side appears difficult due to bad location conditions.

If the excavation is made only from the downstream side, completion will be much behind the work term of two (2) years or so.