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Engineering geology of Sungai Piah Hydro-Electric Project, Perak, Peninsular Malaysia

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Abstract: The Sungai Piah hydro-electric Project is situated some 57 km north-northeast of Ipoh. The area is mountainous and heavily forested.

The general outline of the project is for diverting water from Sungai Temor to Sungai Piah and then through a series of tunnels down to a lower elevation, thus developing an effective head of about 680 m and a generating capacity of 46.5 MW. Approximately 20 km of tunnel lines, comprising 2 stages of diversion and power tunnels, are proposed for the hydro-electric project.

Preliminary geological mapping was conducted in October and November 1982 and a feasibility study consisting of surface mapping together with geotechnical investigation and a diamond drilling programme was undertaken from early August to November 1983.

The area is underlain predominantly by coarse-grained porphyritic biotite granite with a 4 km x 7 km roof pendant to the northwest. The roof pendant consists of quartz-mica schist and calcsilicate hornfels.

The Stage I scheme is expected to encounter more faults than the Stage II scheme which would require more lining for the tunnel. The Chier fault, which is the largest in the area, affected the location of both the tunnel portal sites of the Stage II diversion tunnel. They had to be relocated further downstream away from the fault zone.

INTRODUCTION

The Sungai Piah Project is one of the smaller hydro-electric schemes of the National Electricity Board. It is being investigated by the Shawinigan Engineering Company Limited, a consultant firm from Canada. The Geological Survey of Malaysia provides complementary services and support to this investigation.

The project area which is located about 57 km north-northeast of Ipoh is mountainous and heavily forested (Figure 1). It is accessible by metalled road to Lasah, beyond which only timber tracks exist.

The proposed tunnel line is approximately 20 km long and comprises 2 stages of diversion and power tunnels. Stage I (Upper Scheme) would provide for the diversion of Sungai Piah at elevation 800 m to a conventional surface powerhouse near Sungai Toor at elevation 534 m thereby developing 266 m of head (Figure 2).

Stage II (Lower Scheme) would involve a second diversion of the Sungai Piah immediately downstream of the Sungai Toor - Sungai Piah confluence, with the Piah flows being supplemented by a diversion from the Sungai Temor, to an underground powerhouse at elevation 120 m. Stage II would provide development of 414 m of head. The combined gross head of the two stages of development is 680 m with a generating capacity of 46.5 MW.

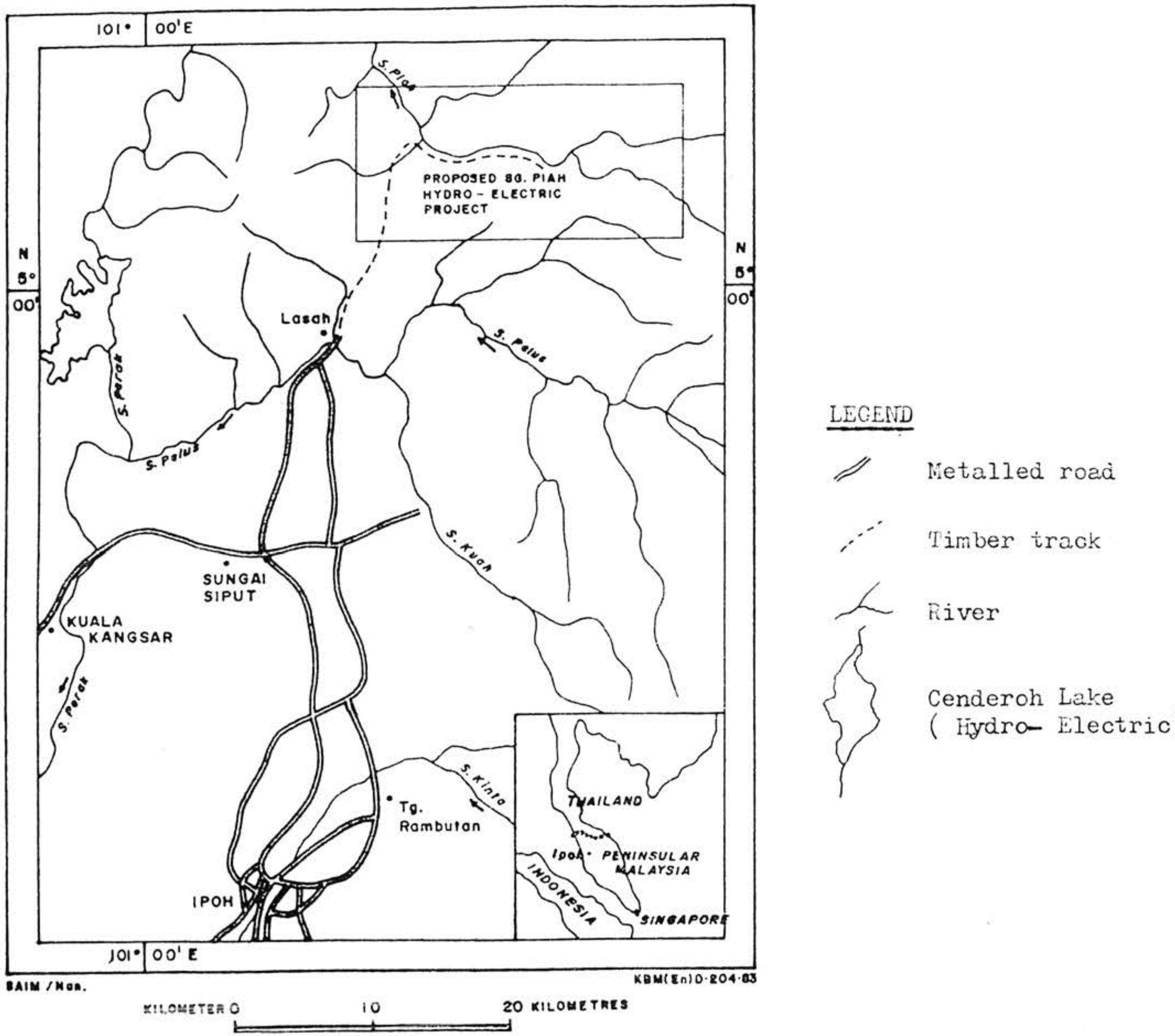


Fig. 1 Location map

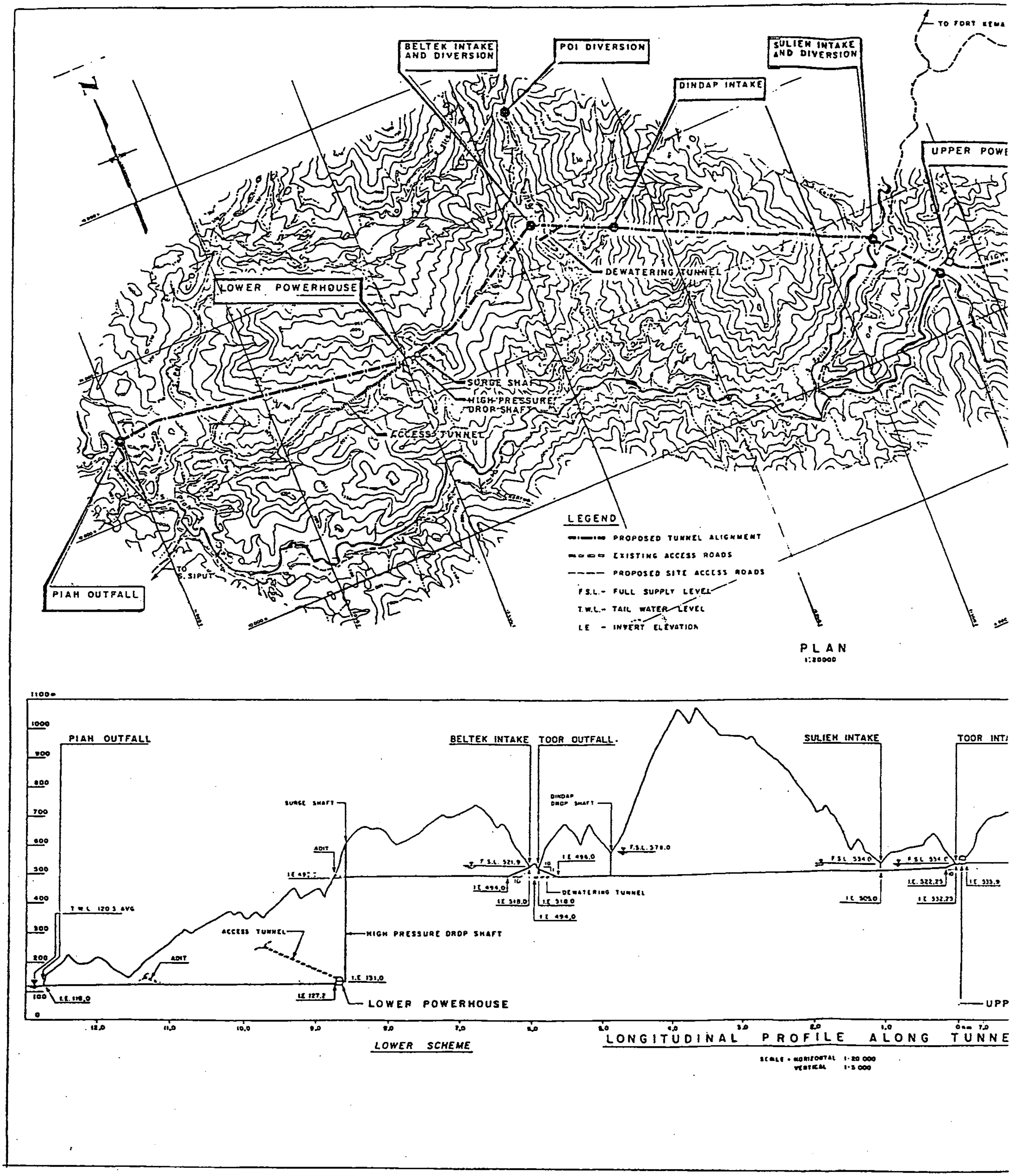


Fig. 2 Longitudinal profile along tunnels

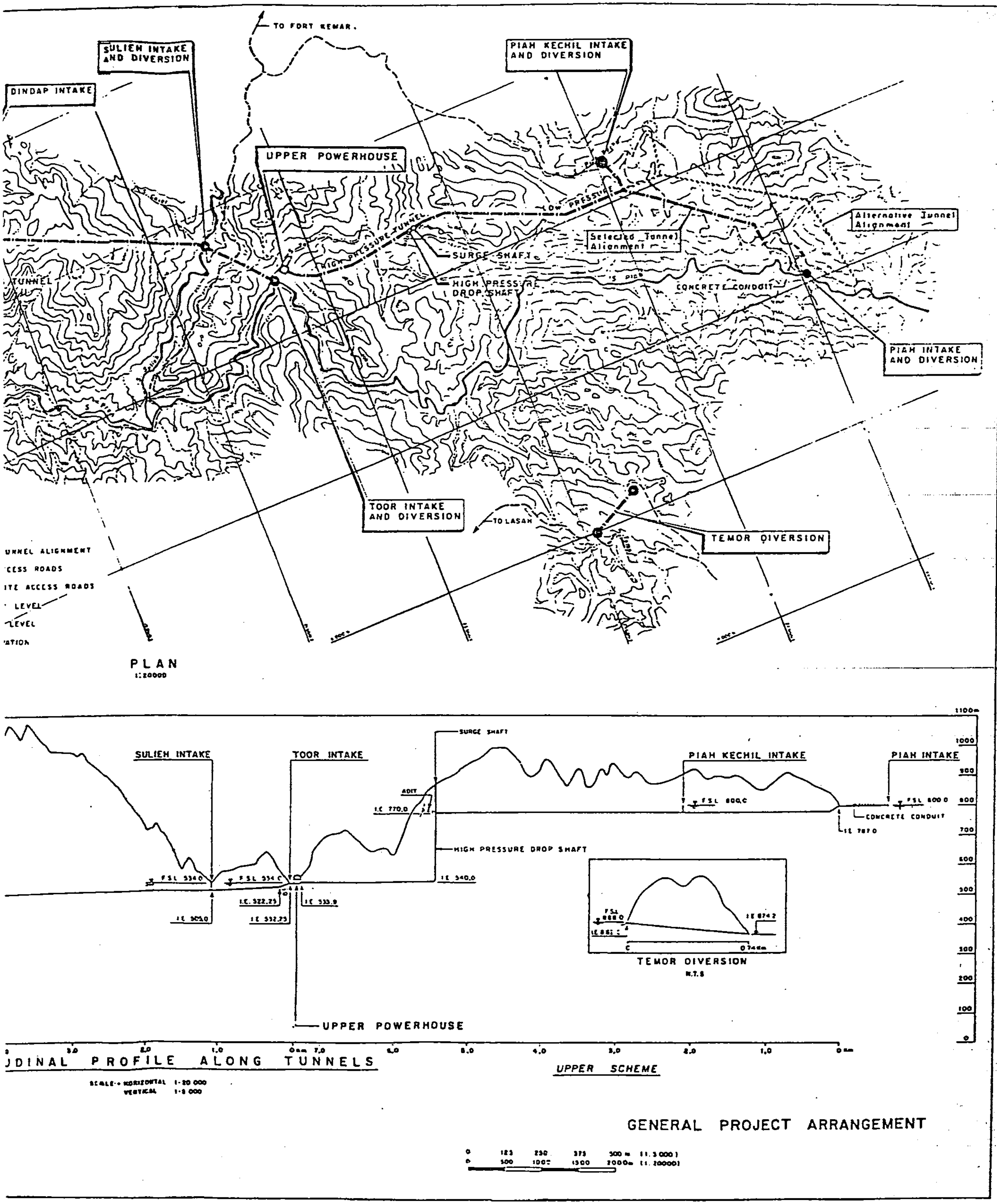


Fig. 2 Longitudinal profile along tunnels

The geological fieldwork was conducted in October and November, 1982 and continued in August and September 1983. A feasibility study consisting geotechnical and subsurface investigations was carried out from early August to November, 1983.

GEOLOGY

Porphyritic biotite granite is the dominant rock-type in the area. Apart from that, the area is also underlain by a roof pendant of quartz-mica schist which is intercalated with bands of calc-silicate hornfels (Figure 3).

The porphyritic granite underlies approximately $^1/_3$ of the length of the Stage II (Lower Scheme) tunnel line and the whole length of the Stage I (Upper Scheme) and the Temor diversion tunnel lines. This medium- to coarse-grained biotite granite has finer-grained varieties near its contacts with the roof pendant. Xenoliths of schistosed materials and dioritic rocks are also common in the granite.

In general, the contact between the porphyritic granite and the roof pendant is sharp. However, fault contacts are occasionally encountered, especially along the Sungai Beltek (tributary of Sg. Dindap). The intrusive contact between the granite and roof pendant is well exposed in a number of localities.

The roof pendant consisting of quartz-mica schist and banded calc-silicate hornfels underlies the north-western part of the map area and covers the western 2/3 of the proposed Stage II tunnel line. Lenses of quartz are commonly developed along the schistosity.

The average joint spacing is 15-75 cm in the granite and 10-100 cm in the metamorphic rocks. The joints trend either NE-SW or NW-SE.

A large number of faults were found in the area. Of these only two are of significance, of which the larger is named the Chier fault. It runs down the Sungai Chier and crosses a narrow ridge to form a short stretch of the Sungai Piah. It trends in a NW-SE direction and is evidenced by the presence of mylonised and shear zones around the confluence of Sungai Piah-Sungai Toor. This fault zone has a collective width of hundreds of metres. The smaller fault, named Beltek fault, follows the Sungai Beltek, a tributary of Sungai Dindap, in a N-S direction. It is also associated with NE-SW direction shear and fracture zones. Minor faults are too numerous to depict on the map, they are normally from 0.3 - 3 m wide with trends of NE-SW, ENE-WSW or NW-SE.

Narrow mylonised, brecciated and silicified zones are fairly common. They are normally a few mm to 4 cm wide and are commonly associated with zones of close spaced joints. These zones commonly strike either in the NW-SE or NE-SW to NNE-SSW directions.

Several major and minor lineaments were located by aerial photographs. All the major lineaments trend either NE-SW or NW-SE whereas the minor lineaments trend in various directions, namely NE-SW, NNE-SSW, NW-SE, E-W, ENE-WSW.

The strong linear physiographic expression of a quartz reef was mapped at the Temor Diversion area. It is approximately 300 m wide and 2.5 km long and trending NW-SE.

SUBSURFACE INVESTIGATIONS

The objective of the subsurface investigation programme was to determine the characteristics of the subsurface materials in selected structure locations, primarily to assess excavation or other foundation treatment requirements. The bulk of the investigation was concentrated on locating the proposed tunnel portals, intake and diversion sites. Location of the drilled holes is shown in Fig. 4.

ENGINEERING GEOLOGY

Upper Scheme (Stage I)

This section of the proposed development is underlain by granite only. Faulting, shearing and jointing are quite prevalent. The most significant fault, and one which is likely to affect the scheme adversely, is the Chier fault, which crosses the Scheme area near its western end.

Generally, fresh but sheared granite was found to occur at depths of about 2 m below the stream beds, with weathering to depths of as much as 11 m along various joints and shear planes. In most instances, fresh rock did not appear to rise within the valley slopes but continued at approximately stream bed levels some 15 m to 20 m into the slopes, with variable weathering (and leaching) continuing into the valley sides for as much as 60 m or more.

The site of the diversion work and the portal of the tunnels on Sungai Piah and Sungai Piah Kechil will be affected by the Chier fault and Gentes Lineament respectively. Most of the joints are associated with these lineaments and strike in much the same direction.

However, sheared rocks will not be encountered throughout the entire length of the tunnel, but will only be confined to major fault zones. From Figure 3 it can be seen that a total of 10 such discontinuities are likely to be encountered along the Upper scheme. In between, fresh unaltered granites with possibly some large quartz veins will be the prominent rock types present. About 100 m either end of the tunnels the rocks are expected to be variably weathered (Grades III and IV). Some 10 m to 20 m of open-cut will normally be required before actual tunnelling can commence. These end sections of the tunnels are not likely to be self supporting and may result in the extensive revelling and spalling unless properly supported and protected by means of ribs, shotcrete, mesh and rock bolts where appropriate.

Along the remaining sections, tunnelling conditions are expected to be reasonably satisfactory, except in areas of extensive faulting, jointing and shearing, as in the vicinity of the Chier fault and other similar discontinuities, as shown in Figure 3.

Lower Scheme (Stage II)

The upper section of this scheme is underlain by granite which continues westward as far as the next prominent lineation or fault zone, known as the Beltek fault. The remaining westerly portion of the Lower Scheme is found in quartz-mica-schist and hornfels, as shown in Figure 3.

In order to make use of all the available heads, the intake structure in the Toor valley is still located near or within the influence of the Chier fault where the bedrock is expected to

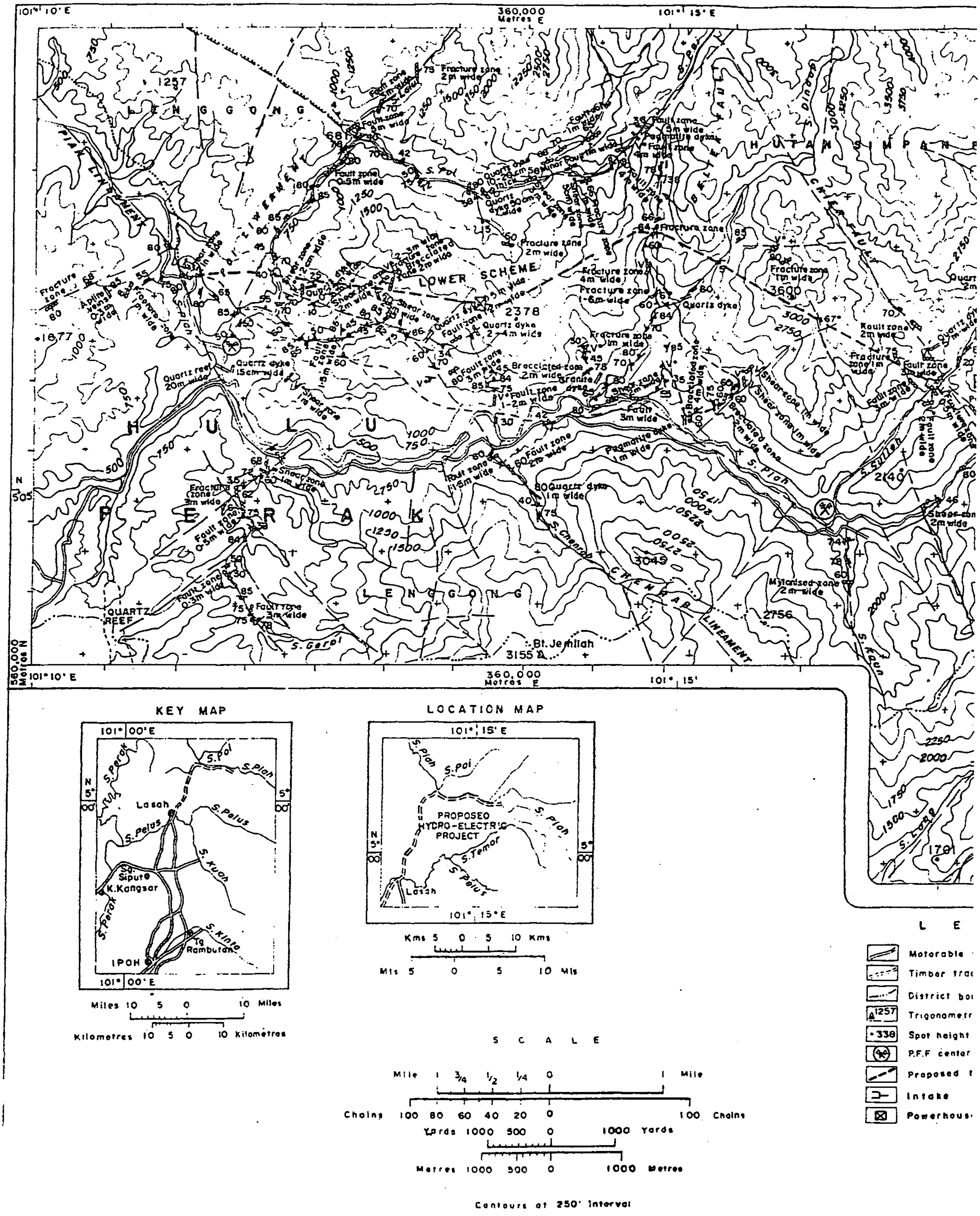
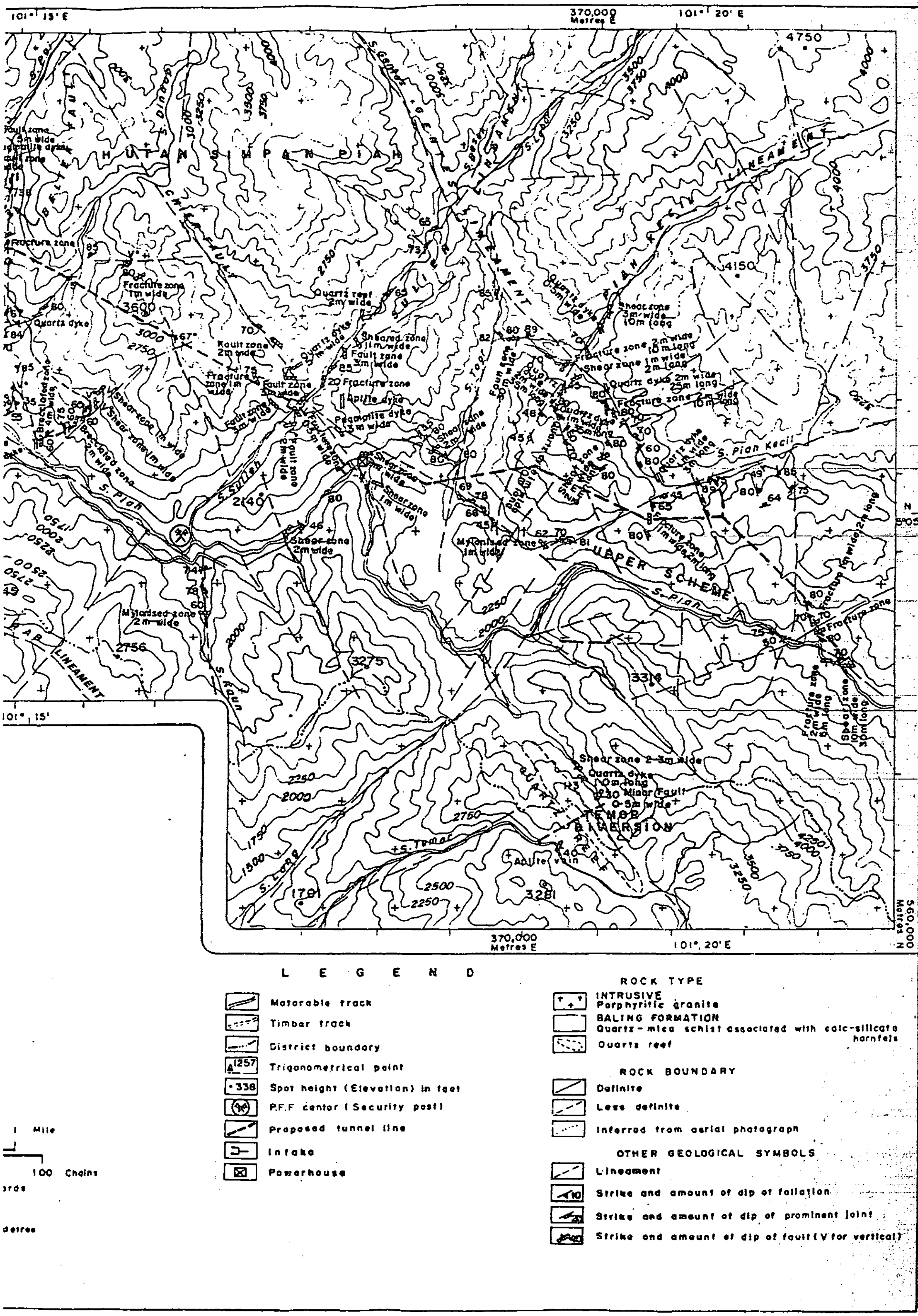
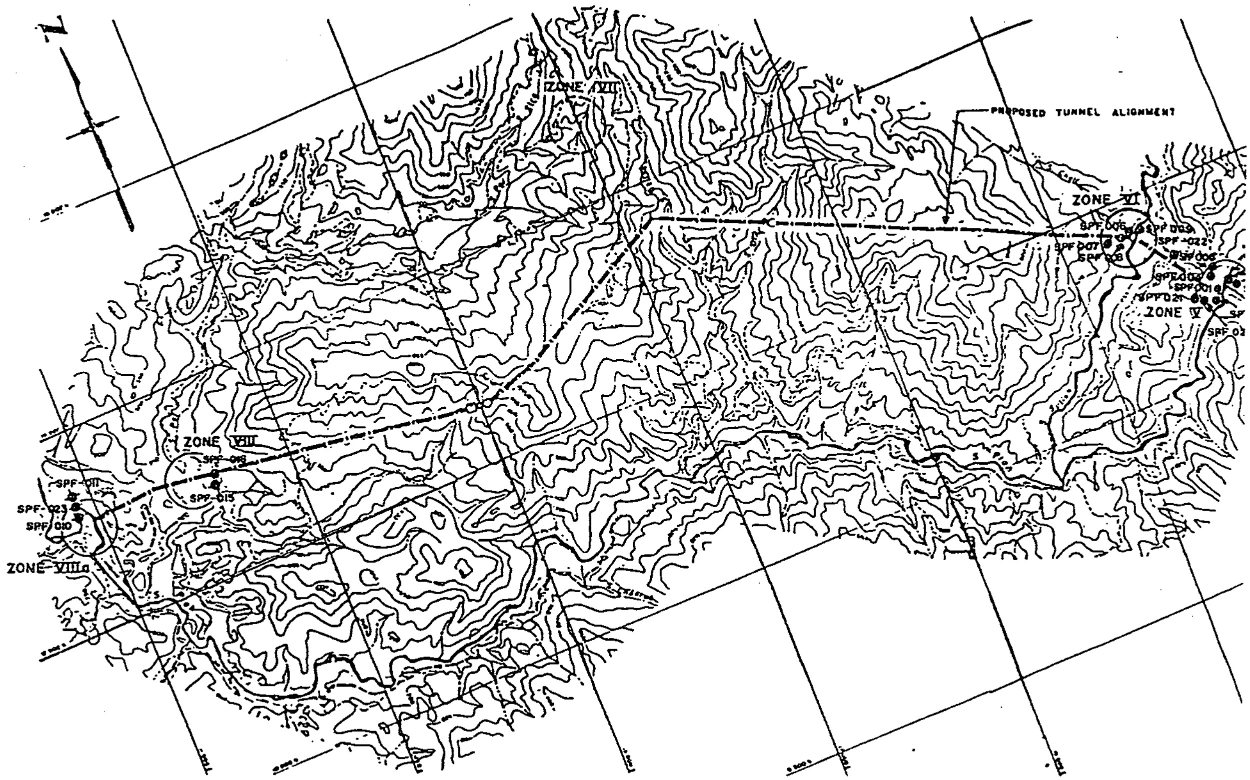


Fig. 3 Geological map of the Sungai Piah area



Geological map of the Sungai Piah area



PLAN

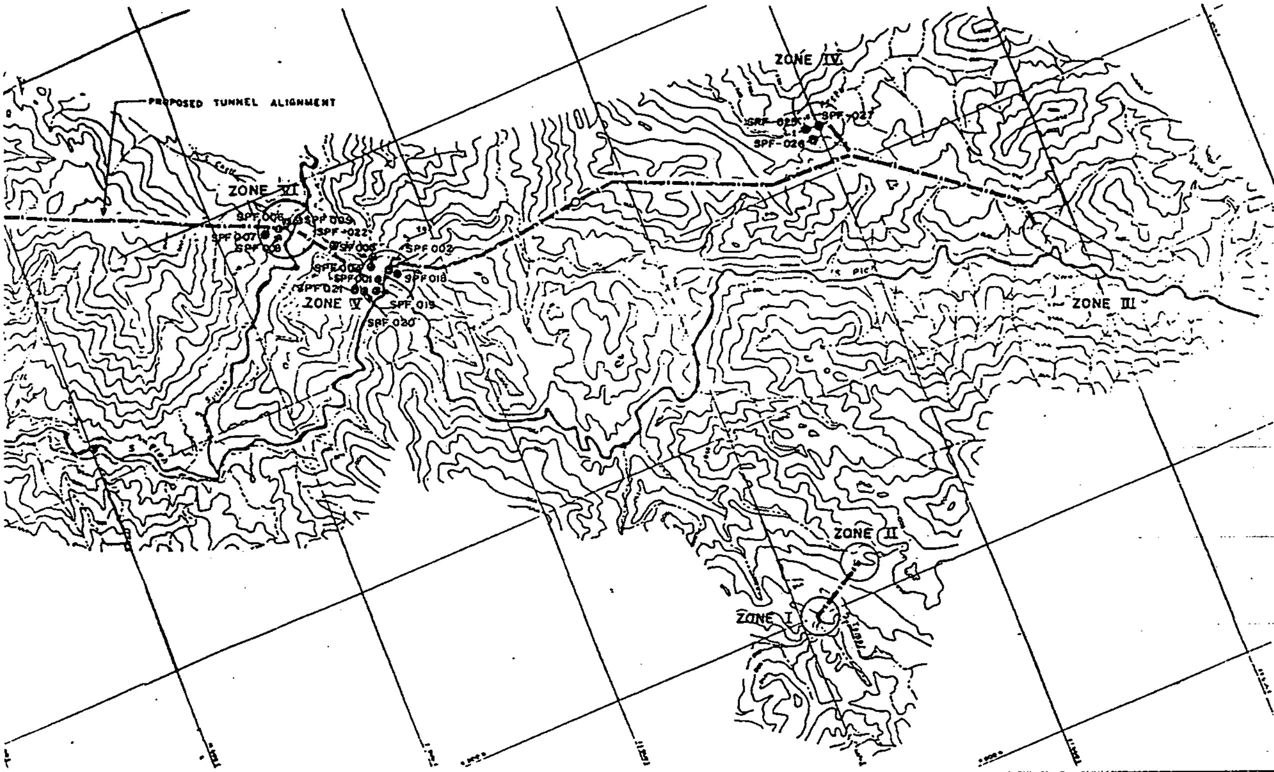
1:20 000

LOCATION OF DRILL HOLES

BOREHOLE NO.	ZONE NO.	AREA	COORDINATES NORTH	COORDINATES EAST	EL	DEPTH OF HOLE	REFERENCE FIGURE FOR DETAILED LOCATION
SPF 001	I	TOOR INTAKE	10 737.00	22 354.0	537.60	23.8 m	FIGURE 37
SPF 002	I	UPPER POWERHOUSE (TOOR)	10 789.0	22 470.5	542.66	12.13 m	FIGURE 37
SPF 003	I	TOOR INTAKE	10 791.5	22 398.0	532.10	16.7 m	FIGURE 37
SPF 004	I	TOOR INTAKE	10 645.5	22 291.5	551.06	24.04 m	FIGURE 37
SPF 005	I	TOOR INTAKE	10 820.5	22 296.5	567.90	24.43 m	FIGURE 37
SPF 006	VI	SALTEN INTAKE	11 581.5	21 645.00	535.96	19.05 m	FIGURE 38
SPF 007	VI	SALTEN INTAKE	11 604.5	21 517.56	519.37	9.39 m	FIGURE 38
SPF 008	VI	SALTEN INTAKE	11 597.00	21 627.50	556.57	44.93 m	FIGURE 38
SPF 009	VI	SALTEN INTAKE	11 631.0	21 768.5	530.56	20.10 m	FIGURE 38
SPF 010	VIIIa	PIAN OUTFALL	13 249.5	10 814.5	177.06	15.40 m	FIGURE 6
SPF 011	VIIIa	PIAN OUTFALL	13 780.3	10 814.00	157.04	31.30 m	FIGURE 6
SPF 012	I	TENOR DIVERSION	(1 067.0)*	(1 051.53)*	900.75	18.17 m	FIGURE 62
SPF 013	I	TENOR DIVERSION	(1 044.53)*	(1 038.50)*	897.03	14.92 m	FIGURE 62
SPF 014	I	TENOR DIVERSION	(1 013.53)*	(1 038.53)*	881.87	28.96 m	FIGURE 62
SPF 015	VIII	PDI FAULT ZONE	12 929.0	12 592.0	144.22	26.05 m	FIGURE 6

BOREHOLE NO.	ZONE NO.	AREA	COORDINATES NORTH	COORDINATES EAST	EL	DEPTH OF HOLE
SPF 016	[illegible]	PDI FAULT ZONE	12 968.0	12 207.0	152.86	24.
SPF 018	I	UPPER POWERHOUSE (TOOR)	10 787.5	22 517.0	540.86	32.
SPF 019	I	TOOR INTAKE	10 668.0	22 315.0	579.70	17.
SPF 020	I	TOOR INTAKE	10 714.00	22 226.5	545.56	27.
SPF 021	I	TOOR INTAKE	10 731.00	22 185.5	561.33	28
SPF 022	[illegible]	SALTEN FAULT & ALONG TUNNEL BETWEEN [illegible]	11 281.82	21 020.04	594.34	30
SPF 023	VIIIa	PIAN OUTFALL	13 705.0	10 807.00	172.54	30.
SPF 025	II	PIAN RECHIL INTAKE	10 452.5	26 917.00	796.43	15.
SPF 026	II	PIAN RECHIL INTAKE	10 417.5	26 928.00	805.77	24.
SPF 027	II	PIAN RECHIL INTAKE	10 451.5	26 976.0	796.48	15.
SPF 028	III	ORIGINAL PIAN INTAKE	-	-	-	17
SPF 029	III	ORIGINAL PIAN INTAKE	-	-	-	15.
SPF 030	III	ORIGINAL PIAN INTAKE	-	-	-	15.

Fig. 4 Location of drill holes



PLAN

1:20 000

HOLES

AREA	COORDINATES		EL	DEPTH OF HOLE	REFERENCE FIGURE FOR DETAILED [illegible]
	NORTH	EAST			
POI FAULT ZONE	12 948.0	12 207.0	752.86	24.06 m	FIGURE 4
UPPER POWERHOUSE (100A)	10 787.5	22 517.0	560.86	52.92 m	FIGURE 37
100A INTAKE	16 448.0	22 315.0	579.70	17.24 m	FIGURE 37
100A INTAKE	10 714.00	27 226.5	563.56	27.22 m	FIGURE 37
100A INTAKE	10 731 OC	22 161.5	563.33	28.9 m	FIGURE 37
[illegible] FAULT & CA. TUNNEL BETWEEN 25/M	11 281 8C	22 020.04	599.34	50 74 m	FIGURE 4
PIAN OUTFALL	13 202.0	10 807.00	172 54	30.00 m	FIGURE 4
PIAN KECHIL INTAKE	10 452.5	26 917.00	794.42	15.08 m	FIGURE 4
PIAN KECHIL INTAKE	10 417.5	26 928.00	805.77	26.91 m	FIGURE 4
PIAN KECHIL INTAKE	10 451.5	26 976.0	796.48	15.00 m	FIGURE 4
ORIGINAL PIAN INTAKE	-	-	-	17 39 m	N/A
ORIGINAL PIAN INTAKE	-	-	-	15.20 m	N/A
ORIGINAL PIAN INTAKE	-	-	-	15.00 m	N/A

LOCATION OF DRILL HOLES

0 400 800 1200 1600 2 000 m (1:20000)

Fig. 4 Location of drill holes

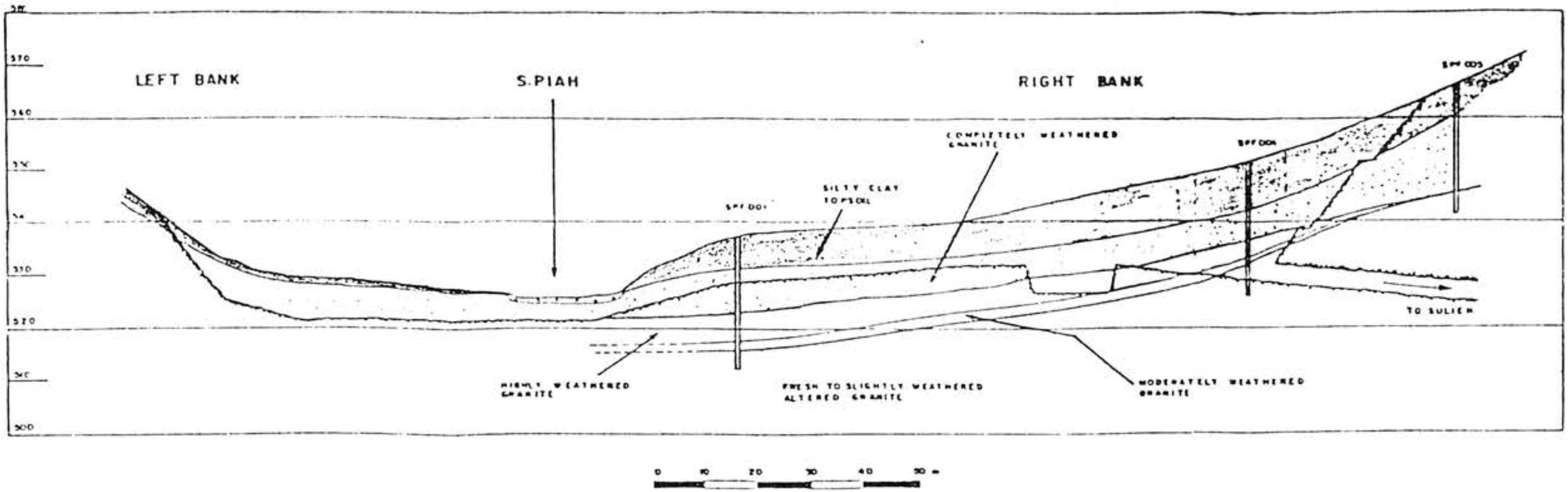


Fig. 5a Geological cross section along Toor intake and diversion structure

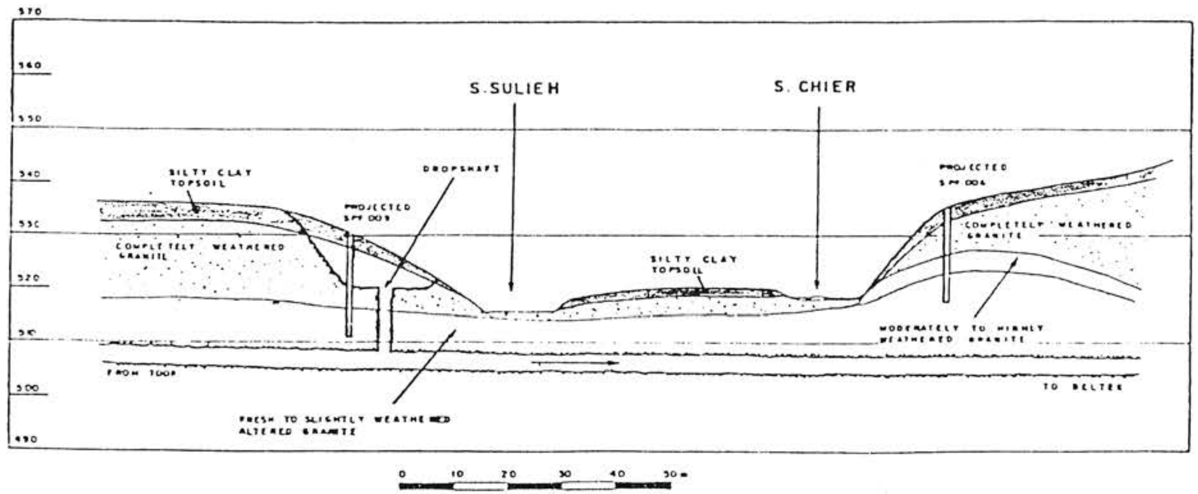


Fig. 5b Geological cross section along Sulieh intake and diversion structure

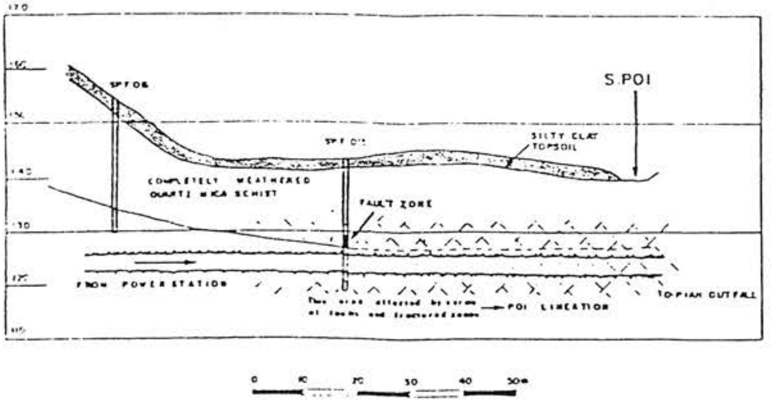


Fig. 5c Geological cross section along tailrace tunnel (Lower scheme) in the vicinity of the Pooi Lineation.

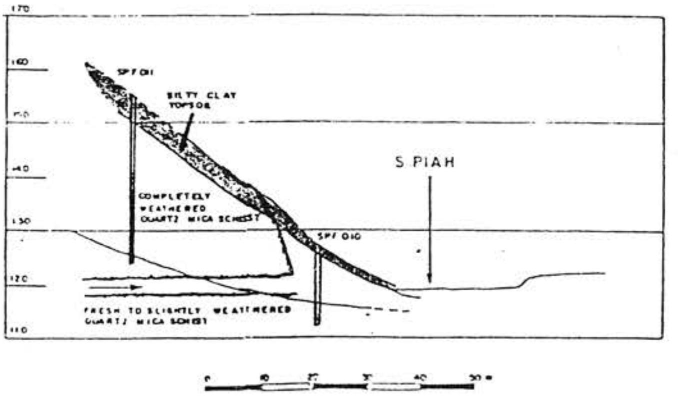


Fig. 5d Geological cross section along Piah outfall

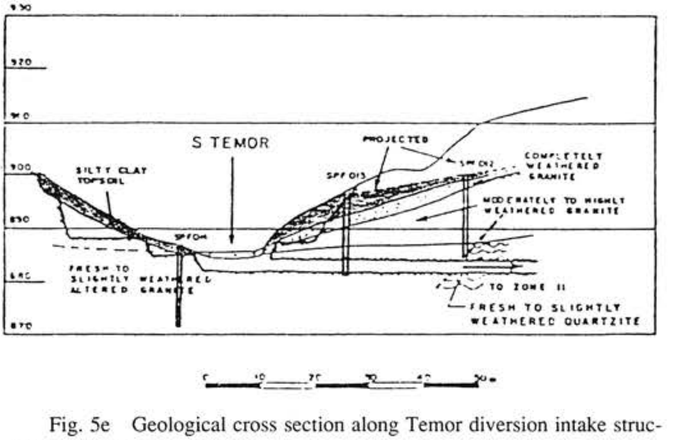


Fig. 5e Geological cross section along Temor diversion intake structure and diversional tunnel.

be variably weathered and extensively sheared, jointed and brecciated. It is expected that the entire length of the tunnel between zone V and VI will be located in sheared but fresh granite. Tunnelling condition will therefore be less favourable and more temporary as well as permanent supports would be needed over this section.

Because of deep weathering in the Toor intake area (zone V), extending up to 11 m below actual riverbed level, a larger and longer open-cut, approximately 75 to 100 m, will be required, before a tunnel portal can be established in reasonably sound rock conditions. Borehole SPF 007, drilled in the river bed in zone VI, encountered fresh rock 2 m below the river bed of Sungai Sulieh. It is anticipited that the tunnel crossing underneath the Sungai Sulieh and the dropshaft of the Sulieh Intake will be located in fresh, but sheared rock.

Tunnelling conditions between the Sulieh Intake (zone VI) and the tailrace tunnel outfall (zone VIIIA) will generally be favourable, except in the area of the Beltek fault and the so-called Poi lineament where some concrete lining in the low pressure tunnel may be necessary. The portion of the tunnel east of the Beltek fault will be in porphyritic biotite granite. The site for the underground powerhouse as well as the surge and high pressure dropshafts, and the entire tailrace tunnel will be within the schist roof pendant.

Because of the deep weathering, open-cut approaches at both inlet and outfall portals of the proposed tunnel line may have to be longer and deeper. This is also the case in the area dominated by schist and hornfels.

Temor Diversion

The Temor diversion was found to be underlain by coarse-grained porphyritic biotite granite. The diversion tunnel, which is only 0.7 km long, is expected to intersect a 200 to 300 m wide quartz reef. The surface length of this quartz reef is at least 2.5 km with a trend of NW-SE. It is possible that at least one of the reef's contact with the granite might be affected by hydrothermal alteration. Pronounced horizontal stress relief joints were found in all boreholes drilled in the area.

CONCLUSIONS

Within the immediate vicinities of the various faults, in particular the Chier fault at the junction area of the two schemes and the Beltek fault which crosses the Lower Scheme tunnel alignment, the rocks are expected to be badly broken, sheared and fractured, with associated weathering and alteration. In spite of these conditions, however, preliminary assessments indicate that the bedrock will provide suitable foundations for the majority of the required surface structures. In most instances the only treatment that will likely be necessary is grouting to consolidate and seal the more pervious underlying zones.

The permeability of the bedrock tends to decrease with depth of cover, generally being highest in the upper 5 m zone. Higher permeability values will be encountered within the zones affected by faulting and shearing. Similar trends can be expected to exist in the valley slopes and along the tunnel alignments with the most permeable zones being the weathered rocks and those in and adjacent to shear and fault zones. Erosion and gullying will be most severe in exposures of soils or disintegrated (Grade V and VI) rocks and generally decreasing as the grade of weathering decreases.

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