

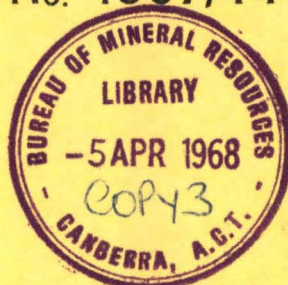
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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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RECORD No. 1967/144



UPPER RAMU
HYDRO-ELECTRIC SCHEME,
NEW GUINEA

GEOLOGICAL INVESTIGATION
OF No. 1 POWER STATION
AND ASSOCIATED WORKS

by

J.P. MACGREGOR

The information contained in this report has been obtained by the Department of National Development as part of the policy of the Commonwealth Government to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus or statement without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.

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SUMMARY

The site for the proposed No. 1 Power Station of the Upper Ramu Hydro-electric Scheme is in the Eastern Highlands of New Guinea, about 110 miles from Lae. The scheme is planned to develop the potential of the Ramu River, arising from its fall of about 2500 feet in nine miles from the highlands east of Kainantu to the Markham Valley depression. The first stage of the scheme consists of a diversion weir with control buildings, a machine hall (No. 1 station) 700 feet below the weir, vertical access and pressure shafts, and a tailrace tunnel 7800 feet long with an outlet portal into the Ramu Gorge about three river miles downstream from the intake.

Geological investigations for a hydro-electric scheme on this stretch of the river have been carried out between 1958 and 1967. They included geological mapping, geophysical surveys, drilling with associated testing, costeaning, sluicing and the recording of seismic events in the area.

The scheme is located at the northern end of the Arona Valley, which is at a level of 4200 feet above sea level and flanked by hills to 6000 feet. The valley floor is composed of Recent unconsolidated lake sediments - the Kainantu Beds - which overlie a thick sequence of meta-sediments called the Omaura Greywacke. The Omaura Greywacke, in turn, overlies schists of the Bena Bena Formation. All rocks older than the Kainantu Beds have been cut by numerous minor basic intrusions. The underground excavations for the Ramu Scheme will probably be entirely in the Omaura Greywacke, much of it, however, in a thick marble bed in the formation.

The Upper Ramu Scheme lies in an area with a high incidence of earthquake shocks. Between 1961 and 1965 nineteen shocks of magnitude greater than 5.0 (Richter) have been recorded in the area; intensities were up to VII on the Modified Mercalli Scale. It is recommended that instrumentation to measure ground response be installed to determine the seismic risk to engineering structures in the area.

The Bena Bena Formation consists of mica schists which are extensively folded and silicified. Although foliated they are strong; they are not expected to be encountered in the scheme, but may be found in the tailrace tunnel.

The Omaura Greywacke consists of a lower marble lens up to at least 400 feet thick in places, overlain by a thick sequence of slightly metamorphosed siltstone-greywacke and shale with a predominance of shale just above the marble. The marble is massive and strong near the surface; caves have developed in it. The greywacke-siltstone and shale are hard and strong; the two rock types are essentially similar but differ in grain size. Because of the lack of marker bands and variations in thickness, recognition of stratigraphic level has been difficult.

The Kainantu Beds consist of a basic conglomerate which is overlain by a horizontal succession of silts and clays.

The Omaura Greywacke in the area of the scheme is folded into a broad anticline with its axis plunging to the south-east. At the intake end of the scheme the rocks dip to the south and at the outlet portal they dip to the north-east. All rocks of the unit are well jointed. Lineations on aerial photographs suggest several faults through the tunnel line but the faults have not been confirmed on the ground. Fault zones are generally expected to be narrow; rock within the fault zones is probably crushed and weak.

The schists of the Bena Bena Formation have been affected by a high grade regional metamorphism prior to the deposition of the other rocks. The Omaura Greywacke has been indurated by the heat of the intrusive basic

dykes. The Kainantu Beds are unmetamorphosed.

Groundwater has been located in drillholes at about the level of fresh bedrock. In the marble to the north of the scheme there has been extensive underground water movement and caves have developed extensively. No large cavities have been located at the site of the scheme.

Slopes on the sides of the Ramu Gorge are steep and the Kainantu Beds are unstable especially after heavy rain. There have been numerous landslips but provided proper care is taken, none should seriously affect the construction and maintenance of the scheme.

Testing of the engineering properties of the rocks have shown ample strength in the greywacke-siltstone and the marble for any underground excavation. Both rocks should be suitable for concrete aggregate but shaly material will probably have to be rejected. Fresh dolerite is also strong and suitable for aggregate.

Two possible sites for diversion weirs have been investigated. Weir Site No. 1 is downstream from a sharp bend to the right in the river; the siltstone-greywacke and shale in the river valley strike normal to the proposed axis. There are several weathered dykes in the bed of the river and a shear zone in the right bank. Overburden in the left bank is unstable. Care will have to be taken in treating these areas.

Weir Site No. 2 is upstream from the bend and the metasediments strike parallel to the weir axis. There are several dolerite dykes oblique to the axis, some open jointing and several small shear zones. Both sites are geologically suitable for the construction of the diversion weir.

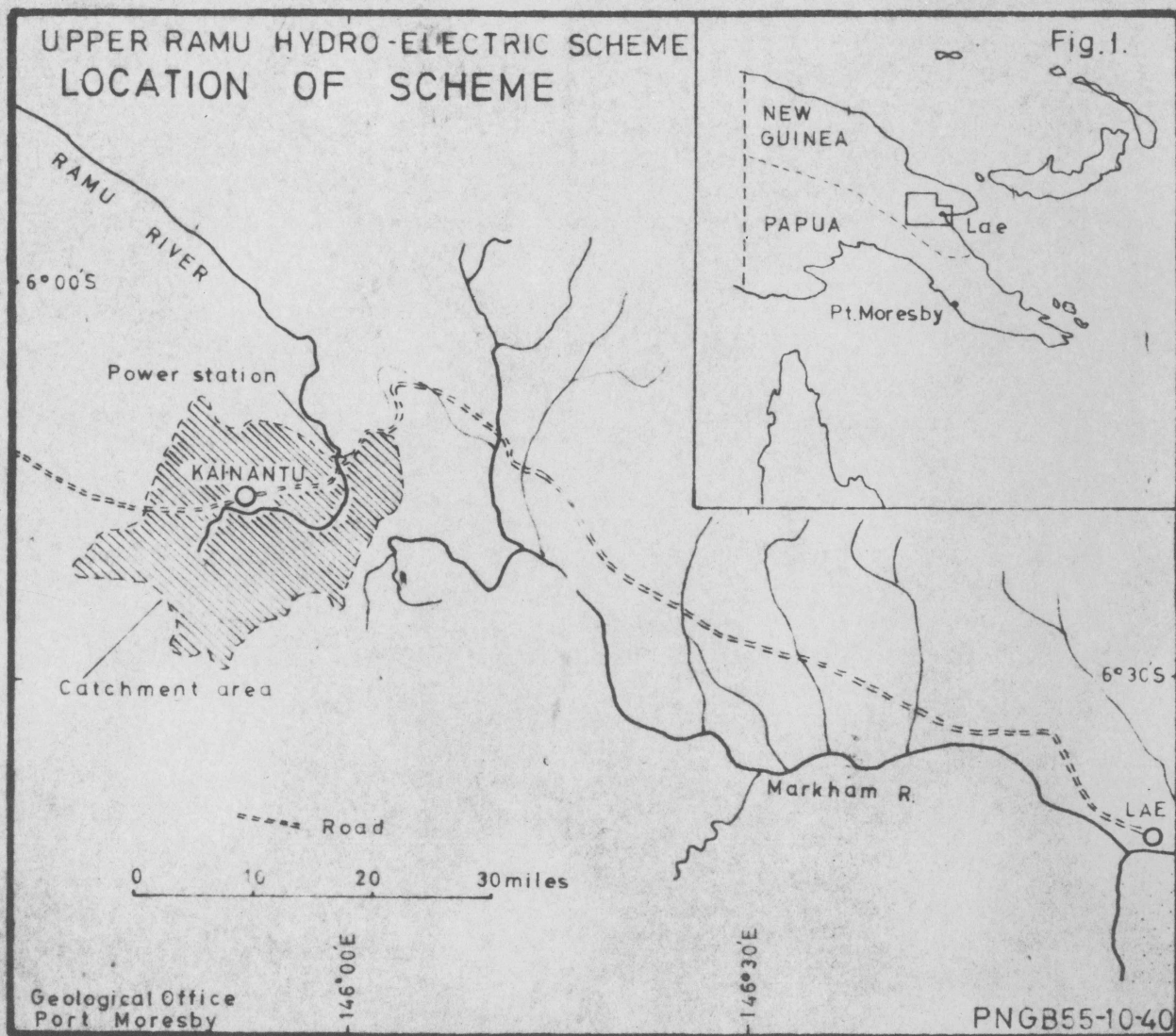
The proposed weir will pond the Ramu River for half a mile upstream. The water will be contained by fresh metasediments and there should be no leakage.

The control building and transformer yard at the right hand end of the weir will be underlain by slightly to moderately weathered siltstone-greywacke and shale, striking normal to the hill-side. Some stabilisation of the slope above the transformer yard will be necessary. The step-up substation will be built on Kainantu Beds. The access road to the surface works will cross several areas affected by landslips and will be partly constructed on Kainantu Beds. Careful control of drainage will be required.

The first 600 feet of the access and pressure shafts will be excavated in jointed siltstone-greywacke and shale. From 600 feet to machine hall level the shafts will be in marble. Water inflows are expected to be low and lining of the access shaft should be largely restricted to the first 100 feet. The pressure shaft will presumably be lined throughout. A shear located in a drill hole may affect the lower sections of the shafts.

The investigation has shown that the machine hall will be excavated in a uniform mass of rock which will be mostly marble. Some siltstone may be found but this will not affect the strength of the rock mass. Several narrow faults are expected in the area, but water inflows should be low and support restricted mainly to rock-bolting. A drilling investigation from the access shaft into the machine hall area is recommended to give more detailed information than is available at present. Stress testing and instrumentation will give important information on the shape, orientation and support required in the machine hall.

The tailrace tunnel will be excavated almost completely in marble; folding and faulting may bring some siltstone and, or, schist to tunnel level. Several fault zones are expected but they should be narrow. The marble has low to moderate fracture permeability. Because of the capping of siltstone-greywacke and shale, which has a low permeability, water inflows are expected



to be low; however local ruptures of the cap rock or interconnections with near-surface marble could result in high inflows. Equipment should be available to cope with any large quantity of water which may be struck. Most of the tunnel could be unlined.

The outlet portal will be built in jointed marble. Care will have to be taken to provide sufficient cover in the first section of the tunnel and to protect the portal against surface slipping. Tunnel spoil can be dumped in the Ramu River downstream from the portal.

The portal access road will cross very difficult country. An alternative alignment or method of access is recommended.

Four sources of construction materials were examined. All rocks apart from the shale appear suitable. Further testing of quantity and quality is required.

Appendices include details of earthquakes in the Kainantu area, petrographic descriptions of rock samples, strength testing of cores from drill holes, detailed geological logs of drill cores and water pressure test computation sheets.

INTRODUCTION

General

The engineering investigation for the development of hydro-electric power on the Upper Ramu River, Trust Territory of New Guinea, is being carried out by the Commonwealth Department of Works on behalf of the Papua and New Guinea Electricity Commission. At the request of the Commonwealth Department of Works, officers of the Bureau of Mineral Resources have handled the geological aspects of the investigation. The report gives a detailed geological appraisal of the scheme and examines the geological aspects of construction. The layout considered is that presented by the Department of Works to the Electricity Commission in March 1966, with subsequent modifications to the diversion weir and intake locations. Geological information has been considered by Department of Works' engineers in arriving at the presently-proposed layout.

The Upper Ramu River Hydro-electric scheme has been designed to make use of the sharp drop in elevation of the Ramu River as it enters the gorge through the eastern end of the Bismarck Range, on its way from the Eastern Highlands of New Guinea to the Markham Valley depression to the north. The scheme, located at latitude 6° 14' South, longitude 145° 58' East, will divert the water from the 340 square miles of catchment of the upper reaches of the Ramu River in the Kainantu area (Fig. 1).

As the Ramu River flows through the gorge it falls about 2500 feet in elevation over a direct distance of about 6½ miles, giving a total power potential of about 250 M.W. (Megawatts) at 55% load factor (C.D.W., 1966). It is presently planned that the total available head will be utilized by the construction of two or more power stations. The No. 1 Power Station would use 700 feet of head at the upper end of the gorge and is designed for an installed capacity of 72 M.W. The second power station using the remaining head would have a capacity of about 180 M.W.

Gauging of the Ramu River has shown that the long term uncontrolled flow for 95% of the time is about 275 cusecs which would support a load of 20 M.W. in Stage I. However, regulating the flow by the construction of a

storage dam would give a constant flow of 750 cusecs which would generate 60 M.W. at a 60% load factor. Preliminary estimates for the first stage of the No. 1 Power Station show that it would cost \$21 million and that the completed scheme with storage dam would cost \$42 million.

Access

About one mile upstream from the proposed intake works the Ramu River is crossed by the reconstructed Highlands Highway, an all-weather road from the seaport of Lae (110 miles to the east) which continues to Goroka some 70 miles to the west. The nearest airstrip is at Kainantu, 11 miles to the west, which is restricted to light aircraft.

The previous alignment of the Highlands Highway runs north-west from the Ramu bridge and passes close to the scheme. From this road several tracks enable vehicles to reach most sections of the scheme in dry weather.

Proposed Layout of Scheme

The Ramu River will be diverted, at a point about half a mile downstream of the junction of Yonki Creek and the Ramu River, by a low concrete weir surmounted by two automatically-operated radial gates (C.D.W., 1966) (see Fig. 1). Daily pondage will be provided by the weir and the opening of the gates will permit passage of floods and flushing of the intake. The water will pass by way of a concrete and steel lined vertical pressure shaft, about 660 feet deep, to an underground machine hall just downstream of the weir and then be discharged back to the river through a concrete-lined tailrace tunnel about 7800 feet long. The tailrace tunnel will be provided with a surge chamber.

The machine hall will house six 12 M.W. generating sets. Permanent access will be by way of a vertical shaft about 720 feet deep from the right bank of the river beside the weir. Two tunnels about 150 feet long will connect the machine hall and the shaft.

An operational control building and hoist house will be located at the top of the access shaft. This building will also include a plant room and workshop.

A bank of step-up transformers will be located adjacent to the control building and these will be connected by overhead lines to a switchyard at the top of the slope to the east of the weir. A permanent access road from the Highlands Highway to the surface works will be built and several miles of temporary access roads will be required during construction.

Previous Investigations

Geological.

A brief geological inspection for a possible hydro-electric scheme on the Upper Ramu River was carried out in 1958 by Noakes and Gardner (1959). The scheme investigated consisted of a weir with a surface pipe-line and surface penstocks to a power station in the bottom of the Ramu gorge.

In 1961 J.K. Hill carried out a detailed geological investigation for a scheme which incorporated a high-level tunnel and surface penstock to a surface power station (Hill, 1962). This investigation included detailed

geological mapping of the proposed weir site, power station site and general geological mapping of the tunnel line. Based on this work, a programme of diamond and percussion drilling was carried out by the Commonwealth Department of Works in 1961, 1963 and 1964. Examination of the cores from the drilling, together with additional geological and geophysical work and a re-appraisal of the economics of the scheme, caused the rejection of the high-level scheme in favour of the present underground scheme.

Geophysical

In 1963 E.J. Polak carried out a series of seismic, magnetic and resistivity traverses along the high-level tunnel line and surface penstock (Polak, 1964). In 1964 W. McDevitt from the Central Testing and Research Laboratory, Commonwealth Department of Works, Melbourne, carried out further seismic traverses at the northern end of the tunnel line and on the penstock slope. This work confirmed the extent and depth of overburden which had been indicated by the drilling in the area and contributed to the rejection of the high-level scheme in favour of the underground scheme.

Magnetic measurements in 1964 by Wainwright and Dooley (1967) have shown that magnetic anomalies previously attributed to dykes are more probably due to granodiorite boulders in the unconsolidated lake sediments.

Present Investigation

Geological Mapping

With the decision to investigate a scheme incorporating an underground power-station and low-level tailrace tunnel, much of the previous geological work had to be re-examined in order to assess its value in the interpretation of rock type, structure and strength along the revised alignment and level. The intake end of the scheme assumed greater importance with the location of power-station, access shaft, pressure-shaft and surface control works in this area, in addition to the weir. At the northern, outlet end of the scheme the system of surge-tanks, penstocks and power-station is replaced by a simple outlet portal near river level.

During 1965, 1966 and 1967 the mapping carried out by Hill was supplemented by costeaning, sluicing and additional mapping at weir sites Nos. 1 and 2 and by further traverses up Yonki Creek, down the Ramu Gorge and along the various creeks that cross the tunnel line. The slope stability of access roads to the intake and outlet works was examined and also the rock strength and stability in the area of the surface control houses. Possible sources of construction materials were examined and sampled. The mapping was carried out by D.E. Gardner between July and October 1965 and during periodic visits by J.P. MacGregor and J.R.L. Read.

Drilling

Before the high-level scheme was abandoned the following 24 diamond drill holes had been completed: DD1, DD1A, DD1B, DD1C, DD2, DD4, DD5, DD6, DD7, DD8, DD9, DD10, DD11, DD12, DD13, DD14, DD15, DD16, DD17, S1, S2, S3, S4 and S4A (Fig. 2). Of these holes DD1, DD1A, DD1B and DD1C investigated foundation conditions for weir site No. 1 and DD16 the foundation conditions at the power-station site - now the site of the tunnel outlet portal (see Appendix 6). The remainder of the holes lie along the high-level tunnel line and penstock line and while they give a general indication of the rock types in the area, do not penetrate to within 600 feet of the proposed tailrace tunnel level. The results of the drilling for the high-level scheme will be presented in a

separate report but information from the holes has been used where necessary. Logs of the holes are available for inspection at Commonwealth Department of Works, Melbourne and Port Moresby, Bureau of Mineral Resources, Canberra and the Resident Geological Office, Department of Lands, Surveys and Mines, Port Moresby.

In the investigation of the underground head-station layout six holes have been drilled: DD18 - a low-angle hole drilled southwards from the outlet portal site; DD19 - a vertical hole on the left bank of the Ramu River into the machine Hall area on the line of a proposed access shaft (earlier layout); DD20 - a vertical hole 3000 feet along the tailrace tunnel from the intake (abandoned at 370 feet owing to continued caving in a zone of broken rock); DD20A - a vertical hole at chainage 3100 feet to tunnel level, replacing DD20; DD21 a hole drilled northwards from the site of DD19 at 70° to the horizontal, to prove rock conditions at the southern end of the tunnel line; and DD22 - a vertical hole down the adopted location for the access shaft on the right hand bank of the Ramu River. Survey control of the underground position of the drill holes was obtained by 'Tropari' survey after completion. Geological logs of the holes form Appendix 6.

Because of the depth of drilling involved in reaching tunnel level, the underground investigation was concentrated in the immediate area of the machine hall with one hole on the tunnel line to confirm general rock types and conditions.

The drilling was initially carried out by drillers from the Commonwealth Department of Works but most of the drilling for the underground scheme was carried out by drillers from the Snowy Mountains Hydro-Electric Authority.

Water Pressure Testing

All sections of drill-holes adjacent to proposed excavations were subjected to careful water pressure testing. Apparatus and techniques were developed in an attempt to increase the accuracy of the results and thus enable the results from various holes to be compared. The water pressure testing was: (a) to determine the water tightness of the weir foundations; (b) to obtain information of the opening of joints; (c) to obtain information on the nature of sections in which core was lost; and (d) to estimate the amount of inflow of water to be expected into an underground excavation.

Water pressure test results, as recorded by the driller, are given in graphical form on the drill logs and the computation sheets, showing equivalent fracture permeability, form Appendix 8. The method of water pressure testing used is given in Appendix 7.

Rock Temperatures

Measurements were made of the rock temperature and thermal gradient in the holes in the power station area. A thermistor probe constructed by the Geophysical Branch Bureau of Mineral Resources, Canberra, was used.

Costeaming and Sluicing

During the geological investigation of weir site No. 1 costeams to bedrock were dug along the weir axis and also on the left abutment to examine possible slope instability in this area. Most of the area to be excavated for the weir and intake structures at weir site No. 2 was sluiced free of overburden prior to detailed geological mapping. Four costeams were dug across the alignment of the proposed access road to the headworks site on the right bank of the river and through the control building area, to determine the depth of overburden and the risk of landslips.

UPPER RAMU HYDRO-ELECTRIC SCHEME RELIEF AND LOCATION OF DRILLHOLES

Fig. 2

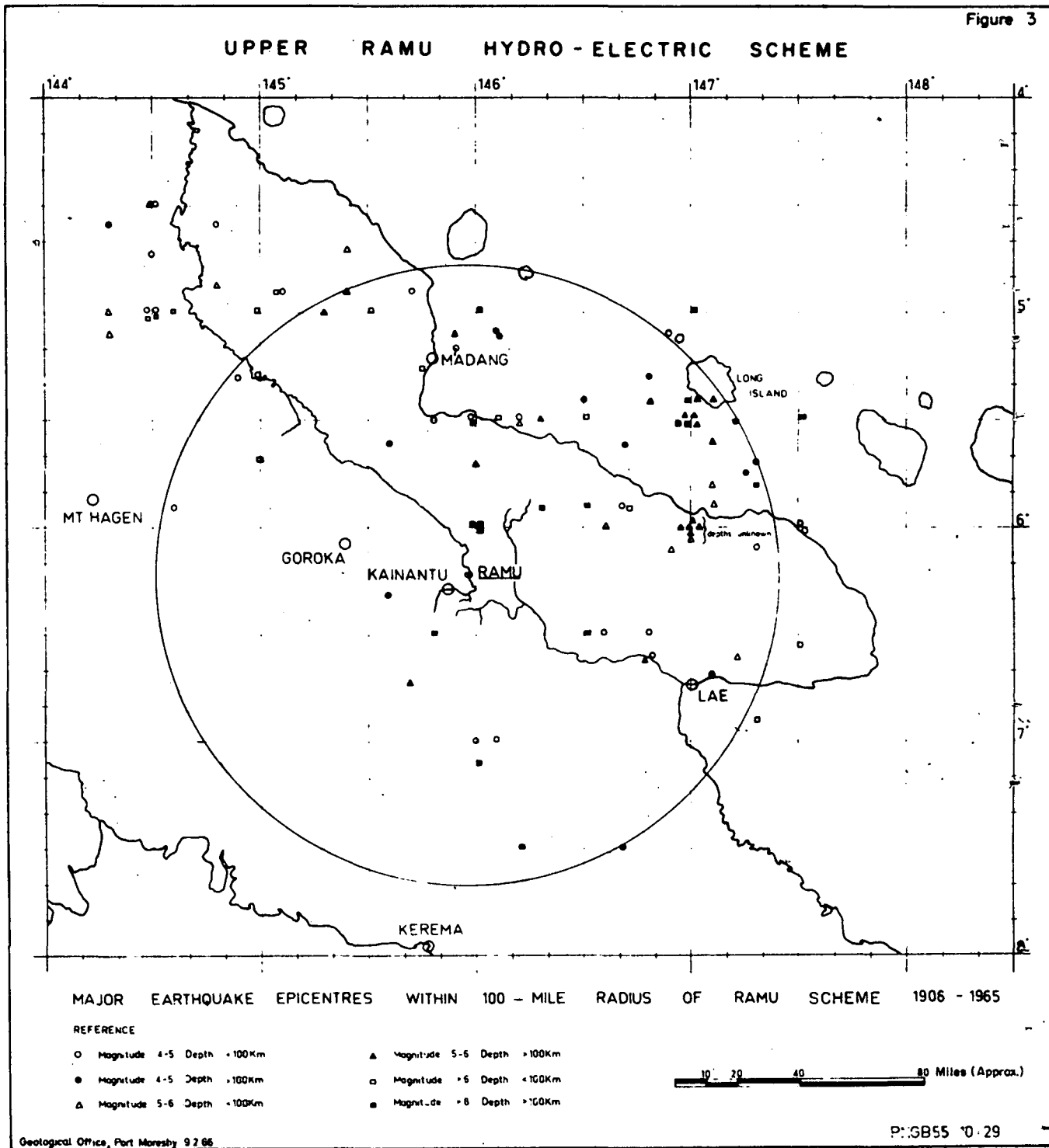


Geological Office Port Moresby 16:9:66

• DD5 Drillhole
--- Proposed tunnel line
~ Limit of forest

PNGB55-10-44

Figure 3



Seismicity

The Upper Ramu scheme is situated in a fairly highly seismic area (see Brooks, 1965) and shocks of intensities III - VI are frequently felt. Records from the Seismological Observatories at Port Moresby and Rabaul were examined for information of the occurrence of major earthquakes in this region (see Fig. 3). Records of felt earth tremors in the Kainantu area between 1961 and 1965 have been kept by Mr. R. Teale of Ogamuga and Fore, (Appendix 3). A programme of investigation of rock response to strong motion earthquakes was proposed but has not yet been implemented; it is unlikely to produce sufficient data to be of use before the design calculations for the scheme have to be completed.

Construction Materials

Four possible sources of sand and aggregate for concrete were briefly examined (see Fig. 24). They are: spoil from excavation on the scheme; river gravel and sand from the Ramu River; marble from Chasm Creek near the Swiss Mission; and gabbro from Yonki Dome close to the reconstructed section of the Highlands Highway.

Related Investigations

Ramu Dam Site No. 1

In addition to the investigation of the underground scheme, preliminary geological mapping of a site for a storage and flow-regulating dam on the Ramu River, one mile upstream from the intake, was carried out by J.P. MacGregor (1965). D.E. Gardner mapped costeans, and examined samples taken from the site in the course of a subsequent investigation by Messrs. Baring and Weatherhead of the Soils Section, Central Testing and Research Laboratory, Commonwealth Department of Works (C.D.W., 1965). W. McDevitt of the Central Testing and Research Laboratory carried out several seismic traverses in the dam site area.

Other Dam Sites

Brief examinations of three other dam sites in the catchment area, near Aiyura and Kainantu, were made by J.P. MacGregor and E.K. Carter. These sites were not investigated in detail as they lack adequate storage capacity.

Development of Ramu Gorge Below the No. 1 Outlet Portal

The implementation of the No. 1 Power Station Scheme would leave undeveloped a head of about 1800 feet, in about seven miles of gorge below the proposed outlet portal for the No. 1 scheme. In order to verify that it would be practicable to develop this head a detailed geological reconnaissance was made in 1967 by a party led by J.R.L. Read. The area mapped covered the gorge and a 3 mile wide strip of country east of the river (Read, 1967).

PHYSIOGRAPHY

The upper reaches of the Ramu River drain several intermontane basins between the Bismarck Range and the Okapa Highlands (McMillan and Malone, 1960). The most northerly basin is the Arona Valley at an average elevation of about 4200 feet; it is a basin of low relief occupied by flat-lying sediments. The valley is flanked on the west by Yonki Dome, a round, dome-shaped igneous intrusion which rises to an elevation of about 6,000 feet, and on the east and north-east by a ridge of intrusive rocks which divides the Eastern Highlands of New Guinea from the Central Depression of the Markham-Ramu River valleys.

At the northern end of the Arona Valley the Ramu River has cut through the sediments and drops into a deep, steep-sided gorge of metamorphic rocks. The gorge is about nine miles long and in it the river drops about 2500 feet. The engineering works which make up Stage 1 of the Upper Ramu Scheme will be located in the metamorphic rocks at the head of the gorge.

REGIONAL GEOLOGY

The geology of the Kainantu area is covered by two Bureau of Mineral Resources Reports - Report No. 48, 'Geology of the eastern Central Highlands of New Guinea' by McMillan and Malone (1960), and Report No. 79 'Geology of the Kainantu Goldfields' by Dow and Plane (1965). The regional geology of the Kainantu area is shown on Plate 1.

Stratigraphy

The oldest rocks exposed in the Kainantu area are probable Palaeozoic metamorphics belonging to the Bena Bena Formation; they are unconformably overlain by Lower Miocene marine sediments named by Dow and Plane (1965) as the Nasananka Conglomerate, the Omaura Greywacke and the Lamari Conglomerate. Local eruptions formed the Aifunka Volcanics, which are regarded as Pliocene in age. The Kainantu beds which are Recent lake sediments, and Recent alluvium, complete the stratigraphic column. A summary of the stratigraphy of the Kainantu area is given in Table 1.

Structure

The Tertiary sediments and the previously deformed and metamorphosed underlying basement have been folded as a unit along axes which trend south-east. In the Kainantu area the main structure recognised is an anticline which plunges to the south-east. A reversal of plunge near Aiyura has led to the postulation of a narrow north-east trending syncline which follows the Arona valley. Faulting is considered by Dow and Plane (1965) to be subordinate to folding in the Kainantu area. None-the-less, several faults of unknown displacement, are known in the scheme area and many more are believed to occur.

TABLE 1.

Regional Stratigraphy of the Kainantu area (after Dow and Plane, 1965)

Unit	Age	Thickness	Lithology	Structure	Remarks
Kainantu Beds	Recent	at least 350 feet	Conglomerate, gravel, sand and clay	Flat-lying, minor jointing due to consolidation	Lake sediments
Unconformity					
Aifunka Volcanics	Pliocene	-	Andesite tuff and agglomerate	-	Not present in area of scheme
Unconformity					
Lamari Conglomerate	Miocene	at least 2000 feet	Volcanic conglomerate, tuffaceous sandstone, basic volcanic rocks, limestone	-	Not present in area of scheme
Slight Angular Unconformity					
Omaura Greywacke	Miocene	at least 6000 feet	Greywacke, siltstone, shale, marble, and pebble conglomerate	Folded on south-east trending axis plunging to south-east; well jointed with numerous faults.	Indurated by intrusions; most of scheme to be excavated in this formation
Nasananka Conglomerate	Miocene	50-8000 feet	Conglomerate, arkose, greywacke and siltstone		Not present in area of scheme.
Regional Unconformity					
Bena Bena Formation	Palaeozoic or Mesozoic	Not known	Schist, gneiss and quartzite	Intensely folded and injected, jointed and faulted	Regionally metamorphosed
INTRUSIVE ROCKS					
Akuna Dolerite	Tertiary, younger than Omaura Greywacke	-	Gabbro and dolerite masses, minor dolerite dykes	Forms Yonki Dome	Minor dykes throughout scheme
?	Tertiary, younger than Omaura Greywacke	-	Quartz diorite and granodiorite	Intrusion in Ramu Gorge	Origin of acid boulders in lake sediments

SEISMICITY

Occurrence of Earthquakes

The Upper Ramu scheme lies in an area with a high incidence of earthquake shocks.

The strength of earthquakes is usually measured by two scales: the Richter scale which gives an indication of the energy release at the earthquake focus, and the Modified Mercalli scale which indicates the felt intensity of an earthquake at any particular locality. The Richter scale ranges from 2 to 8.8, with each step of 1 roughly equivalent to a one-hundred-fold increase in energy. The Modified Mercalli scale, 1956 Version, has twelve grades, and is given in Appendix 2 (Richter, 1958). The depth of the focus of an earthquake is an important factor as damage from a large deep earthquake will cover a larger area than a shallow earthquake of the same magnitude on the Richter Scale. The intensity at the epicentre of a shallow quake would be expected to be higher than that at the epicentre of a deeper quake of the same magnitude.

Brooks (1965) estimates that statistically this region of the Eastern Highlands can expect to experience at least one earthquake of intensity VIII in a 25-year period and intensity IX in a 50-year period. Figure 3 shows the positions of the epicentres, the depths of the foci and the magnitudes on the Richter scale of major earthquakes recorded within a radius of 100 miles of the Ramu Scheme between 1906 and 1965.

Effect of Earthquakes

Records of felt intensities of earthquakes in the Kainantu area between 1961 and 1966 have been kept by Mr. R. Teale, of Onamuga and Fore, and by Mr. R. Jones, of Kainantu (Appendix 3). Table 2 gives the felt intensities which can be correlated with recorded major earthquakes during this period. Most of the shocks which were felt and cannot be correlated with observatory seismic records are probably related to minor earthquakes of local origin.

The slopes in the area of the Ramu valley and gorge are steep and there is abundant evidence of minor surface landslips. While it is impossible to estimate to what extent earthquake action has initiated the slipping it is considered that the main cause of instability in this area has been a combination of heavy rainfall, leading to saturation of low-strength, unconsolidated sediments, and the rapid downcutting by rivers and streams. There is little doubt that the combination of an earthquake and a period of heavy rain would result in slipping of a soil mass which would otherwise have remained stable.

In order to assess the seismic response of the various rock types at the scheme to earthquake movement a programme of investigation using a strong motion accelerometer and several seismoscopes has been proposed. It is unlikely that the instrumentation will be installed before the end of 1967 and thus insufficient time will be available to obtain data which can be incorporated in design calculations.

It is considered that while surface instability caused primarily by earthquake movement is unlikely to endanger the operation of the underground scheme, it will certainly have to be seriously considered in the protection of surface works and access roads. As a large amount of unconsolidated material will be used in the construction of the storage dam in the second stage of the scheme, a programme of investigation of seismic response should yield important information on the stability of the dam under earthquake stresses.

Table 2

Details of Seismic Record of Earthquakes felt at Kainantu
1961 - 1966

(Information as determined by United States Coast and Geodetic Survey)

Date	Felt Intensity (m.m.)	Distance to Epicentre (miles)	Depth of Focus (Km)	Magnitude (Richter)
24. 6.61	IV - V	134	212	6.2
13. 9.61	V - VI	92	100	5.3
9. 3.62	IV - V	42	76	6.0
24. 3.62	VI - VII	75	111	6.0
27. 12.62	III	95	35	6.0
6. 2.63	IV	95	90	5.1
14. 2.63	V - VI	130	80	6.0
16. 2.63	I	135	82	4.6
26. 2.63	VI - VII	85	171	7.1
8. 6.63	II - III	95	170	5.1
23. 6.63	III	55	61	5.3
11. 8.63	III	115	86	5.5
22. 12.63	III	70	102	5.4
12. 1.64	III	90	229	5.6
24. 4.64	IV - V	145	106	6.6
4. 10.65	IV	100	75	5.8
6. 10.66	IV	30	113	5.8
25. 10.66	IV	90	67	5.6
15. 12.66	V	91	91	5.3
23. 12.66	V	165	43	6.7

GENERAL GEOLOGY

Lithology and Stratigraphy

Bena Bena Formation

To the west of the tunnel line, in Yonki Creek, there are many exposures of a finely banded mica schist which is extensively folded and contains mainly siliceous veins. The rocks dip steeply and no regional structural pattern is obvious. In thin section the quartz-muscovite-biotite schist was found to contain a few grains of cordierite; the minerals form small folds and crenulations within a metamorphic layering (Appendix 4). The rock has undergone two stages of metamorphism, the first regional and the second contact thermal in effect. The second metamorphic phase is probably due to the intrusion of the Akuna Dolerite which forms Yonki Dome.

The contact between the schists, which are believed to be part of the Bena Bena Formation, and the overlying marble of the Omaura Greywacke is not exposed; at one location on Yonki Creek the marble is downfaulted against the schist. The conglomeratic band which may mark the basal horizon of the marble, is exposed on a tributary of Yonki Creek, but its relationship to the underlying rock is obscured by a dolerite intrusion. The metamorphic grade and degree of folding in the Omaura Greywacke is much lower than in the Bena Bena Formation.

No schists were encountered at any stage of the tunnel investigation but D.D. 20A penetrated over 400 feet of marble and the northern section of the tunnel may possibly penetrate the underlying Bena Bena Formation.

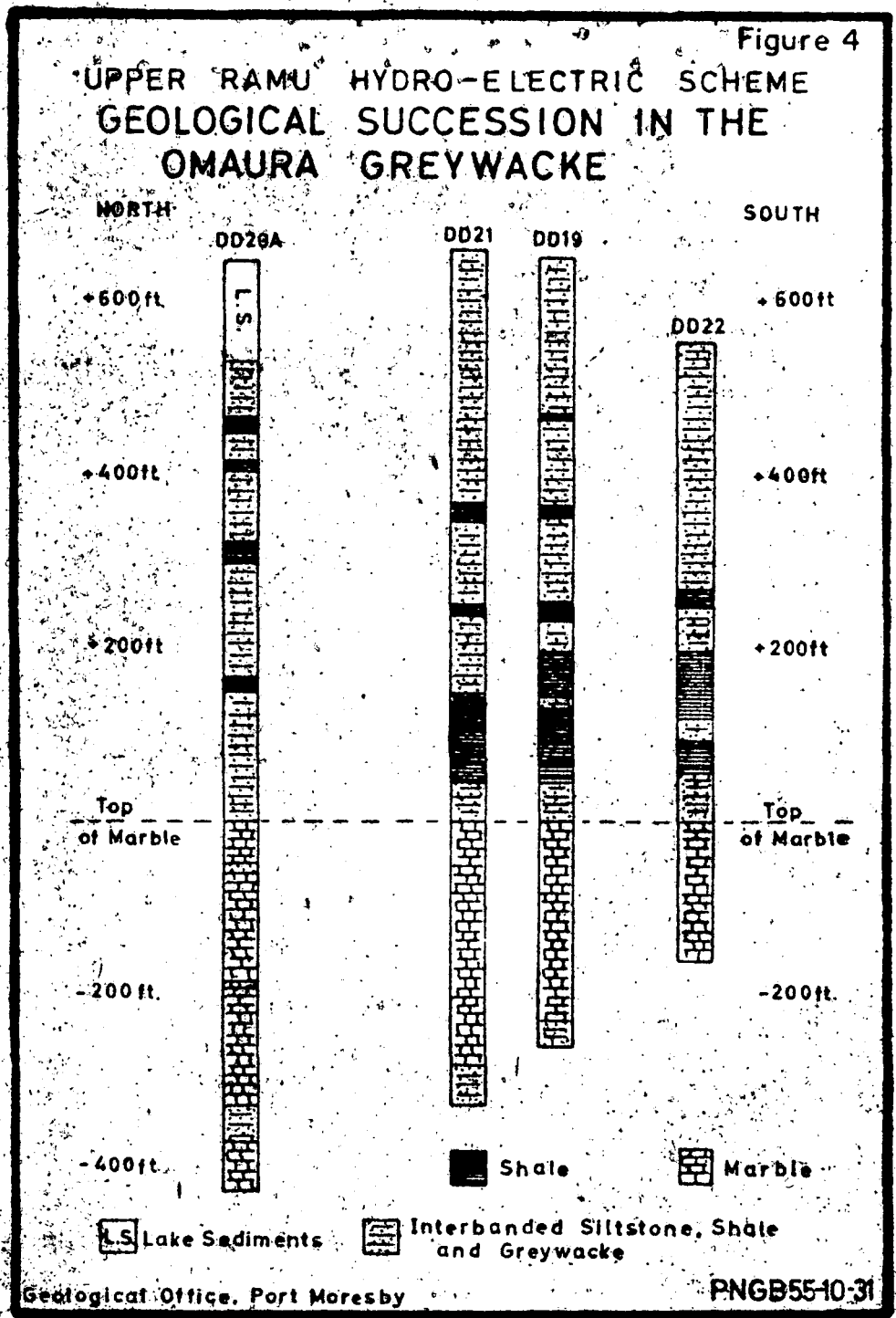
Omaura Greywacke

In the area around the proposed hydro-electric scheme the tightly folded, high-grade metamorphic rocks are overlain by a sequence of gently folded, faulted, indurated and partly recrystallized sedimentary rocks of Lower Miocene age. The Miocene rocks are part of the Omaura Greywacke (Dow and Plane, 1965) and almost all the underground excavation for the scheme is expected to be in this formation.

A partial succession of the Omaura Greywacke is shown in Figure 4, compiled from holes DD20A, DD21, DD19 and DD22. The rock thickness is corrected for bedding attitude. The formation consists of a lower, marble, bed overlain by a thick succession of fine-grained greywacke, siltstone and shale. All rocks have been consolidated by diagenesis and indurated by thermal metamorphism due to the nearby intrusion of igneous rocks. Mapping has shown that beds, including the marble, tend to be lenticular, making detailed correlation between exposures and drillholes impossible.

The marble is of unknown thickness: DD20A passed through over 400 feet of marble, which included a few narrow siltstone bands; DD21 and DD19 passed into siltstone after about 250 feet of marble but the drilling was stopped before it could be definitely concluded that the base of the marble had been reached. The cliffs on the northern side of the Ramu gorge downstream of the outlet have exposures of marble which must be at least 400 feet high. The thickness in the drillholes may be affected by faulting although definite signs of shearing were found only in DD22.

It is apparent from the drill cores that there is some siltstone below the marble; it is, however, probably not a thick band. Several exposures of a conglomeratic bed occur at a low level in the marble on Yonki Creek. The bed consists of rounded boulders of schist and igneous rock in a marble matrix and may represent the basal conglomerate of the Miocene rocks



in the area (Plate 2). Alternatively it may represent a skarn at the contact of a dolerite intrusion, with blocks of the dolerite and the underlying schist enclosed in a partially liquified limestone matrix.

The marble is exposed in Yonki Creek, in the Ramu Gorge at the outlet portal, and north of the Swiss Mission in Chasm Creek. It was also located in each of the drill holes for the underground works. It is likely that most of the tunnel and machine hall will be excavated in marble.

The marble is massive, white and crystalline with very faint banding. Occasional impurities indicate the bedding planes and discolour the rock slightly. Jointing is well developed and in outcrops extensive solution has taken place, with the formation of caves and sink-holes. The stream north of the Swiss Mission runs underground through a sink hole and emerges half a mile distant as Chasm Creek, which drains into the Ramu Gorge 50 yards downstream of the proposed tunnel outlet portal. The marble located in the drill holes shows no sign of extensive solution but there is evidence of water action along joints. In thin section the marble consists of even-sized grains of calcite with a few grains of quartz and feldspar. There is a slight preferred orientation with some evidence of shearing (Appendix 4).

Above the marble there is a considerable thickness of interbanded siltstone, greywacke and shale. DD21 passed through at least 700 feet of these rocks and it is evident from exposures that the siltstone, greywacke and shale succession is several thousand feet thick. The greywacke is light-grey, fine to medium grained with visible individual particles and commonly well-developed graded bedding; the siltstone is finer grained and dark blue and grey in colour with some recognisable graded bedding; the shale is very fine grained and black with a faint lamination which is accentuated in weathered outcrops. In some places the lamination is absent and the rock resembles a fine dark mudstone or claystone.

In thin section the greywacke consists of grains of quartz and feldspar with recognisable rock fragments and a matrix mainly of clay minerals. The same minerals are in the finer grained siltstone and greywacke with a decrease in grain size and an increase in the amount of matrix (Appendix 4). In the shale the matrix contains an appreciable amount of carbonaceous matter; the zeolite prehnite has formed in some shales by recrystallisation. It is obvious that these rocks are of the same origin and that differences are due to slight changes in the conditions of deposition.

Throughout the succession the greywacke and siltstone are finely interbanded and in most cases it is preferable to refer to the rock as a greywacke-siltstone. The shale is often found in more or less clearly defined bands although it is also closely associated with the other rock types. In the upper part of the succession the greywacke and siltstone are predominant and lower down there are thick bands of shale.

Immediately above the marble there is a sequence of siltstone and shale with occasional impure limey bands, then thicker bands of shale with interbedded siltstone and shale. The thick shale bands are prominent at the southern end of the scheme but not farther north. The drill cores confirm the considerable variation in the succession and attempts to correlate individual beds or groups of beds within this section of the Omaura Greywacke have been found to be impracticable.

As a result it has proved impossible to relate exposures in the Ramu Gorge to a precise stratigraphic position or to correlate them with sections of drill core. As the marble is exposed only near the outlet portal it has not proved possible to determine precisely the structure of the area nor, in particular, to assess displacement on faults.

Kainantu Beds

The Omaura Greywacke and older rocks are unconformably overlain by horizontal Pleistocene to Recent lake sediments. These sediments consist of a basal conglomerate overlain by a succession of fine-grained silt, sand and clay with rare thin conglomerate lenses. The basal conglomerate ranges in thickness from over 60 feet in the south at the damsite about 1 mile upstream from the intake (MacGregor, 1965) to about 10 feet in the north above the outlet portal. The conglomerate contains boulders, cobbles and pebbles of the older sedimentary, igneous and metamorphic rocks of the area, in a matrix of silty clay. At the base of the conglomerate there are several large boulders of gabbro, diorite and granodiorite (Hill, 1962), some of which measure over 20 feet across. The boulders crop out on the sides of the Ramu Gorge at the level of the base of the Kainantu Beds and, as a result of erosion, are found on the lower slopes and in the river. Geological mapping to the north of the No. 1 Scheme has shown that the lower section of the gorge and the area to the east of the river is underlain by a large quartz diorite and granodiorite mass. The boulders at the base of the Kainantu Beds are most probably derived from this body.

A specimen of carbonised wood located in the basal conglomerate at a depth of 116 feet in drill-hole S.3 has given a radiocarbon age of 36,900 years $\pm$ 2000 years (CR. 1767). A sample of carbonised wood collected from the conglomerate in a cliff beside the Ramu river upstream of the weir site has given a radio-carbon age of greater than 54,000 years (CR. 2012). It seems likely that the second reading is more accurate but even this places these beds well into Recent times. The true age may be greater than 54,000 years.

Above the conglomerate there is up to 300 feet of clay and silt bands with occasional thin lenses of gravel. There are numerous signs of scouring and other primary sedimentary structures. The succession is exposed in numerous landslips and in road cuttings in the area. All the sediments are poorly consolidated; some are jointed. Typical sections and descriptions are given in MacGregor (1965).

The fine-grained nature of these beds and their low permeability give rise to a relatively unstable material in the wet season. There has been extensive land-slipping in the upper parts of the formation.

No excavation for the underground scheme will be carried out in the Kainantu Beds but they are important as they will underlie most of the construction tracks and access roads.

Akuna Dolerite

After the deposition of the Omaura Greywacke and before the formation of the Kainantu Beds, the area was affected by several major basic igneous intrusions accompanied by a series of minor basic dykes. To the west of the scheme the Omaura Greywacke and the Bena Bena Formation have been intruded by the Akuna Dolerite in the form of the Yonki Dome - a large mass of gabbro, dolerite and peridotite (Appendix 4). Around the margin of this mass there are many basic dykes and sills ranging in composition from augite andesite to dolerite. The dykes are generally porphyritic with either a coarse or fine grained matrix; many have fine-grained chilled edges and range in width from a few inches to over 20 feet. Most of the dykes trend east-west, approximately at right angles to the proposed tunnel line.

The excavations for the Ramu Scheme are not expected to encounter the main mass of the Yonki Dome but will intersect many minor basic dykes.

Structure

In the area of the scheme the Omaura Greywacke is folded into a broad anticline plunging at a gentle angle to the south-east. The anticline contains minor folds and is extensively faulted.

Folding

Near the intake works the interbedded, indurated siltstone, greywacke and shale strike at about 060° and dip to the south at angles ranging from 25° to 40° (see Plate 3 and Fig. 22). Exposures along the Ramu Gorge between the intake and the outlet portal show a decrease in angle of dip to the south and then a dip to the north-east which at the tunnel outlet has reached 25° , with a strike of 120° (Plate 2). Both in the Ramu Gorge and along Loop Creek there are several minor anticlines and synclines which are conformable with the major structure.

Within the Bena Bena Formation there are complex minor folds, faults and shears which were clearly formed before the overlying Omaura Greywacke was laid down; they bear little relation to the major structure described above.

Jointing

All the rocks in the area, with the exception of the Kainantu Beds, are extensively jointed. Most joints are either parallel or normal to the bedding; some are related to fault zones. An analysis of joint directions in the weir site area is given in Figure 17. It was found that the intensity of jointing is commonly related to rock type: joints are more numerous in the fine-grained dolerite and shale than in the coarser-grained greywacke and gabbro. In weathered shale parting parallel to the lamination is very prevalent. In the marble joints are rectilinear and show some signs of solution. In areas of outcrop extensive solution has formed large caves. All jointing in the drill cores has been noted and fracture summaries are given in the drill logs (Appendix 6). In the cores there is no indication of large underground openings in the marble. Jointing in the Bena Bena Formation is similar to that found in the overlying beds. Earlier joints are filled with siliceous veins and are tight.

In the Kainantu Beds consolidation has resulted in the formation of vertical joints in some beds; joint faces are commonly stained with iron transported by groundwater.

Faulting

Several exposures of narrow fault zones were located in the creek beds but because of the lack of marker bands an accurate determination of displacement is not possible. Examination of the aerial photographs of the area suggest that some large faults may be present (Fig. 19).

A shear zone ranging in width from 6 inches to 2 feet and trending east-west can be traced for several hundred feet just downstream of the weir site (Plate 3). The fault plane appears to dip steeply to the south. A shear zone picked up at a depth of 660 feet in DD22 has been tentatively correlated with the surface zone. Drilling in the machine hall area indicates that between DD19 and DD22 the siltstone-marble contact has been displaced by between 80 and 150 feet presumably by this and associated faults (Plate 5).

Several shear zones in the intake area seem to be related to the margins of dolerite dykes. In the drill cores most dolerite dykes show no sign of shearing.

In Yonki Creek marble is found down-faulted against the Bena Bena Schists with considerable discordance in strike and dip.

It is considered that faults will be encountered in the underground excavations but that zones related to these faults will be narrow. It is not possible to forecast accurately where the faults will be encountered.

Metamorphism

The schists of the Bena Bena Formation have been extensively re-crystallised, with the production of metamorphic minerals such as cordierite and epidote. Two stages of metamorphism, the first regional and the second thermal, can be recognised (Appendix 4).

Thin section examination of rocks from the Omaura Greywacke has shown some alteration of the clay minerals in the siltstone to prehnite and chlorite and also the recrystallisation of the calcite in the marble. This indicates low-grade thermal metamorphism - presumably due to the nearby gabbro and dolerite intrusions.

The sediments making up the Kainantu Beds are unaffected by metamorphism.

The metamorphic history of the area therefore consists of two episodes; the first a low-grade regional metamorphism presumably associated with the complex folding before the Omaura Greywacke was deposited; the second a low-grade thermal metamorphism associated with the intrusion of basic igneous bodies at some time after the deposition of the Omaura Greywacke and before the formation of the Kainantu Beds. The thermal metamorphism probably was contemporaneous with, or post-dated, the folding of the Miocene sediments.

Groundwater

The drilling for the high-level tunnel line located groundwater at about the level of fresh bedrock (Figure 5). The drilling for the low-level scheme initially located groundwater at about the same level (about 100 feet) but in drillholes DD19 and DD21 the static water level dropped to 250 feet shortly before the hole entered marble at about 700 feet. No groundwater was found in DD18. Extensive groundwater movement has taken place, and caves have formed in areas where the marble crops out, but examination of cores and water pressure testing failed to reveal evidence for substantial water movement in the machine hall area or in the section of the tunnel line which has been drilled, apart from a section of DD18 below Recorder Creek.

Slope Stability

The rapid downcutting of the Ramu River and its tributaries has resulted in steep slopes, especially on the sides of the Ramu Gorge. The lower slopes are composed of Omaura Greywacke meta-sediments with minor intrusions; the upper slopes are underlain by conglomerate, silt and clay of the Kainantu Beds.

The metasediments are strong, and instability of the slopes under which they lie is restricted to slipping in overburden made up of weathered and fresh fragments of bedrock in a clayey matrix. The chief danger in this area is the movement of isolated boulders of rock.

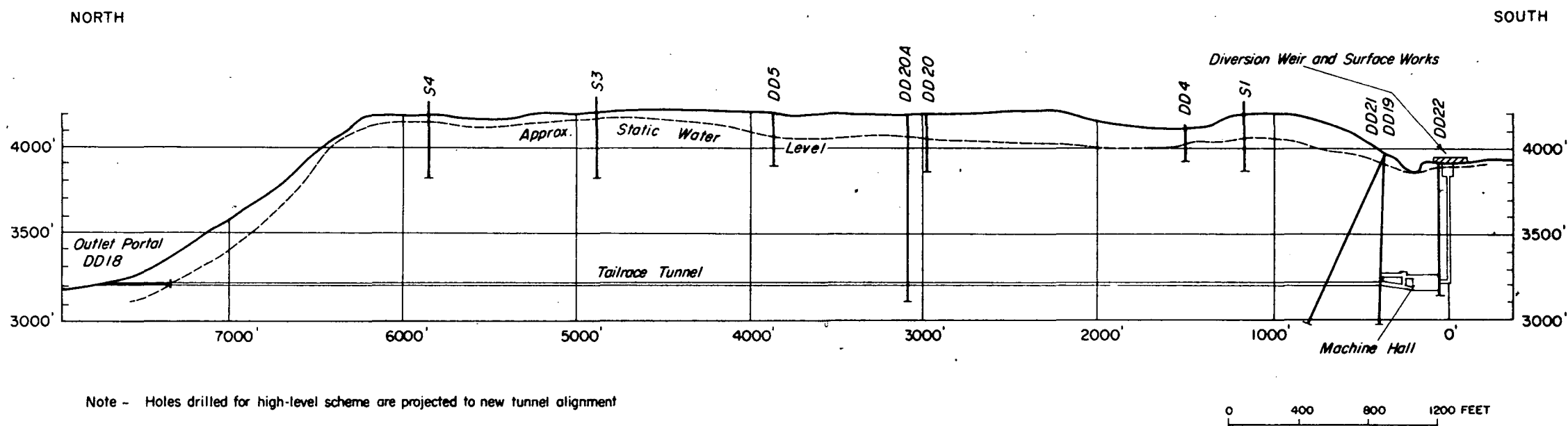


Fig. 5 Layout, Drillholes and Groundwater Levels



Figure 6a: Basal conglomerate in marble of Omaura Greywacke; Yonki Creek.



Figure 6b: Massive marble in Omaura Greywacke near point of entry underground of Chasm Creek, north of Swiss Mission.

The strength of the Kainantu Beds is much lower and there are many instances of slipping in this formation. The slipping consists normally of a low-angle movement of silty and clayey material along a water-saturated plane of weakness after prolonged rainfall. Most of the slips are small but in places masses of sediments several hundred feet wide have moved. Tension cracks are found in many places.

The instability of the Kainantu Beds should not seriously affect the construction of the scheme. In the weir and intake area there are several small slips of Kainantu Beds over metasediments which will have to be taken into consideration during construction of the surface works and access road. The tunnel outlet will have to be protected against slipping in overburden and also against isolated falling rocks. The proposed alignment of the access track to the tunnel portal cuts across the lower slopes of the gorge and traverses several slipped areas.

ENGINEERING PROPERTIES OF ROCKS

Bena Bena Formation

The exposures of mica schist in Yonki Creek have a strongly developed foliation (Appendix 4). Folding and minor puckering of the foliation planes followed by siliceous injection along joints has bonded the rock, and it is now strong and hard. In weathered exposures however there is a tendency for the rock to break along the foliation. Later jointing is moderate, with some clay-filled fractures. If encountered in underground excavation the schists should prove durable and easy to mine; there may be some preferred parting along foliae and joints, but, apart from zones of faulting and shearing, little overbreak should occur and support should not be needed. The condition of the previously exposed Bena Bena metamorphics at the time the Omaura Greywacke was deposited, is not known; even if there was a thick zone of weathering, the weathered rock would have been compacted and indurated to produce a rock at least as strong as the Omaura Greywacke.

Omaura Greywacke

Basal Beds

The thin conglomerate at the base of the marble in Yonki Creek is composed of rounded boulders of schist and basic igneous rock, in a matrix of marble (Fig. 6a). The boulders are fresh to moderately weathered and moderately strong, and metamorphism of the matrix has bonded the rock into a uniform strong body. Jointing is rare. In exposures, extensive solution has weakened the conglomerate by removal of the matrix but, if encountered underground, the rock should be strong and fairly easy to mine.

Marble

The marble is massive, hard and strong. (Fig. 6b). Metamorphism has recrystallised the calcite and produced an interlocking fabric which has resulted in an isotropic body with few traces of the original bedding. On some horizons, however, areas of impurity in the limestone have been converted into a marble with visible bedding which, in places, provides planes of weakness.

The rock is cut by widely spaced rectilinear joints; it breaks into blocks except close to faults where sheet jointing may be present. The metamorphism has rebonded many of the fractures. Jointing is tight but the rounding

of a few joint surfaces in drill cores indicates solution by groundwater. Joints not affected by solution are thinly coated by calcitic material. At the surface the marble contains extensive solution cavities but no large voids were found in drill holes. The lack of signs of collapse in the caves on Chasm Creek indicates that the marble is strong enough to support large excavations.

Shear zones in the marble are bordered by strong but broken rock and filled by small crushed fragments of marble in a matrix of soft crushed calcite with the physical properties of sandy clay. In DD22 there was little water loss through a wide shear zone in the marble.

Tests on core samples from DD21 (Appendix 5) give a range in compressive strength of the marble from 2440 pounds per square inch (p.s.i.) to 16480 p.s.i. The high values were obtained from a sample of massive marble with no apparent bedding and the low values from an impure marble with prominent bedding at 50° to the core axis. The impure marble presumably failed along the bedding. Both samples were located close to basic dykes.

The marble should prove an easy rock to mine - it is not very abrasive and the shape of the underground excavations should be easy to control except where joints or faults cause overbreak.

Siltstone-Greywacke and Shale

The thick succession of metasediments overlying the marble consists of medium to fine grained clastics of generally similar composition which can be differentiated by grain size (Fig. 7a). The strata have been hornfelsed and, where fresh, are hard and strong.

The coarser-grained greywacke and medium-grained siltstone have similar compositions and properties and for most purposes the rock can best be termed siltstone-greywacke as it consists of closely interbedded siltstone and greywacke with a gradation of grain-size from one to the other. Mineralogically, they consist of subangular fragments of quartz, feldspar and rock fragments in a fine-grained matrix of silt and clay sizes. Metamorphism has bonded the rock, destroyed most of the original texture and produced some new minerals.

Tests on fresh siltstone-greywacke have shown that although commonly thin-bedded it shows little tendency to fracture along the bedding. Joints are widely spaced and regular. In fresh rock joints are clean or have a thin coating of calcite but where weathered the joints are filled by limonite or clay.

The finer-grained and laminated rock, shale, is composed of fine laminae of quartz, feldspar and rock fragments in a fine-grained groundmass of clay-size material. The groundmass contains carbonaceous matter, clay and its alteration products, and some pyrite. The alteration products include prehnite, chlorite and mica. The clay has been examined and found to be non-swelling, but some shale on exposure appears to slake and fret slightly. Metamorphism has bonded the rock but the lamination is still prominent in weathered shale.

The shale is more jointed than the siltstone-greywacke and tends to break along the lamination. The joints are clean or with a thin calcite or pyrite infilling where the rock is fresh but coated with clay and limonite where weathered.

Tests on core samples of siltstone-greywacke and shale (Appendix 5) gave a range in compressive strength from 2330 p.s.i. to 12660 p.s.i. The low value is for a fine-grained, thinly laminated siltstone and shale with bedding at 60° to the core axis. The sample almost certainly failed along an



Figure 7a: Interbedded siltstone-greywacke and shale of Omaura Greywacke at No. 1 weir site, Ramu River. Boulder of basic igneous rock at right.

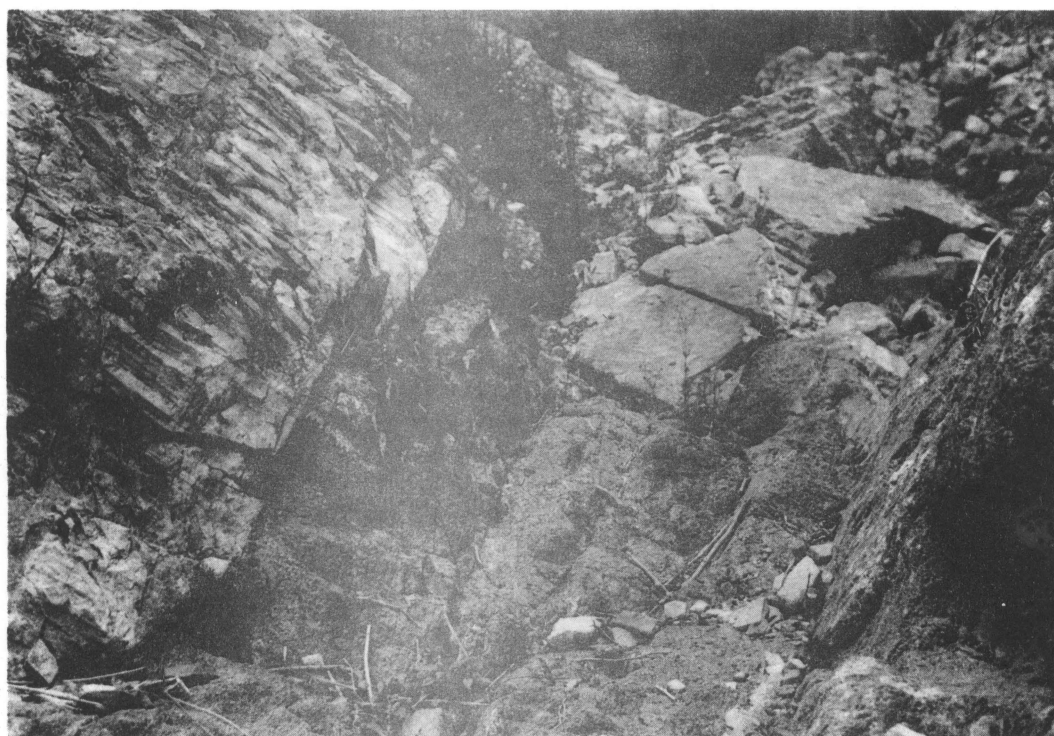


Figure 7b: Weathered basic dyke cutting fresh siltstone; No. 1 weir site, Ramu River.

incipient joint. The high reading was obtained from a relatively coarse-grained specimen of siltstone-greywacke with shale interbeds; the bedding has an attitude of 50° to the core axis. The sample was obtained from about 8 feet above the siltstone-marble contact.

The presence of clay minerals, prehnite and pyrite in the shale indicates that the shale may be unsuitable for use in concrete; it is recommended that, should spoil from mining be considered for use as concrete aggregate, extensive tests be carried out before a decision to use it is taken.

The metamorphism of the siltstone-greywacke succession has produced a hard, strong rock which is abrasive and will give fairly slow drilling. The rock is jointed and may present some problems of overbreak but it is tight and trouble with support and water inflow in underground excavations is unlikely.

Where shale dips at low angles into the roof of underground excavations partings along/planes may lead to some overbreak or require support in the roof. bedding

Kainantu Beds

A preliminary study of the engineering properties of the lake sediments at the proposed dam site was carried out in 1965 by the Central Testing and Research Laboratory, Commonwealth Department of Works (C.D.W., 1965). It was found by field tests that the basal conglomerate and overlying clays and silty clays have permeabilities of 5 - 400 feet per year. Laboratory tests of four undisturbed samples ranging from clay to clayey sand gave cohesion values from 3-32 p.s.i. and angles of friction from $0-29^{\circ}$; plasticity index was from 39 to 87 and permeability co-efficient was from 0.01 to 1.2 feet per year. No underground works will be excavated in the Kainantu Beds but their properties are important in the construction of the access roads, the step-up substations and minor buildings which will be founded on lake sediments. Numerous small landslips in the wet season indicate that care will have to be taken to install proper drainage. The possibility of partial liquefaction of saturated clays during earthquake activity will have to be considered.

Intrusive rocks

The numerous basic dykes are composed of a range of doleritic types, the names of which are determined by mineral composition, grain-size and texture. They consist essentially of various amounts of ferromagnesian minerals set in an interlocking groundmass of feldspar. They generally contain no free quartz. Because of the fabric and the minerals present the rocks are strong, durable and tough where fresh but in weathered rocks the alteration of the feldspar leads to a serious loss in strength. Textures range from fine-grained, equigranular to coarse-grained, porphyritic.

In outcrop, weathering in the basic dykes is much more profound than in the metasediments (Fig. 7b). In the headworks area soft, and friable dyke material was proved to a depth of 12 feet (Hill, 1962). In general, the fine-grained dykes are much more resistant to weathering. Drilling for weir site No. 1 shows a decrease in weathering with depth - by 50 feet the dykes are fresh and approach the strength of the metasediments.

Jointing in the fine-grained dykes is regular but normally unconnected with the jointing in the metasediments. In the coarser igneous rocks jointing is poor but has a greater effect on the weathering of the rock. In weathered dykes the joints are commonly filled with clay alteration products.

The contacts between fresh dykes and the country rocks are, except where sheared, strong, with evidence of chilling in the dyke and contact metamorphism of the metasediments. In weathered rocks and where shearing has taken place within the dyke a zone of weakness has frequently developed along the contact.

No compressive strength tests have been carried out on basic dyke rock but fresh dolerite at depth undoubtedly has strengths comparable with those of the marble and siltstone-greywacke. Slight weathering reduces this strength considerably and all dolerite bodies near the surface should be carefully examined for possible weakness.

In excavation for the weir site the weathered dolerite will have to be removed or grouted to ensure the maintenance of rock strength. Dykes which contain fault or shear zones will require special attention. In depth the quality of the dolerite increases and in many cases appears to have increased the strength of the country rock. Fresh dykes have few joints and should prove durable and present few difficulties during excavation of underground works.

WEIR AND INTAKE SITE

Location

Two possible sites for the construction of the weir and intake works for the underground power station have been investigated. Weir site No. 1 is located downstream of a right-angled bend in the Ramu River (Plate 2 and Fig. 8a); weir site No. 2, upstream of the bend, gives a 10-foot increase in head available for power production, for the same height of dam, and the design of the structure is simplified as possible hydraulic loadings arising from floods turning through the sharp bend are avoided.

Geological Investigation

Mapping

Detailed surface geological mapping of the area around the proposed sites by J.K. Hill in 1961 was extended and re-examined by D.E. Gardner and J.P. MacGregor between 1964 and 1966 (Plate 3). Mapping of the sluiced area at weir site No. 2 was carried out in 1967 by J.R.L. Read.

The area is underlain by the Omaura Greywacke comprising hornfelsed siltstone and greywacke, with interbedded shale. The rocks are generally thin-bedded; they strike at an average of 060° magnetic and dip between 25° and 40° south-east.

The metasediments are intruded by several doleritic dykes and sills and are faulted and sheared.

On both banks of the river the hill-slopes are capped by horizontally-bedded clays and silts of the Recent Kainantu Beds.

Bedrock is covered by overburden made up of either slumped lake sediments or fragments of fresh and weathered metasediments in a clay matrix. The thickness of the overburden ranges from a few inches to 8 feet, with an average depth of about 3 feet.



Figure 8a: Weir site No.1, Ramu River, looking downstream. Slope of left abutment is closely controlled by dip of bedding in metasediments.

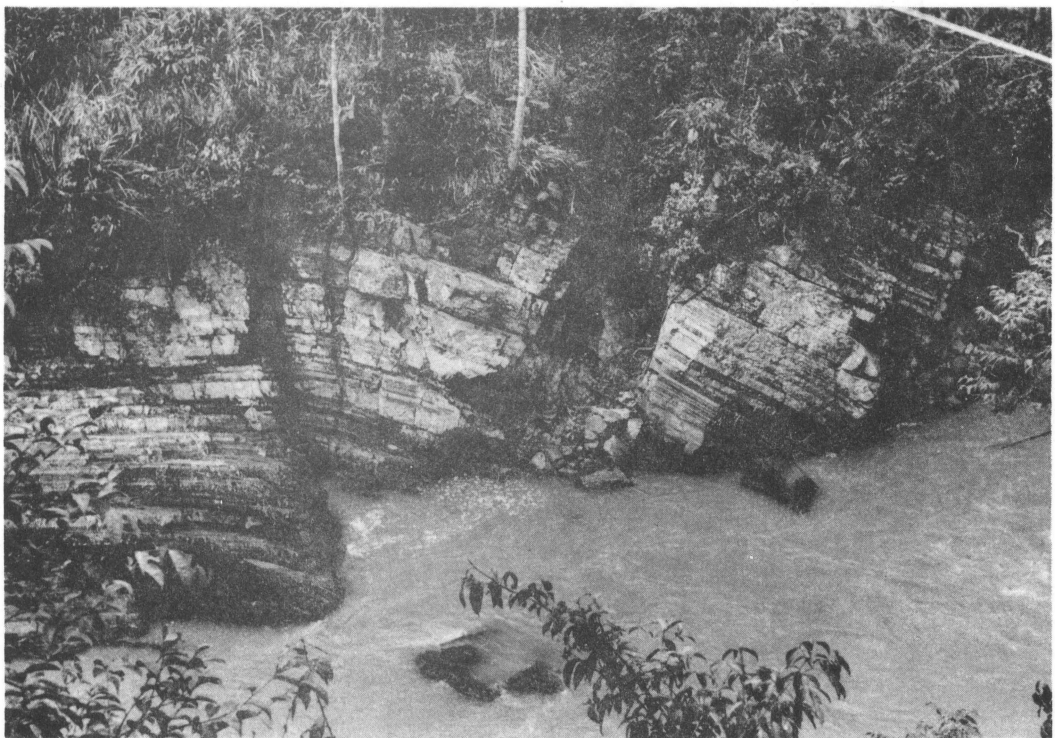


Figure 8b: Metasediments cut by basic dykes, open joints and minor faults; weir site No.2.

The engineering properties of the rocks have already been discussed (p. 18); the metasediments are generally fresh and strong in the banks of the river but somewhat weaker and moderately weathered higher up the sides of the valley. Bedding in the siltstone-greywacke is strongly developed and rectilinear jointing produces blocky fragments. Highly weathered shale breaks along the lamination suggesting that superficial fretting could occur on dehydration; care should be taken to ensure that all loose material is removed before concrete is placed.

The basic intrusions consist of dykes and transgressive sills which range in thickness from a few inches to over 30 feet. Most dykes strike east-west and dip steeply to the north. Chilled edges and contact metamorphism of the surrounding sediments are common. Two main types of igneous rock are present, a fine-grained, equigranular doleritic rock with well-developed jointing, and a coarse-grained, porphyritic gabbroic rock with poor jointing. The coarse rock is susceptible to weathering and is commonly soft and weak at the surface. This thorough weathering extends to a depth of at least 12 feet.

In addition to the extensive jointing, several fault and shear zones have been located in the area. The lack of marker bands makes an estimate of the displacement along the fractures difficult. Some involve a movement of only a few inches. One shear which follows the right bank of the river at weir site No. 1 is tentatively related to the shear zone found near the bottom of DD22 (Plate 5). The shear is downstream of weir site No. 2.

A structural study of the attitude of bedding, jointing and dykes in the weir site area by J.K. Hill is reproduced in Figure 17.

Drilling

A programme of drilling was carried out at weir site No. 1 to confirm the rock conditions in the abutments and establish the rock types and conditions beneath the river (Appendix 6).

DD1 was drilled beneath the river for 200 feet at an angle of -40° on a bearing of 045° magnetic from a site on the right bank upstream of the weir axis (Plates 3 and 4). It encountered broken siltstone, shale and greywacke for 56 feet and then strong rocks of the same type with several fresh basic intrusions. Several small shear zones were found in the broken section and one was located between 162 feet and 163 feet.

DD1A was drilled to intersect DD1 from a site on the weir axis on the left abutment. The hole was drilled 130 feet at -70° on a bearing of 190° magnetic. It intersected fresh greywacke, siltstone and shale with weathered gabbro between 36 feet and 43 feet, and weathered and fresh gabbro from 103 feet. Few signs of shearing were found.

DD1B was drilled 60 feet at -80° on a bearing of 010° magnetic from a site on the right abutment on the weir axis to intersect the broken zone located in DD1. Broken siltstone, shale and greywacke was recovered with few signs of shearing.

DD1C was drilled 49 feet at -70° on a bearing of 190° magnetic from a site on the weir axis above DD1B. It intersected metasediments similar to those in the other three drillholes and some moderately weathered basic intrusions.

No drilling has been carried out at weir site No. 2.

Water Pressure Testing

All four holes at weir site No. 1 were pressure tested in sections to determine possible leakage through the abutments or foundations. Fracture permeabilities were found to be low (see Appendices 7 and 8) indicating that grout take during preparation of the foundations and leakage past the weir would be small.

Costeaming and Sluicing

Three costeams were excavated close to weir site No. 1. On the right abutment a costeam through DD1C and DD1B located fresh to slightly weathered siltstone, shale and greywacke at depths up to 5 feet. Close to the river a shear zone filled with crushed metasediments and dolerite dips to the south at 75°. On the left abutment a costeam on the axis revealed the dip slope of the siltstone-greywacke cut by several basic dykes. A third costeam on the left abutment to the north of DD19 located fresh to slightly weathered bedrock at depths up to 5 feet.

At weir site No. 2 most of the area which will be covered by the foundations and the river bank for a short distance upstream and downstream was sluiced clear of overburden and mapped.

Results

Weir Site No. 1

The investigation has proved that strong, relatively impermeable rocks underlie the proposed weir site. The metasediments dip uniformly to the south striking at right angles to the weir axis and are cut by several almost vertical basic dykes. The siltstone-greywacke is fresh and strong but the weathered dyke material will have to be removed and backfilled. Special care will have to be taken to treat and grout these bodies and also the broken and sheared zone on the right abutment. Hill describes the sheared zone just upstream of the weir site as a fault zone 3 - 4 feet wide, filled with blue-grey gouge and fragments of brecciated country rock. "The gouge consists of tough, plastic, platy clay with numerous polished surfaces, and no difficulty was experienced in excavating this material with pick and bar to a depth of 6 feet. The walls of the fault zone are corrugated and extensively polished and striated. The corrugations and striae plunge at 41° on a bearing of 057°. The gouge is unstable in water; when a sample was placed in still water decrepitation commenced immediately and was complete within two hours" (Hill, 1962, p.9).

The shear zone on either side of this exposure lenses to a few inches and in the area of the weir axis is about 9 inches wide. However it is possible that similar lenses may be present at depth and care will have to be taken to excavate and treat this zone.

The left abutment of this weir site should provide few problems as the rock is strong apart from some weathered dyke material which will have to be removed.

Beneath the river the drill holes have confirmed that the rocks are similar to those in the abutments. Again, care will have to be taken with treatment of the dolerite dykes.

On the slopes above the right abutment there is little overburden and the bedding dips to the south, into the hill, so there is little chance of major landslipping (Fig. 9). On the left abutment, however, the unfavourable angle of the bedding has led to sliding along the rock-overburden face (Fig. 10). If

Drilling rig is over drillhole DD22.

Drillholes DD1B and DD1C are marked by concrete slabs in the costean up the bank below and left of the drilling rig. The shear referred to in the text passes along the foot of the bank, behind the log in the centre foreground.

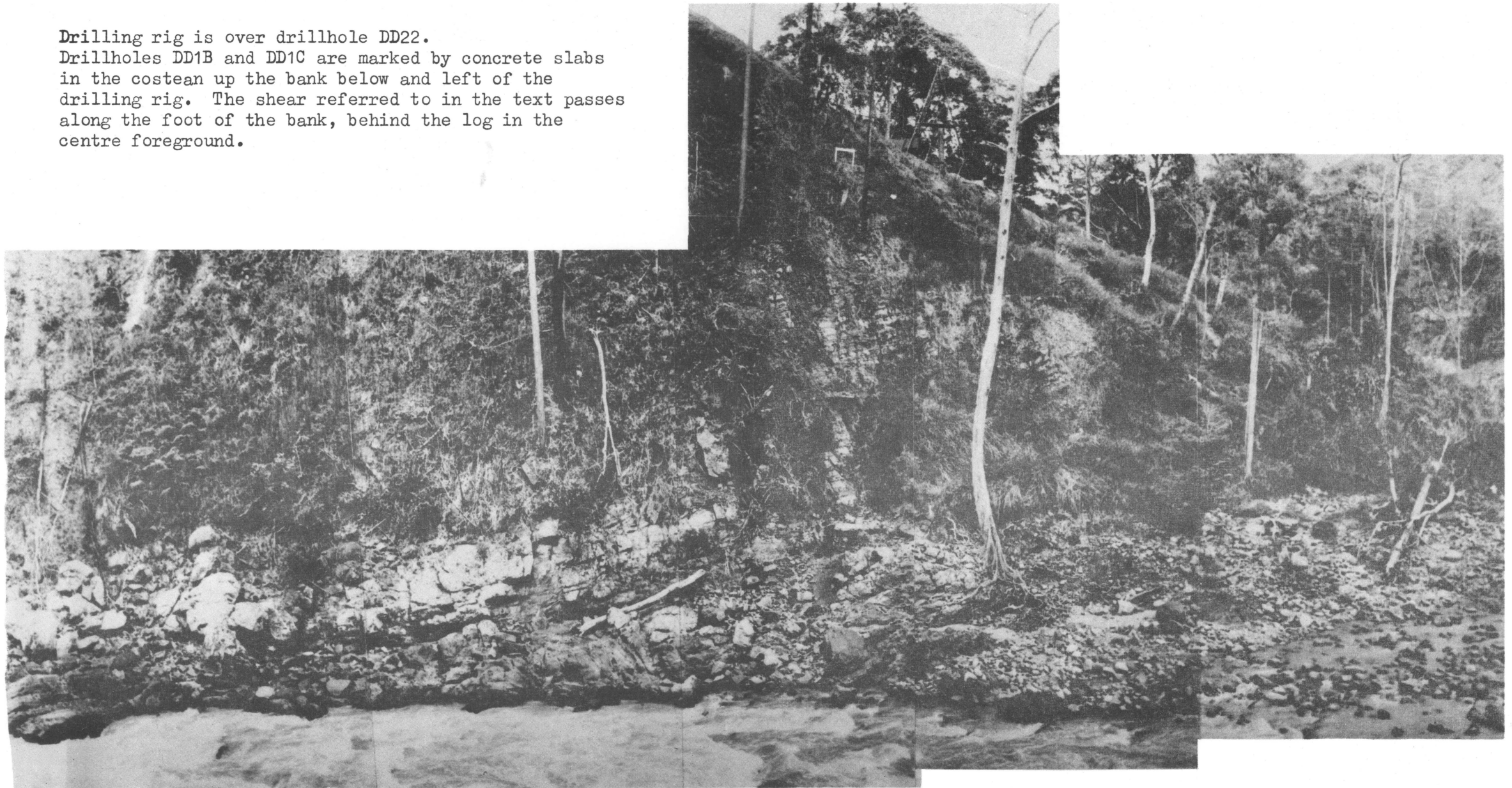


Figure 9: Right abutment of weir site No. 1

To accompany Record 1967/144



Figure 10: Left abutment of weir site No. 1. Collar of drillhole DD1A is in level grassed area in centre of photograph. Note the weathered basic dyke marked by the shallow depression parallel to the bank.

To accompany Record 1967/144

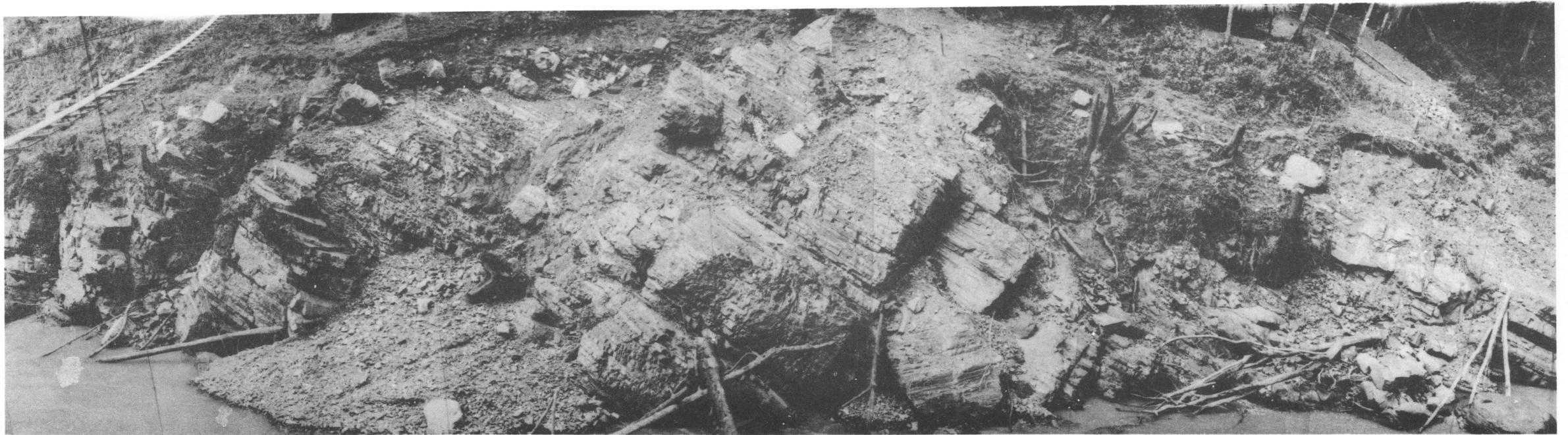


Figure 11: Right abutment of weir site No. 2

To accompany Record 1967/144



Figure 12: Left abutment of weir site No. 2

To accompany Record 1967/144

this weir site is chosen it will be necessary to remove a considerable amount of slipped material and also to drain the overburden in order to stabilise the area and protect the weir.

Weir Site No. 2

Rock types at this weir site are essentially the same as those at the lower site: shale, siltstone and greywacke intersected by numerous irregular dolerite dykes and some dolerite sills.

The shale, siltstone and greywacke are closely interbedded, strike roughly parallel to the weir axis, and dip upstream at about 35 degrees. Greywacke is dominant, forming beds 4-12 inches thick separated by $\frac{1}{2}$ -2 inch-thick layers of siltstone, and laminations of shale which are up to $\frac{1}{2}$ inch thick. The dolerite dykes range in thickness from 6 inches to 20 feet, strike across the sediments slightly north of west, and dip between 70 and 60 degrees to the northeast. Three dolerite sills which are associated with dykes on the right abutment are oriented along the bedding planes.

Although slight weathering and associated loss of strength has taken place at the surface, especially in areas overlain by soil and scree, siltstone and greywacke are dominantly fresh, strong and hard. The shale is less competent than the other two rock types, being somewhat brittle and shattering on impact into small rock slivers. Weathered laminae are weakly bonded to the surrounding siltstone and greywacke: parting of bedding planes along the laminae is common and surface exposures can be readily broken away with a light hammer blow.

The dolerite is almost entirely highly to completely weathered, soft and weak. The results of diamond drilling at the lower weir site indicate however that the dykes and sills should be fresh and strong within 10-12 feet of the surface.

Two widely spaced sets of nearly mutually perpendicular joints strike roughly parallel and normal to the weir axis. The joints are mostly closed, showing as faint surface traces across outcrops. The few open joints, which are shown on Plate 3, dip steeply and, particularly on the right abutment, show evidence of movement: exposed faces are slickensided and some joints are filled with up to three inches of gouge and silicified, crushed rock. The maximum movement observed occurs on the right abutment upstream of the weir axis where a set of dolerite dykes have been offset by up to eight feet. Overall the joints, shears and dykes have apparently cut the metasediments into large blocks oriented at a small angle to the weir axis.

A large block of interbedded shale, siltstone and greywacke protrudes from the river valley wall along the axis of the left abutment. The block is separated from the wall by a steeply-dipping, fractured joint normal to the axis. Excavation for the abutment will have to be carried beyond the joint into the wall to provide a uniform footing for the left hand pier (as shown in Commonwealth Department of Works Drawing HC66/180/B); to ensure this the centre line of the pier should not be east of co-ordinate line 42,820E. Any areas of fragmented, incompetent shale exposed in the excavation should also be removed prior to the placing of concrete. This measure should be carried out in all areas where foundations are to be formed. A weathered dolerite dyke located in the sill area downstream of the pier will have to be excavated to sound rock and back-filled with concrete.

The foundations of the central pier have not been investigated. The sequence of shale, siltstone and greywacke exposed in the left and right abutments is however almost certainly continuous beneath the river and conditions for excavation should be similar to those in the abutments. A dolerite dyke should be encountered on the left hand side of the river channel which,

if weathered, will require cleaning out to sound rock and back-filling with concrete.

If the centre line of the left pier is fixed along the line of co-ordinate 42,820E the centre line of the right pier will be approximately located along the line of co-ordinate 42915E (weir dimensions as in drawing HC66/180/B). In this area the pier footing will be located on a block of superficially weathered interbedded shale, siltstone and greywacke cut by a steeply west-dipping sheared joint which strikes at 55 degrees to the weir axis. During excavation for the pier footing the downward extension of the joint will have to be checked and, if necessary, treated, to ensure that it does not interfere with the stability of the foundation. Similarly, the weathered multiple dyke exposed immediately downstream of the pier area will have to be excavated to sound rock and back-filling with concrete.

The highest exposure of rock in the vicinity of the right abutment is at R.L. 3900 feet. Excavations in costean number 1 (Plate 4) indicate that this rock surface extends horizontally approximately 45 feet east of the right pier and does not rise to the assumed top level of the pier (3930 feet) for at least another 50 feet to the east. It will therefore be necessary to construct a cut-off wall from the upstream face of the floatwell structure to intersect bedrock above top storage level in the side of the river valley east of the weir. The wall will have to be keyed into sound rock and the area between the wall and the centre line of the weir should be backfilled with suitable rock material.

Overburden on the slopes above the left hand side of the weir is considered to be stable. Although the shale, siltstone and greywacke dip outward slightly the depth of overburden has rarely been observed to exceed two feet and there is no evidence of landslide activity either immediately upstream or downstream of the weir axis.

Type of Structure

It is considered that the strength of the rocks at either weir site is adequate to support the type of structure proposed: a sill on which large radial gates are mounted.

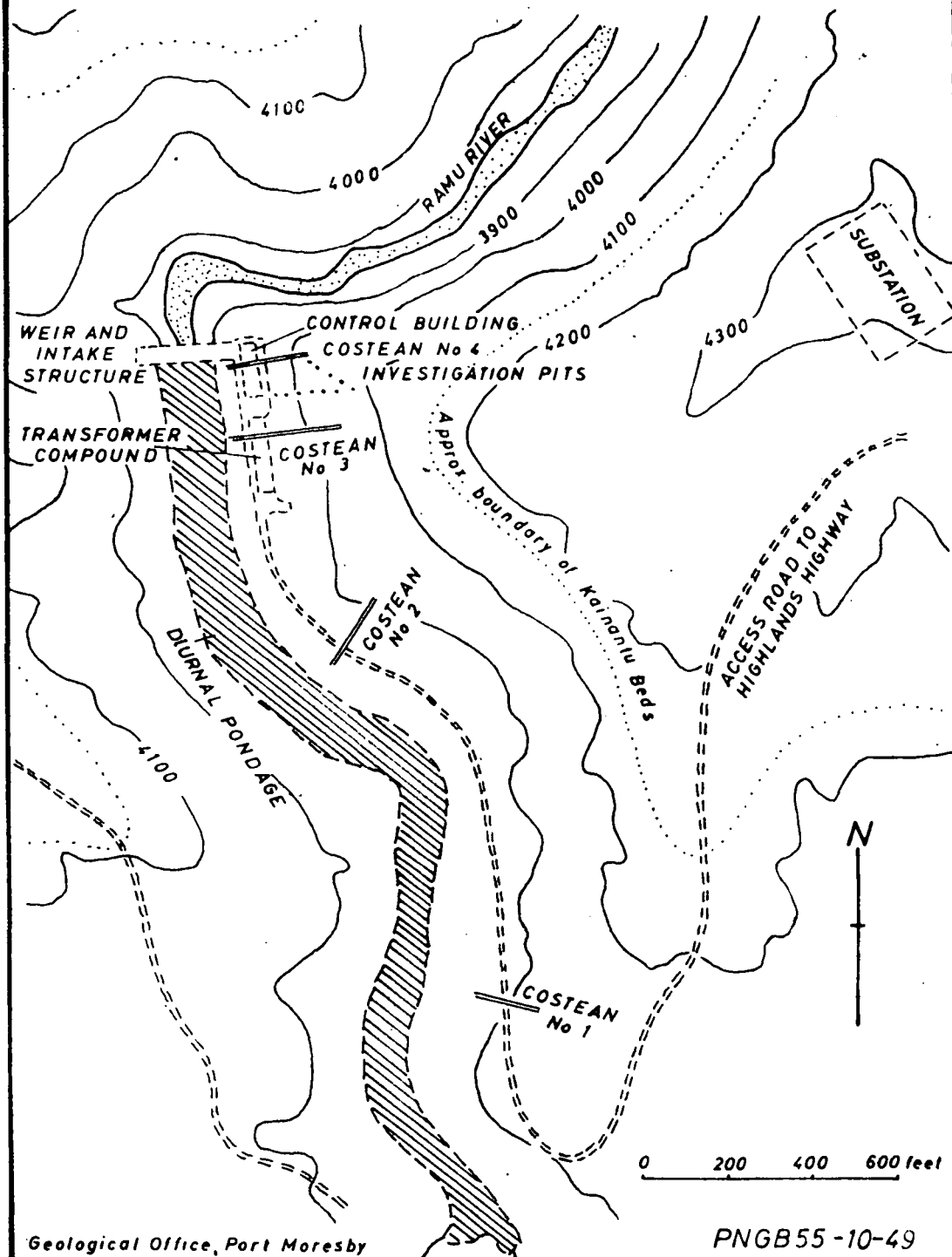
As this type of structure is subjected to severe sliding and overturning forces the foundations must behave monolithically; in particular they should be free of near horizontal discontinuities. At weir site No. 2 there is no evidence for near-horizontal joints; however, the bedding dips upstream at about 35° to the horizontal. One possible weakness would be along partings parallel to the bedding planes. Mapping of the area has shown no extensive soft, weak beds which could provide this plane of weakness but the structure should be stabilised by keying the sill into the rock through as many beds as possible. It may be necessary to tie the sill to the rock with anchor bars or bolts, which should be so oriented and of such a length that they intersect many bedding planes.

Conditions at weir site No. 1 are expected to be similar but, with the differing orientation of the geology relative to the weir, particular care would have to be taken to tie together the beds on the left abutment.

Grouting

Permeabilities calculated from water pressure testing of the holes drilled at weir site No. 1 (Appendix 8) indicate that, in most sections of the foundations, grout take will be low. However, the deep weathering of dykes striking at right angles to the weir axis forms a possible leakage path which will have to be sealed by a curtain grout. At weir site No. 2 the rock condition is similar and although the dykes are at an oblique angle to the weir axis a grout curtain is still required to eliminate leakage.

UPPER RAMU HYDRO-ELECTRIC SCHEME Fig 13
**SURFACE WORKS SHOWING DIURNAL PONDAGE
 AND LOCATION OF PITS AND COSTEANS**



Geological Office, Port Moresby

PNGB55-10-49

At both sites consolidation grouting of the foundations will be required to ensure the bonding of the rock into a sufficiently large mass to resist the overturning and sliding forces acting on the weir. This grouting is especially important at weir site No. 2 where the beds in the foundation rocks dip upstream. The layout of grout holes and details of depth and grouting pressures should be calculated by the site geologist based on grouting tests during construction.

Earthquake Response

The design of the weir and intake structure should include a safety factor to allow for the high seismic risk in this area. (see p. 10 for probable intensities).

Diversion During Construction

It is considered that the construction of the weir in two sections allowing the Ramu River to flow through the section not under construction would adequately cope with the problem of diversion. Overtopping of the cofferdam by flood is likely to occur in the course of construction.

Suspended Material and Bedload

The Ramu River in flood carries much surface debris and suspended silt and clay. During low flows the water is still muddy owing to the sluice water from gold workings on Yonki Creek. No measurements of quantities have been made but tests should be carried out on the abrasive properties of the suspended material and the weir should be designed to allow for periodic flushing of the diurnal pondage.

DIURNAL PONDAGE

Location

On completion of the intake works the Ramu River will be ponded for about half a mile upstream from the weir - as far as the confluence of Yonki Creek with the Ramu River (Fig. 13). The exact level and extent of the pond will depend on which weir site is chosen for the scheme.

Geological Investigation

Mapping of the weir site by Hill (1962) was extended to include the remainder of the pondage by D.E. Gardner in 1965. Costeans for the access road and the surface works have given indications of the stability of the slopes in the pondage area.

Results

Lithology and Structure

The pond will be underlain entirely by interbedded hornfelsed siltstone-greywacke and shale which has been intruded by numerous basic dykes. No marble was found. The metasediments are hard and strong and although many

of the dolerite dykes are weathered and soft at the surface the drilling at the weir site indicates that they become fresh at shallow depths.

The structure of the rock is constant with the metasediments striking between 040° and 060° magnetic and dipping to the south-east at angles between 30° and 60° . The basic dykes strike between 090° and 120° magnetic and dip steeply either north or south. There are several thin fault zones and much open jointing at the surface.

Leakage

The rocks throughout the pondage area are tight at depth and it is extremely unlikely that any significant leakage would occur from the reservoir.

Slope stability

The slopes on both sides of the pondage are capped at about R.L. 4150 feet by soft unconsolidated silts and clays of the Kainantu Beds. These are, however, well back from the sides of the river and no major slips from the lake sediments into the valley have been found. On the lower slopes there has been slipping in the weathered Omaura Greywacke and in costean No. 2 for the access road deeply weathered material contains several tension cracks. The slips which have occurred on the right bank of the river are shallow and have stopped on a platform of fresh bedrock close to the proposed top water level of the pondage.

It is considered that any landslips into the reservoir would not be large enough to affect the reservoir capacity or the operation of the weir, intake structures and power generation plant.

POWER STATION SURFACE WORKS

Location

The surface works for the underground power station, comprising control house and transformer yard, will be constructed on the right hand bank of the Ramu River immediately upstream from the weir site. The control building will be located on the spur forming the corner of the river and the transformer yard will be built just to the south. The step-up substation is sited about a quarter of a mile to the east, on the top of the slope, at R.L. 4300 feet (Fig. 13).

Geological Investigation

The detailed examination of the weir site area was extended to include the surface works. To confirm the depth of overburden and the nature of the bedrock several pits were sunk on the slope above the control house site and also costeans were dug through the control house location and across the alignment of the access road from the Highlands Highway.

Results

Lithology and Structure

Examination of outcrops, pits and costeans show that the control building and transformer yard site is underlain by slightly to moderately weathered siltstone-greywacke and shale dipping at 30-40° to the south-east and cut by minor basic dykes. The dyke rock is more highly weathered than the metasediments and many exposures are soft. Overburden above the control building averages 6 feet in depth but in places 13 feet of loose material was found: costean No. 4 revealed on average overburden thickness of 7 feet (maximum depth 13 feet) and costean No. 3 average is 5 feet (maximum 9 feet).

Slope Stability

The control building is located on a spur and there is little danger of a slip from the slope above. The transformer yard to the south is at the foot of a small slip but it is estimated that most of this slip will have to be removed during the excavation of the yard. It will be necessary to stabilise the slope by the removal of some overburden, the construction of lined drains leading any run off to the south of the transformer yard, and the building of a low retaining wall. Two test pits have been proposed to ascertain the extent of treatment required.

Aseismic Design of Buildings

The design of the surface works should include a factor of safety to allow for the high seismic risk in this area (see p. 10). All structures should be founded on rock.

Step-up Substation

The substation for the transmission lines is located on the top of the hill to the east of the transformer yard. It will be underlain by about 150 feet of unconsolidated sediments belonging to the Kainantu Beds. As foundation loads are generally light the lake sediments should provide adequate foundations, but the design of layout and foundation loading should take the following into consideration:

1. The site should be protected against surface run-off and any rainfall should be carried away in impervious drains.
2. Installations should not be positioned on a slope and any unit imposing high loads should be based on a raft footing to reduce load intensity.
3. Elements should be so spaced, designed and anchored as to withstand ground acceleration in the event of earthquake. The effect of an earthquake on unconsolidated sediments would be greater than on the underlying strong metasediments.

Access Road

Examination of the costeans and outcrops along the access road alignment has shown that the first 500 feet from the control building (Fig. 13) will be cut in a moderate side-slope in strong metasediments. Explosives may be required for minor sections of the excavation. Farther south, in the area cut by costean No. 2, the angle of side-slope increases and the depth of overburden is greater than 10 feet. In costean No. 2 tension cracks showing instability were located; deep excavation will be necessary to construct a stable road. Between costean No. 2 and costean No. 1 the alignment crosses the toes of two small slips. The slipped material on the road line should be removed and replaced by more stable material from cuts to the south and adequate drainage under the roadway provided to maintain stability. From costean No. 1

the road climbs up out of the valley in a long box cut which will be excavated in slightly to moderately weathered metasediments and dykes. The rock should be rippable but sufficiently strong to stand up in reasonable batters. Costean No. 1 has shown only 2-3 feet of overburden. The section of the road from the top of the valley to the Highlands' Highway will be formed on unconsolidated Kainantu Beds and care will have to be taken in the preparation of a sufficiently strong pavement with good drainage to ensure the permanency of the road. Experience with the Kassam Pass - Kainantu section of the Highlands Highway should provide a valuable guide for the design of this section of road.

It should be possible to provide a permanent access road at moderate cost; minor slips may require remedial treatment from time to time but maintenance should not present any special problems if the road is properly designed and constructed.

PRESSURE AND ACCESS SHAFTS

Location

The two shafts which connect the surface works and the underground machine hall will be located on the right bank of the Ramu River. The pressure shaft will be built into the right hand side of the weir and its exact position will depend on the choice of weir sites. In Plate 3 it is shown associated with weir site No. 2 upstream of the bend in the river. At weir site No. 1 the pressure shaft is located downstream of the bend.

With either weir position the control building will be in approximately the same place and the access shaft will be sunk close to DD22.

Geological Investigation

The immediate area of the collars of both shafts was examined in detail during the geological mapping of the weir and intake area. DD22 was drilled at the tentative access shaft site to machine hall level; the hole was water-pressure tested and rock temperatures were measured to assess conditions in the shaft.

Results

Lithology and Structure

The surface mapping and the core from DD22 (Fig. 14 and Appendix 6) indicates that the first 600 feet of both the access and pressure shafts will be sunk in interbedded siltstone-greywacke and shale with numerous dolerite dykes. Between 400 and 550 feet there is a marked increase in the shale content of the rock. From 600 feet to machine hall level at 750 feet the shaft should be excavated in marble. Bedding is well developed in the metasediments, other than marble, at between 15° and 50° to the horizontal.

The rocks are slightly to moderately weathered close to the surface but below 75 feet they are fresh and strong.

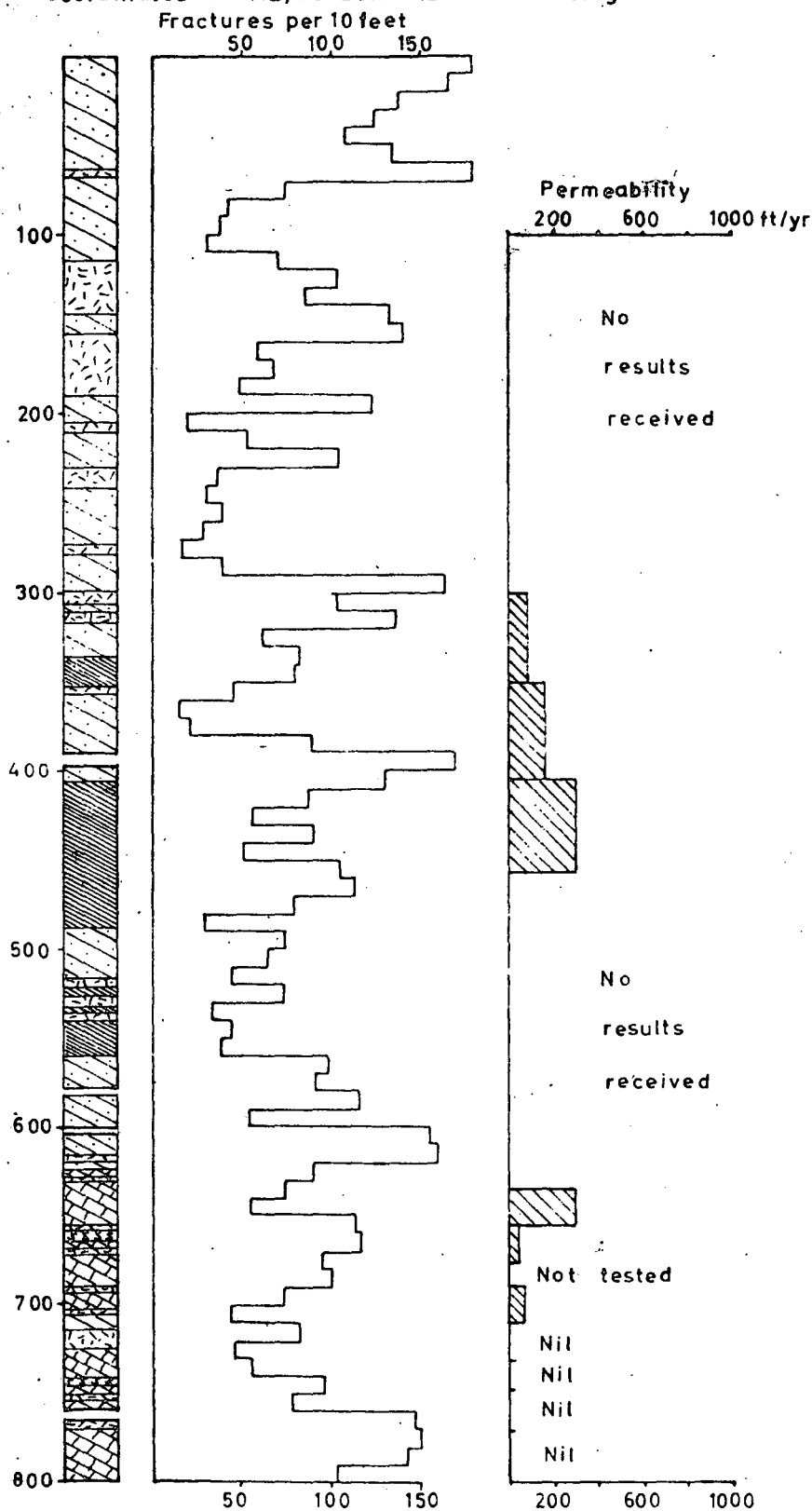
Jointing is well developed but the joints are mostly tight and clean. In several narrow broken zones the joint faces are coated with a thin layer of clay. Near the bottom of DD22 two shear zones were located in marble, one was intersected from 659 to 664 feet; the other from 742 to 743 feet; assuming a

UPPER RAMU HYDRO-ELECTRIC SCHEME

SUMMARY LOG OF DRILLHOLE DD 22

Fig. 14

Coordinates 43011E, 78429N R.L. 3951.4 ft. Angle -90°



LEGEND

- Siltstone shale and greywacke
- Shale
- Marble
- Dolerite
- No core recovered
- Shear

NOTE:

Calculated permeability based on water pressure test results.

dip of 75° for the shears the true widths are one foot eight inches and five inches respectively. As the siltstone-marble contact between DD19 and DD22 has been raised by at least 80 feet it is likely that the shears have been associated with this movement. The shear picked up on the right bank of the river in the weir site area has been tentatively correlated with the shears located in the core. If this is confirmed the shear zone strikes east-west and dips to the south at 75° . The access shaft and pressure shaft sites for weir site No. 2 have been chosen so that this shear will cut across the access tunnel between the base of the shafts and the machine hall.

At weir site No. 1 the shaft collar is cut by the shear, which would affect the shaft for about the first 100 feet.

Probably other, similar, shears are present in the area. They are expected to be narrow with strong rock on either side.

Water Tightness

Unfortunately not all the results from the pressure testing of DD22 have been received but the corrected losses from those sections which have been processed (Appendix 8) indicate that although jointing is prominent water losses are small. Calculated permeability (through joints) ranges from 5 to 300 feet per year and averages 120 feet per year for the 300 feet of hole tested (see Appendix 7).

Excavation and Support

The metasediments are moderately hard and the greywacke-siltstone is abrasive; the rock may prove to be slow and fairly expensive to excavate; the marble towards the bottom of the shafts is less abrasive and should not present any particular problems. Although jointing and bedding is well developed the bedding is well bonded and the jointing tight so there should be little overbreak. In the first 70 - 100 feet of the access shaft the rocks will be found to be weathered and may require some support, but the rest of the shaft could be left unlined, except for local treatment shear and fault zones and closely-jointed sections. Allowance should be made for 10-15% lining and 20% of rock bolting below a depth of 100 feet. Weathering in the pressure shaft may not extend as deeply as in the access shaft. The pressure shaft will presumably be lined throughout. The collar of both shafts should extend to a depth of at least 20 feet into reasonably sound bedrock because of the need to couple the surface structure to bedrock to minimize earthquake damage.

Stress Measurement

During excavation of the access shaft it will be important to evaluate the stress pattern in this area. This can be carried out by the in situ testing of stress relief, using extensometers and flat jacks; the tests should be carried out in both siltstone and marble at a depth not less than 500 feet from the surface. The results from this testing will indicate the amount of support required and the preferred shape of the machine hall.

Seismicity

Although it is unlikely that the shafts will be disrupted by an earthquake, there is a danger that the opening of joints after seismic activity will result in the loosening of blocks of rock and a possible increase in inflow of ground water. To allow for this possibility a conservative approach should be used in the support and lining used in the shafts.

MACHINE HALL

Location

The selection of the most suitable location for the underground machine hall and associated excavations depends greatly on civil engineering requirements which are based essentially on the economics of the scheme - maximum power for minimum expenditure.

Based on these requirements, the level of the generator floor of the machine hall at the Upper Ramu has been fixed at R.L. 3196 feet with excavation extending from R.L. 3170 feet to R.L. 3270 feet. The position of the pressure and access shafts is governed by surface conditions and it has been decided that these should be situated on the southern or right hand bank of the river. To preserve a simple layout with minimum length of tunnels the machine hall must be sited as close as possible to the bottom of the pressure shaft and aligned roughly north-south - in the direction of the outlet portal.

The purpose of the geological investigation of the machine hall area was:

1. to establish that it is geologically feasible to construct a machine hall in the general area;
2. to determine the site with the best geological conditions that will suit engineering requirements;
3. to give an indication of excavation conditions, rock types, support requirements, rock temperature, ground-water conditions, response to earthquakes and any special problems which might be encountered during excavation.

Geological Investigation

Drilling

The depth of the machine hall area from the surface (700 feet) and the cost of diamond drilling seriously limited the amount of investigation which could be undertaken. At the Upper Ramu Scheme three holes, DD19, DD21 and DD22, were drilled to machine hall level at the intake end of the scheme. During drilling the holes were water-pressure tested in stages and the cores geologically logged and photographed. After completion the positions of the holes at depth were surveyed, using a 'Tropari' borehole survey instrument, and the temperature gradient was measured, using a thermistor probe. Detailed geological logs are given in Appendix 6, water pressure test computation sheets are in Appendix 8, and summaries of the results are shown on Figures 15, 16 and 14.

DD19 (Fig. 15) was sited on the axis of a possible access shaft on the left bank of the river. This vertical hole passed through fresh hornfelsed siltstone-greywacke and shale to a depth of 728 feet where the hole entered massive marble which continued for at least 270 feet. Intrusions of fresh basic rocks are found in all rock types. They are strong at machine hall level and do not adversely affect the mechanical properties of the rock mass.

The level at which the marble was struck in DD19 is about R.L. 3250 feet (Plate 5), that is about 20 feet below the highest excavation of the expansion chamber and close to the level of the roof of the machine hall. As the metasediments at the surface dip to the south at between 30° and 40° it appeared likely that, if there was continuity of geological structure at depth,

UPPER RAMU HYDRO-ELECTRIC SCHEME SUMMARY LOG OF DRILLHOLE DD 19

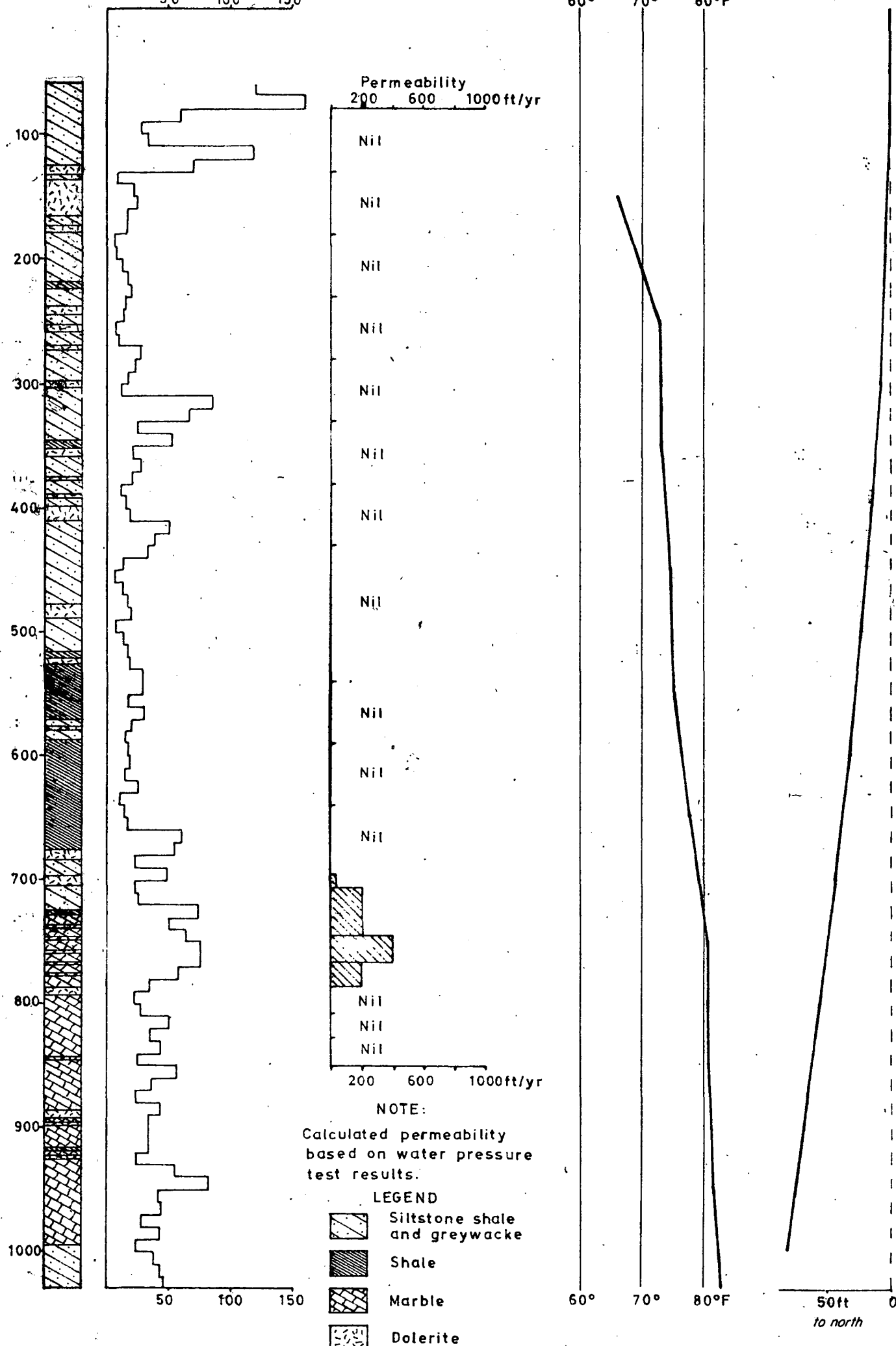
Fig 15

Coordinates 43060E. 78622N R.L. 3971.5ft Angle -90°

Fractures per 10 feet
50 100 150

Temperature Survey
60° 70° 80°F

Borehole
Survey



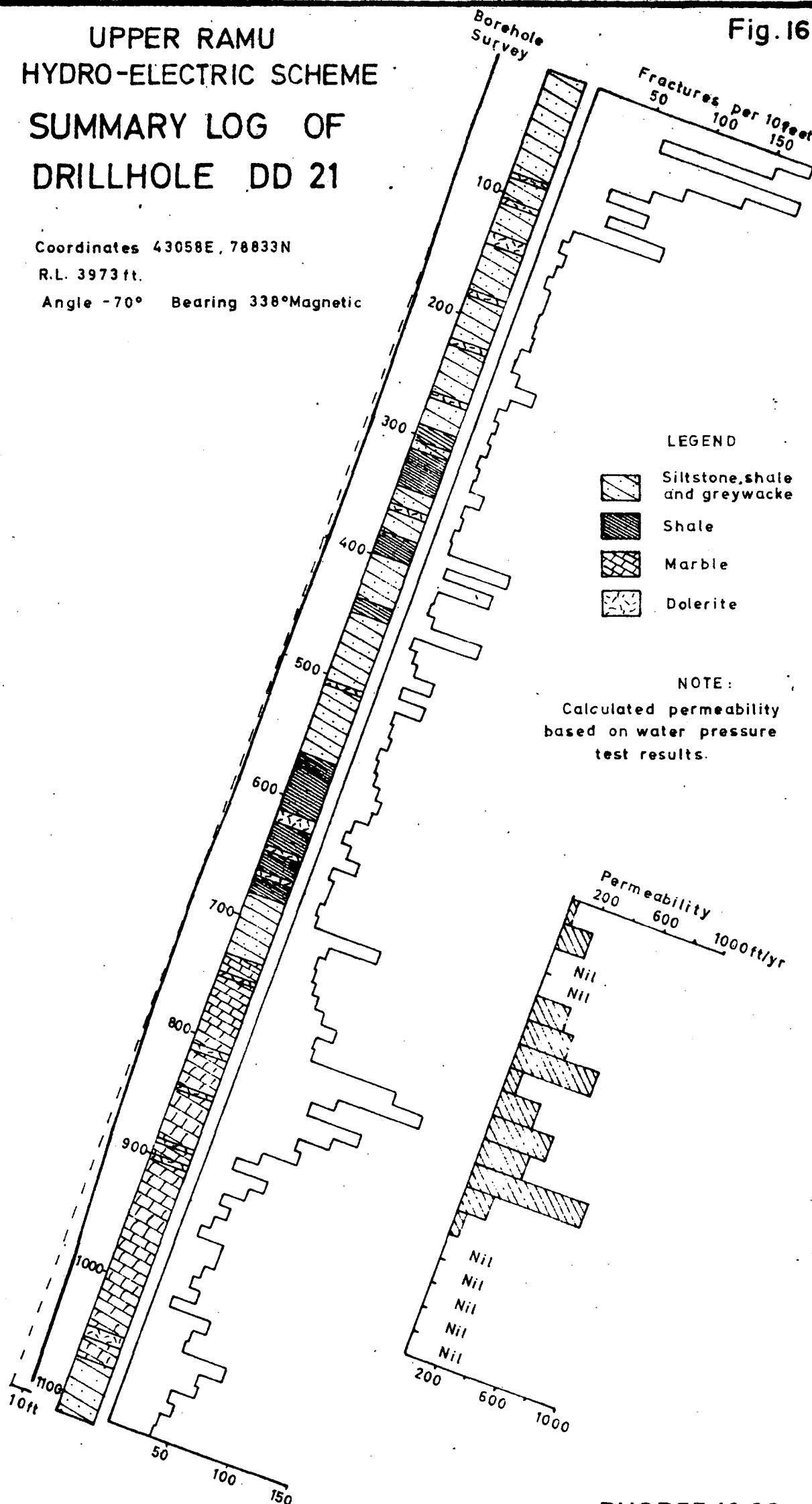
Geological Office Port Moresby 24.8.66

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UPPER RAMU HYDRO-ELECTRIC SCHEME SUMMARY LOG OF DRILLHOLE DD 21

Coordinates 43058E, 78833N
R.L. 3973 ft.
Angle -70° Bearing 338°Magnetic

Fig.16



the contact between siltstone and marble would run diagonally from roof to floor of the machine hall.

In order to explore further the geological structure of the area and to confirm if it would be possible to site the machine hall entirely in marble by moving it some distance to the north DD21 (Fig. 16) was drilled from the site of DD19 but angled at -70° on a bearing of 338° magnetic. This hole encountered similar rock types as those in DD19 and reached massive marble at a depth of 733 feet (R.L. 3280). The marble is over 300 feet thick.

DD21 showed that along the line of the tailrace tunnel the contact between siltstone and shale and the underlying marble rises gradually and not at the angle indicated at the surface. This could be explained by faulting or by a change in the structural direction at depth. The core from DD21 is sound with little sign of either faulting or shearing.

Investigation for the surface works at this time indicated that these should be moved to the right hand bank of the river. Accordingly DD22 (Fig. 14) was drilled vertically down the axis of the revised access shaft position. In order to maintain the most economic layout the machine hall was moved some distance to the south to the position shown on Plate 5. DD22 penetrated the same rock types as the other two holes but the marble contact was struck at 622 feet (R.L. 3320).

The presence of two shear zones in DD22, evidence on the surface and the general increase in jointing in DD22 indicates that the most likely explanation of the difference in level of the top of the marble is the presence of one or more faults, at machine hall level between DD19 and DD22.

Rock Properties and Strength

The engineering properties of the siltstone-greywacke and shale succession, the marble and the basic intrusions have already been discussed (p. 17). The results of compressive strength tests on samples of core from the machine hall area are given in Appendix 5. Petrographic descriptions of these rock types are given in Appendix 4.

All rocks are fresh and strong with clean, tight joints (Condition 4-5, see Appendix I). In the marble there are some signs of water solution along joints but no large cavities were located. The two shear zones in the marble in DD22 contain crushed calcitic material with rare fragments of dolerite (Condition 2-3). Rocks on both sides of the shears are fresh and water losses in this area were low.

In DD19 there is a slight increase in jointing in the marble horizon. This increase is also found in the siltstone and shale some 40 feet above the contact. In DD22 the rocks are more fractured throughout and there is little difference in joint frequency between the siltstone-greywacke, shale and marble.

Orientation of the Machine Hall

A detailed study by J.K. Hill (unpublished note) of the jointing, faulting and bedding at the surface in the intake area, indicated that if these structures continue at depth the optimum orientation of the axis of the machine hall to reduce the effect of the structures would be on a bearing of 333° magnetic (338° True) (Fig. 17). The proposed alignment of the long axis of the machine hall is close to this bearing but it is recommended that a decision on the final orientation of the machine hall be left until the detailed investigation of the area is carried out from either the tailrace tunnel or the access shaft.

The selection of the machine hall position below weir site No. 2 had to take into account the southerly dipping shear zone which is found at the surface downstream of the weir. In addition to the need to keep the access and pressure shafts as short as possible it is desirable to cut the 75° dipping shear at right angles; to position the southern wall of the machine hall at least 25 feet from the shear and not parallel to it. More accurate information on the nature of this shear and its position will be provided by the exploratory drilling during construction.

Water-Pressure Testing

Figure 18 shows the calculated fracture permeability of the rocks in the machine hall area based on water-pressure tests carried out on the drill holes. The effective pressures used in these tests were calculated assuming the action of total hydrostatic head on the test section (see Appendix 7). However, the water tightness of the rocks above the machine hall indicate that it is likely that the actual hydrostatic pressure is much lower. This would raise the effective pressure and thus the fracture permeabilities may be much less than the results show.

In all holes there is an increase in permeability close to the top of the marble - related possibly to the increase in jointing and opening by solution. It is notable that although joints in DD22 are more numerous than in DD19 and DD21 they must be tight as the rocks at machine hall level range from 0 - 750 feet per year with most readings below 300 feet per year; water inflows based on these tests are expected to be small.

The outcrop of marble in Yonki Creek contains many solution cavities and this may be the source of any movement of water into the excavations. It is worth noting that the marble below machine hall level gives extremely low permeabilities even in sections which include shear zones.

Rock Temperature

Results of the measurement of temperature gradient on drill holes DD19 and DD22 are given in Figures 15 and 14. These indicate that the temperature at machine hall level would be just above 80° Fahrenheit so that no special measures will be required to lower the temperature during excavation or operation of the station.

Results

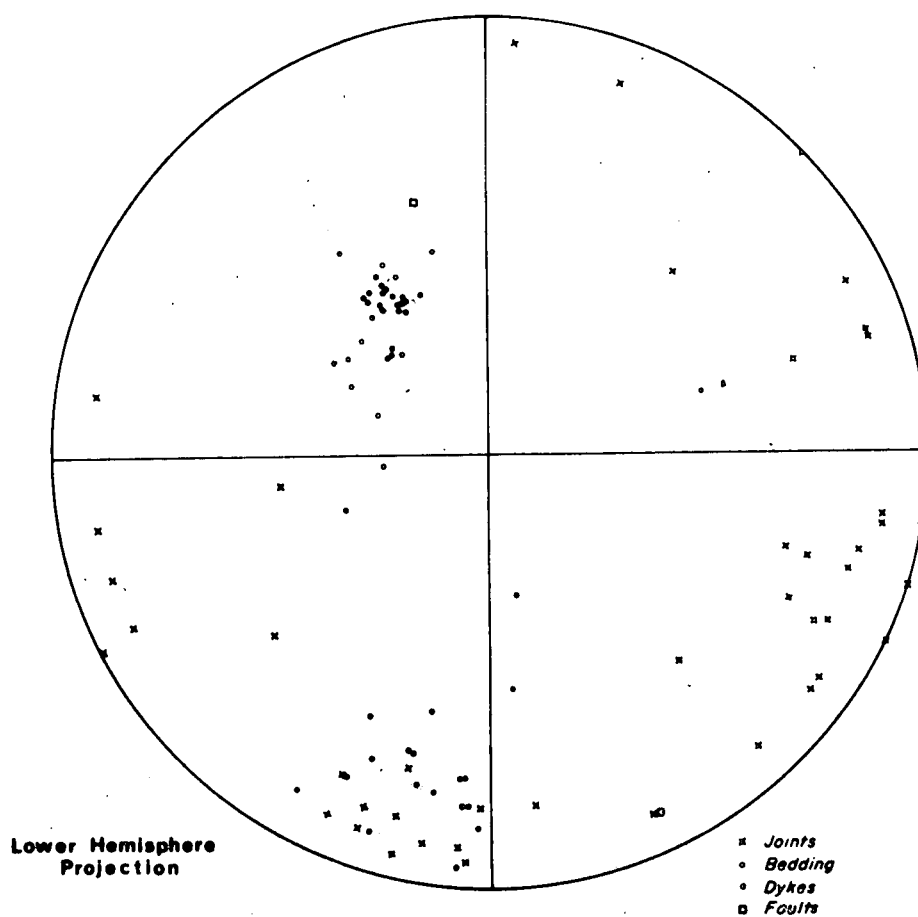
Lithology and Structure

The holes drilled in the machine hall area have indicated that the machine hall will be excavated in a uniform, stable mass of rock in which any inhomogeneity would be caused by a structural feature. Thermal metamorphism of the area has bonded the siltstone-greywacke and marble together; their properties are similar (see Appendix 5).

Marble at high temperatures and pressures yields plastically; however at the temperatures and pressures likely to be encountered in the machine hall the marble is expected to behave elastically to both short term (e.g. seismic) and long term stresses.

The difference in level of the siltstone-marble contact in the three drillholes in the machine hall area could be explained by folding, but it is much more likely that one or more faults pass through the proposed machine hall area. The exact position and effects of these faults cannot be determined

Stereogram of Poles to Joints, Bedding, Dykes and Fault



Stereogram showing relationship of Power Station to Joints, Dykes and Bedding

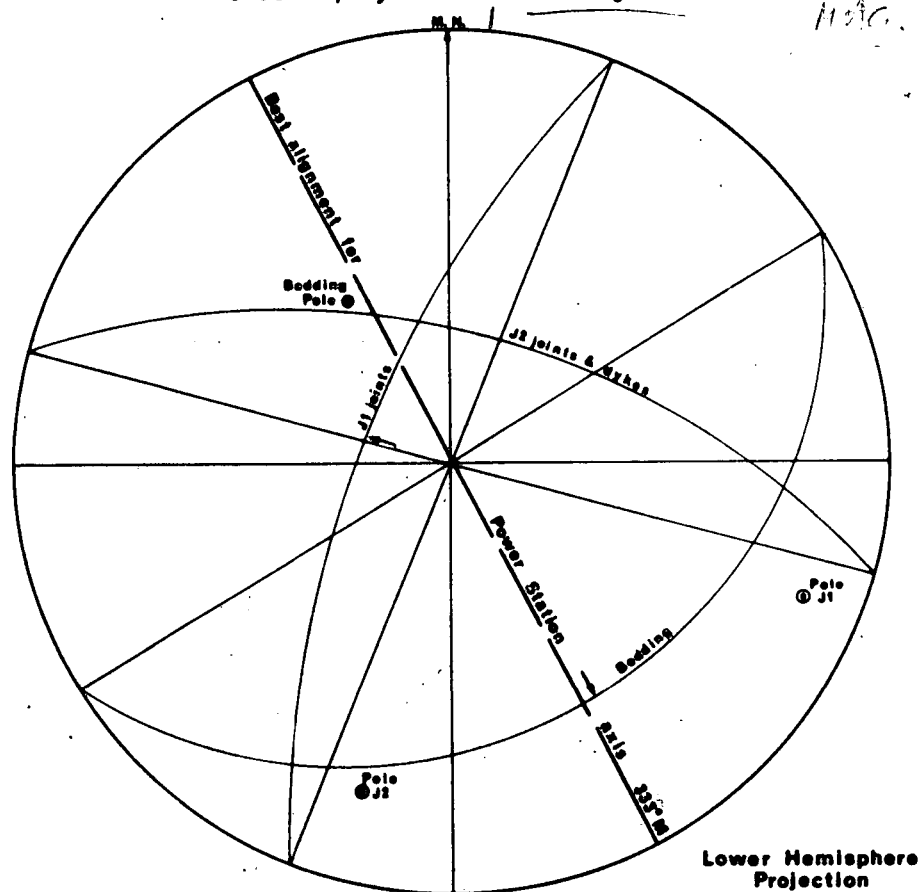


Fig. 17 Analysis of joints, bedding and dykes in the intake area

without further drilling investigation. It is quite possible that the faults will be tight and rebonded by the metamorphism and so will cause few problems during excavation.

There is little difference in fracture characteristics of the various rocks within 50 feet of the contact between marble and the siltstone; water losses are higher but not excessive and are negligible above and below the machine hall level.

Feasibility

It is considered that rock conditions and strengths are sufficiently good for an underground excavation of the type proposed to be constructed somewhere in the area below the intake works at reasonable cost.

Suitability of Proposed Location of Machine Hall

The roof and upper part of the machine hall and related excavated openings may be composed of hornfelsed interbedded siltstone and shale and however, most of the excavation will be in marble as the effect of faults on the distribution of the various rock types is not known. Cross-cutting basic dykes will doubtless be present. Ideally it is desirable that the excavations be in a single, homogeneous medium; however, as the ranges of mechanical properties of the various rock types present do not differ greatly from another (see Appendix 5), no serious problems are expected because of the presence of a variety of rocks in different parts of the excavation (see next section).

If the proposed site of the machine hall is severely faulted and sheared it may be cheaper to relocate it in nearby sound rock (see below).

Rock condition, support requirements, water tightness and the effects of seismicity are discussed below.

Possibility of moving the Machine Hall

Although it is ideally desirable to have the machine hall entirely within one type of rock, on the evidence available a major change of location, with substantially longer access and pressure tunnels, would be needed to achieve this. If the machine hall were moved to the north until the contact between siltstone - shale and marble is at least 20 feet above the excavation level, the movement involved would be more than 500 feet. There is also the possibility that a fault would lower the contact to give exactly the same conditions as at the present site. The discrepancy between the structural information at the surface and at depth makes it impossible to estimate accurately the effect of any movement to the east or west without additional drilling. It seems likely that a move to the east would place the machine hall higher in the geological succession, i.e. into the siltstone and shale, and a movement to the west would place it in the marble. Any movement would have to be considerable and would require investigation by drilling.

The removal of the machine hall from the proposed position because of the kind of rocks present could not be justified on the evidence at present available.

Rock Condition

As stated above (p.17&3), the rocks should be sound (condition 4-5) with little problem of overbreak. Where strong bedding is present line drilling may be necessary to control the shape of the opening. There is no indication that any considerable stress difference exists which could cause spalling

of the rock faces. Instrumentation as recommended on p.29 and below will be needed to provide data on rock stresses. Faulting may weaken thin bands of rock to condition 3-4.

In view of the depth of the station and the possibility of asymmetrical primary stress in the rock, excavation shapes should be kept as simple as possible.

Support

Support requirements in the machine hall and associated works can only be determined in detail by mapping of exposures as excavation proceeds. This can be supported by stress measurements, photo-elastic studies and determination of the seismic loading which can be expected. On present evidence it is considered that the machine hall will require rock bolts at close spacing. If any wide and weak fault zones are encountered steel support and concrete lining may be needed. In areas of closely spaced jointing steel mesh and gunite (pneumatically applied mortar) will be needed as support.

Water Tightness

Water losses in testing were low (see Figure 18 and Appendix 8), but in view of the possibility of encountering a large water-filled fracture in the marble, equipment should be available to cope with a large inflow of water. Water seepage may require that a ceiling to the machine hall be provided.

Seismicity

The high incidence of earthquakes in the region requires that a careful examination of all structures be carried out and all support designed with this additional hazard in mind.

Additional Investigation During Construction

Drilling

The possibility of faulting and the uncertainty about the position of the siltstone-marble contact in the proposed machine hall area require that additional drilling be carried out, preferably from near the bottom of the access shaft or from the tailrace tunnel during construction. Geological information from the mapping of the shaft and tunnel should clarify the structural position but it will be necessary to drill several exploratory holes of up to 300 feet each to confirm the position of the contact, the rock conditions and the final orientation of the machine hall. It is expected that three holes would provide the information.

Stress Measurement

Measurement of rock stress and movement following excavation will have to be carried out in each rock type either in the access shaft or the tailrace tunnel prior to the excavation of the machine hall (see above). These measurements should be made sufficiently early for the results to be analysed and recommendations made before the construction of the machine hall commences (see also 'Instrumentation' below).

UPPER RAMU HYDRO-ELECTRIC SCHEME ROCK PERMEABILITY IN MACHINE HALL AREA

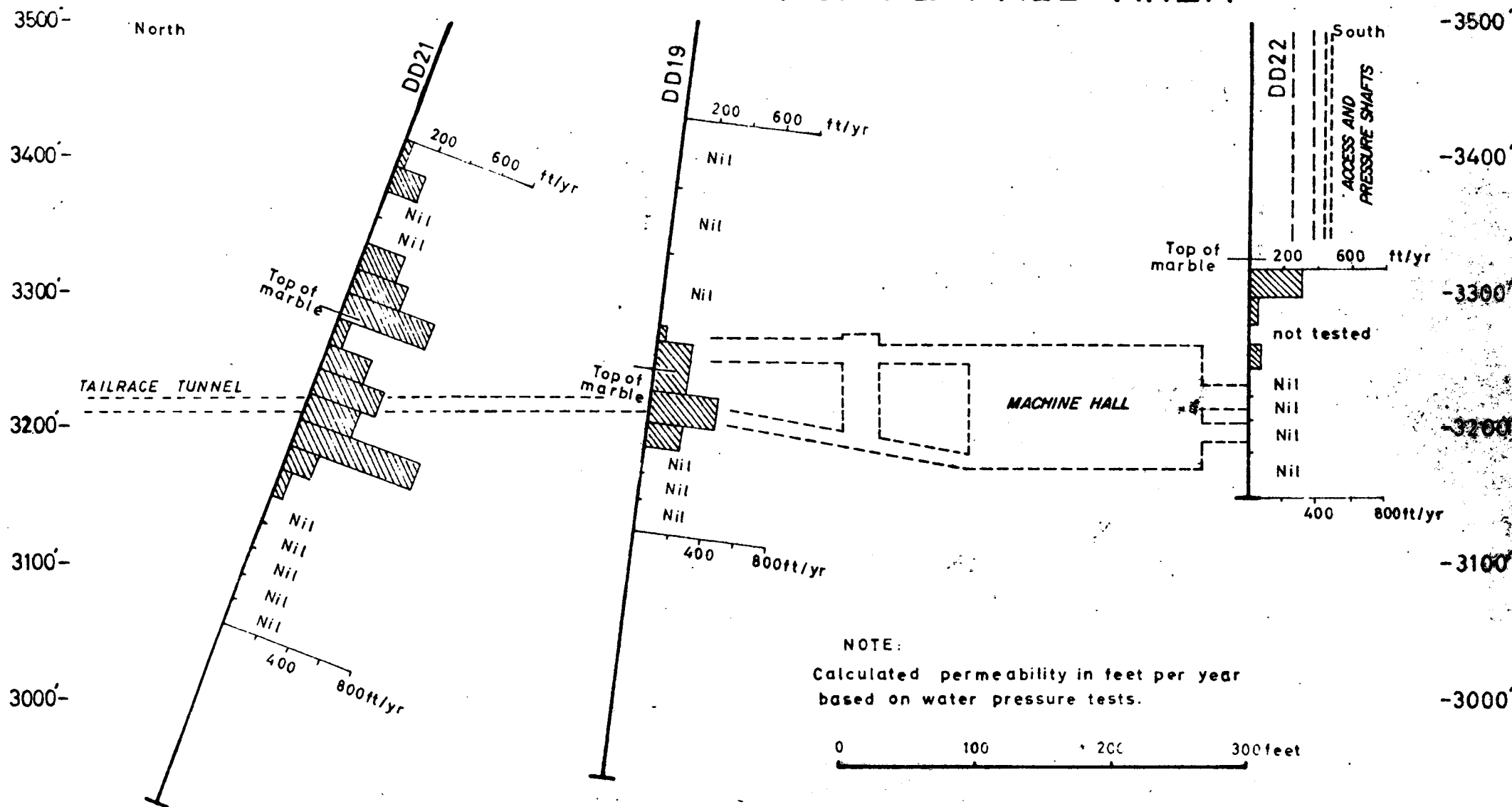


Figure 18

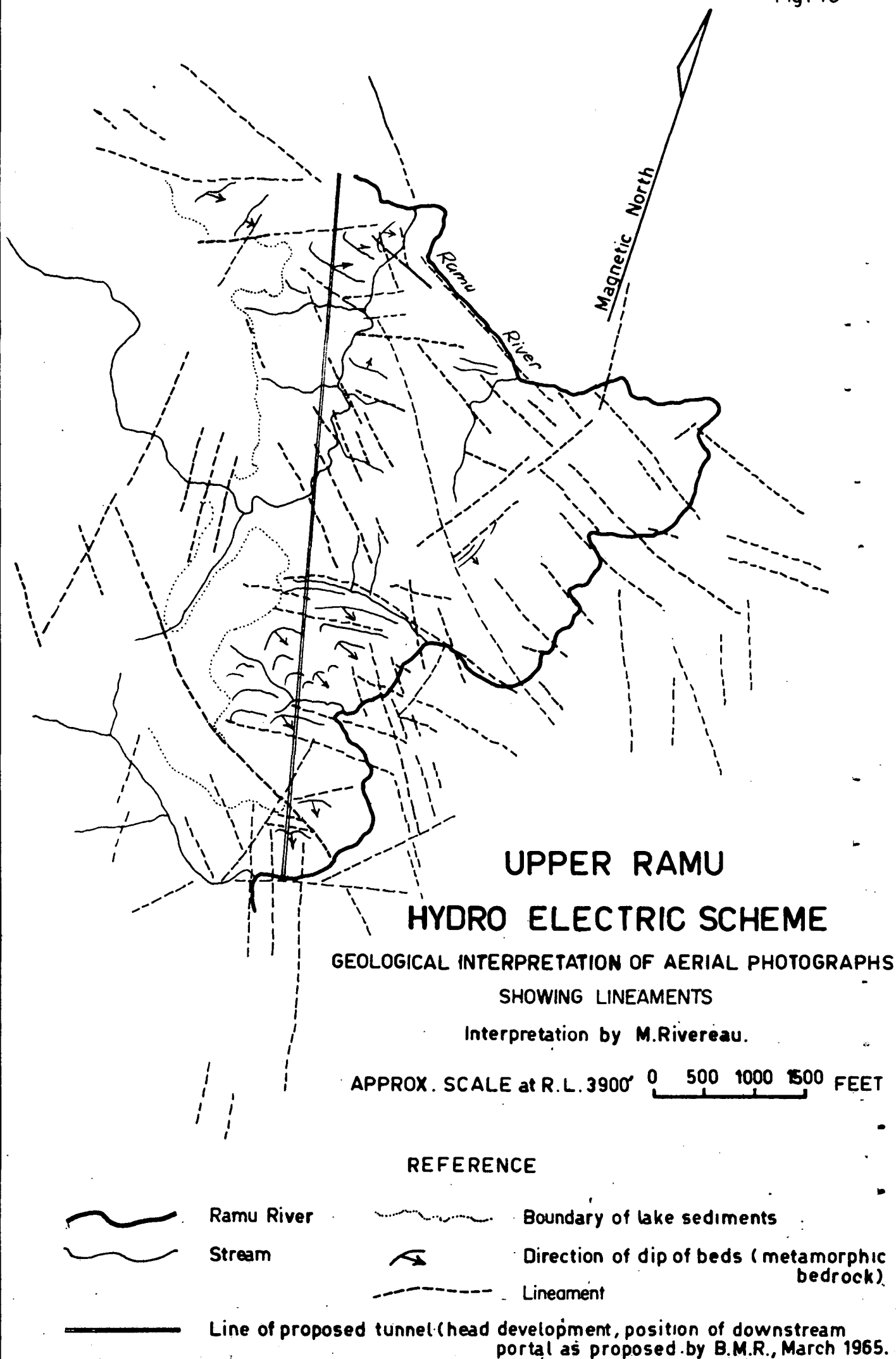


Photo-elastic Studies

The distribution of stress in the rock and relief of stress during excavation should be the subject of photo-elastic studies to verify that the machine hall shape and orientation are satisfactory. These studies will also indicate areas where special support is required.

Instrumentation

During construction of the machine hall it is recommended that instruments to measure the short and long term movement and stress in the rock be installed. The spacing of the rock bolting can be determined from this work. Care should be taken that these instruments are well protected and positioned so that regular readings can be taken (see Appendix 9). Instruments should be installed as soon as possible after the area of installation is exposed, in order to measure as much of the resulting relaxation as possible and periodic access to the instruments as excavation proceeds should be arranged.

TAILRACE TUNNEL

Location

The proposed tailrace tunnel will be excavated at about R.L. 3200 feet in an almost straight line from the expansion chamber at the machine hall to the outlet portal some 7800 feet to the north (Fig. 2).

Geological Investigation

The geological investigation of the tunnel was directed to prove whether it would be geologically feasible to construct a tunnel in this area, to indicate the types and properties of rock which would be encountered during excavation, to indicate possible problems, such as faulting or the inflow of pressure water, and to recommend support and methods of excavation.

Mapping

In the investigation for the high-level tunnel J.K. Hill (1962) mapped exposures in the Ramu River and along the creeks which cross the tunnel line. This enabled the general geological succession and structure to be recognised. When the investigation for the low-level tunnel was started D.E. Gardner, J.R.L. Read and J.P. MacGregor re-examined some of the area and extended the coverage westward to include Yonki Creek.

Examination of aerial photographs of the area reveals many lineations which may represent faults or zones of extensive jointing (Fig. 19). However the origin of many of these lineations cannot be confirmed on the ground and mapping of the Ramu Gorge located few faults.

Drilling

Extensive drilling for the high-level tunnel proved the depth of weathered rock and also rock-types in the area to R.L. 3800 (Plate 6). Drilling for the low-level tunnel was restricted to the machine hall area - DD19, DD21 and DD22 (already described, p. 31), the outlet area - DD18 (Fig. 20), a hole at $-3\frac{1}{2}^{\circ}$ on a bearing of 181° to prove rock condition in the first 400 feet of tunnel, and near the centre of the tunnel line-DD20A (Fig. 21) a vertical hole 3150 feet from the machine hall end of the tunnel to R.L. 3130 feet. DD20, a

hole drilled at 3000 feet from the inlet end of the tunnel, had to be abandoned at 370 feet because of continued caving.

Water-pressure Testing

All sections of the holes close to tunnel level were water pressure tested and losses proved to be low apart from one section of DD18 which was 120 feet below a deep gully (Plate 8 and Figure 20). Probably, in the tests of sections well below the ground surface the total hydrostatic head due to the groundwater is not acting on the section and the actual permeability is much less than that calculated.

Rock Strength

Rock strengths of samples of core from DD21 are given in Appendix 5. With a compressive strength of the order of 12,000 p.s.i. the fresh rock has ample strength for tunnel excavation; cores from the other holes appear to have similar properties.

Results

Lithology

The geological investigation has shown that most of the tunnel will be driven in rocks belonging to the lower horizons of the Omaura Greywacke. At the southern end in DD19 and DD21 the marble is found at tunnel level and at the northern end DD18 is in marble for its entire length of 400 feet. In the central section of the tunnel, towards the axis of the anticline, DD20A penetrated siltstone-greywacke at tunnel level (R.L. 3190 - 3230) but marble is found for 350 feet above the tunnel and for at least 60 feet below it. All rocks are cut by fresh basic dykes.

In Yonki Creek, at the base of the marble a limestone-bonded conglomerate crops out unconformably above the schists of the Bena Bena Formation. As described earlier (p. 12) this may be skarn rock formed by the melting of the marble by an igneous intrusion. The tunnel will cut the lower parts of the marble and it is possible that towards the northern end of the tunnel, at the crest of the anticline, it will pass through conglomerate into schist. Both rocks are strong (see p. 17). Faulting in the tunnel line could bring either the conglomerate and schist in the centre, or the siltstone-greywacke at the northern and southern ends to tunnel level but it is expected that at least 80% of the tunnel will be in marble. All the rocks likely to be encountered have ample strength, except where faulted and sheared.

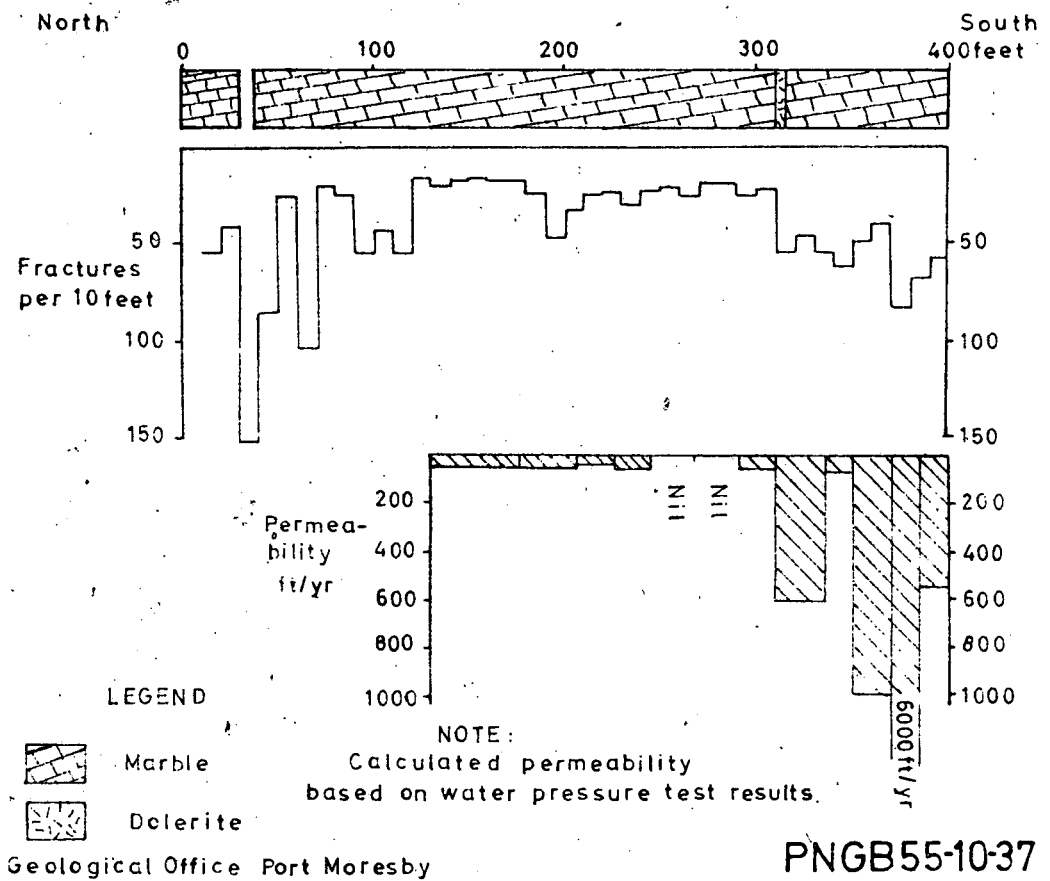
The schist, metasediments (including marble) and basic intrusive rocks are all stable and resistant to erosion. Winkler (1966) has estimated that rainwater will corrode roughly 1.4 mm of calcium carbonate (at atmospheric pressure) in 25 years. As rainwater is more aggressive to carbonate rocks than most stream water, corrosion of marble in the tailrace tunnel will not present a problem.

Structure

Examination of the surface geology has shown that the rocks in the area of the tunnel are folded in a broad anticline with its axis about half way along the tunnel and plunging to the south-east. At the intake end of the scheme the siltstone-greywacke and shale dip to the south at angles between 25° and 40° and at the outlet portal the marble and overlying siltstone dip to the north-east at 2° to 25°. Mapping along the gorge shows a gradual change in

UPPER RAMU HYDRO-ELECTRIC SCHEME Fig. 20 SUMMARY LOG OF DRILLHOLE DD 18

Coordinates 41790E, 86120N RL 3205ft. Angle $-3\frac{1}{2}^{\circ}$ Bearing $181^{\circ}15'$ True

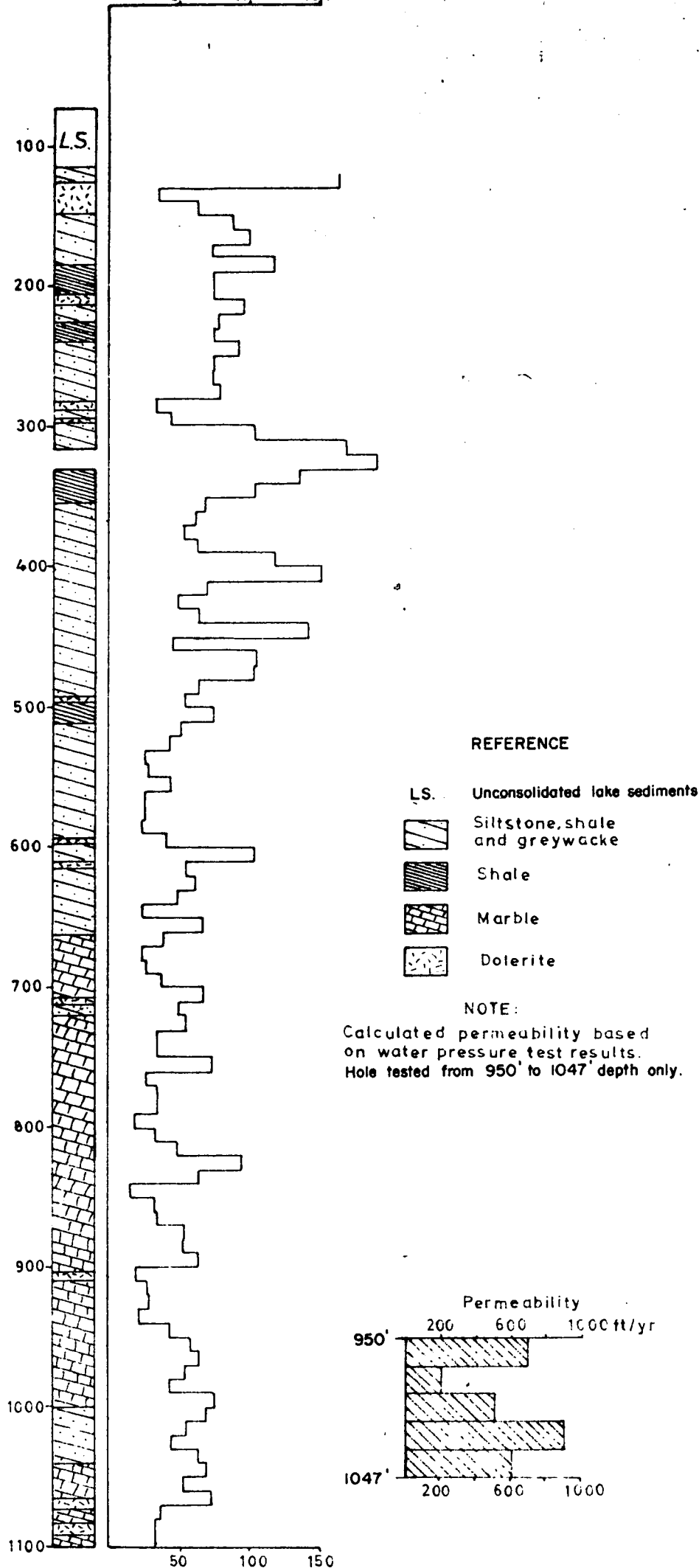


UPPER RAMU HYDRO-ELECTRIC SCHEME Fig. 21 SUMMARY LOG OF DRILLHOLE DD 20A

Coordinates 42490E, 81740N R.L. 4230ft. Angle -90°

Fractures per 10 feet
50 100 150

Borehole
survey



dip, with several minor reversals. Along the tunnel it is expected the dips will be shallow except possibly close to fault planes (at tunnel level in DD20A the bedding dips at 75° to the horizontal). Changes in dip and strike indicate that there may be several smaller folds within the major structure.

The rocks throughout the tunnel are expected to contain widely spaced rectilinear joints at high angles and occasional low-angle sheet joints. Joints are most numerous in the finer-grained siltstone and shale. In the dolerite dykes, the jointing is commonly related to the orientation of the dyke and not to the jointing in the metasediments. The joints in the drill cores are clean and tight at tunnel level, the rock is therefore expected to be strong and overbreak slight. In the marble, however, a few fractures have been enlarged by solution.

The uniform nature of the siltstone-greywacke and shale make an estimation of the extent of faulting difficult. Several thin fault zones were observed in the surface mapping and several shears located in the drilling. In most cases it was not possible to estimate the throw of the fault but in the machine hall area the siltstone-marble contact has been displaced vertically by at least 80 feet, presumably by faulting.

Most fault zones are expected to be 1-2 feet wide with strong rock on either side; they contain crushed country rock in the form of finely cominuted fragments of siltstone, marble or dolerite.

Several holes drilled to investigate the high-level scheme passed through broken zones, from which there was either little core recovered or the core consisted of small fragments of rock only. The lengths of completely broken zones in the holes ranged up to 30 feet (in DD5). The cause of the broken zones is not fully understood, nor are their true thickness known. Several occur below fresh, sound, rock, and are probably of tectonic origin. However, no evidence was found for major crush zones in the Ramu Gorge and it is considered unlikely that any fault zone more than 100 feet wide will be encountered in the tunnel. Large fault displacements may occur on the tunnel line but this is unlikely to effect the stability of the tunnel.

Examination of the aerial photographs of the area show two sets of lineations crossing the tunnel-line one in an westerly direction and the other trending north-west (Fig. 19). None of these structures, with the possible exception of the shear at the weir site, have been confirmed by mapping on the ground.

In several instances shearing has been observed at the surface associated with dolerite dykes (Hill, 1963). It has been suggested that the fault movement and the intrusion of the dolerites are linked but examination of the drill cores and numerous outcrops does not support this. It seems that the prominence of shears within the dolerite is due to the general lowering of strength of the dolerite where a fault cuts across the dyke. Siltstone and shale cut by the same movement are much more resistant.

Figure 22 shows an interpretation of the geology along the tunnel line using the information from surface mapping, drill logs and photogeological interpretation. The exact position of any faulting and the amount of displacement cannot be accurately determined so the actual rock types in the tunnel may be higher or lower in the succession than is shown.

Water Tightness

Water pressure testing of the drill holes at the intake end of the scheme and in the centre of the tunnel line gave low water losses (Fig. 21 and Appendix 8). There is some rounding of joint faces in the drill core which indicates some water movement through the marble, but no large cavities were

found. DD18, at the outlet portal of the tunnel gave low to moderate water losses apart from a section below Recorder Creek where between 370 feet and 385 feet an average loss of 4 gallons per minute per foot of hole, at a gauge pressure of 100 p.s.i., was recorded.

A large part of the tunnel will probably be in marble and, as there is some cave development in this marble elsewhere, and having regard for the general formation of solution cavities in carbonate rocks, there is the possibility of encountering an underground channel with considerable quantities of pressure water. However no evidence has been found, at the surface or elsewhere, for substantial solution cavities at, or below, R.L. 3200 feet. Most of the tunnel is expected to be in sound rocks and to be dry but as a precaution against possible pressure water it is recommended that during driving of the tunnel feeler holes be drilled at least 50 feet ahead of the face, and that facilities be available to deal with large inflows of water. When concrete lining is placed in the tunnel care should be taken to provide adequate drainage.

Excavation and Support

Preliminary civil estimates allow for complete lining of the tailrace tunnel for more efficient hydraulic flow. The following comments are based on the possibility of leaving part of the tunnel unlined.

The orientation of the tunnel is ideal for economical mining; most joints, beds, faults and dykes are expected to cut the tunnel at high angles, thereby reducing overbreak and support requirements to a minimum. The marble should be easily mined, non-abrasive and, except where pronounced low-angle bedding or sheet jointing is present, there should be little problem controlling the shape of the tunnel. In any zones with slabby roof or walls rock-bolting may be necessary and open joints and faults will have to be treated by raking-out, back-filling with concrete and covering with steel mesh and gunite.

In the larger fault zones and in jointed marble close to the outlet portal steel support and concrete lining will be required but it is estimated that at least 80% of the tunnel (excluding portal zone) will not require to be lined, and about 10% of the unlined section will require rock bolting.

Stress Measurement

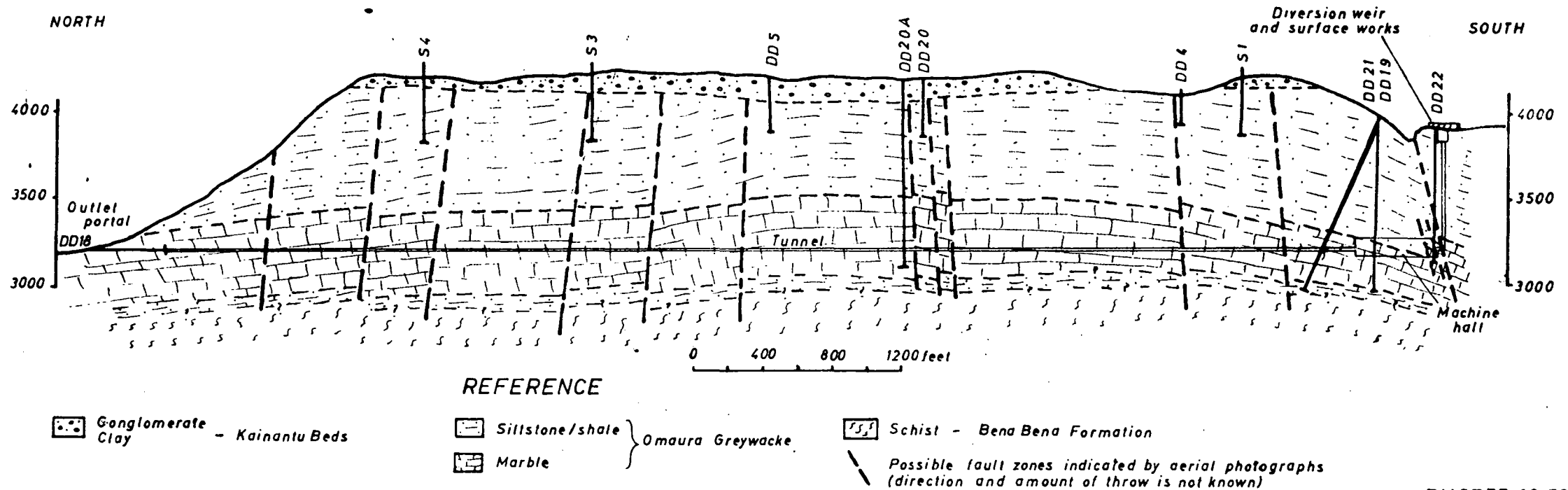
If the tailrace tunnel approaches the machine hall area before the access shaft, stress and strain, tests should be carried out using extensometers and flat jacks. These results will confirm support requirements for the tunnel and indicate conditions to be expected in the machine hall.

Seismicity

The earthquake risk to the tunnel is not high, but when designing support for the tunnel the probable effect of a strong earthquake should be considered.

UPPER RAMU HYRO-ELECTRIC SCHEME AN INTERPRETATION OF THE GEOLOGY ALONG THE TUNNEL LINE

Fig. 22



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OUTLET PORTAL

Location

The outlet of the tailrace tunnel is situated on a platform of marble on the left bank of the Ramu River some three river miles downstream from the intake.

Geological Investigation

Mapping

The portal site was mapped in detail by Hill (1962) and later by Read (Plate 7). The rocks consists of massive, jointed marble cut by narrow dolerite dykes. The dyke material is fresh and the contacts are well bonded to the marble and seem to increase the strength of the adjoining marble. Bedding in the marble dips to the north-east at $20-25^{\circ}$. Parting along the bedding is found in some places but in general the rock is massive. Rectilinear high-angled joints and sheet jointing in the marble at river level have been extensively opened up by solution and caves are found on Chasm Creek (but at a level several hundred feet higher) to the west.

About 200 feet south-west of the portal the marble is conformably overlain by siltstone and shale. These rocks are strong but are not expected to be located in the tunnel portal excavations.

Drilling

The rock conditions for the first 400 feet of tunnel from the outlet were investigated by the drilling of a near-horizontal drillhole DD18 which located jointed marble throughout its length; one minor dolerite dyke was intersected. A zone between 30 and 37 feet from the collar of the hole was filled with brown clay and marble fragments, and may be a fault zone or an infilled cavity. Fracturing and solution effects were moderate but between 370 feet and 390 feet an increase in fracturing was found at a depth of 120 feet below Recorder Creek.

DD16, a hole drilled close to the present portal site at 65° to horizontal, for the foundations of an earlier proposed power station, proved at least 70 feet of strong, moderately-jointed, marble below the tunnel invert.

Water Pressure Testing

Tests on DD18 (see Appendix 8) gave low water losses apart from the zone at 370-385 feet which is below Recorder Creek. In this zone high water loss indicated that a large inflow of water into the tunnel may be expected. Testing of DD16 gave low water losses.

Results

Location

The tailrace tunnel will open on to a marble platform which is about 80 feet wide and extends from 200 feet upstream of DD18 as far as Chasm Creek. Downstream from the creek a narrower platform continues for some distance along the left bank of the Ramu River.

It is desirable that tail-water be discharged directly downstream to

reduce scouring in the river channel. The exact position of the portal will probably depend on the contractor's plans for using the rock platform as working space but several other factors should be considered. These include the strength of the rocks, the angle of entry of the tunnel into the hill-side, the presence of adequate cover over the tunnel, the depth of overburden and chances of landslips at the portal site.

Rock Strength and Support Requirements

The marble, as described earlier (p. 17), is strong but in this area there has been solution along joints near the surface. Mining conditions should be good provided the portal is kept clear of the Recorder Creek area where there appears to be a zone of fracturing. The open jointing found in DD18 indicates that probably the first 100 feet of the tunnel will require steel support and concrete lining. Although no water pressure testing was carried out in this section of the hole the presence of opened and rounded joints indicate that some inflow of groundwater may be expected in this area.

Orientation of Portal and Rock Cover over Tunnel

To the west of the rock platform there is a steep scree slope surmounted by a low cliff. All the rock is marble. The tunnel should be driven at an angle as close as possible to normal to the slope in order to obtain maximum cover in the shortest distance and also to reduce the danger of blockage of the portal by landslipping.

The tunnel will pass under Recorder Creek and the drilling has shown that it is desirable to have a much cover as possible in this area. The position of the portal shown in Plate 7 is designed to provide at least 100 feet of cover below Recorder Creek (Plate 8) and is a compromise between the portal discharging directly downstream and the tunnel driven normal to the hill. It is expected that at least 100 feet of the tunnel in the Recorder Creek area will have to be lined to cope with the increased jointing and water flow in the area.

Overburden Depth and Slope Stability

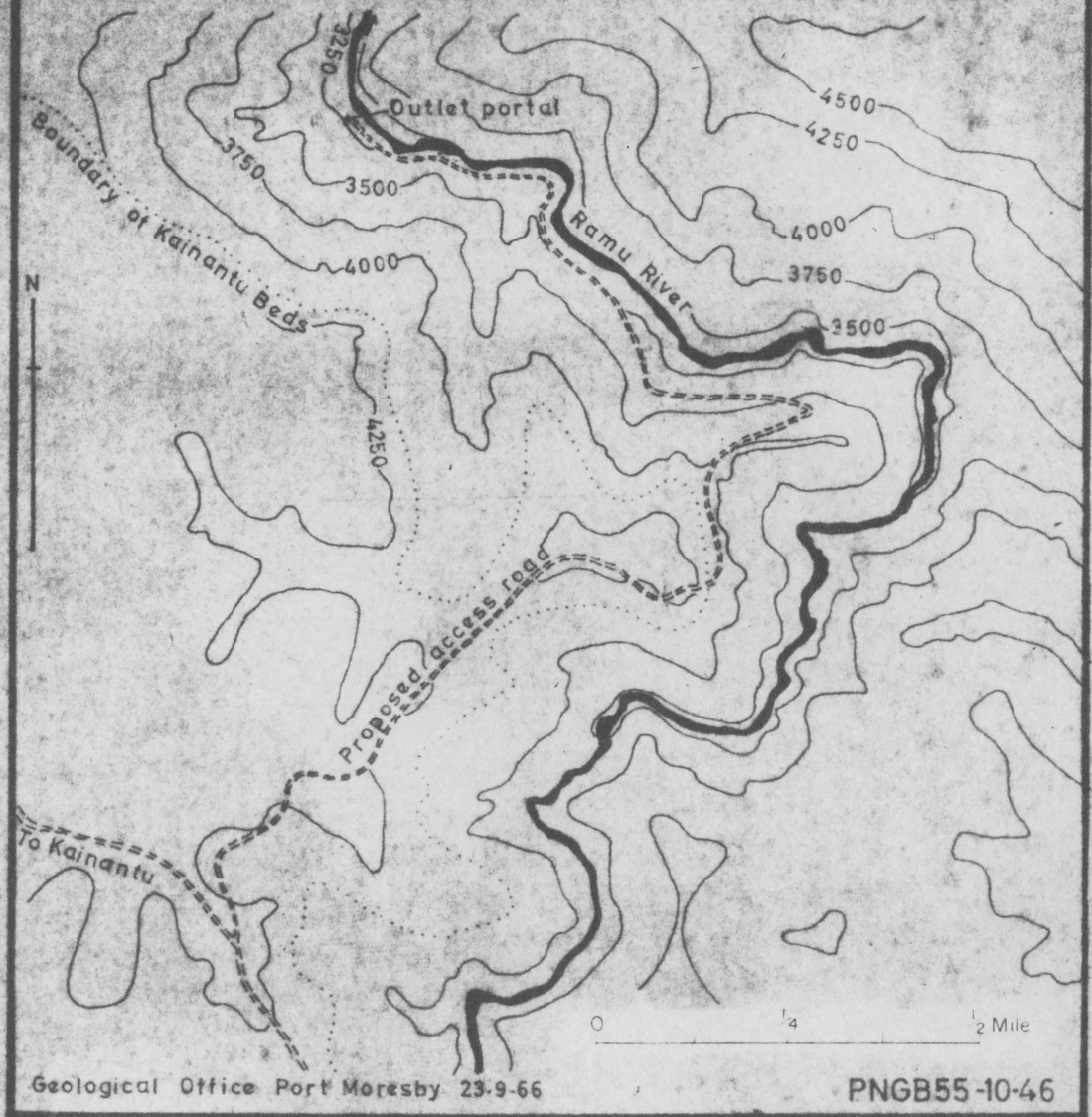
Costeans sunk by Hill revealed bedrock in the slope in the portal area at depths between 4 and 5 feet (1962) but probably some of the rock exposed is not in situ.

The overburden is composed of fragments of marble and siltstone in a brown clayey matrix. The low cliff above the scree slope is at the lower end of a prominent spur and it is unlikely that major landslipping from the higher slopes of the Ramu Gorge would endanger a portal located in the centre of the rock platform. Towards the upstream end of the platform the cliff is not present and there is some danger from boulders and slide material from higher up the slope. Loose boulders from the front of the cliff should be barred down or rock-bolted and drains constructed in the overburden areas above and below the cliff to take away excess water and ensure the stability of the slope in the immediate area of the portal.

Possible Blockage by Flood

The Ramu River frequently floods during the wet season and although the portal invert is raised above normal river level, it is positioned on the outside of a bend in the river and measures will have to be taken to avoid the blockage of the portal by debris. Further, in view of the active erosion and high seismicity in the area, a major rock fall from cliffs bounding the river immediately downstream from the outlet portal would possibly cause the tailrace tunnel to be flooded.

UPPER RAMU HYDRO-ELECTRIC SCHEME Fig 23
LOCATION OF OUTLET PORTAL ACCESS ROAD



Disposal of Tunnel Spoil

Spoil from the tunnel could be used for extending the rock platform in the portal area. It should be possible to construct a narrow-gauge railway crossing Chasm Creek and following the left bank of the river. Spoil could be dumped from the railway farther down the gorge.

OUTLET PORTAL ACCESS ROAD

A possible alignment for an access road, about two miles long, from the old Kassam-Kainantu road to the outlet portal of the tunnel has been surveyed and is shown on Figure 23. This road line has been briefly examined. The first mile would be located on clays and silts of the Kainantu Beds. Slopes are low but considerable trouble has been found constructing the Highlands Highway over similar material and it is considered that even a construction road for 4-wheel drive vehicles would require pre-drainage of the sub-grade area and the formation of a thick pavement of river gravel or other suitable material if the road is to remain open in the wet season.

The second mile of the access road descends the side of the Ramu Gorge from R.L. 4200 feet to R.L. 3200 feet. In some places the overburden is not deep and the road could be side-cut in strong siltstone and shale but in other places extensive slipping has occurred and deep cuts would be required to locate the road on sound rock. The last 600 feet of the road before the outlet portal would have to be blasted from strong siltstone and shale.

Failure of the banks of the side cuts needed would, from time to time, block the road but, provided the integrity of the road base and pavement can be maintained by sound design (including drainage and a thick pavement of river gravel or blasted rock from lower on the road) and maintenance, embankment failures in this section of the road should not seriously interfere with access to the tunnel portal. Experience with the Highlands Highway should provide a useful guide to construction specifications.

The general instability of the sides of the Ramu gorge, due to steep slopes, high rainfall (with consequent saturation of the ground and erosion) and frequent earthquakes, indicate that a road on this alignment would be difficult and expensive to construct and would require constant maintenance.

A possible alternative would be to build a construction road down the spur and valley immediately to the west of the outlet portal. A very temporary access road has already been constructed in this area. The first section of the road would be on the Kainantu Beds and the gorge section would probably have steeper grades but, although slip material and erosion of the scree from the cliff at the top of the slope could pose serious problems, the side-slopes are lower and it has the advantage that all sections of the road in the gorge can be seen from one place. This road would also require a great deal of maintenance.

Consideration should be given to the use of an alternative method of access during construction, such as a cableway or tramway.

CONSTRUCTION MATERIALS

Four sources of construction materials have been briefly examined. These are

- a) spoil from the tunnel, shaft and machine hall excavations,
- b) river gravel and sand from the Ramu River, upstream of the intake site,
- c) marble from Chasm Creek, north of the Swiss Mission and
- d) gabbro and associated rocks from the Yonki Dome intrusion (Fig. 24). Extensive testing of these materials for relevant properties and quantities will have to be carried out prior to construction in order to determine the suitability of any of them.

Excavation Spoil

The geological investigation of the scheme has shown that the rock to be excavated from the tailrace tunnel and the machine hall will be composed to a large extent of marble of a type similar to that found outcropping at the outlet portal. This marble is cut by numerous dolerite dykes which are, however, generally fresh and strong. Both marble and dyke rock should prove suitable for concrete aggregate as they contain no deleterious minerals. They have an interlocking texture and are massive, the rock should therefore break without flaking and provide a high-strength concrete (Appendix 4).

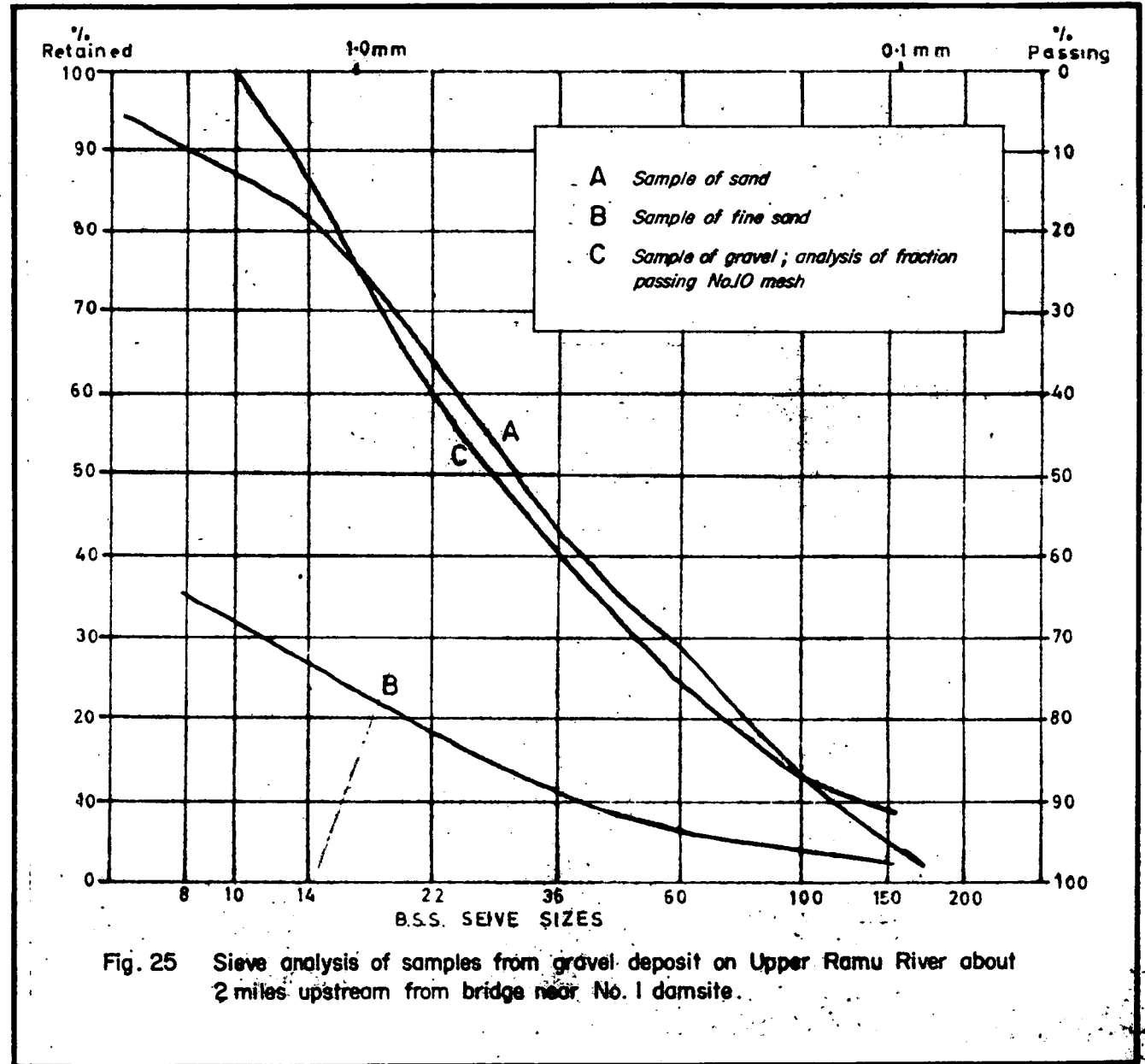
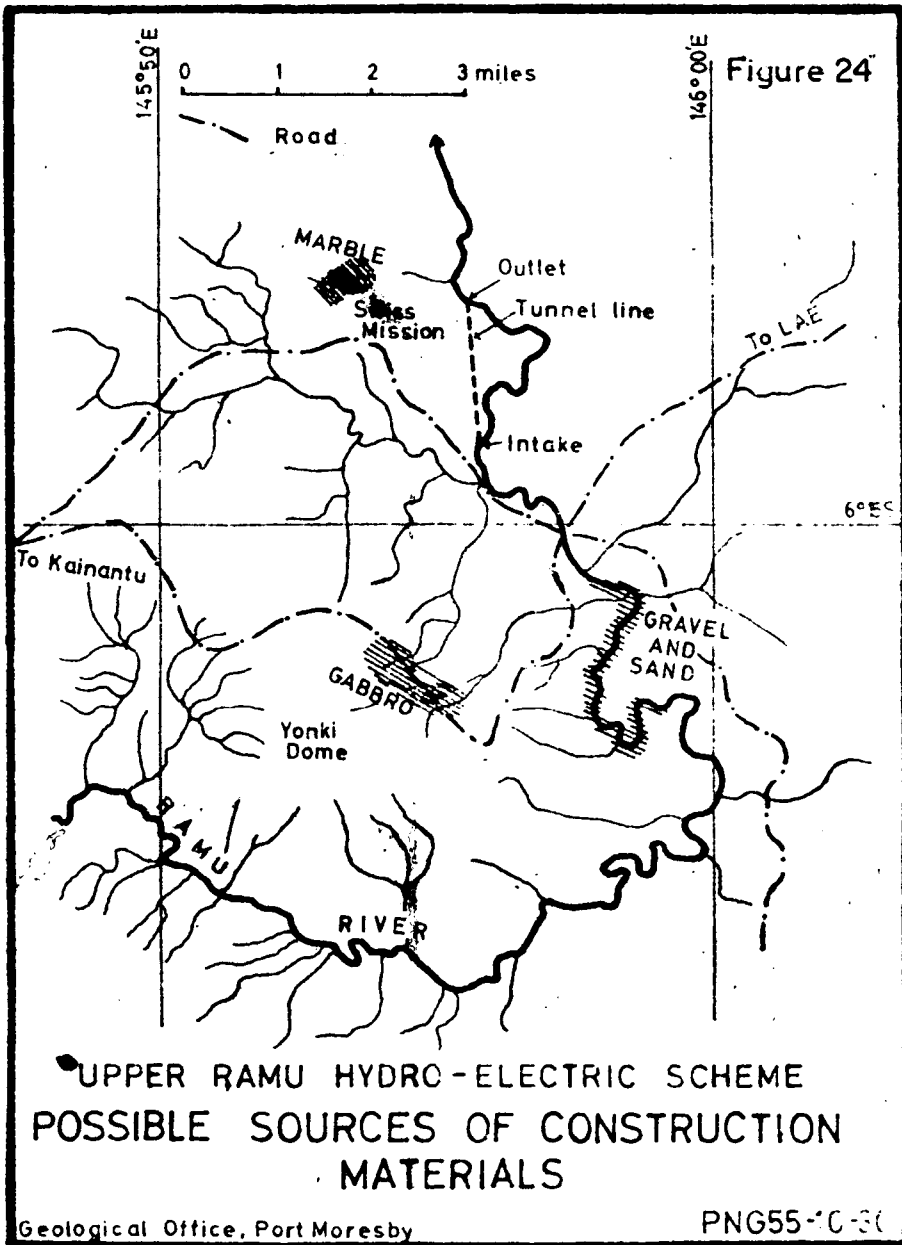
In the pressure and access shafts at the intake end of the scheme several hundred feet of interbanded greywacke-siltstone and shale will be mined before the marble is reached. Where these rocks are fresh there is a strong bonding between the individual bands but where weathered and in sections where a large percentage of shale occurs there is a tendency to break along the lamination to produce elongated fragments and an unacceptable clay content. If this rock is to be used for aggregate careful control will have to be maintained on quality. Shale should not be used.

The dolerite intrusions are weathered at the surface but the drill holes indicate that they are fresh and strong at depth. Compressive strength tests on core samples (Appendix 5) give adequate strength in all fresh rocks tested.

River Gravel

Extensive deposits of Recent river gravel occur along the banks and in the Ramu River in the Arona Valley from two miles above the intake site. Some of the deposits have been used for road construction materials for the Lae-Kainantu road but there should be ample material available. Examination of a gravel pit about 3 miles upstream of the intake showed a preponderance of coarse gravel with some sand lenses. The gravel pebbles reach a diameter of six inches but most are from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in diameter. The gravel is poorly to well-graded and contains pebbles of quartz, marble, andesite, siltstone, dolerite, gabbro, gneiss, mudstone and some siliceous vein material. The rock fragments are generally strong but some weathered volcanic material was observed.

Deposits of sand are small and many of the sand grains are coated with limonite. A mechanical analyses of a small grab sample of the gravel and sand is given in Figure 25. Further examination of the river - especially several infilled meanders in the area - should reveal a good supply of fine aggregate.



Marble

Marble of a similar quality to that found at the outlet portal crops out in the upper reaches of Chasm Creek, immediately north of the Swiss Mission, and also in a series of low hills to the north of the creek. In the hills extensive water action has produced cavities which have been infilled with soil and debris. The removal of this material for aggregate would involve selective mining. In the creek the limestone is massive (Figure 6b); the cavities are not extensive and the area should be suitable for mining. An access road could readily be constructed to the creek from the old Kassam-Kainantu road.

Gabbro

The recently constructed Lae-Kainantu section of the Highlands Highway crosses the eastern flank of the Yonki Dome, which is composed of gabbro and related basic rocks. No fresh exposures of gabbro were located in the road cuttings but in one section about 7 miles from the Upper Ramu scheme an abundance of fresh gabbro and dolerite boulders indicate that fresh bedrock probably exists at a shallow depth. A traverse up the creek at this spot failed to locate bedrock in place but it is considered that, if necessary, shallow drilling could determine whether the area is suitable as an aggregate source. The fresh gabbro boulders on the surface would provide excellent riprap for use in the protection of surface works adjacent to the pondage. The gabbroic rocks are hard and strong and, subject to the usual reactivity tests, appear to be suitable for use as concrete aggregate. They would be expensive to crush (see Appendix 4, specimens 66370010 (1-3)) and for this reason the marble appears to be a more acceptable source of concrete aggregate if tests prove it suitable.

CONCLUSIONS

1. Power Station No. 1 and its associated works will be largely excavated in metasediments of Tertiary age, called the Omaura Greywacke.
2. Within the Omaura Greywacke two main types of rock are present: an upper, hard, strong, interbedded succession of greywacke-siltstone and shale, and a lower massive bed, or beds, of marble. (see p. 12).
3. The Omaura Greywacke is underlain by Palaeozoic(?) schists called the Bena Bena Formation (p. 12) and is overlain by Recent unconsolidated, lake sediments - conglomerate, silt and clay - named the Kainantu Beds (see p. 14).
4. All rocks, except the Kainantu Beds, are cut by numerous minor basic dykes. Many of the dykes are deeply weathered at the surface but all are fresh and strong at depth (see p. 14).
5. The Omaura Greywacke in the area of the scheme has been folded into a broad anticline plunging gently to the south-east. The anticline contains several minor flexures. The bedding is clear but individual beds are strongly bonded together (p. 15).
6. The Bena Bena Formation was strongly folded prior to the deposition of the Omaura Greywacke (p. 15); the Kainantu Beds are unaffected by folding.
7. All rocks, other than the Kainantu Beds, are extensively jointed. The joints normally form a rectilinear pattern and are clean and tight except close to fault zones. Some solution of joint faces has taken place in the marble (see 10, below). In the Bena Bena Formation early-formed joints have been filled by siliceous material (see p. 15).

8. Several fault zones have been located but the uniformity of the succession makes an estimation of displacement on the faults difficult. The fault zones are narrow and bounded by strong rock; many more will doubtless be found in excavations than are known at present (p. 15).

9. The Omaura Greywacke has been affected by a low grade thermal metamorphism which is attributed to nearby igneous intrusions. The Bena Bena Formation has been recrystallised by an earlier phase of regional metamorphism (see p. 16).

10. Static groundwater levels in the drill holes are at about the level of fresh bedrock. Close to the surface caves have been formed in the marble, but no large cavities were located in the marble at depth (see p. 16).

11. Landslipping has taken place in the metasediments forming the sides of the Ramu Gorge but is much more common in the Kainantu Beds. All slips observed are shallow (see p. 16).

12. Nineteen earthquakes of magnitude greater than 5.0 (Richter) and with epicentres within 100 miles of the site have been felt in the Upper Ramu area between 1961 and 1966. The shocks have given intensities up to VII on the Modified Mercalli Scale and it has been estimated that, statistically, a shock of intensity IX can be expected in a 50-year period (see p. 10). No instability which could be directly attributed to earthquake activity was observed, but doubtless a strong earthquake would initiate or accelerate slipping of unstable ground. A shock of intensity IX would cause extensive disruption of the land surface and would probably close Kassam Pass, the supply route for the scheme.

13. Testing has shown that the rocks of the Omaura Greywacke have ample strength for underground excavation. The marble is hard and strong, and not very abrasive (p. 17); many of the fractures in it have been rebonded by metamorphism. The siltstone-greywacke is also hard and strong but is abrasive; jointing is tight but lamination is prominent in weathered shale, which is not very abrasive (p. 18).

14. Schists of the Bena Bena Formation are strong (p. 17); however the unconsolidated Kainantu Beds are weak with many landslips indicating their instability (p. 19). The Kainantu Beds would not be encountered in any sub-surface excavation.

15. Two weir sites have been investigated. Weir Site No. 1 is underlain by fresh, strong greywacke-siltstone and shale dipping to the south and striking at right angles to the axis of the weir. These rocks are cut by weathered basic dykes, also at right angles to the weir. A shear zone runs through the right abutment. Some of the shale may fret on exposure (p. 22).

16. Weir Site No. 2 is underlain by rocks similar to those at No. 1 site but the metasediments strike parallel to the weir axis. There is minor faulting in this area (see p. 23).

17. Drilling of weir site No. 1 has shown that the rocks are strong and tight at depth. Similar conditions are expected at weir site No. 2. Overburden averages 3 feet and reaches 8 feet (p. 20).

18. Both weir sites are considered geologically suitable for the structures proposed (p. 24).

19. The diurnal pondage will be underlain by strong greywacke-siltstone and shale cut by basic dykes. These rocks are tight and there should be no appreciable leakage. Some minor slips into the pond may occur (see p. 25).

20. The control building and transformer yard will be underlain by slightly to moderately weathered siltstone-greywacke and shale striking at right-angles to the hill-side. Overburden above the buildings averages 6 feet but reaches

13 feet. Some slipping has taken place close to the transformer yard site (p.27) and further testing is planned.

21. The access road to the surface works will follow the right bank of the river upstream of the weir. Its alignment crosses several small slips and it will be partly constructed on Kainantu Beds (see p. 27).

22. The step-up substation will be build on Kainantu Beds to the east of the transformer yard. These sediments would not support high loadings (see p.27).

23. The pressure and access shafts will be sunk through the same succession of rocks. The first 600 feet will be in greywacke-siltstone and shale, with an increase in shale content in the lower horizons. From 600 feet to machine hall level the shafts are expected to be in marble (see p. 28).

24. The rock in the shafts will be strong although affected by well developed jointing. Water inflows are expected to be small. A shear located on the surface and in DD22 should cut across the access tunnel and the pressure tunnel below weir site No. 2. The top 100 feet of the pressure shaft would be affected by the shear if weir site No. 1 is used (see p. 29).

25. Concrete lining of the access shaft is expected to be largely restricted to 100 feet from ground level although some support and local lining may be required in other places. Overbreak is expected to be slight (see p. 29).

26. The machine hall will be excavated in a uniform stable mass of rock which will be mostly marble. Faults in the area may result in the siltstone-marble contact crossing the machine hall. The rocks are strong and there is little indication of weakness at the contact (see p. 32).

27. Fracture permeability measurements at machine hall level, taken in conjunction with the very low permeability of the overlying rock, indicate that water flows into the machine hall should be low (p. 32). Temperature surveys of drill holes indicate a machine hall temperature of about 80°F. (p. 32).

28. Assessment of support requirements for the machine hall will depend on in-situ testing. It is expected that it will probably be closely rockbolted with concrete lining in fault zones (p. 34). Rock structures are so oriented that overbreak should be slight. Some line drilling may be required to control the shape of the machine hall.

29. Investigation has shown that the tailrace tunnel will be largely excavated in marble (p. 36). The rock is strong and tight and is not unduly susceptible to erosion or corrosion; some water inflows can be expected near the outlet portal. No evidence was found for significant solution cavities at tunnel level, but testing has not been adequate to prove that none exist. Some major inflows are theoretically possible (p. 38).

30. Aerial photographs indicate several possible faults crossing the tunnel line but none have been confirmed. These faults may bring either the schists of the Bena Bena Formation or the siltstone-greywacke to tunnel level. The faults are expected to be narrow (generally only a few feet at most) and bounded by strong rock. No fault or crush zones wider than 100 feet are expected (p. 37).

31. The orientation of the tunnel line is ideal for economical mining and overbreak should be low. Support over most of the tunnel should be limited to rock-bolting and mesh in areas of close jointing, minor faulting and any areas where thin-bedded sediments dip or strike at a small angle to the roof or walls. It is estimated that at least 80% of the tunnel could be unlined; possibly as little as 10% will require lining (excluding the outlet portal area) (p. 38).

32. The outlet portal will be constructed in strong, jointed marble. Some water inflows can be expected in this area, especially under Recorder Creek. Lining of this section of the tunnel will be necessary (p. 40).
33. Overburden depth at the portal is at least 4 feet but there is some danger of landslipping from the slopes above (p. 40).
34. Tunnel spoil could be dumped in the Ramu River downstream of the portal area (see p. 41).
35. A surveyed access road to the portal crosses Kainantu Beds and then descends the gorge across steep side-slopes and several slips. Any road in this area will be difficult to construct and maintain (p. 41).
36. The use of tunnel spoil, river gravel, marble and gabbro as construction materials was examined. All appear to be suitable (subject to standard tests) but shaly material from the Omaura Greywacke would have to be rejected (see p. 42).

RECOMMENDATIONS

1. Instrumentation should be installed as soon as possibly to measure the response of the various rock and soil types to seismic activity. This will enable a more accurate estimate to be made of the seismic loadings which can be expected on the various elements of the scheme and will provide comprehensive data for later stages of the scheme. If this information is not available all designs should include a factor of safety for seismic loadings (see p. 10).
2. In view of the considerable amount of excavation which will be carried out in the marble, additional testing of the engineering properties of this rock should be carried out. Tests should determine unconfined and confined compressive strengths, elasticity, and abrasive properties (p. 18).
3. Further soil testing of the Kainantu Beds and soils should be carried out to determine the stability of slopes in the area of the surface works (p. 19).
4. During construction of the weir overburden and strongly weathered rock must be removed from the foundations. Especial care must be taken with dolerite dykes which may have to be excavated for several feet below the level of fresh siltstone. All weathered shale should be removed before placing concrete (see p. 22).
5. If weir site No. 1 is used, the shear on the right abutment and any other faults will have to be carefully cleaned out and back-filled with concrete. Overburden on the left bank of the river at this site will have to be stabilised by the removal of some material and the installation of drains (p. 22).
6. On either weir site consolidation grouting will be required beneath the foundations to ensure a stable, tight rock mass. Curtain grouting will be necessary in areas where dykes and faults are found (see p. 24).
7. Tests should be carried out on the abrasive properties of suspended material carried by the Ramu River in flood. It may be necessary also to measure the bedload carried by the river (see p. 25).
8. It will be necessary to stabilise the slope above the control building and transformer yard by the removal of unstable material and the construction of drains (p. 27).

9. If high loadings are required at the step-up substation consideration should be given to its relocation at a lower level on more stable foundations. If the presently proposed site is used the recommendations on page 27 should be followed.
10. During construction of the access road to the surface works unstable slipped material on the road alignment will have to be removed and replaced by stronger material. Careful control of drainage on all sections of the road is required to prevent both slipping and erosion. The road should be surfaced with suitable material such as river gravel (p.27).
11. The access and pressure shaft collars should be constructed to a depth of at least 20 feet into reasonably sound rock (p. 29).
12. During excavation of the access shaft measurement of the stress pattern in this area should be carried out at a depth of not less than 500 feet by the installation of extensometers and flat-jacks. This testing should be carried out in time for the results to be used in photoelastic studies of the machine hall before excavation (p. 29).
13. The final position of the machine hall will depend on the drilling investigation carried out either from the access shaft or the tailrace tunnel. This investigation could be carried out from a chamber at the side of the shaft or tunnel and would consist of up to 6 holes (possibly only 3) of up to 300 feet in length. The holes should be designed by the site geologist in the light of the geology of the access shaft and tailrace tunnel (p. 34). The final location, shape and orientation of the machine hall will depend on the drilling and the stress measurements. Machine hall shape should be kept as simple as possible.
14. Equipment should be available at all times in underground excavations to cope with large flows of pressure water (see pp. 34 and 37).
15. During construction of the machine hall it is recommended that instruments to measure the short and long term deflection of, and stress in, the rock be installed. Care should be taken that these instruments are well protected and positioned so that regular readings can be taken (p. 34).
16. During excavation of the tailrace tunnel it may be necessary to carry out stress measurements similar to those in the access shaft (p. 38). The instruments should be installed within 1500 feet of the proposed machine hall site.
17. During driving of the tunnel feeler holes should be drilled at least 50 feet ahead of the working face (see Appendix 9 and p. 38).
18. Care should be taken when placing concrete lining to provide adequate drainage for any inflow of water into the tunnel (p. 38).
19. The outlet portal of the tailrace tunnel should be so located and oriented that: the tunnel is driven roughly at right angles to the slope; the alignment gives adequate cover under Recorder Creek; and the portal is protected against slips from the sides of the gorge (p. 39).
20. Measures will have to be taken to avoid the blockage of the outlet portal by debris from the Ramu River in flood, or by flooding in the event of a rock fall blocking the river immediately downstream (p.40).
21. Consideration should be given to an alternative alignment for the outlet portal access road or possibly the use of another method of access, such as a cableway or tramway (see p. 41).

22. Further testing of the possible sources of construction materials to prove adequate resources will be required. Some drilling to prove the extent of the fresh gabbro on Yonki Dome may be necessary. There is a shortage of fine aggregate and pits will have to be sunk in the Ramu River flats in the Arona Valley to prove quantities of suitable sand (p. 42).

23. Recommended contract provisions are given in Appendix 9.

ACKNOWLEDGEMENTS

The geological investigation has been carried out in close co-operation with officers of the Papua and New Guinea Branch of the Commonwealth Department of Works. They have been responsible for the provision of accommodation, transport, and labour: organising survey work, drilling, testing and sluicing and all the minor details which contributed to the investigation. At all times they have been of the greatest assistance.

Strength testing of the cores from the Upper Ramu was carried out by the Central Testing and Research Laboratories, Commonwealth Department of Works, Melbourne.

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Most of the drilling for the underground scheme was carried out by a team of drillers from the Snowy Mountains Hydro-electric Authority under Mr. Paul Grech. They went to considerable trouble to obtain the information required for the geological investigation.

Mr. R. Teale and Mr. R. Jones have kept records of seismic events in the Kainantu area between 1961 and 1966.

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(i)

APPENDIX I

DEFINITIONS OF SEMI-QUANTITATIVE DESCRIPTIVE TERMS

The following terms have been used as much as possible in this report:

Grade Scale

Very coarse grained	Greater than 1 mm in diameter
Coarse grained	$\frac{1}{2}$ mm to 1 mm in diameter
Medium grained	$\frac{1}{4}$ mm to $\frac{1}{2}$ mm in diameter
Fine grained	$\frac{1}{8}$ mm to $\frac{1}{4}$ mm in diameter
Very fine grained	Less than $\frac{1}{8}$ mm in diameter

Bedding

Laminated	Less than 10 mm thick
Thinly bedded	10 mm to 100 mm thick
Thickly bedded	Greater than 100 mm thick

Hardness

Hard to very hard	Impossible to scratch with knife blade
Moderately hard	Shallow scratches with knife blade
Soft	Deep scratches with knife blade

Percussive strength

Strong to very strong	Cannot be broken after repeated blows with a hammer
Moderately strong	Rock breaks after 3 or 4 heavy blows with a hammer
Weak	Rock breaks after one blow with a hammer.

Weathering

Fresh	Rock shows no discolouration, loss of strength, or any other effect of weathering.
Slightly weathered	Rock is slightly discoloured, but not noticeably lower in strength than the fresh rock.
Moderately weathered	Rock is discoloured and noticeably weakened, but a 2-inch diameter drill core cannot usually be broken up by hand across the rock fabric.
Highly weathered	Rock is usually discoloured and weakened to such an extent that 2-inch diameter cores can be broken up readily by hand, across the rock fabric. Wet strength usually much lower than dry strength.
Completely weathered	Rock is discoloured and entirely changed to a soil, but the original fabric of the rock is mostly preserved. The properties of the soil depend on the composition and structure of the parent rock.

(ii)

Rock Condition (Pender, Hoskins & Mattner, 1963)

<u>Class</u>	<u>Condition</u>	<u>Characteristics</u>	<u>Support</u>
5	Excellent	Sound, compact, usually dry rock, either unjointed or with tightly closed, strongly cemented joints. Tends to break across the rock itself on excavation rather than along joint planes, hence traces of blast holes usually remain.	No support except in large excavations such as power stations.
5S	Excellent (but highly stressed)	As above but 'spalling' or 'popping' occurs.	
4	Good	Hard rock, generally dry with tightly closed, weakly cemented joints; some slightly open joints with water seepages and flows. May contain some narrow sheared or crushed zones. Tends to break along weakly cemented joints on excavation rather than across the rock itself. The percentage breakage along joints planes in any particular case largely depends upon the orientation of the excavation surfaces in relation to the joint planes. Rock mass slightly altered.	Mainly unsupported or with few rock bolts in pin shoulders if orientation of excavation is adverse in relation to main jointing. Generally less than one bolt per linear foot of 20-foot diameter tunnel.
3	Very fair	Mainly hard rock but considerably loosened by the opening up of weakly cemented joints on excavation, or due to the presence of slightly open joints or narrow sheared or crushed zones. May be dry but usually wet. Tends to break entirely along joint planes on excavation regardless of the orientation of excavation surfaces in relation to the joint planes. Rock mass moderately altered.	Light steel sets or "completely" supported in roof by rock bolts, occasionally supplemented by steel channels and wire mesh. Usually 2-3 bolts per linear foot of 20-foot diameter tunnel.
2	Fair	Partly hard rock but usually containing more than 10% of soft materials classifiable as soil. i.e., crushed zones loosely jointed sheared zones or highly to completely altered zones.	Generally heavy steel sets in tunnels and light steel sets or rock bolts with mesh in shafts.

(iii)

<u>Class</u>	<u>Condition</u>	<u>Characteristics</u>	<u>Support</u>
1	Poor	Consists of more than 50% soft material classifiable as soil, i.e., crushed zones, loosely jointed shear zones or highly to completely altered zones. Can be excavated without the use of explosives. Exerts pressure on support.	Generally heavy steel sets with close timbering in both tunnels and shafts. Invert struts occasionally required in tunnels.
0	Very Poor	Consists entirely of soft materials classifiable as soil, usually crushed or completely altered rock. Exerts pressure on top and sides of supports. Includes both squeezing and swelling ground	Heavy steel sets at close spacing in both tunnels and shafts. Invert struts required in tunnels. Timber or steel spiling required. Pilot drifts and other special tunnelling techniques required.

APPENDIX 2MODIFIED MERCALLI INTENSITY SCALE, 1956 Version (Richter, 1958)

- I Not felt. Marginal and long-period effects of large earthquakes.
- II Felt by persons at rest, on upper floors, or favorably placed.
- III Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
- IV Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.
- V Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
- VI Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knick-knacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken, visibly, or heard to rustle.
- VII Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, also unbraced parapets and architectural ornaments. Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
- VIII Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
- IX General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged (General damage to foundations). Frame structures, if not bolted, shifted off foundations. Frames cracked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.
- X Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dykes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
- XI Rails bent greatly. Underground pipelines completely out of service.
- XII Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

(ii)

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

(i)

APPENDIX 3

Record of Felt Earth Tremours in the Kainantu area 1961 - 1966

<u>Date</u>	<u>Time</u> (G.M.T)	<u>Intensity</u> (M.M.)	<u>Remarks</u>
21. 6.61		II	
24. 6.61	1620	IV-V	Sharp jolts, articles fell.
3. 7.61	0920	II-III	
4. 7.61	1715	II-III	
6. 7.61	1415	II-III	
7. 7.61	2206	II-III	
13. 7.61	1115	II-III	
18. 8.61	0837	II-III	
13. 9.61	0310	V-VI	Articles fell, people alarmed
23. 2.62	1030	I-II	
25. 2.62	0930	IV-V	
9. 3.62	2208	IV-V	NE - SW
24. 3.62	1300	VI-VII	Stove displaced, ground opened up round piles.
24. 3.62	2000	I-II	
1. 4.62	1300	II	
21. 4.62	0235	I	
22. 4.62	0915	I-II	
3. 6.62	1500	I-II	
22. 6.62	1457	II	
30. 6.62	2319	I	
8. 7.62	2050	II	
14. 7.62	0438	II	
30. 7.62	1718	I-II	
14. 8.62	1710	II	
25. 8.62	0315	III	
30. 8.62	0029	II	
12. 9.62	1716	I-II	
3.10.62	1200	I-II	
6.10.62	2140	II	
7.10.62	1240	I	
17.10.62	1900	I	
15.11.62	1415	II-III	
30.11.62	2310	III	
1.12.62	0305	I	
27.12.62	1403	III	
19. 1.63	1046	II-III	
25. 1.63	0845	III	
30. 1.63	0710	II	
6. 2.63	0542	IV	Sharp shock
12. 2.63	1745	I	
14. 2.63	2210	V-VI	Sharp shock, water spilt
16. 2.63	2338	I	
17. 2.63	0653	II-III	
26. 2.63	2014	VI-VII	Stove moved, ground opened up round piles - 3 shocks
27. 2.63	0700	II-III	
31. 3.63	0708	II	
5. 4.63	1453	II-III	
8. 6.63	0435	II-III	
23. 6.63	0853	III	
11. 8.63	1245	III	
13. 8.63	0545	IV	Sharp shock
20.11.63	0405	III	
27.11.63	2340	III	

(ii)

<u>Date</u>	<u>Time</u> (G.M.T)	<u>Intensity</u> (M.M.)	<u>Remarks</u>
22. 12. 63	1157	III	
12. 1. 64	1114	III	
8. 4. 64	1945	II	
24. 4. 64	0555	IV-V	4 shocks, flagpole swayed
10. 5. 64	0520	II-III	
25. 5. 64	0304	III-IV	Sharp shock
17. 8. 65	0310	II	
4. 10. 65	0013	IV	
21. 6. 66	1800	III	
19. 7. 66	1150	II	
24. 7. 66	1125	III	
31. 7. 66	2042	I	
26. 8. 66	1204	II	
17. 9. 66	-	III-IV	
6. 10. 66	0311	IV	
25. 10. 66	0027	IV	
6. 11. 66	-	II	
19. 11. 66	1450	II-III	
8. 12. 66	-	IV	
15. 12. 66	0926	V	
23. 12. 66	1550	V	

Notes: Observers R. Teale, J.K. Hill, R. Jones. In 1964 - 1966
no records were kept for several months.
Reports September 1966 - December 1966 by official observers,
made to B.M.R. Geophysical Observatory, Port Moresby.

(i)

APPENDIX 4

Petrographic Description of Rocks from the Upper Ramu
Hydro-Electric Scheme Area

by

C.E. Newbigin

66370002-FINE BLACK SILTSTONE, FROM DRILLHOLE DD21, AT 550-FOOT DEPTH

The siltstone appears in thin section to consist of sub-angular, subhedral to anhedral grains of quartz (10%), feldspar-plagioclase and potash feldspar (20%), and biotite (2-3%), set in a groundmass of intergrown flakes of chlorite, micaceous and clay minerals and granules of opaque material (mainly carbonaceous).

The feldspars have been altered to sericite and clay and incipient prehnitisation of the groundmass is noticeable. Veins of zeolites cut the slide. The composition of the zeolites has not been determined.

Engineering properties

Bedding is not apparent in either the thin section or the hand specimen; no marked alignment of the very-fine-grained platy minerals is evident. Therefore there appears to be no inherent plane of weakness in the rock. Behaviour under normal stress and in unsupported underground openings would be determined by features such as joints, faults, and megascopically recognizable, poorly-bonded, bedding planes, or cleavage planes.

As the rock contains clays, although probably not swelling clays, and zeolites, it may possibly be unsatisfactory as aggregate. If such a use is contemplated the material should be subjected to standard acceptance tests, including reactivity.

66370003-METAMORPHOSED LITHIC ARENITE, (GREYWACKE) FROM DRILLHOLE DD21 AT 229-FOOT DEPTH

The rock is well cemented and poorly sorted, with angular to sub-angular altered mineral and rock fragments.

The fragments comprise 10% quartz, generally unaltered and including both igneous and hydrothermal quartz; 20-25% feldspar of albite composition altered to clay minerals, prehnite and chlorite; less than 1% augite in fresh rounded grains. The rock fragments, which make up 20% of the rock, are varied in composition; 10% volcanic fragments containing clay minerals derived from the feldspar laths and devitrified groundmass, 5% chert fragments and 5% fragments of a quartz-biotite schist. The remainder of the rock - 45% - consists of cement and possible matrix completely altered to intergrown chlorite, actinolite, authigenic clay minerals and prehnite. Alteration was probably effected during late stage diagenesis.

Engineering properties

As this rock is believed to contain minerals which would make it unstable as an aggregate, e.g. devitrified volcanic fragments and chert fragments, it would be advisable to test it for reactivity. Should this test show no deleterious reactions the rock is probably sound enough for aggregate.

(ii)

There is no evidence of bedding or alignment of platy minerals and the same comments regarding strength under stress apply to this rock as to 66370002.

66370004-METAMORPHOSED (?) LITHIC ARENITE, (GREYWACKE), FROM DRILLHOLE DD21 AT 384-FOOT DEPTH

The rock has an average grain size of 0.6 mm and consists of altered rock and mineral fragments cemented by a largely reconstituted matrix and cement. The mineral fragments include 20-25% quartz grains, embayed and altered by calcite and the minerals of the groundmass; 20% feldspar grains were recognized but originally there were probably many more that are now completely altered. Many grains show alteration to zeolites, amphiboles or calcite while others are altered to sericite and clay and contain opaque minerals. The opaque material is largely carbonaceous; it occurs also in the groundmass and constitutes about 20% of the slide. Only about 5% of the slide can be recognized as rock fragments: highly altered volcanic fragments contain amphibole, epidote and chlorite, while others consist mainly of derived clay.

The groundmass, 30-35% of the rock, consists largely of a fibrous sodic amphibole, with minor development of epidote and calcite. Veins of zeolites, chlorite and calcite transect the rock; they presumably were formed at a late stage. Generally the rock has been metamorphosed to a level equivalent to the upper greenschist facies.

The same comment on engineering properties applies to this rock as to 66370003.

66370005-MARBLE, FROM DRILLHOLE DD21, AT 959-FOOT DEPTH

The marble consists of fine even-sized grains of calcite, which show a slight preferred elongation. A few larger grains of quartz and altered feldspar disturb the otherwise uniform fabric.

Parallel to the direction of preferred orientation in the slide are two or three narrow lenses where the calcite grains have been sheared. These are presumably due to movement within the rock.

Engineering properties

The slight preferred orientation of this rock may yield a preferred direction of fracture but this would not be strongly developed. The small shears, some of which have been healed by calcite, would possibly provide passages for water.

The rock should be examined for larger shears, joints and planes of slip as these will determine the behaviour of the marble in unsupported underground openings.

The rock does not appear to contain any deleterious minerals which would prevent its use as concrete aggregate.

(iii)

66370006-METASOMATIC TREMOLITE TALC ROCK, FROM DRILLHOLE DD21, AT 105-FOOT DEPTH

The rock is igneous in origin but has been almost entirely reconstituted so that it now consists of large anhedral grains of primary augite, with altered rims, small irregular grains of secondary hornblende, rimmed by an altered groundmass and in some cases containing relict augite grains, irregular altered biotite laths and large pseudomorphs consisting of radiating aggregates of tremolite. Some of these aggregates have cores, with either mesh or spiral structure, that consist of urallite, calcite, muscovite, and finely divided opaque material.

The former groundmass has been reconstituted as fine-grained intergrown laths of talc with minor veins of actinolite and veinlets of urallite. Opaque material is scattered through the groundmass in small irregular veins.

Engineering Properties

The rock does not have a greasy texture but sawn surfaces polish readily. The talc forms about 35 percent of the rock but is intergrown with the groundmass in which are set large grains of other minerals. Sound rock of this type is therefore unlikely to have an adverse effect on the stability of any openings in which it may occur. Any sheared bodies of tremolite talc rock encountered, however, could provide lubricated surfaces along which blocks of unsupported rock could move.

If encountered in underground openings this rock should be carefully examined for shears or greasy joints along which movement could occur. Its use as concrete aggregate should be avoided.

66370007-MARBLE, FROM DRILLHOLE DD19, AT 927-FOOT DEPTH

This rock is very similar to 66370005; it displays a saccharoidal fabric showing slight preferred elongation of grains and consists almost entirely of calcite with some small grains of quartz and streaks of intergrown chlorite and mica. There is no sign in the slide of the granulation noted in 66370005.

Engineering Properties

The engineering properties are very similar to 66370005 and the same comments apply. There is possibly a faint preferred direction of fracture but the main cause of any lack of strength would be macroscopic features such as joints, faults and bedding planes.

The hand specimen shows that the marble has a variety of textures; it may therefore be differentially soluble. The slide does not show any deleterious minerals.

66370008 (1-4) - SHALE AND SILTSTONE FROM DRILLHOLE DD21

These slides represent shale and siltstone from drillhole DD21. Generally the fabric shows grains of fine sand size included in a matrix of silt-sized or clay-sized particles. The percentage of mineral detritus ranges from 50% in 66370008 (4) to 15% in 66370008 (2). For the composition of the rocks, see the attached table.

Engineering properties

Although the shale contains clays, X-ray work has shown that they are probably not swelling clays and that they are not present in larger quantities than is normal for shale. 66370008 (2) contains zeolites and should be submitted for reactivity tests if use as aggregate is contemplated.

Preserved orientation in the grains is only poorly developed. Bedding as seen in the slides ranges from transitional, with no erosional break, to sharp clearly-defined breaks where cohesion may be poor. The main causes of weakness however will be macroscopic features such as the joints, coated with pyrite, calcite and zeolite, which are apparent in hand specimen.

66370009 (2) - FOLIATED QUARTZ MICA SCHIST, FROM UPPER YONKI CREEK

The rock exhibits a saccharoidal texture superimposed on a fabric of small irregular mesoscopic folds and crenulations in a metamorphic layering. The rock consists of grains of various sizes, mainly fine-grained quartz, muscovite, biotite, and a few large poikilitic grains of cordierite, with finely divided opaque material present throughout.

The minerals are fresh with only minor alteration of muscovite to chlorite and cordierite to pinitite. The layering is defined by the segregations of minerals as a result of deformation. Quartz is concentrated in the crests of folds and fine-grained quartz and mica flakes are concentrated in the limbs; other layers are composed entirely of quartz.

The rock has undergone two stages of metamorphism, the first regional and the second contact thermal in effect. The rock is equivalent in metamorphic grade to the albite-epidote-hornfels facies.

Engineering Properties

The rock contains no minerals which are considered undesirable in aggregate. The interlocking nature of the fabric may make the rock very tough and expensive to crush, however the metamorphic layering in some cases forms an irregular preferred cleavage direction. This has not been sufficiently developed in the hand specimen to form a schistosity cleavage and it is probable that when considering the behaviour of the rock in unsupported underground openings, any significant planes of weakness will be megascopic, e.g. joints or faults.

66370009 (1) FOLIATED QUARTZ MICA SCHIST

This rock is very similar to 66370009 (2). The metamorphic layering is well developed, but the saccharoidal texture is less evident. These features could be the result of the attitude of the thin section.

The rock consists of quartz, biotite, muscovite, and cordierite (again present in poikilitic grains and altered to pinitite). Opaque minerals are finely disseminated in the rock. A few grains of hornblende are present.

The engineering properties are similar to those of 66370009 (2).

(v)

COMPOSITIONS OF SPECIMENS 6637008 (1-4), FROM DRILLHOLE DD 21

	Shale (1) 166' 7" depth	Quartz siltstone (3) 295' depth	Quartz siltstone (4) 357' 6" depth	Shale (2) 390' depth
	Average grain size 0.15mm	Average grain size 0.07mm	Average grain size 0.1-0.2mm	Average grain size 0.1mm
Quartz	20% - in the coarser laminae - fresh angular grains	15-25% - altered by authigenic cement	30% - fresh angular grains	5 to 10% - fresh angular grains
Feldspar	10% - slightly altered grains; fine laminae contain 10% quartz and feldspar. Average grain size 0.08mm	10% - minor sericitization, otherwise grains fresh	15 to 20% - angular grains, many sericitized and altered to clay minerals	45% - fresh angular grains
Opaque material	2-3% pyrite 8-10% carbonaceous material	2-3% pyrite 10% carbonaceous material	Negligible	Less than 1% pyrite
Mafic minerals	4% pyroxene-fresh	-	2-3% biotite-bleached, ragged grains	-
Matrix and cement	65% - brownish fibrous layer silicates, probably clays	15 to 20% - minor clay minerals, mainly brownish chlorite with minor intergrown green chlorite	40% - fine clay minerals intergrown with secondary minerals	70% - fine grained micaceous material and considerable carbonaceous material
Authigenic material	The matrix and cement are altered to prehnite and brownish chlorite	35-47% reconstituted grains - (i) chlorite intergrown with prehnite (ii) brownish phyllosilicate (chlorite?). The latter is mainly found in the cement	(i) green cement - intergrown prehnite and illite (ii) brown cement - intergrown brownish clay minerals, probably illite	Minor and patchy alteration to prehnite. Chlorite, prehnite and, in some places zeolites, fill foram shells. The slide is cut by veins of unidentified zeolites, chlorite and calcite
Fossil remains	-	-	-	5-10% forams and foram fragments.

66370010 (3) - DOLERITE - BOULDER FROM CREEK ON NORTH FLANK OF YONKI DOME

The rock consists of large anhedral grains of augite and both fresh and altered grains of olivine, all in a groundmass of interlocking irregular laths of plagioclase, the composition of which is estimated as more calcic than An 65. Chromite is found as irregular resorbed, and commonly interstitial, grains.

The rock is fairly fresh; the plagioclase shows minor veining by sericite. Both augite and olivine show inclusions; the augite contains some grains of brown amphibole and clouds of minute inclusions. The olivine contains plagioclase grains and opaque material, possibly chromite, included along cracks and within the grains.

Engineering Properties

The rock contains no minerals recognised as deleterious in concrete aggregate. Owing to the interlocking grains the rock is very tough and would probably be expensive to crush.

66370010 (1) DOLERITE

This rock is very similar in composition to 66370010 (3). It consists of strongly resorbed grains of augite and olivine, with included interstitial biotite and chromite, and a groundmass of plagioclase (approximately An 60%-65%) slightly less altered than the previous slide.

Overall, the minerals are more altered than 66370010 (3). The pyroxene is generally fresh, and contains many inclusions of feldspar, biotite and chromite. The olivine also contains chromite as well as a considerable amount of the alteration product uraltite. The plagioclase of the groundmass shows minor alteration to a fibrous amphibole. The grains of the groundmass have developed a vague coarse saccharoidal texture with diffusions of lamellae in the plagioclase.

The engineering properties are similar to those of 66370010 (3).

66370010 (2) PERIDOTITE

The rock appears in thin section to have an interlocking fabric of coarse rounded euhedral-anhedral grains, of augite (60%) and an iron-rich olivine (40%). Both minerals have been altered to uraltite, particularly at pyroxene olivine interfaces, and a pale blue-green amphibole has developed in some grains of pyroxene. Magnetite is present as inclusions in the rim of many smaller grains of olivine.

Engineering Properties

The rock shows a coarsely interlocking texture, and a homogeneous rock mass shows clean slightly platy fracturing. It is not known if any of the alteration minerals would react with cement; it is therefore advised that the material be tested with high alkali cement, if it is to be used as concrete aggregate.

APPENDIX 5

SUMMARY OF TESTING OF DRILL CORES FROM UPPER RAMU HYDRO-ELECTRIC SCHEME

Lab. * Sample No.	Bore	Depth	Description	Specific Gravities				Absorption 90	Sonic Velocities		Dimensions		Ultimate Compressive Strength (psi)	Young's Modulus (psi x 10 ⁻⁶)
				Apparent	Gross S.S.D.	App. Oven	Gross Dry		Dry	Saturated	Diam. (ins)	Length (capped) (ins)		
11-L-11	DD21	688'	Hornfelsic Rock	A	2.75	2.70	2.67	1.1	13,400	12,300	Not tested			
				B	2.90	2.88	2.87	0.3	15,100	15,300	2.05	2.98	6050	1.8
				C	2.81	2.80	2.79	0.3	14,400	14,600	2.04	2.62	2330	1.3
11-L-12	DD21	725'	Hornfelsic Rock	A	2.81	2.80	2.79	0.2	16,900	17,200	2.03	4.13	12660	2.2
				B	2.81	2.80	2.79	0.2	16,300	16,600	2.03	4.28	11920	2.3
11-L-13	DD21	752'	Marble	A	2.73	2.72	2.71	0.3	15,300	17,700	2.03	4.14	16480	2.0 - 2.6
				B	2.73	2.72	2.71	0.3	15,500	16,100	2.03	4.23	13000	2.1
				C	2.73	2.71	2.70	0.4	13,300	13,300	2.03	1.61	9100	-
11-L-14	DD21	883'	Marble	A	2.72	2.70	2.69	0.4	10,300	12,000	2.04	4.17	6340	1.5 - 1.6
				B	2.72	2.69	2.68	0.6	10,700	11,800	2.04	3.97	2440	0.9
				C	2.72	2.70	2.69	0.5	12,000	13,900	2.04	2.42	7580	1.1 - 1.5

* Testing carried out by the Central Testing and Research Laboratory, Commonwealth Department of Works, Melbourne.

APPENDIX 6

GEOLOGICAL LOGS OF DRILL HOLES

DD 1

DD 1A

DD 1B

DD 1C

DD 16

DD 18

DD 19

DD 20

DD 20A

DD 21

DD 22

BUREAU OF MINERAL RESOURCES. GEOLOGY AND GEOPHYSICS									
GEOLOGICAL LOG OF DRILL HOLE									
PROJECT		UPPER RAMU - Weir Site		HOLE NO.		D.D.1 or U.R.1		R.L. 3877'	
LOCATION		Collar on S. bank of Ramu River 60ft. upstream from Weir site		ANGLE FROM HORIZONTAL		-40°		DIRECTION 045° Mag	
ROCK TYPE & DEGREE OF WEATHERING		Fracture Log		WATER LEVEL		WATER PRESSURE TEST Gallons per minute per foot loss.			
Overburden		Clay and boulders							
Fresh Shale		Medium grey, fresh, moderately indurated, moderately strong, hard shale, with fine laminae (<2mm) of light grey siltstone, 1 to 5mm. apart. Core very broken. Pieces minute to 6", mode 1"		NMLC		95%		Rock has two or more well developed cleavage systems with numerous calcite, chlorite and talc covered surfaces. Many polished and striated surfaces. Traces of limonite staining common. A few clay coated fractures. Core badly ground in places. Slickensides and fragments of gouge or grey-white clay and brecciated rock at 8'9", 11'1"-11'7", 10'1"-26", 29'0" to 31'8". The shale in these zones has been closely sheared and/or crushed. Hole caved from surface to 40'. Hole cemented to 50'. Lost circulation at 32'. Thereafter intermittent for short period.	
Fresh interbedded Greywacke and Shale		Light bluish grey, fresh, siliceous, strong, very hard, very fine grained greywacke with thin shale interbeds (generally sheared or crushed). Pieces 1/4" to 6", mode 2"		NMLC BMLC		Lifts not marked		Some fracture surfaces coated with calcite and clay. Most limonite stained. Narrow band of sheared and faulted indurated shale from 34'6"-34'11"-consists of shale fragments with much calcareous gritty gouge and crushed material. Shale fragments at 38'11" show traces of gouge and brecciated rock. Most bedding planes at 40" to core axis. Fragments of clay and brecciated shale at 40'8". No traces of gouge, clay or brecciated rock.	
Fresh Shale		A few badly ground fragments of greyish-black, fresh, mod. ind. mod. strong hard shale.				0%			
Fresh interbedded Greywacke, Siltstone and Shale		Fresh, moderately indurated, strong, hard, thinly bedded or laminated rocks. Shale interbeds 1-10mm. thick, 1-10mm. apart. Greywacke beds graded. Pieces 1/2" to 14", mode 3"				100%		Many fracture surfaces coated with calcite and limonite. Some calcite veins up to 3mm. thick. No sign of shearing or faulting, except for core loss. Bedding planes at 35° to core axis.	
Fresh Dolerite or Gabbro		Greenish-grey, fresh, massive, very strong, very hard gabbro or dolerite. Pieces 1" to 36", mode 10". Length of soft, moderately strong, altered rock from 80'-82'.		BMLC		100%		Change from metamorphic rocks to igneous is gradational over distance of 5". Most joints clean, but a few thin clay veins present. 2mm. vein zeolite? at 88'8". Sections 79'-83', 86'-89', 93'-94' display well developed but irregular incipient closely spaced (<5mm) fractures. Possibly indicate rock has been stressed.	
DRILL NO.		Mindrill E 1000 Hydraulic Feed		NOTES: Fracture log records number of fractures per foot of core. Zones of core loss are assumed to have been completely sheared or crushed.		LOGGED		J.K. Hill 29-5-63	
DRILLER				2. - indicates strongly sheared rock or other evidence of extensive faulting.		VERT. CAL.		10 feet : 1 inch.	
COMPLETED				3. Mode - most common length of unbroken core.		SCALE			

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS									
GEOLOGICAL LOG OF DRILL HOLE									
PROJECT		UPPER RAMU - Weir Site		HOLE NO		D.D.1 or U.R.1		3877'	
LOCATION		Collar on S. bank of Ramu River 60ft upstream from Weir site.				ANGLE FROM HORIZONTAL		-40°	
WATER PRESSURE TEST		Gallons per minute per foot loss							
ROCK TYPE		DESCRIPTION		Fracture Log		STRUCTURES		WATER LEVEL	
A DEGREE OF WEATHERING						JOINTS VEINS SEAMS FAULTS CRUSHED ZONE			
Fresh Dolomite or Gabbro		Described above, pos 1'-28'; mode 8". (Diffuse boundary)		BMLC		Described above. Stress zones 103'-104'; 106'-9'-107'-2'. Slickensided joints at 104'-5" and 105'.			
Fresh Hornfels		Light bluish-grey, fresh, very strong, very hard, porphyro-blastic hornfels, pieces 2"-6"		108'-0"		Very soft fibrous talc/actinolite fills fracture at 109'-5"; and may indicate faulted contact.			
Fresh interbedded Greywacke Siltstone and Shale		Described above. Bedding at 30°-40° to core axis. Graded bedding and other sedimentary structures present. Very fine grained silicified greywacke bed from 126' to 128'-8". Bedding at 50° to core axis. Graded beds indicate ↑ up.		109'-10"		Clay and limonite coated fractures common. Some Ca-chlorite lined. Only few clean joints. No slickensides present. Fine veins of zeolites? common. Rock has been slightly sheared as shown by displacement of shale laminae by up to 5mm. along shear planes. (Latter filled with zeolite?). Euhedral zeolite? xstals at 127'-3" indicate joint prob. open. Laminae displaced 5mm. by shear at 129'. 1mm. yellow brown silty limonite material on joint at 130'.			
Fresh Dolomite or Gabbro		Described above. Pieces 1/2"-10", mode 5"		132'-8"		Contact abrupt and unfaulted. Slickensides and talc on fracture at 138'-0"			
Fresh interbedded Greywacke Siltstone and Shale		Described above. Pieces 1/4"-6", mode 2"		136'-3"		Euhedral crystals of calcite and zeolite indicate open joints at 131', 148', 148'-10". No slickensides observed, but smooth talc or serpentine-filled joints present. Off-set laminae present. Hole caved 136'-138'			
Fresh Dolomite or Gabbro		Described above. Pieces 1/4"-24", mode 12". Changes in grain size occur throughout.		149'-6"		12" longitudinal joint filled with zeolite? and with 2mm wide cavities. Euhedral crystals at 153'. Slickensides present. Numerous thin veins of calcite and/or zeolite. Sheared zone 162'-165'. Rock soft and friable, slickensides present and much green chloritic material. Traces of silty clay or tremolite - actinolite. Several calcite veins up to 5mm. thick. Most joints coated with calcite, chlorite or limonite (thick). Slickensided fibrous fracture surfaces at 181'-5".		100%	
Fresh interbedded Greywacke Siltstone and Shale		Described above. Pieces 1'-16", mode 3". Bedding at 30° to core axis. Graded bedding indicates ↑ up		190'-4"		Most fractures lined with quartz (or? zeolite). Open joint at 198'-2".			
END OF HOLE									
LOG NO		Mindrill E 1000 Hydraulic Feed		LOGGED		J.K.Hill 29-5-63			
DATE				SCALE		10 feet : 1 inch			

BUREAU OF MINERAL RESOURCES. GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRICHOLE NO DDIAH L 3875 feetLOCATION 268' at 101° magnetic from 000 drainage on surveyed tunnel line. ANGLE FROM HORIZONTAL -70° DIRECTION 190° mag.

HOLE TYPE & DEGREE OF WEATHERING	DESCRIPTION	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRACTURE LOG	LIFT & CORE RECOVERY %	STRUCTURES JOINTS VEINS STAMPS FAULTS CRUSHED ZONES	WATER PRESSURE TEST	
							Gallons per minute per foot loss	
							0.25	0.50
FRESH INTERBANDED SILTSTONE AND SHALE	Light to dark blue-gray strong hard, fresh medium-fine grained interbedded indurated siltstone and shale with occasional $\frac{1}{2}$ to 2" wide bands of medium grained graywacke. Shale bands range from $\frac{1}{4}$ to 8". Many minor sedimentary structures such as load casts, graded bedding etc. are present. Bedding at 35° to core axis. Pieces range from $\frac{1}{4}$ " - 24", mode 9"		0 10 20 30 40 50 60 70 80 90			Joints contain some calcite and clay. Clay and calcite crystals in open joints from 7' 9" - 8' 2", 12' 6" - 12' 8", 31' 11" - 32' 4" occasional 1-2 mm wide veinlets of calcite.		
WEATHERED GABBRO	Blue-green, med. strong-weak, mod hard-soft, slightly-lightly weathered coarse-grained equigranular gabbro. Pieces min to 6" mode 2". Upper contact sharp at 20' to 43' 2" core axis and 40° to bedding. Lower contact gradational over 2" at 70° to core axis					Joints contain clay and calcite. Upper contact is followed by joint containing calcite. Completely weathered to clay between 40' 9" and 41' 3". Some of high weathering from 39' 2" - 41' 6".		
FRESH INTERBANDED SILTSTONE AND SHALE	As above. Banding at 40° to core axis. Pieces 2"-18", mode 9"					Core breaks along calcite filled joints 1-3 mm wide. There is little clay. Joints in general parallel to bedding. Some pyrites in the calcite filled joints.		
						From 97' 4" prominent joint at 10° to core axis with calcite crystals and 1-2 mm of clay.		

HOLE NO

PROJECT UPPER RAMU F.C.SHEET 1DATE 1-2-64BY J.F.B.

Notes: 1. Fracture by means of number of fractures per
foot of core. Core log is shown by a graphic log.
2. Notes on core recovery and other data.

VERTICAL
SCALE 1" = 10 feet

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRICHOLE NO D.D. 1AR.L. 3875 feetLOCATION 268' at 101 magnetic from change 000 on surveyed tunnel lineANGLE FROM HORIZONTAL -70°DIRECTION 120° mag.

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRACTURE LOG	LIFT & CORE RECOVERY %	STRUCTURES JOINTS VEINS STAMPS FAULTS CRUSHED ZONES	WATER PRESSURE TEST Gallons per minute per foot loss
							0.25 0.50
FRESH SLYSTONE AND SHALE	As above		0 12 13+			Broken zone from 102' 7" - 102' 4"	
WEATHERED AND FRESH GABBRO	103' 4" Slightly to moderately weathered gabbro as above. Increases in hardness and strength with depth. Sharp contact to fine -grained gabbro at 118' 10". Grain size increases again below contact. This finer-grained rock is strong and fresh. Pieces $\frac{1}{2}$ " - 24" max 5".		110 120 130			2-3 mm clay and some shikensiding at 10° to core axis on joints at 40° to core axis. Some calcite. Slight shearing at 111' 9" - 112' 1" 113' 1" - 115' 0".	
	END OF HOLE						

0.25 0.50

DRILL NO

TYPE MINDRILL F. 6.DRILLER M. GarnerCOMMENCED 10-4-64COMPLETED 9-5-64

Notes. 1. Fracture log shows number of fractures per foot of core.
2. Made - most common length of unbroken core.

LOGGED J. P. MacGregorVERTICAL
SCALE 1" = 10 feet

BUREAU OF MINERAL RESOURCES. GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRICHOLE NO DD1BRL 3870 feet approx.LOCATION 394' at 125° magnetic from 000 chainage on surveyed Tunnel lineANGLE FROM HORIZONTAL -80°DIRECTION 010° mag.

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRAC- TURE LOG	LIST & CORR. RECOVERY %	CASING	STRUCTURES JOINTS VEINS SEAMS FAULTS CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST Gallons per minute per foot loss
									0.25 0.50
RIVER GRAVEL	Pebbles of river gravel with a band of medium to fine river sand from 5' to 5'4". There is a lot of caving and core grinding. Pebbles are of sillstone, greywacke and dolomite. 6'0"								
FRESH GREYWACKE	Light blue-grey strong, hard, fresh to slightly weathered fine-grained greywacke. Fracture minute 6'2" - 14'2"						Calcite, chlorite and clay on joints		
FRESH SHALE	Dark blue-grey, strong, hard, fresh to slightly weathered fine grained shale with thin sillstone and greywacke bands at 70° to core axis 36'6"						Lot of calcite veining usually 3-6 mm wide but one is 1 1/2" thick at 26'6". Some pyrites on joints Broken zone 35'0" - 36'1"		
FRESH GREYWACKE	As above from 9'0" - 14'2" greywacke and sillstone 50'6"								
FRESH SHALE, SILTSTONE AND GREYWACKE	As above with interbanded shale, sillstone and greywacke 60'0"						Broken zone 52'0" - 60'0"		
	END OF HOLE								

DRILL NO
TYPE MINORILL F-6DRILLER W. ADAMS
COMPLETED 11-6-64
LOGGED 9-7-64

Notes: 1. Fracture log records number of fractures per foot of core. Core loss is shown by a gap in the graphic log and corresponding blacked out fracture log.
2. Mode - most common length of unbroken core.
3. Pressure test losses calculated for NX hole.

LOGGED J. P. MacGregorVERTICAL
SCALE 1" = 10 feet

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRICHOLE NO DD-2CR.L. 3900 feet approx.LOCATION 324' at 129° ms. north from 000 drainage on surveyed tunnel lineANGLE FROM HORIZONTAL -70°DIRECTION 190 mag.

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRACTURE LOG	LIFT & CORE RECOVERY %	STRUCTURES JOINTS VEINS SEAMS FAULTS CRUSHED ZONES	WATER PRESSURE TEST	
							WATER LEVEL	Gallons per minute per foot loss 0-25 0-50
BROKEN AND WEATHERED SILTSTONE AND GREYWACKE	Light blue-gray mod. strong, mod hard, mod. weathered fine grained thinly bedded siltstone and greywacke. Broken with caving and con grinding. Pieces 1/4"-2" mod 1/2". 9'7"		0 12 13+			Very broken with limonite and clay on joints		
FRESH GREYWACKE	Light blue-gray strong hard, fresh fine-grained greywacke with several thin (up to 15mm) shale bands at 45° to core axis. Pieces 1/2"-6" mod 1". 20'7"		10			Some limonite staining and clay on joint surfaces		
FRESH AND WEATHERED GABBRO	Gray-green strong to mod. strong, hard to mod. hard, fresh to mod. weathered medium to coarse grained porphyritic gabbro. Very fragile in places. Contains occasional lenses of shale. Contact sharp. Pieces minute - 12", mod 1". 31'6"		20			1-2 mm of clay on joints		
FRESH GREYWACKE	As above Pieces 1"-6" mod 2" 34'9"		30					
FRESH GABBRO	Fresh to slightly weathered as above. Pieces 1"-9", mod 2". 39'2"		40					
FRESH GREYWACKE	As above 42'8"							
FRESH SHALE	Dark blue-gray strong, hard, fresh fine-grained shale. Pieces minute - 4", mod 1/2". Contact sharp at 45° to core axis. 49'0"					Pyrites and some limonite staining on joint surfaces.		
END OF HOLE								

DRILL NO
TYPE MINDRILL F-6DRILLER W. ADAMSCOMMENCED 10-27-67COMPLETED 22-7-67

Notes 1. Fracture log records number of fractures per foot of core.
Core loss is shown by a gap in the graphic log and corresponding
blacked out fracture log.

2. Ashtr = most common length of submergence.

DRAWN J. B. MacGregor

0-25 0-50

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER KAMU HYDRO-ELECTRICHOLE NO D.D. 16 R.L. 3382 feetLOCATION Fla. map 172 on base stock line 20' from BM VII.ANGLE FROM HORIZONTAL -65° DIRECTION 220° mag.

TIME DATE OF WEATHERING	DESCRIPTION	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRAC- TURE LOG	LITH- E CODE RECOVERY %	STRUCTURES JOINTS VEINS STAMPS FAULTS CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST Gallons per minute per foot loss 0-25 0-50
CRYSTALLINE LIMESTONE CAVITY	White to light grey strong, hard, fresh, fine-grained crystalline limestone.		0 6 12 18			Joints are normally clean but sometimes show signs of water wearing and carry fine sand. Strong water action evident from 5'0"-5'9", 13'2"-14'0". Joints at 90° to core axis and occasionally at 20° to core axis.		
FRESH CRYSTALLINE LIMESTONE	With faint banding at 85°-90° to core axis. Pieces 1" to 25" mode 2".		10					
CAVITY WITH RIVER GRAVEL	Rounded pebbles of shale, siltstone, quartzite.		15'0"					
LIMESTONE	As above.		16'10"					
CAVITY	Pebbles of river gravel.		18'10"					
FRESH CRYSTALLINE LIMESTONE	As above. Darker band- possibly containing a little shaley material from 20' to 22'.		20					
			30					
			40					
			45'					
FRESH CRYSTALLINE LIMESTONE	Light green strong, hard, fresh, med- fine-grained dolomite. Sharp contact at 90° to core axis.		45'6"					
	As above		50					
			60			Water washing on joints at 61'3", 62'7", 63'8", 65'8", 67'4", 67'10", 68'6", 69'8".		
			70					
	END OF HOLE		70'					

DRILL NO

TYPE MINDRILL F6DRILLER R. MADDINGSCOMMENCED 21:8:64COMPLETED 1:9:64

Notes: Fracture log records number of fractures per foot of
core. Core loss is shown by gaps in the graphic log and
corresponding blacked out fracture log.

2. Mode - most common length of unbroken core

LOGGED J. P. MacGregorVERTICAL
SCALE 1" = 10 feet

DD 18

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL 32°
COORDINATES 41790E 86120

DIRECTION 181° 15' True

SHEET 1 OF 2

[illegible]

DRILL TYPE: MINDRILL E 1000

FEED Hydraulic

ONE BARREL TYPE *Triple tube*
NMLC

DRILLER T. J. Condon

COMMENCED 16-6-65

COMPLETED 7-8-65

INDEXED BY B.E. Gardner

VERTICAL SCALE 1 inch = 20 feet

FRacture LOG - Number of fractures per inch of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis.

WATER PRESSURE TESTS

PACKER TYPE Hydraulic
SUPPLY LINE "AX" casing

1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 26

VERTICAL SCALE _____

Figures given are gauge pressures

fast sections are indicated graphically by the

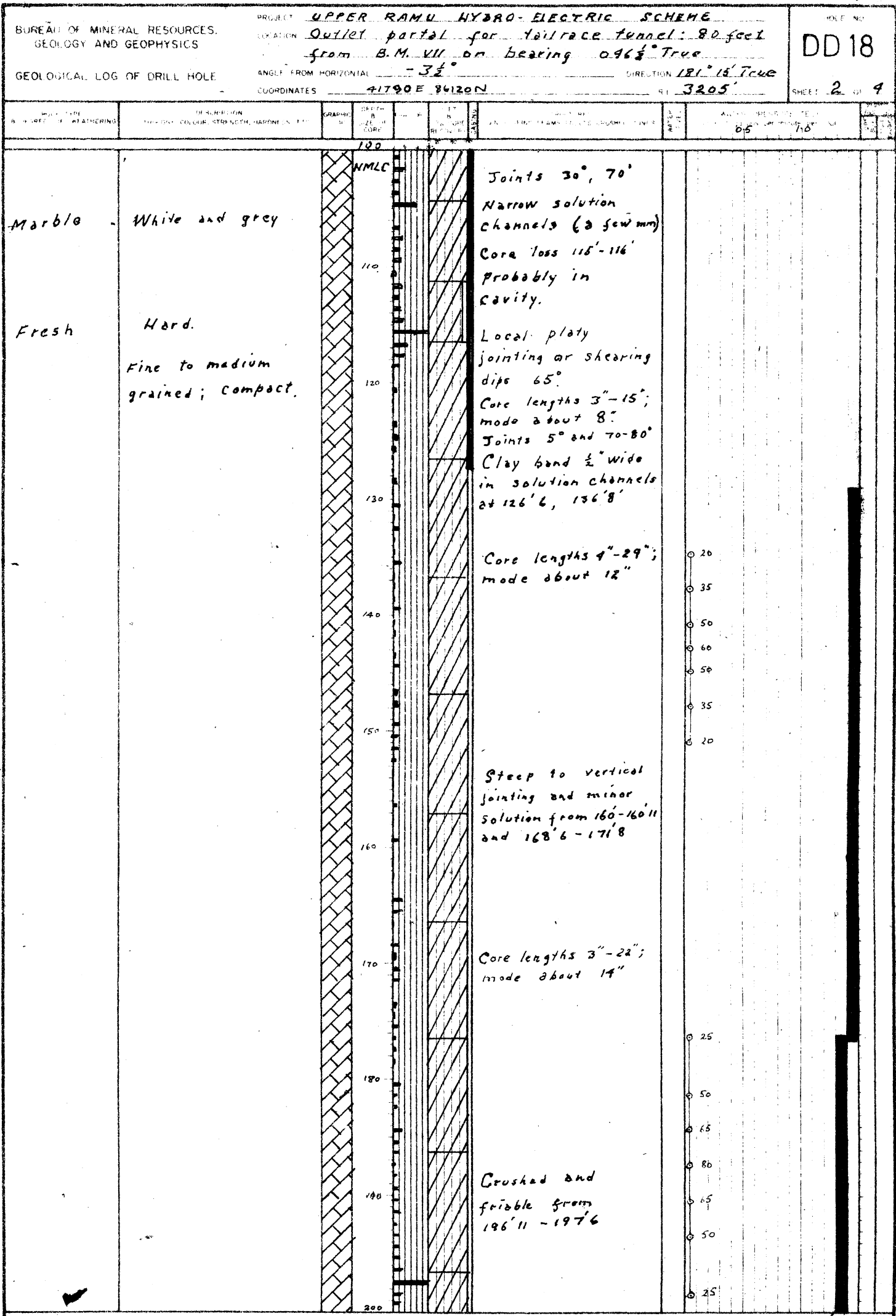
PHOTOGRAPH REFERENCE SYS

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BLA, P. 411, WP(1) - 2000-2001-2002

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DRILL TYPE <u>MINDRILL E1000</u> REMARKS <u>Hydraulic</u> REMARKS <u>NMHC</u> REMARKS <u>Triple tube</u> REMARKS <u>T.J. Condon</u> REMARKS <u>16-6-65</u> REMARKS <u>7-8-65</u> REMARKS <u>D.E. Gardner</u> REMARKS <u>Vertical scale 1 inch = 10 feet</u>	WATER PRESSURE TESTS REMARKS <u>Hydraulic</u> REMARKS <u>"AX" casing</u> REMARKS <u>Vertical scale 1" = 50 psi</u> REMARKS <u>PHOTOGRAPHIC REFERENCE SYSTEM</u>
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BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT

LOCATION

ANGLE FROM HORIZONTAL

COORDINATES

UPPER RAMU HYDRO-ELECTRIC SCHEME

Outlet portal for tailrace tunnel: 80 feet
from B.M. VII on bearing 094½° True

- 3½°

41790 E 86120 N

HOLE NO

DD18

SHEET 3 OF 4

ROCK TYPE

DESCRIPTION

GRAPHIC LOG

DEPTH & SIZE OF CORE

FRACTURE LOG

LIFT & % CORE RECOVERY

STRUCTURES

WATER PRESSURE TEST

ROCK TYPE

DESCRIPTION

GRAPHIC LOG

DEPTH & SIZE OF CORE

FRACTURE LOG

LIFT & % CORE RECOVERY

STRUCTURES

WATER PRESSURE TEST

Marble

Fresh

White, with indistinct grey banding.

Fine to medium grained.

Hard

Indistinct grey banding inclined 60°; probable bedding

NMLC

200

210

220

230

240

250

260

270

280

290

300

Joints 20°, 75-80°

Grey banding at 70° (bedding?)

Joints 20°, 60°, 75°

Solution common along 75° joints

Joints 30°, 70° and near vertical; narrow solution channels along many of these joints.

Rock sound but jointed.

Core lengths 6-19"; made about 13"

See sheet 2

35

55

75

100

75

55

35

30

45

70

110

95

70

30

35

80

105

130

105

80

35

40

90

110

140

MINIBALL E.1000

Hydraulic

TYPE NMLC

Triple tube

T. J. Condon

16-6-65

7-8-65

D. E. Gardner

1 inch = 10 feet

FRACTURE LOG

BEDDING AND JOINT PLACEMENT

WATER PRESSURE TESTS

PAPER TYPE Hydraulic

SUPPLY LINE AX casing

VERTICAL SCALE 1" = 200 psi

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME
LOCATION Outlet portal for tailrace tunnel: 80 feet
from B.M. VII on bearing 046 1/2° True
ANGLE FROM HORIZONTAL - 3 1/2° DIRECTION 181° 15' True
COORDINATES 41790E 86120N RL 3205'

HOLE NO.

DD18

SHEET 9 OF 9

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	UNITS LOG	DEPTH SIZE OF CORE	FRAC. LOG LOG	LIFT LOG % CORE RECOVERED	JOINTS, VEIN, SEAMS, FOLDING, ETC.	WATER PRESSURE TEST PSI PER MINUTE PER FOOT
Marble Fresh	White; indistinct grey banding (bedding?) dips 60°; banding prominent from 310'9" - 311'9" Hard	NMLC	310			Jointing 80°, 75° Narrow solution channels on 75° joints	140 110 90 40
Soleite Slight weathering	Green-gray, irregular contact. Fairly hard.		311 311'3			Close irregular jointing from 315'9" - 319'; minor solution, and breaking of core. Extensive solution on joints from 315'3" - 319'	40 60 80 75 60 40
Marble Mainly fresh, except locally where friable because of solution adjacent to joints.	White. Hard, except locally as noted in first column. Grey banding below 360'; dip 85° at 371'6" 70° at 376'6", 60° at 387'9"		330 340 350 360 370 380 390			Numerous joints 50°, 70° and 5-15°. Core broken at intersecting joints, and at joints widened by solution. Minor shearing, crushing, and solution at 355'10" - 356', 358'4" - 358'8"; approx. dip 0-10° Crushing, probable faulting at 371'1" - 371'4", 375' - 376' (6" core loss) Brecciated 378' - 378'6" (re-cemented), 381'4" - 381'6" (friable), 385'4" - 385'9" (friable from 385'6" - 385'9") Core lengths 1-17"; mode about 4". Narrow solution channels along joints.	40 80 120 80 40 40 100 120 150 120 100 40 100 120 150 100 40 100 120 150 100 40

END OF HOLE

DRILL TYPE MINDRILL B1000
FIELD Hydraulic
CORE BARREL TYPE NMLC
Triple tube
DRILLER T. J. Condon
COMMENCED 16-6-65
COMPLETED 7-8-65
LOGGED BY D. E. Gardner
VERTICAL SCALE 1 inch = 10 feet

FRAC. LOG Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis.

NOTES

WATER PRESSURE TEST

PACKER TYPE Hydraulic
SUPPLY LINE AX casing
VERTICAL SCALE 1" = 200 psi

Figures given are gauge pressures.
Test sections are indicated graphically by blocks in steps.

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

CORRECTION

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT

LOCATION

ANGLE FROM HORIZONTAL

COORDINATES

UPPER RAMU

15.5 feet on bearing 350° mag from c/L of access shaft, Drawing N° HC 65/76/B

-90°

43060E 78922N

ACCESS SHAFT

DIRECTION

RL

3971.5'

SHEET 1 OF 11

PACKER TYPE

LOG TYPE

WEATHERING

DESCRIPTION

THEORY

CLONING

STRENGTH

HARDNESS

GRAPHIC

SCALE

SIZE

OF

CORE

RECOVERED

BY

RECOVERY

STRUCTURES

JOINTS

VEINS

BEAMS

FAULTS

CRUSHED

ZONES

WATER PRESSURE TEST

LOSS

IN

POUNDS

PER

MINUTE

PER

FOOT

Overburden

Drilling through fill

Shale Decomposed

Peeces minute to 1-inch, mode 1/2 inch

Shale, minor siltstones, weathered

Fragments 1/2-inch to 2-inch; two 4-inch core lengths

Siltstone weathered

Broken core; hard 1/2-inch to 4-inch, mode 2-inch

Siltstone, weathered and decomposed

Crushed; some clay

Siltstone, banded from 32'-44'6", 47'8"-49'6", 54'-59'

Dark siltstone; bands of black shale and of grey fine-grained greywacke

Mainly fresh

Hard
Joints thinly coated with iron oxide and clay
Trace sulphide on joint at 51'

Siltstone, and interbeds of shale and of fine-grained greywacke

Grey siltstone and greywacke; dark grey to black shale

Fairly fresh

Hard
Shearing, crushing, weathering, some clay at 69'6"-70' 77'6"-78', and at 81'.
Jointing vertical and 40° to 70°

Shale and interbeds of siltstone

Dark grey to black

Pale grey

Some joints lined with carbonate from others carbonate(?) lining has been leached
Bedding dips 35°-40°

LOG TYPE

MINORILL F62B

PACKER TYPE

Hydraulic

LOG TYPE

MINAC

LOG TYPE

Triple tube

LOG TYPE

P. Graph

LOG TYPE

11-6-65

LOG TYPE

17-8-66

LOG TYPE

D. E. Gardner

LOG TYPE

Vertical scale 1 inch = 10 feet

FRACURE LOG

Number of fractures per foot at core. Zones of core loss are blocked in.

BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis.

WATER PRESSURE TESTS

PACKER TYPE

N-Hydraulic

SUPPLY LINE

N- rods

VERTICAL SCALE

Figures given are gauge pressures.

Test sections are indicated graphically by marked in strips.

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

COLOR

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT <u>UPPER RAMU - ACCESS SHAFT</u>		HOLE NO. <u>DD19</u>			
GEOLOGICAL LOG OF DRILL HOLE		LOCATION <u>15.5 feet on bearing 350°M from C/L of access shaft, Drawing N: HC65/76/B</u>		SHEET <u>2</u> OF <u>11</u>			
ANGLE FROM HORIZONTAL <u>90°</u>		COORDINATES <u>43060E 78822N</u>		DIRECTION <u>RL 3971 - 5 feet</u>			
ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH SIZE OF CORE	FRAC- TURE LOG	LIFT & % CORE RECOVERY	JOINTS: VEINS, SEAMS, FAULTS, "FISHED" ZONES	WATER PRESSURE TEST LBS. / sq. in. per foot
Siltstone, Shale, fine- grained greywacke.	Pale grey Dark grey Dip 30 to 35° Pale grey Fairly fresh; hard.					Most joints sealed with calcite. Occasional iron- stained joints with trace of sulphide. Close, irregular jointing from 114'6"-120' A 2-inch sheared band from 116'6"-120' Strikes 60° to bedding, and dips 60°. Crushing, with clay, from 118' - 118'6"	
Dolerite; mainly fresh	Pale green, coarse porphyritic; chilled margins. Lower contact dips 60°, opposite bedding					Joints dip 45°, 85°, 90° at about 60° to bedding.	
Siltstone, shale. Fresh	Hard					Crushed and weathered from 126'2" - 126'6"	
Dolerite, fresh	Fine grained, hard. Concord.					Close, irregular joints 126'6" - 127' and 127' 8" - 127' 10"	
Siltstone, shale	Fresh, hard					Joints wholly and partly sealed by calcite.	
Dolerite; fresh. Inclusions of siltstone and shale from 136' to 137' and 140'6" - 141'6"	Dolerite is coarse, porphyritic, with chilled margins. Hard excepting decomposed clayey section from 158'3" - 158'6"					Three joints lined calcite are partly leached.	
Dolerite decomposed 158'3" - 158'6"	Siltstone and shale fresh and hard					Other joints tight, excepting narrow shear at 158'3" - 158'6".	
mainly Siltstone; interbeds of shale. Fresh	Discordant hard dolerite Pale grey. Hard Brown-grey Hard					Dolerite throughout is very firmly bonded to sedimentary beds.	
Dolerite; Fresh	Pale-green, very coarsely porphyritic Hard. Concordant.						
Siltstone, fine grained greywacke and	Pale grey } Beds 2-2 inch } Beds 3-13 inch					Seven joints sealed with calcite.	
Shale	Dark-gray to black Beds 1mm. to 15mm.					Others tight	
Fresh	Graded bedding Hard					Three on bedding planes.	See sheet 3
DRILL TYPE <u>MINIDRILL F&B B...</u>		RECORDING METHOD <u>Hydraulic</u>		WATER PRESSURE TESTS		PUMP TYPE <u>N-Hydraulic</u>	
CORE BARRE TYPE <u>Triple</u>		TUBE <u>Tube</u>		SUPPORT <u>N rods</u>		VERT. SCALE <u>1" = 50psi</u>	
DRILLER <u>P. Grech</u>		COMMENCED <u>11-6-65</u>		STOPPED <u>17-8-65</u>		LOGGED BY <u>D.E. Gardner</u>	
VERT. SCALE <u>1 inch = 10 feet</u>						PHOTOGRAPH RE-EXPOSE SYSTEM	

PROJECT UPPER RAMU - ACCESS SHAFT
LOCATION 15.5 feet on bearing 360°M from C/L of
Access Shaft, Drawing N° HC 65/76/B
ANGLE FROM HORIZONTAL -90° DIRECTION —
COORDINATES 43060 E 75822 N R.L. 3971.5 feet

HOLE NO.

DD19

SHEET 3 OF 11

DEPTH & SIZE OF CORE	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRAC- TURE LOG	LIFT & % CORE RECOVERY	STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST Loss in pounds per minute per foot
200			200					
Interbedded Siltstone, Shale, and fine-grained greywacke Fresh	Pale grey Dark grey or black Pale grey Hard		210			Joints tight; filled with calcite Three joints with traces of sulphide	30	
Shale Fresh	Dark grey or black Hard		218			Two joints very thinly veneered with sulphide.	55	
Siltstone and shale Fresh	Pale grey Dark grey Hard		220			Joints dip 60° and along bedding	75	
Siltstone and shale Fresh	Pale grey Dark grey Hard		223			Bedding dips 40° A crush zone 1/2 to 1 inch wide between 235' 6 and 237' 2" is filled (cemented) with calcite; it dips 70-80°	100	
Siltstone; minor shale Fresh	As above Hard		230				75	
Dolerite Fresh	Pale green; chilled margins; coarse porphyritic; hard. Discordant		232 6				55	
Siltstone; a few interbeds of shale. Fresh	Pale grey Hard		238				30	
Dolerite Fresh	As above; not so coarsely porphyritic. Upper surface discordant, dip 70°; lower concordant, dip 40°		240				90	
Siltstone; thin shale interbeds. Fresh	As above Hard		245 3			Joints tight. Dip 40-45° across bedding, and also along bedding, dip 35-40°	100	
Dolerite Fresh	As above Hard		251			Early joints lined with calcite; later joints with skin of chlorite (?)	120	
Siltstone; minor shale. Hard	As above Fresh, Hard		256 9			At 250' 6 calcite lined joints dipping 76° is cut by later joint dipping 50°; Crushing, solution and weathering of 1 inch of core.	150	
Dolerite Fresh	Pale green, chilled margins porphyritic; concordant Hard		260			At 271' minor shear dips 70°, and is lined with calcite and chlorite. Core from 279' 8-280' is crushed and weathered	120	
Siltstone, fine grained greywacke, minor shale Fresh	As above Hard		262 3			Steep to vertical calcite lined joints between 289-279 8, 290 9-293' and 295 4-297 4	100	
Dolerite Fresh	As above Hard		264				40	
			269 8					
			273 3					
			290					
			290					
			297 4					
			300					

MINIDILL F62.B
Hydraulic
Packer TYPE Triple
tube
P. Grech
11-6-65
17-8-65
D.E. Gardner
1 inch: 10 feetFRAC-
TURE LOG: Number of fractures per foot of core. Joints of core loss are blocked in.
BEDDING SHEAR PLANE: Angles are measured relative to a plane normal to the core axis.

WATER PRESSURE TESTS

PACKER TYPE N-HydraulicSUPPLY LINE N-rodsVERTICAL SCALE 1" = 100 psiFigures given are gauge pressures.
Test sections are indicated graphically by blocks in well log.

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

COLOUR

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU - ACCESS SHAFT
LOCATION 15.5 feet on bearing 75° M from C/L of
Access shaft, Drawing HC 65/76 1A
ANGLE FROM HORIZONTAL -90°
COORDINATES 43060E 78822N
DIRECTION -
RL 39745 feet

DD19
SHEET 4 OF 11

DEPTH FEET	ROCK TYPE WEATHERING	DESCRIPTION LITHOLOGY, STRENGTH, HARDNESS, ETC.	GRAPHIC CORRECTION	DIAMETER INCHES	REMARKS	WATER PRESSURE PSI	WATER TEMPERATURE °F	WATER ANALYSIS
300	Dolerite	Discordant Hard			Joints tight			
302.10	Siltstone	Hard			At 308' a shear	40		
309.0	Dolerite	As above			4 inch wide dips			
	Siltstone	Pale gray			75°; filled with	100		
	Shale	Dark grey or black			Calcite	120		
	Graywacke	Pale gray			From 309'2 - 318'6	150		
	Fresh	Hard (except			Steep to vertical	120		
		along two narrow			Shearing and jointing	100		
		shears)			Sealed with Calcite			
					Close jointing, crushing			
					and weathering			
					321'6 - 322'2' and	40		
					in 1 inch band,			
					dipping about 70°,			
					at 323'			
					Joints tight, dip			
					about 30° and 70°			
	Siltstone	Pale gray, fresh,			Joints sealed with	40		
	and fine	very hard.			Calcite, dip about			
	grained gray-	Slump folding at			30°, 70°, 90°			
	wacke. Hard	contact with shale						
	Siliceous	Dark grey.				100		
	shale	Very hard; brittle.				120		
	Fresh					150		
	Dolerite	Fine-grained				120		
	Fresh	Discordant				100		
		Hard						
	Siliceous	As above						
	Shale							
	Graywacke,	Tuffaceous bands						
	Shale, and	358'6 - 362'9						
	Siltstone,	376'6 - 377'9						
	probably	Hard						
	tuffaceous							
	Fresh							
	Dolerite	Concordant, hard, fresh			Close jointing in			
	Siltstone;	As above			band 2 inches wide			
	minor shale				at 379' sealed			
	bands.				with Calcite			
	Fresh	Very hard			(dip 70-90°)			
					Shear 4 inch wide			
					at 397'10 - 398'6			
					dips 60°; sealed			
					with Calcite; one			
					joint open through			
					solution of Calcite			
	Dolerite	Discordant. As above						
	Siltstone	Thin bedded.						
	and shale							
	Fresh	Very hard						
	Dolerite	Siltstone inclusion						
	Siltstone	398'3-399' and 399'9-						
		Fresh. Very hard						

MINDRIL F82B
Hydraulic
Triple
tube
P. Grech
11-6-65
17-8-65
D.E. Gardner
1 inch: 10 feet

1. The number of...
2. The number of...
3. The number of...

WATER PRESSURE
N - Hydraulic
N - rods
1" = 100psi
PHOTOGRAPH REFERENCE SYSTEM

LITHOLOGY		DEPTH (feet)		REMARKS	
Dolerite	Fine grained; porphyritic.	400	N	Joints tight.	
Fresh	Very hard	409.11	C	Dip 10°, 50° Sealed calcite; or veneer of chlorite	
Thin bedded siltstone	Pale grey	420		Sheared and broken in 2-inch bands at 413', 413'4, 413'9; little weathering.	
and siliceous shale	Dark grey or black	430		Joints tight, dip 70°, 50°. Near-vertical calcite-lined.	
Fresh	Very hard	440		Joints dip 16°, 30°, 60°	
		450		Breaking and solution along calcite lined joint 232'4 - 232'10	
Siliceous shale, minor siltstone	Dark grey	460		Joints tight; Veneer of calcite on some, chlorite on others	
Fresh	Very hard	470		Between 432'2 and 432'10 a calcite vein 1/2 inch wide, dipping 60° is cut by later joint dipping 30°. Minor weathering and solution	
		480		Joints tight; dip 30-50°	
Dolerite	Pale green-grey. Chilled upper margin.	490		Joints sealed with calcite have not broken open.	
Fresh	Remainder coarse porphyritic. Very hard	500		Joints tight	
Shale and siltstone	Thin bedded Shale siliceous			Some sealed with calcite. Others smeared with chlorite and some with traces of sulphide	
Fresh	Very hard			Bedding dip variable (contemporary deformation) Probably 30° Jointing dips 30° and 60°	

DRILL TYPE **Mindril F62B**
TESTED **Hydraulic**
CORE BARREL TYPE **Triple
tube**
DRILLER **P. Grech**
COMMENCED **11-6-65**
COMPLETED **17-8-65**
LOGGED BY **D. E. Gardner**
VERTICAL SCALE **1 inch = 10 feet**

TEMPERATURE (°F) _____ Number of tests _____
BEDDING PLANE (°) _____ Dip (°) _____

WATER PRESSURE TESTS
N/B Hydraulic
N rods
1" = 100 psi
SCALE _____
PRESSURE _____
PHOTOGRAPH REFERENCE SYSTEM

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT UPPER RAMU - ACCESS SHAFT		HOLE NO DD19	
GEOLOGICAL LOG OF DRILL HOLE		LOCATION 15.5 feet on bearing 350° M from C/L of access shaft, Drawing HC65/76 JB		ANGLE FROM HORIZONTAL -90°	
		COORDINATES 43060E 78922N		DIRECTION R 3971-5 feet	
ROCK TYPE	DESCRIPTION	DEPTH FEET	CORRECTION	STRUCTURES JOINTS VEINS SEAMS FAULTS CRACKS LINES	WATER PRESSURE TEST PSI PER FOOT PER MINUTE
Thin bedded siliceous shale and siltstone fresh	As above Very hard	500 510 516'		Joints dip 40°, 60° Tight. Bedding dips 20-25° Graded; contemporaneous deformation (minor)	
Siliceous shale fresh	Black Very hard and brittle	516' 520'10"		Minor solution along calcite-lined joint at 503'	
Dolerite	Concordant. Very hard	522'6"		Two joints dip 80° between 528'-530' and 536'-536'9"	
Siliceous shale.	As above (516'1 - 520'10)	530'		Core broken on cross joints dipping 30°. Joints tight Not weathered.	
Fresh		540'		Joints tight. Sealed calcite; Smearred with chlorite Joints dip 70-80° 30-40° Core broken locally where the two sets of joints intersect	
Siliceous shale and silty shale	Black and dark grey Very hard; brittle	551'3" 560'			
Shale and siltstone fresh	Thin bedded or laminated. Very hard; brittle.	570'6"			
Dolerite fresh	Concordant. Coarse porphyritic; chilled margin Hard	575'2"		Slight weathering and breaking of core from 579'1-579'3 and 578'9-578'11	
Siliceous siltstone and shale fresh	Thin bedded and laminated. Very hard, brittle.	579'3" 586'9"		Bedding dips 25-35°	
Shale and silty shale fresh	Siliceous. Black and dark grey Very hard, brittle	590'			

DRILL TYPE MINORAIL F42 B

FEED Hydraulic

CORE BARREL TYPE Triple tube

DRILLER P. BROCH

COMMENCED 11-6-65

COMPLETED 17-8-65

LOGGED BY D.E. Gardner

VERTICAL SCALE Linch 10 feet

NOTES

FRACTURE LOG Number of fractures per foot of core Zones of core loss are checked in

BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis

WATER PRESSURE TESTS

PICKER TYPE B Hydraulic

SUPPLY LINE N-rods

VERTICAL SCALE 1" = 100 psi

Figures given are gauge pressures
Test sections are indicated graphically by blocked-in strip

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT: <u>UPPER RAMU - ACCESS SHAFT</u>		HOLE NO. <u>DD19</u>	
GEOLOGICAL LOG OF DRILL HOLE		LOCATION: <u>15.5 feet on bearing 350° M from C/L of access shaft, Drawing CH.65 / 76 / B</u>		SHEET <u>7</u> OF <u>11</u>	
ANGLE FROM HORIZONTAL: <u>-90°</u>		COORDINATES: <u>93060 E 78822 N</u>		R.L. <u>3971.5 feet</u>	
ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH & SIZE OF CORE	STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES.	WATER PRESSURE TEST LOSS IN GALLONS PER MINUTE PER 100'
Shale;	Black		600	Calcrete sealed joints dip 40°, 80°. Cross Joints dip 10-20°	
bands of silty shale	Dark grey		610	Several breaks along bedding not logged	
Fresh	Hard. Shale will probably weather rapidly		620	Tight joints, some with traces of sulphide, dip 50° and 10-20°	
Shale; minor siltstone	Fresh. Hard to very hard.		630'4	Bedding dips 20-25°	
Shale; bands of silty shale	As above (600'-630'4')		635'11	Four partings on bedding not logged	
			640	Jointing tight; as above.	
			650	Joints tight.	
			660	Joints dipping 70° cut by others dipping 10-20° This causes broken core.	
			670	Some joints sealed calcite; others have thin chloritic coating.	
Dolerite - Fresh and slightly weathered	Discordant. Very hard to fairly hard		674	Along shears dipping about 50° at 677'-677'6 and 680'-680'6 the bedrock is altered to chloritic material, probably of low strength	
Thin bedded and laminated siltstone and shale	Pale grey Dark grey and black		683'2	Fragmentation of core where close, tight joints intersect.	
Fresh	Hard to very hard		690	Joints open because of solution of calcite between 695'4 and 706'; water lost	
Dolerite - Fresh	Discordant. Porphyritic. Pale green Very hard		695'7		
			700		
DRILL TYPE <u>MINI-DRILL F62B</u>		NOTES		WATER PRESSURE TESTS	
FEED <u>Hydraulic</u>		FRACTURE LOG Number of fractures per foot of core. Zones of core loss are blacked in.		PACER TYPE <u>B-Hydraulic</u>	
CORE BARREL TYPE <u>Triple tube *</u>		BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis		SUPPLY LINE <u>N-roads</u>	
DRILLER <u>P. Grech</u>				VERTICAL SCALE: <u>1" = 100 feet</u>	
COMMENCED <u>11-6-65</u>				Figures given are gauge pressures. Test sections are indicated graphically by marks in steps.	
COMPLETED <u>17-8-65</u>				PHOTOGRAPH REFERENCE SYSTEM	
LOGGED BY <u>D.E. Gardner</u>				BLACK AND WHITES	
VERTICAL SCALE <u>1 inch = 10 feet</u>				COLOUR	
* Double tube below 694'10 (to 706')					

ANGLE FROM HORIZONTAL -90° DIRECTION -
COORDINATES 43060 E 78822 N RL 3971 fcs

Sea Sheet 7

B-Hydraulic

N Mechanical

B Hydraulic

N Mechanical

WATER PRESSURE TESTS

MEASUREMENT B Hydraulic + N Mechanical

UPPER ME N rod.

INTERIAL SCALE 1" = 100 p.s.i.

NO. 11 1/2 IN. O. D. JOINT PRESS. TEST

NO. 10 1/2 IN. O. D. NOTED GRAPH C. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

EXPI. GRAPH REFERENCE SYSTEM

COLONIA

DIRECTION

SHEET 9 OF 11

DRILL TYPE <i>MIN. DRILL F128</i> RECD <i>Hydraulic</i> CORE BARREL TYPE <i>Triple</i> <i>Tube</i> DRILLER <i>P. Grech</i> COMMENCED <i>"-6-65</i> COMPLETED <i>"7-8-65</i> OUGHT BY <i>D.E. Gardner</i> VERTICAL SCALE <i>1 inch = 10 feet</i>	SCALE FRACTURE LOG Number of fractures per foot of core & notes on core logs are marked on BEDDING AND JOINT PLANES. Angles are measured relative to bore normal to the core axis. <i>* See under Fractures</i>	WATER PRESSURE TESTS FALKEM TYPE <i>N-Mechanical</i> UPP. F. NE. <i>N-Rods</i> VERTICAL SCALE <i>1" = 100 psi</i> 1 inch on graph the gauge pressure 100 ft section the adjusted depth is marked on the PHOTOGRAPH REFERENCE SYSTEM B.A. = 4000 PSI
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BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT

UPPER RAMU - ACCESS SHAFT

LOCATION

15.5 feet on bearing 350° mag. from c/L of access shaft

Drawing CH65/76/B

ANGLE FROM HORIZONTAL

-90°

COORDINATES

43060E 78822N

DIRECTION

RL 3971.5 ft

HOLE NO

DD19

SHEET 19 OF 11

ROCK TYPE B. GRADE OF WEATHERING	DESCRIPTION THICKNESS, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH B SIZE OF CORE	FRAC- TURE LOG	1 FT B % CORE RECOVERY	STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST 1000' - 1000' per 100' per 100'	PHOTO LOG
Marble Fresh. Argillitic bands from 906'7"-917'	White grey bands (1-10 mm. thick, mode 3 mm) of argillitic marble Hard =		900 910 917' 918' 921' 923'			Joints dip 40°, 70°, 80-100°. Some joints opened 1-3 mm by solution Argillitic banding dips 50°			
Siltstone	Fine grained hard								
Marble	Hard								
Dolerite	Fairly hard or firm								
Marble Fresh	White: Grey banding or mottling dips 50° Hard, except where crushed and friable between 934'10"-935'		930 935 936'			Core lengths 1-10"; mode about 4" Joints 10°, 20-35°, 75-80° Narrow solution channels (say, to 3 mm.) Crushed 934'10"-935' (intersecting joints) and 934'7"-944'2" (probable shear, dip 70°)			
Marble Fresh	Dolerite. Almost fresh. Hard As above. Crushed and friable 943'7"-944'2"		945 945'						
Marble Fresh	Dolerite. Weathered. Fairly hard White, with grey banding, dip 40-50°		950 960 970 980 990 995'			Core lengths 12-15"; mode about 6" "Biscuits" of core 983'6"-984'5" and 986'4"-986'9" are probably due to drilling pressure. Joints 20°, 40-55°, 80° Fragmented core (during drilling) along steeply dipping joints at 956'-957' m 962'10"-963'6".			
Fine-grained grey marble	Fresh, hard Calcareous.		1000'			Core lengths 2.5-15"; mode 5" Bedding indeterminate			

DRILL TYPE MINDRILL F62-B
FEED Hydraulic
CORE BARREL TYPE NMAG
TRIP TUBE
DRILLER P. GRACH
COMMENCED 11.6.65
COMPLETED 16.8.65
LOGGED BY D.E. GARDNER
VERTICAL SCALE 1 inch = 10 feet

NOTES

FRAC-
TURE LOG - Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLACES - Angles are measured relative to a plane normal to the core axis.

WATER PRESSURE TESTS

PACKER TYPE _____
SUPPLY LINE _____
VERTICAL SCALE _____
Figures given are gauge pressures.
Test sections are indicated graphically by blocked + areas.
PHOTOGRAPH REFERENCE SYSTEM
BLACK AND WHITE _____
COLOUR _____

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT <u>UPPER RAMU - ACCESS SHAFT</u>		HOLE NO DD19	
GEOLOGICAL LOG OF DRILL HOLE		LOCATION <u>15.5 km on bearing 350° mag. from c/h of access shaft</u>		DRAWING <u>CH 65/16/B</u>	
ANGLE FROM HORIZONTAL <u>-90°</u>		COORDINATES <u>43060E 78822N</u>		DIRECTION <u>3971.5 ft</u> SHEET <u>11</u> OF <u>11</u>	
ROCK TYPE 8 DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH IN FEET	TIME IN HOURS	WATER PRESSURE TEST LOSS IN PSI PER MINUTE PER FOOT
Gray wacke	Fine grained		1000		
Fresh and slightly weathered	Hard Bedding dips 30°		1010		
			1020		
			1030		
			1040		
			1050		
			1060		
			1070		
			1080		
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			1100		
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT <u>UPPER RAMU HYDRO-ELECTRIC SCHEME.</u>		HOLE NO.	
GEOLOGICAL LOG OF DRILL HOLE		LOCATION <u>TAILRACE TUNNEL.</u>		DD 20	
		ANGLE FROM HORIZONTAL <u>VERTICAL</u>		SHEET <u>1</u> OF <u>4</u>	
		COORDINATES <u>81680 N. 42150 E</u>		R. <u>4233 ft.</u>	
ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, etc.	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRACTURE LOG	TEST & CORE RECOVERY
				JOINTS, LENS, SEAMS, FAULTS, CRUSHED CONDS	WATER PRESSURE TEST Loss in gallons per minute per foot
		<u>NMLC</u>			
			10		
			20		
			30		
			40		
			50		
			60		
			70		
			80		
SANDY SILT.	Grey. Compacted but soft.		85'		
			86'3"		
			90		
			95'		
SILTY CLAY	Light grey. Compacted but soft.		99'7"		
				Core broken & crumbled.	

DRILL TYPE Mindril F62 B.

TEST Hydraulic

CORE BARREL TYPE NMLC

TRIPLE TUBE

DRILLER P. Grech. S.M.A.

COMMENCED 18.10.65

FINISHED 16.11.65.

OPERATED BY J.R.L. Read

VELOCITY 1 inch = 10 ft.

WATER PRESSURE TEST

LOSS IN GALLONS PER MINUTE PER FOOT

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL VERTICAL

DIRECTION

COORDINATES 816 80 N. 42510 E.R.L. 4233 ft.SHEET 2 OF 4

DEPTH (ft.)	ROCK TYPE	DESCRIPTION	REMARKS
102' 2"			NHLC
108'	SILTY CLAY	Greenish-grey. Moderately compacted but soft & easily broken.	Bedding 55°
110'	SILTY CLAY	As above but brown in colour	Few fragments > 1". Most of core completely broken
115'	SILTSTONE	Black. Fine-grained. Hard	Broken zone 115' - 115' 9"
116' 6"	SILTY CLAY	Greenish-grey, as above	
118' 6"			
120'	SILTSTONE	Black. Fine-grained, well indurated. Hard. Fresh.	Very broken, crushed zone 121' - 122'
130'			Joints 15°, 30°, 55°, 75°, coated with quartz & minor pyrite.
131' 9"			Broken zone 130' - 131' 9"
140'	MUDSTONE	Brown. Moderately indurated. Moderately hard but brittle & easily broken.	Very broken, fragments coated with clay, calcite & zeolites.
148'			
150'	SILTSTONE	Siltstone, as above. Fresh.	Broken zones 148' - 150' 151' - 151' 10"
156' 6"			Joints 10°, 50-60°, 80°, coated with clay, quartz & minor pyrite.
159' 4"	DOLOMITE	Greenish-grey. Medium grained. Moderately hard. Slightly weathered.	Broken zones at contacts.
160'			
162'	SILTSTONE	Siltstone, as above. Fresh.	Broken zones 162' - 163' 4" 164' 4" - 165'
170'			
175'			
179' 4"	SILTSTONE	Light grey. Fragments soft. Moderately altered, & readily crumbled in hand.	Crushed zone
180'			
190'	SILTSTONE	Siltstone, as above. Fresh.	Broken zone across joint at 188' 2"
			Sheared joint, 10°, at 191' 5"

Mudrill F62 B
Hydraulic

NHLC

Triple Tube

P. Brech, S.M.A.

18.10.65

16.11.65

J.R.L. Reed.

1 inch = 10 ft.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT <u>UPPER RAMU HYDRO-ELECTRIC SCHEME</u>		HOLE NO <u>DD 20</u>			
GEOLOGICAL LOG OF DRILL HOLE		LOCATION <u>TAILRACE TUNNEL</u>		SHEET <u>3</u> OF <u>4</u>			
ANDRE FROM HORIZONTAL <u>VERTICAL</u>		COORDINATES <u>81680 N. 42510 E.</u>		R.L. <u>4233 ft.</u>			
DRILL TYPE <u>Hydraulic</u>	DESCRIPTION <u>Siltstone, as above</u>	GRAPHIC LOG	DEPTH & SIZE OF CORE <u>NMLC</u>	LIFT & % CORE RECOVERY	STRUCTURES <u>Broken zone 208'-210'4"</u> <u>Joints 10°, 20-25°, 35°</u> <u>55° & 80°.</u> <u>Bedding 83°.</u> <u>Broken zones 219'5"-220'6"</u> <u>223'2"-223'8"</u> <u>Broken zones 228'5"-228'7"</u> <u>232'3"-233'</u> <u>Broken zone at contact.</u> <u>Joint parallel to core</u> <u>239'-242'6". Coated with</u> <u>clay & zeolite.</u> <u>Bedding 80°.</u> <u>Joint parallel to core</u> <u>253'4"-255'3", coated</u> <u>with quartz & calcite.</u> <u>Broken zone 260'9"-264'3"</u> <u>Fragments clay coated</u> <u>& slickensided.</u> <u>Broken zone 271'3"-274'10"</u> <u>Broken zone 277'8"-280'</u> <u>Joints 10-15° 30°, 55-65°</u> <u>Very broken from 287'-</u> <u>297', completely</u> <u>& crushed beyond</u> <u>297'.</u>	WATER PRESSURE TEST Loss in gallons per minute per foot	PHOTO REF. NO.
SILTSTONE Fresh.							
DOLOERITE Slightly weathered.							
SANDSTONE WITH INTER-BEDS OF SILTSTONE. Fresh.							
SILTSTONE. Fresh.							
DRILL TYPE <u>Mandrel F628</u>		REMARKS <u>Number of fractures per foot of core - as if one loss are blocked in</u>		WATER PRESSURE TESTS PACKER TYPE SUPPLY VERTICAL SCALE COLOUR		PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR	
CORE BARREL TYPE <u>Triplet Tube</u>		REMARKS <u>Number of fractures per foot of core - as if one loss are blocked in</u>		WATER PRESSURE TESTS PACKER TYPE SUPPLY VERTICAL SCALE COLOUR		PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR	
DRILLER <u>P. Grech S.M.A.</u>		REMARKS <u>Number of fractures per foot of core - as if one loss are blocked in</u>		WATER PRESSURE TESTS PACKER TYPE SUPPLY VERTICAL SCALE COLOUR		PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR	
COMMENCED <u>18.10.65</u>		REMARKS <u>Number of fractures per foot of core - as if one loss are blocked in</u>		WATER PRESSURE TESTS PACKER TYPE SUPPLY VERTICAL SCALE COLOUR		PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR	
COMPLETED <u>16.11.65</u>		REMARKS <u>Number of fractures per foot of core - as if one loss are blocked in</u>		WATER PRESSURE TESTS PACKER TYPE SUPPLY VERTICAL SCALE COLOUR		PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR	
LOGGED BY <u>J.R.L. Reed.</u>		REMARKS <u>Number of fractures per foot of core - as if one loss are blocked in</u>		WATER PRESSURE TESTS PACKER TYPE SUPPLY VERTICAL SCALE COLOUR		PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR	
VERTICAL SCALE <u>1 inch = 10 ft.</u>		REMARKS <u>Number of fractures per foot of core - as if one loss are blocked in</u>		WATER PRESSURE TESTS PACKER TYPE SUPPLY VERTICAL SCALE COLOUR		PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR	

BUREAU OF MINERAL RESOURCES. GEOLOGY AND GEOPHYSICS		PROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME.		HOLE NO					
GEOLOGICAL LOG OF DRILL HOLE		TAIL RACE TUNNEL.		DD 20					
ANGLE FROM HORIZONTAL		VERTICAL		DIRECTION					
COORDINATES		81680 N. 42510 E.		R.L. 4233 ft.					
SHEET A OF 4									
PACKER TYPE A. EFFECT OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH IN FEET OF CORE	FRACTURE LOG	LIFT IN FEET % CORE RECOVERY	JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST Loss in gallons per minute per foot	PHOTO REF. NO.
	SILTSTONE	Siltstone, as above	310	318'		Completely broken & crushed, with rare larger pieces (<2"), to 318'. Fragments coated with calcite quartz & minor pyrite. Slight slickensiding			
	DOLERITE.	Greenish-grey. Medium-grained. Moderately hard. Slightly weathered.	320	323'					
	SILTSTONE.	Siltstone, as above. Fresh.	330			Completely broken 323'-330'. Crushed 330'-331'.			
	DOLERITE.	Dolerite as above	340	340'2"		Broken.			
	SILTSTONE	Siltstone, as above. Fresh.	350			Remainder of core broken but not crushed. Fragments coated with quartz, calcite & minor pyrite.			
		Hole abandoned at 370 ft.	370						

DRILLER P. Grech, S.M.A.	COMPLETED 16.11.65	LOGGED BY J.R.L. Reed	VERTICAL SCALE 1 inch = 10 ft.
FRACTURE LOG: Number of fractures per foot of core. If a fracture is broken in bedding and joint planes, angles are measured relative to the core axis.			
WATER PRESSURE TESTS			
PACKER TYPE			
SUPPLY LINE			
VERTICAL SCALE			
Figures given are gauge pressures.			
Test sections are indicated graphically by blocked in strip.			
PHOTOGRAPH REFERENCE SYSTEM			
BLACK AND WHITE			
COLOUR			

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME

LOCATION TAILRACE TUNNEL

HOLE NO. 90

DD 20A

ANGLE FROM HORIZONTAL VERTICAL

DIRECTION

COORDINATES 81740 N, 42490 E

RL 4230 FT.

SHEET 1 OF 11

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH & SIZE OF CORE	RECOVERY	REMARKS FIS, VEINS, REAMS, FAULTS, DISCONTINUITIES	WATER LEVEL	WATER PRESSURE TESTS FOOT CUBIC PER MINUTE PER FOOT	LOG NO.
			NM/LC					
			10					
			20					
			30					
			40					
			50					
			60					
			70					
Completely Weathered	Lake Sediments		80					
Completely Weathered	Lake Sediments		90					

DRILL TYPE Mindril F62B
 METHOD Hydraulic
 CORE BARREL TYPE NM/LC
Triple Barrel
 OPER. BY P. Brech S.M.A.
 COMMENCED 18-11-65
 COMPLETED 15-3-66
 CHECKED BY J.P. McS. & J.R.L.R.
 GRAPHIC SCALE 1 inch = 100 ft.

REMARKS: (1) Number of fractures per foot of core (2) Fractures lost are blocked in
 BEDDING AND LITHOLOGY AND OTHER FEATURES OF THE DRILLING SECTION TO THE CORE LOG

WATER PRESSURE TESTS

TEST NO.
 DATE
 TIME
 PRESSURE
 FLOW
 PHOTOGRAPH REFERENCE SYSTEM
 BY

BUREAU OF MINERAL RESOURCES. GEOLOGY AND GEOPHYSICS		PROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME		HOLE NO DD 20A	
GEOLOGICAL LOG OF DRILL HOLE		LOCATION TAILRACE TUNNEL		SHEET 2 OF 11	
ANGLE FROM HORIZONTAL VERTICAL		COORDINATES 81740 N, 42490 E		R.L. 4230 FT.	
ROCK TYPE SILTSTONE	DESCRIPTION Light grey. Moderately hard. Moderately strong. Pieces 1/4" - 1/2". Average pieces 1/4".	GRAPHIC [Symbol]	DEPTH 110	RECOVERY 100%	WATER PRESSURE TEST Loss in gallons per minute per foot
Completely Weathered.	Lake Sediments				
SILTSTONE	Light grey. Moderately hard. Moderately strong. Pieces 1/4" - 1/2". Average pieces 1/4".		115'		Irregular calcite veins 1/2" thick. Fracturing parallel to core axis.
DOLERITE.	Light green. Medium-grained. Soft. Very weak.		119'		
SILTSTONE	Light grey. Moderately soft & weak to moderately strong & hard. Pieces < 1/4", mode 1/4".		120'		Broken zones 122'6" - 124'12" - 125'6"
Fresh - Highly Weathered.			121'		Joints irregular, limonite stained. Fault banding 90°.
DOLERITE	Light - dark green, medium-coarse-grained. Moderately to very soft. Weak. Pieces < 16", mode 3".		126'		Highly broken & friable 126' - 129'.
Moderately - Completely Weathered.			130'		Very broken zone, 132'6" - 132'8"
			140'		
			148'6"		Very broken zones, 148'3" - 148'6" 148'8" - 148'11"
INTERBEDDED SHALE, SILTSTONE & GREYWACK.	Light - dark grey. Fine to medium-grained. Moderately hard to soft. Moderately strong to weak. Pieces < 10", mode 3/4".		150'		Thin calcite veins, 15°.
Moderately - Highly Weathered.			151'8"		Broken zones 150'10" - 151'1" 151'8" - 153'
			160'		Bedding 75°. Beds < 1/2". Jointing parallel to bedding, & 5-10°.
			170'		Broken zones, 160'6" - 160'9" 163'6" - 163'9" 165'6" - 167'6" 168'2" - 168'8" 171'6" - 172'
			180'		Broken zone, 179' - 182'8".
SHALE	Black - dark grey. Well indurated, hard, strong. Pieces < 9", mode 1".		185'		Slightly broken zones, 186'4" - 187'2" 189'6" - 191'6"
Fresh.			190'		Bedding 70-75°. Jointing parallel to bedding. Moderately - highly broken zone 195' - 196'.
NOTES FRACTURE LOG - Number of fractures per foot of core. Zones of core loss are blocked in. BEDDING AND JOINT PLANES - Angles are measured relative to the core axis.					
WATER PRESSURE TESTS PACKER TYPE SUPPLY LINE VERTICAL SCALE Figures given are gauge pressures. Lost sections are indicated graphically by blocked-in strips. PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR					

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAIRU HYDRO-ELECTRIC SCHEME

LOCATION TAILRACE TUNNEL

HOLE NO.

DD 20A

ANGLE FROM HORIZONTAL VERTICAL

DIRECTION

COORDINATES 81740 N, 42490 E

R.L. 4230 ft

SHEET 3 OF 11

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION (LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.)	GRAPHIC LOG	DEPTH & SIZE OF CORE	TEMPERATURE & % CORE RECOVERY	STRUCTURES (JOINTS, VEINS, SEAMS, FAULTS, FOLDED ZONES)	WATER LEVEL	WATER PRESSURE TEST (Loss in gallons per minute per foot)	TEST DATE TIME DRILLER
INTERBEDDED SHALE SILTSTONE & GREYWACKE. Fresh.	Light grey. Hard, strong. Pieces $\frac{1}{4}$ " - 5", mode 3"		201' 5"		Slightly broken zones, 201' 9" - 202' 202' 7" - 202' 10" 203' 6" - 203' 9" 203' 5" - 203' 9"			
DOLERITE. Fresh - Slightly Weathered.	Light green. Medium - coarse grained. Hard, strong. Pieces $\frac{1}{4}$ " - 10", mode 4"		210		Light calcite cementing 10" x 55" Broken zones, 208' 4" - 209' 212' 0" - 213' 3" 213' 8" - 213' 11"			
INTERBEDDED SILTSTONE & GREYWACKE. Fresh.	Light grey. Fine grained, well indurated. Hard, strong. Pieces $\frac{1}{4}$ " - 6", mode 2"		220		Bedding 81-90°. Jointing parallel to bedding & 10° Slightly broken zones, 216' 8" - 217' 3" 217' 10" - 218' 222' 2" - 222' 6" 223' 1" - 223' 4"			
SHALE. Fresh.	Black - dark grey. Well indurated. Hard, strong. Pieces $\frac{1}{4}$ " - 8", mode 2"		230		Slightly broken zones, 228' 7" - 228' 16" 229' 4" - 230' Bedding 80°. Jointing parallel to bedding. Joints lightly coated with calcite. Slightly broken zones, 232' 10" - 234' 8" 236' 2" - 236' 8" 239' - 239' 9"			
INTERBEDDED SHALE & SILTSTONE. Fresh.	Light - dark grey. Fine- grained, well indurated. Hard, strong. Pieces $\frac{1}{4}$ " - 10", mode 1"		240		Moderately broken zone 240' 8" - 241' 5" Slightly broken zone 242' 9" - 243' Bedding 75° - 85°. Joints parallel to bedding & 15°, lightly coated with calcite.			
			250					
			260					
			270		Bedding 65-75°			
			280					
			290		Slightly broken zone 287' 1" - 287' 6"			
DOLERITE Fresh.	Light green. Medium - coarse- grained. Hard, strong. Pieces 1" - 10", mode 6"		291' 7"		Control 60°, approximately at 90° to bedding.			
INTERBEDDED SHALE SILTSTONE & GREYWACKE. Fresh.	Light grey. Hard, strong. Pieces $\frac{1}{4}$ " - 10", mode 5"		290		Bedding 75°. Joints parallel to bedding & 25°, lightly coated with calcite.			
DOLERITE Fresh.	Dolomite as above		291'					
INTERBEDDED			291' 6"					

LOG TYPE Mineral Field
Hydroelectric
LOG NUMBER N.M.L.
DATE 18-11-65
DRILLER J. P. O'NEILL & J. A. O'NEILL

NOTE: The logs, including the lithology, are to be used as a guide only. The logs are to be used as a guide only. The logs are to be used as a guide only.

WATER PRESSURE TESTS
PRESSURE TYPE
PRESSURE
VERTICAL SCALE
PHOTOGRAPH REFERENCE SYSTEM
COLOUR

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

PROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME

LOCATION TAILRACE TUNNEL

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL VERTICAL

COORDINATES 81740 N, 42490 E

DIRECTION _____

RL 4230 FT

HOLE NO.
DD 20A

SHEET 4 OF 11

ROCK TYPE BY DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC	GRAPHIC LOG	DEPTH IN FEET SIZE OF CORE	FRAC- TURE LOG	RECOVERY % CORE RECOVERY	STRUCTURED JOINTS, VEINS SEAMS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST LOSS IN POUNDS PER MINUTE PER FOOT
SHALE SILTSTONE & GREYWACKE. Fresh.	Light grey. Fine-medium grained. Hard, strong. Pieces 1/2" - 12", mode 5"		305' 6"			Moderately broken zone, 301' 1" - 301' 7".		
DOLERITE.	Fresh dolerite, as above		306' 1"					
INTERBEDDED SHALE & SILTSTONE.	Dark-light grey, fresh. Fine grained. Hard, strong Pieces < 1" mode 1/2"		310			Irregular joints, lightly coated with calcite.		
DOLERITE.	Fresh dolerite, as above		310'					
INTERBEDDED SHALE & SILTSTONE.	Dark-light grey. Moderately hard, moderately strong. Pieces 1/2" - 2", mode 1/2"		320			Very broken due to close, irregular joints. Rare chert nodules. Light calcite & minor pyrite on fragments		
	Fresh. Slightly weathered.		330					
SHALE.	Black. Well indurated. Moderately hard, moderately strong. Pieces 1/4" - 6", mode 1/2"		339' 3"			Broken due to close, irregular joints except 334' - 336' 3" which is sheared. Slight calcite & minor pyrites on fragments.		
GREYWACKE Fresh.	Light-grey. Fine-medium grained Hard, strong. Pieces 8" - 6"		340			Bedding 75°.		
SHALE.	Dark grey. Well indurated. Moderately hard, moderately strong. Pieces 1/4" - 6", mode 1/2"		341' 6"			Moderately broken zone, 341' 6" - 345'		
	Fresh - Slightly weathered.		350			Jointing 10°, 50°. Irregular, fine calcite veining		
			353' 6"			Moderately broken zone, 352' 6" - 353' 6".		
INTERBEDDED SHALE SILTSTONE & GREYWACKE.	Light grey. Fine-medium grained. Hard, strong. Pieces 1/2" - 12", mode 2"		360			Moderately broken zone, 354' - 354' 9". Bedding 65-75°. Jointing parallel to bedding Irregular calcite veins < 1/4".		
	Fresh.		370			Slightly broken zone, 356' - 358' 6"		
			380			Slightly broken zone, 369' 3" - 370'		
			390			Slightly broken zone, 380' 9" - 383'.		
			396' 6"			Highly broken zones, 396' 6" - 396' 11" 398' 4" - 398' 10"		

DRILL TYPE Minidrill F62B

FEED Hydraulic

CORE BARREL TYPE N.M.C.

Triple Tube

DRILLER P. Beech S.M.A.

COMMENTED 18-11-65

COMP. LTD 15-3-65

LOGGED BY T.P. McG. & J.R.L.R.

VERTICAL SCALE 1 inch = 100 ft

NOTES
FRACTURE LOG Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLANE - Cores are measured relative to the core axis

WATER PRESSURE TESTS
PACKER TYPE _____
APPLY LINE _____
VERTICAL SCALE _____
Figures given in a gauge pressure.
Test sections are indicated graphically by blocks in strip
PHOTOGRAPH REFERENCE SYSTEM
BLACK AND WHITE _____
COLOUR _____

DEPTH (FT.)	ROCK TYPE	DESCRIPTION	REMARKS
389' 5" - 401' 8"	INTERBEDDED SHALE & SILTSTONE.	Light-grey. Very soft, very weak. Pieces < 6", mode < 1/4".	Intense calcite veining & highly broken zone.
401' 8" - 404' 8"			Intensely sheared 402' - 403' 4".
404' 8" - 412' 6"			Slickensides 25°. Highly broken zones between 404' 8" - 412' 6".
412' 6" - 422' 6"	SILTSTONE.	Light-dark grey. Fine-grained. Hard, strong. Pieces 1/4" - 1 1/4", mode 3".	Bedding 60°. Joints irregular & clean - lightly coated with calcite.
422' 6" - 425' 3"			Slightly broken zones.
425' 3" - 426' 8"			422' - 424' 6"
426' 8" - 430' 1"			425' - 425' 3"
430' 1" - 435' 1"			426' 8" - 427' 8"
435' 1" - 436' 1"			430' - 431' 1"
436' 1" - 437' 1"			435' - 436' 1"
437' 1" - 440' 3"	SILTSTONE.	Light grey, fine-grained. Hard - soft, strong-weak. Pieces < 6", mode 1/4".	Joints 5° & 80°, slightly coated with calcite & minor pyrites.
440' 3" - 443' 6"			Shear zone, 10°, 437' - 438'.
443' 6" - 448' 3"			Slickensiding 80°.
448' 3" - 450' 3"			Moderately broken zone, 438' 6" - 439'.
450' 3" - 454' 8"			Shear zone, 20°, 440' 3" - 441' 8".
454' 8" - 455' 1"			Shear zone, 10°, 444' - 450'.
455' 1" - 457' 6"			Slickensides 85°.
457' 6" - 464' 4"	INTERBEDDED SHALE & SILTSTONE.	Light-dark grey. Fine-medium grained. Hard strong. Pieces < 10", mode 1/2".	Moderately broken zone, 451' 6" - 457' 6".
464' 4" - 473' 6"			Bedding 85°. Irregular thin, < 1/2", calcite veins.
473' 6" - 475' 8"			Moderately broken zone, 464' 4" - 473' 6".
475' 8" - 477' 8"	GREYWACKE.	Light grey, fine-medium grained. Very hard, very strong. Pieces 1" - 12", mode 3".	Highly broken zones, 475' - 475' 8".
477' 8" - 481' 8"			475' 8" - 477' 8".
481' 8" - 489' 1"			Slightly sheared zone, 481' - 481' 8". Slickensides 60°.
489' 1" - 494' 7"			Below 489' numerous, irregular, thin calcite veins.
494' 7" - 496' 1"	DOLERITE.	Light green. Medium grained. Hard, strong. Pieces 3".	Slightly broken zone, 494' - 494' 4".
496' 1" - 496' 1"	GREYWACKE.	Fresh greywacke as above.	

NO. 1000 Mindrill, FB2B.
Type Hydraulic
Type NMTLC
Triple Tube
P. Brech S.M.A.
18-11-65
15-3-66
J.B. McG & J.R.L.R.
1 inch = 100 ft.

NO. 1000 Mindrill, FB2B.
Type Hydraulic
Type NMTLC
Triple Tube
P. Brech S.M.A.
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15-3-66
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1 inch = 100 ft.

BUREAU OF MINERAL RESOURCES. GEOLOGY AND GEOPHYSICS		PROJECT <u>UPPER RAMU HYDRO-ELECTRIC SCHEME</u>		HOLE NO.	
GEOLOGICAL LOG OF DRILL HOLE		LOCATION <u>TAILRACE TUNNEL</u>		DD 20A	
		ANGLE FROM HORIZONTAL <u>VERTICAL</u>		SHEET <u>6</u> OF <u>11</u>	
		COORDINATES <u>81740 N, 42490 E.</u>		R.L. <u>4230 FT.</u>	
ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC SCALE	DEPTH & SIZE OF CORE	STRUCTURED JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER PRESSURE TEST LBS PER SQUARE INCH PER FOOT
SHALE. Slightly weathered.	Black-dark grey. Well indurated. Hard, strong. Pieces $\frac{1}{4}$ " - 6", mode 1".		510	Slightly broken zone 503' - 505'. Joints 45°, calcitic. Increase in calcite veins below 505'.	
INTERBEDDED SHALE & SILTSTONE. Fresh.	Light-dark grey. Well indurated. Fine-grained. Hard, strong. Pieces $\frac{3}{4}$ " - 17", mode 6".		520	Numerous irregular calcite veins	
			530	Slightly broken zone 528' 8" - 528' 10" Numerous irregular calcite veins Joints 90°, 45°, calcitic	
			540	Slightly broken zones 538' 2" - 538' 5" 540' 6" - 540' 8"	
INTERBEDDED SHALE SILTSTONE & GREYWACKE Fresh	Light-dark grey. Fine-medium-grained. Hard, strong. Pieces $\frac{1}{4}$ " - 17", mode 6".		550	Bedding 80°. Greywacke beds 1", others c. $\frac{1}{2}$ ". Joints parallel bedding, 45°, calcitic	
			560	Moderately broken zone 558' 2" - 558' 10"	
			570		
			580		
			590	Moderately broken zone 592' 5" - 593' 1"	
			595'		
DIORITE Fresh	Fresh, hard, as above.		597' 8"	Contact indeterminate	
INTERBEDDED				Joints 80-90°.	

DRILL TYPE Middle Feet
FEET Hydraulic
CORE BARREL TYPE NALC
Triple Tube
DRILLER P. Gough S.M.A.
COMMENCED 18-11-65
COMPLETED 15-2-66
LOGGED BY J.R.L. Read
VERTICAL SCALE 1 inch = 100 ft.

WATER PRESSURE TESTS
Pressure at depth _____
Water level _____
Vertical scale _____
Remarks _____
Geological Reference System _____
Colour _____

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT UPPER RAMA HYDRO-ELECTRIC SCHEME		HOLE NO.	
GEOLOGICAL LOG OF DRILL HOLE		LOCATION TAIL RACE TUNNEL		DD 20A	
ANGLE FROM HORIZONTAL VERTICAL		DIRECTION N. 62.30 E.		SHEET 7 OF 11	
COORDINATES 81740 N, 42490 E					
ROCK TYPE & DEGREE OF WEATHERING		DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, MINOR, ETC.		STRUCTURES FRACTURES, JOINTS, SEAMS, FOLDS, DRUPEL, CONES	
		DEPTH IN FEET		WATER PRESSURE TEST APPLY IN GALLONS PER MINUTE PER FOOT	
SHALE & SILTSTONE.		Black - dark grey. Well indurated. Fine-grained. Hard, strong. Pieces $\frac{1}{4}$ " - 6", mode $\frac{1}{2}$ ".		Shear zone 600' 9" - 601' 2". Moderately broken zones - 601' 11" - 602' 3", 602' 6" - 602' 8". Slightly broken zones - 604' 1" - 605', 606' 11" - 607' 3", 607' 11" - 608' 9", 609' 7" - 610'. Joints 25', 45', calcitic.	
DOLOMITE Fresh.		Fresh hard, as above. Pieces $\frac{1}{4}$ " - 10", mode 5".		Slightly broken zone - 612' - 612' 3".	
INTERBEDDED SHALE & SILTSTONE Fresh		Black - dark grey. Well indurated. Fine-grained. Hard, strong. Pieces $\frac{1}{4}$ " - 14", mode 4".		Moderately broken zone - 613' 7" - 613' 11". Shear zone, soft & friable, 614' 7" - 615'. Moderately broken zone - 615' 6" - 615' 10". Slightly broken zones - 616' 10" - 617' 4", 622' 7" - 622' 10", 623' 10" - 624' 2", 629' 3" - 630", 631' 2" - 631' 5". Joints 30', 75', 45', calcitic. Minor irregular calcite veins.	
GREYWACKE Fresh		Light grey. Medium-grained. Hard, strong. Pieces $\frac{1}{4}$ " - 10", mode 2".		Slightly broken zones 650' 5" - 651' 2", 652' - 652' 4". Slightly broken zone - 656' 2" - 656' 5".	
MARBLE Fresh.		White - greyish white. Fine - medium - grained. Moderately hard, strong. Pieces 1" - 28", mode 8". Occasional thin, $\frac{1}{4}$ " bands of grey, impure marble.		Joints 45', 70', 30', calcitic, commonly showing traces of solution action. Slightly broken zone 693' - 693' 3".	
DRILL TYPE Mindrill F62B		FEED Hydraulic		CORE BARREL TYPE NHL	
DRILLER P. Grech S.M.A.		COMMENCED 18-11-65		COMPLETED 15-3-66	
LOGGED BY J.R.L. Read		VERTICAL SCALE 1 inch = 100 ft.		NOTES FRACTURE LOG - Number of fractures per foot of core. Zones of core loss are blocked in. BEDDING AND JOINT PLANES - Angles are measured relative to the core axis	
				WATER PRESSURE TESTS PACKER TYPE SUPPLY LINE VERTICAL SCALE Figures given are gauge pressures. Test sections are indicated graphically by blocked-in strip. PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOUR	

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL VERTICAL

DIRECTION

COORDINATES 81740 N 42490 E

R1 4230 ft

SHEET 8 OF 11

PCT. TYPE D. MEET. OF WEATHER NO.	DESCRIPTION (THICKNESS), COLOUR, STRENGTH, HARDNESS, ETC.	DRAWING 100	DEPTH & SIZE OF CORR.	NO. OF LITS	STRUCTURES JOINTS, VENE, SLABS, FAULTS, CRACKED ZONES	WATER PRESSURE, T.C. Loss in gallons per minute per foot
MARBLE Fresh	Marble as above. Pieces $\frac{1}{2}$ " - 14", mode 2"		708'9" 710' 711'6"		Highly broken zone, calcitic. 700'6" - 700'9". Slightly broken zones. 704'9" - 705' 706'1" - 706'9" 707'7" - 708' 709'9" - 710'	
DOLERITE Fresh	Fresh, hard, as above.				Contact 70°.	
GREYWACKE Fresh	Light grey, Medium-grained. Hard, strong. Pieces $\frac{1}{4}$ " - 8", mode 2"		720' 720'3"		Slightly broken zones 715'5" - 715'9" 716'2" - 716'9" Joints parallel to core, 20°, 45° & 70°, calcitic.	
MARBLE Fresh	White - greyish white. Fine - medium - grained. Moderately hard, strong. Pieces $\frac{1}{4}$ " - 22", mode 8". Occasional thin, $<\frac{1}{2}$ ", bands of grey impure marble.		730' 740' 750' 760' 770' 780' 790'		Slightly broken zone, across irregular joints 720'10" - 721'9" Highly broken zone showing slight solution action. 730' - 730'6". Joints 30°, 45°, 75°, calcitic & showing traces of solution action. Highly broken zone - 746'9" - 747'3" Moderately broken zone across irregular joints 755'3" - 758'6" Slightly broken zone. 732' - 733'6". Slightly broken zones - 701'7" - 702' 704'2" - 704'5". Joints 10°, 45°, 70° & 90°.	
	Pieces $\frac{1}{4}$ " - 15", mode 4"					
	Pieces $\frac{1}{3}$ " - 32", mode 10"					

Casing Type Midwell P63B
 (F) Hydraulic
 Type Casing Type NMCC
Triple Tube
 Casing P. Grack S.M.A.
 Commenced 18-11-65
 Completed 15-3-66
 Logged By J.R.L. Read
 Vertical Scale 1 inch = 100 ft.

FRACTURE LOG Name of fractures per foot of core (lines 1 thru 32 are blocked in)
BEDDING AND FOLIO PLANES - Angles are measured relative to to the core axis

WATCH PRESSURE TESTS

PAIRED TYPE
UPPER LIP
VERTICAL SCALE
... ..
... ..
... ..
PHOTOCHEMICAL REFERENCE SYSTEM
BLACK AND WHITE

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT <u>UPPER RAMU HYDRO-ELECTRIC SCHEME</u>		HOLE NO. <u>DD 20A</u>		
GEOLOGICAL LOG OF DRILL HOLE		LOCATION <u>TAILRALE TUNNEL</u>		SHEET <u>9 of 11</u>		
ANGLE FROM HORIZONTAL <u>VERTICAL</u>		DIRECTION		R.L. <u>4230 ft.</u>		
COORDINATES <u>81740 N, 42490 E.</u>						
ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION (Texture, color, strength, hardness, etc.)	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRAC- TURE LOG	STRUCTURED LOG (JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES)	WATER PRESSURE TEST (Less in gallons per minute per foot)
MARBLE	Marble, as above.				Slightly broken zone. 806' 2" - 806' 7"	
Fresh	Pieces $\frac{1}{4}$ " - 16", made 3"				Slightly broken zones 816' 9" - 816' 816' 11" - 817' 1".	
					Colitic joint parallel to core axis 817' - 819' 9".	
					Moderately broken zones due to close, irregular jointing - 824' 5" - 825' 825' 5" - 826' 9" 827' - 827' 6" 829' 1" - 830'.	
					Slightly broken zones. 832' - 832' 3" 832' 7" - 833' 4" 835' - 835' 3"	
	Pieces 1" - 26", made 10"				Joints parallel core axis, 30°, 45° & parallel to bedding.	
	Numerous thin, $\frac{1}{2}$ ", bands of grey, impure marble.				Bedding 80°	
SILTSTONE FRESH	Dark grey. Hard strong				Bedding 65	
MARBLE FRESH	Marble, as above					
DOLERITE FRESH	Fresh hard as above				Contact 75°.	
SILTSTONE FRESH	Dark grey. Hard strong.					
MARBLE	Marble, as above				Bedding 60°.	
Fresh	Numerous thin, $\frac{1}{2}$ ", bands of grey, impure marble.					
	Pieces $\frac{3}{4}$ " - 30", made 8"					
					Slightly broken zones. 879' 4" - 880' 880' 2" - 880' 8"	
	Pieces $\frac{1}{4}$ " - 22", made 6"				Joints 25°, 45°, 65° & 80°, calcitic	
					Slightly broken zones. 895' 2" - 895' 8" 896' 5" - 897'.	
Mudrot F628				WATER PRESSURE TEST		
Hydraulic				HICKER TYPE		
PIPE NAME TYPE M.D.C.				SUPPLY LINE		
Type Tube				VERTICAL SCALE		
P. Green S.M.A.				100 ft. gauge pressure		
18-11-65				test sections are indicated graphically by marked in strip		
15-2-66				PHOTOGRAPH REFERENCE SYSTEM		
J.H.L. Road				BLACK AND WHITE		
100 ft. 1 inch = 100 ft.						

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

SUPER RAMBLER ROAD - ELECTRIC SCHEME

TAILRACE TUNNEL

HOLE NO.

DD 20A

ANAL. FROM HORIZON: VERTICAL

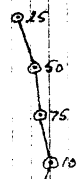
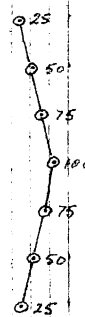
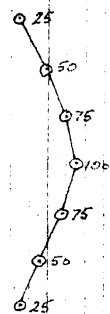
COORDINATES 8174.0 N, 42490 E.

ELEVATION 4230 FT.

SHEET 10 OF 11

ROCK TYPE	DESCRIPTION	FRAC. LOG	REMARKS	WATER PRESSURE TEST	REMARKS
ROCK TYPE	DESCRIPTION	FRAC. LOG	REMARKS	WATER PRESSURE TEST	REMARKS

DOLERITE	Fresh, hard, as above. Pieces 1"-8", mode 5".	903'	Contact 75". Joints 15°, 30°, 70°, closed to slightly calcitic.
MARBLE	White-greyish white. Fine-medium grained. Moderately hard, strong. Pieces 1/2"-16", mode 10".	909'6" 910'	
Fresh		920'	Slightly broken zone. 924'2" - 924'4"
	Pieces < 1/4" - 22", mode 8". Minor thin, < 1/4", bands of grey, impure marble	930'	Slightly broken zone. 934'3" - 934'7"
		940'	Slightly broken zones. 944' - 945' 948'1" - 948'4" 948'9" - 949' 950'10" - 951'
		950'	Shear zone 951'8" - 952'3".
		960'	Slightly broken zones. 956'9" - 957' 958'3" - 958'7" 960'1" - 963'2" 964'4" - 964'7".
	Pieces 1/4" - 14", mode 4". Minor thin, < 1/4", bands of grey, impure marble	970'	Joint parallel to core axis 967'7" - 970'.
		980'	Joints 20°, 45°, 75°-80°, calcitic.
		990'	Slightly broken zone. 979'9" - 980'
		996'2"	Slightly broken zones. 988'4" - 988'8" 993'11" - 994'2"
SILTSTONE	Dark grey. Fine-grained.	998'	
Slightly weathered	Moderately hard, moderately strong.		
MARBLE Fresh	Marble as above.		Moderately broken zone. 999' - 1000'.



DRILL TYPE: Mudrill, F628
FLUID: Hydraulic
CORE BARREL TYPE: NMLC
TRIPLE TUBE
DRILLER: R. Green, S.M.A.
COMMENCED: 18-11-65
COMPLETED: 15-3-66
LOGGED BY: J.R.L. Read
VERTICAL SCALE: 1 inch = 100 ft.

FRAC. LOG: Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLANES: Angles are measured relative to the core axis.

WATER PRESSURE TESTS
PACKER TYPE: N. Mechanical
SUPPLY LINE: AX Casing
VERTICAL SCALE: 1 inch = 100 PSI
Figures given are gauge pressures.
Test sections are indicated graphically by blocked-in strips.
PHOTOGRAPH REFERENCE SYSTEM
BLACK AND WHITE
COLOUR

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICSPROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME
LOCATION TALLRACE TUNNEL

HOLE NO.

DD 20A

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL VERTICAL DIRECTION _____
COORDINATES R1740N, 42490E R.L. 4230 FT.SHEET 11 OF 11

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRAC- TURE LOG	LIFT & % CORE RECOVERY	STRUCTURE JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST LOSS IN GALLONS PER MINUTE PER FOOT
SILTSTONE Fresh	Dark grey. Fine-grained. Well indurated. Hard, strong. Pieces $\frac{1}{2}$ " - 10", mode 2".		1008'			Slightly broken zones - 1000' 6" - 1000' 10" 1006' 3" - 1006' 6" 1007' 2" - 1007' 4" Bedding 75°.		
INTERBEDDED SILTSTONE & GREYWACKE. Fresh.	Light-dark grey. Fine- medium-grained. Hard, strong. Pieces $\frac{1}{4}$ " - 10", mode 3"		1010'			Slightly broken zones. 1010' 3" - 1010' 6" 1011' 10" - 1012' 1" Joint parallel bedding, 25°, 45°, calcitic. Minor irregular calcite veins		
DOLERITE Moderately weathered	Greenish-grey, medium-grained. Moderately soft, moderately weak.		1018' 2" 1019' 6" 1020'			Slightly broken zones. 1018' 9" - 1019' 1" 1020' - 1020' 3" 1021' 3" - 1021' 6" Soft, friable broken zone 1022' 6" - 1023' 3".		
INTERBEDDED SILTSTONE & GREYWACKE Fresh	Light-dark grey. Fine- medium-grained. Hard strong. Pieces $\frac{1}{4}$ " - 20", mode 4".		1030'			Bedding 75°.		
DOLERITE. Fresh	Fresh, hard, as above		1039'			Slightly broken zones. 1038' - 1038' 7" 1039' 8" - 1040'.		
MARBLE Fresh	Marble, as above.		1040'			Joint parallel core axis 1040' - 1042' 10".		
DOLERITE Fresh	Fresh hard as above		1045'					
MARBLE Fresh	Marble, as above. Pieces $\frac{1}{4}$ " - 22", mode 10". Occasional thin, $< \frac{1}{4}$ ", bands of grey, impure marble.		1050'			Slightly broken zones. 1044' 8" - 1046' 1046' 7" - 1047' 1047' 9" - 1048' 1" 1052' 2" - 1052' 6" 1052' 10" - 1053' 5" Bedding 75°. Joints parallel bedding. 20°, 45°, calcitic.		
DOLERITE. Fresh	Fresh hard as above		1058' 10" 1059' 6" 1060'			Slightly broken zones. 1057' - 1057' 8" 1061' 4" - 1061' 6" 1062' - 1062' 10" 1063' 5" - 1065'.		
MARBLE Fresh	Marble as above. Pieces $\frac{1}{2}$ " - 10" mode 4". Occasional thin, $< \frac{1}{2}$ ", bands of grey, impure marble.		1067' 3"			Moderately broken zone. 1067' - 1067' 4" Contact 65°.		
DOLERITE Fresh	Fresh, hard, as above. Pieces $\frac{1}{4}$ " - 18", mode 14".		1070' 1076'			Slightly broken zone - 1074' 1" - 1074' 5" Joints parallel core axis, 20°, 80°, calcitic, showing slight traces of solution action.		
MARBLE Fresh	Marble as above. Pieces $\frac{1}{2}$ " - 15", mode 6".		1080'					
DOLERITE Fresh	Fresh, hard, as above. Pieces $\frac{1}{2}$ " - 8", mode 4".		1084' 9" 1090'			Slightly broken zone - 1092' 9" - 1093.		
MARBLE Fresh.	Marble, as above Pieces $\frac{1}{2}$ " - 18", mode 10".		1092' 10"			Joints 30°, 45°, 80°.		

END OF HOLE 1101' 6", IN MARBLE.

DRILL TYPE Mindoll F62BMETHOD HydraulicCORE BARREL TYPE NMLCTriple TubeDRILLER P. Grech S.M.A.COMMENCED 18-11-65COMPLETED 18-3-66LOGGED BY J.R.L. ReadVERTICAL SCALE 1 inch = 100 ft.FRACTURE LOG. Number of fractures per foot of core. Zones of core loss are checked in.
BEDDING AND JOINT PLANE. - Angles are measured relative to the core axis.

WATER PRESSURE TESTS

PACKER TYPE N. MechanicalSUPPLY LINE 3/4" CasingVERTICAL SCALE 1 inch = 100 p.s.i.

Figures given are gauge pressures.

Test sections are indicated graphically by blocks or wavy

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

COLOUR

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME

LOCATION Intake Works, near access shaft, 11.8 feet from

DD 19 on bearing 338° magnetic

ANGLE FROM HORIZONTAL - 70° DIRECTION 338° magnetic

COORDINATES 43058 E 78833 N RL 3973'

HOLE NO

DD 21

SHEET 1 OF 12

DEPTH FEET	DESCRIPTION TEXTURE, COLOR, STRENGTH, HARDNESS, ETC.	REMARKS STRUCTURES JOINTS, VEINS, STRAMS, FAULTS, CRUSHED ZONES	WATER TEMP.	WATER PRESSURE TEST PSI PER 100 FEET PER MINUTE PER FOOT	PHOTOGRAPH REF. NO.
0	Rubble; Siltstone frags.	Fragments range from sand size to 3". A few pebbles			
5	Siltstone, shale, greywacke.	Angular fragments, 1/4" - 3", made 1"; Indistinct siltstone.			
10					
18.7	Siltstone, greywacke	Beds are 1 mm. to 2" thick Grey; 1/2" - 2" beds Graded bedding Hard.			
20					
23.8	Greywacke Siltstone	Pale grey; thin bedded, 1/2" - 3" beds Black interbeds 1 mm. - 1/2 inch			
30					
38.4	Dolerite?				
40					
43.4	Dolerite				
44.1					
50	Greywacke, siltstone, minor shale FRESH	Thin bedded and laminated Hard			
60.1	Greywacke, siltstone	Fine grained Thick bedded			
70					
73.1	Siltstone, greywacke, minor shale FRESH	Thin bedded Hard			
80					
85	Dolerite Fairly fresh	Porphyritic Hard			
87.9	Greywacke, siltstone, minor shale FRESH.	Fine grained Thin bedded Hard			
90					
100					

Weathered along
joints down to 70';
Solution, oxidation,
and ready parting;
Short core lengths
and broken core.

Crushed, small
fragments, dust
size to 1/2-inch,
from 19' - 19'6

Bedding 25°
Core fragmented
along steeply dipping
joints

Core loss probably
in decomposed
dolerite

Joints 75-80°,
35-40°, 20°

Cementing (lime) leached
from cemented breccia
Bedding 15°
Core broken along
steep joints.

Core broken along
steep joint.

Some joints weathered
and not bedded; others
sealed by calcite
Joints 10°, 60-70°, 80°

Platy jointing, 20°
Close jointing along
steeply dipping joint;
Very steep and vertical
Bedding 20°

Joints 20°, 40°, 80-85°
Bedding 15-20°
Calcite leached
from joints

MINDRILL F62B
Hydraulic

TRIPLE TUBE
P. Grech
23-8-65
9-10-65
D.E. Gardner
1 inch: 10 feet

WATER PRESSURE TESTS

WATER TYPE
SURFACE
VERTICAL SCALE
PHOTOGRAPH REFERENCE SYSTEM
B.A. & ONE WHITE

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME

LOCATION Intake Works, near access shaft, 11.5 feet
from DD19 on bearing 338° magnetic

ANGLE FROM HORIZONTAL - 70°

COORDINATES 43058E 78833N

DIRECTION 338° magnetic

R.L. 3973'

HOLE NO

DD 21

SHEET 2 OF 12

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION THINNESS, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC SYMBOL	DEPTH & SIZE OF CORE	DIAGRAM OF CORE RECOVERY	STRUCTURES FAULTS, SLIPS, FOLDS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST Loss in quarts per minute per foot	ANALYSIS REF. NO.
Greywacke, Siltstone, minor shale	Fine-grained, grey. Dark grey. Thin bedded. Fresh, hard.		100 N M L C 105.3 106.3 107.11		Crushing, weathering 106' 10 - 108' 3 and 108' 10 - 109' at intersecting joints dipping 20°, 50-60° and 90°			
Dolerite	Fresh, hard		110' 8		Joints 10-25°, 50°, 75-80° Bedding 15-20°			
Siltstone, shale	Fresh, hard							
Dolerite	Fresh, hard; strong banding							
Greywacke, siltstone, minor shale	Pale grey Dark grey Dark grey or black Thin bedded and laminated Hard		120 N M L C		Joints 5°, 25°, 85-90° Bedding 15-20° Core broken along steep joint			
Dolerite	Pale green-grey Large phenocrysts in fine groundmass Hard; strongly bonded to sedimentary rock.		135 140 141.5					
Greywacke, siltstone Fresh	Thick bedded below 147' 6 Hard Thin bedded from 167' 10 - 178'		150 160 170		Bedding 15-20° Joints 10°, 80°			
Dolerite	Fresh, hard		186.4 182.3					
Greywacke Siltstone Fresh	Graded bedding Thick bedded Hard		190 200		Joints 10°, 20° Bedding 15-20°			

DRILLER MINDRILL FCB
TEST Hydraulic
TRIPLE TUBE
P. Grech
22.8-65
8-10-65
D.E. Gardner
LINEA 10 feet

WATER PRESSURE TEST
Loss in quarts per minute per foot

WATER PRESSURE TEST
Loss in quarts per minute per foot
PHOTOGRAPH REFERENCE SYSTEM
B.M. AND W.M.

338' mps n.

B: 3973'

CH 257 J 12

CORE NUMBER <u>MIN DRILL F42B</u> TYPE <u>Hydraulic</u> CORE BARREL TYPE <u>Triple tube</u> NO. OF <u>P. Green</u> LENGTH <u>23 - 8 - 65</u> DATED <u>9 - 10 - 65</u> CORED BY <u>D. E. Gardner</u> VERTICAL SCALE <u>Linear - 10 feet</u>	NOTES FRACTURE LOG Number 1 Fractures 1 to 10 are listed. Fractures 11 and 12 are marked in BEDDING AND PLANE TRENCH - Angles - measured in degrees - 1 to 10 are normal to the bedrock	WATER PRELIMINARY NO. OF TUBES VERTICAL SCALE PHOTOGRAPH REFERENCE D. E. GARDNER
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ROCK TYPE IN DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH IN FEET SIZE OF CORE	FRACTURE LOG	JOINTS, VEINS, SEAMS, FAULTS, DISJUNCTIONS, ZONES	STRUCTURES	WATER LEVEL	WATER PRESSURE TEST LOSS IN GALLONS PER MINUTE PER FOOT
Shale, siltstone Fresh	Black Dark grey Hard		300 N M L C 306.2		Joints 10-15°, 20° Bedding 15-20°			
Graywacke, minor shale	Very fine grained Fresh, hard		310.2					
Shale (tuffaceous?), minor thin bands of siltstone and graywacke Fresh	Black; scattered angular fragments Very fine grained Hard		320		Joints 20°, 30-35° Bedding 20°			
Graywacke, minor siltstone and shale	Very fine grained Thin bedded and laminated from 342'5" - 344', 353'-354'8", 355'5" - 358'5"; elsewhere medium bedded.		330 331		Core broken along steep joint			
			340		Core broken along steep joint			
			350		Joints 10-15°, 40°, 80° Bedding 20°			
Dolerite Fresh	Hard		359.5 360 361.8					
Graywacke, Siltstone, minor shale Fresh	Fine grained Interbeds Mainly thin bedded		370		Joints 15°, 40°, 60°, 80-90° Bedding 20°			
Shale, siltstone, minor graywacke Fresh	Black Dark grey Pale grey Hard		379 390		Core broken between three joints spaced 1/4" - 1/2" Core broken at intersecting joints 381'6" - 381'8" Sheet 385'10" - 385'11 1/2" Core broken along three steep to vertical joints 386'3" - 386'11" Joints 5°, 30-40°			
Siltstone Fresh	Black; cherty appearance Hard; brittle		397.1					

MINORILL F62B
Hydraulic
Triple tube
P. Grech
23 x 8 x 65
7' 10" 65
D.M. Gardner
1 inch: 10 feet

NOTES
The following notes are taken from the log of the hole and are placed in the log for the purpose of giving a complete record of the work done.

WATER PRESSURE TEST
The following notes are taken from the log of the hole and are placed in the log for the purpose of giving a complete record of the work done.

CORE TYPE <u>MINDRILL F22 B</u> FEED <u>Hydraulic</u> CORE BARREL TYPE <u>Triple tube</u> DRILLER <u>P. Grech</u> COMMENCED <u>2-3-8-65</u> COMPLETED <u>9-10-65</u> LOGGED BY <u>D.E. Gardner</u> VERBAL SCALE <u>1 inch = 10 feet</u>	FRACTURE LOG - Number of fractures per foot in core. Times of core loss are blocked in. BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis. In general, joints are sealed by calcite; Some tight joints veneered by chloritic mineral	WATER PRESSURE TESTS PACKER LINE SHUT OFF LINE CEMENT SEAL PLUG PHOTOGRAPH REFERENCE SYSTEM 1/2" = 10'
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NO. OF TESTS S - SEE IN WEATHERING		DESCRIPTION LITHOLOGY, COLOR, STRENGTH, HARDNESS, ETC.	GRAPHIC LITHO	DEPTH IN FEET OF CORE	DIAMETER IN INCHES	TEST RESULTS SHEAR, TENSILE, COMPRESSIVE, ETC.	LYTHO. NOTES JOINTS, STAIN, ROOTS, FRACTURES, ZONES	WATER LEVEL	WATER PRESSURE TEST Loss in gallons per minute per foot	REMARKS
		Siltstone Fresh		500						
		Dark grey Hard		502.5			Joints 40°, 50-60°, 70°			
		Underite Fresh, Hard		503.3						
		Siltstone Fresh, Hard		504.2						
		Dolerite Fresh, Hard, except from 505.3 - 505.5.		506.4			Weathered and broken on shear 505.3-505.5, dip 20° Bedding 30-35° Joints in dolerite Coated with chlorite			
		Siltstone; minor silty shale or mudstone		520						
		Mainly massive; black. Silty argillite 514.8-516.2 Thin bands fine grey. wacke, 516.7 - 518.3		522			Joints 20°, 70° Bedding about 20-30°; Contemporaneous deformation			
		Fresh		525.4						
		Siltstone Greywacke		530						
		Finely banded Fresh, Hard		533.4						
		Siltstone; silty shale, and mudstone		536.1						
		Finely banded or laminated from 528.4 to 529.2, 530.5-531.1		540						
		Graywacke Fresh		550						
		Fine grained Hard		560						
		Silty shale and mudstone; Siltstone		565			Joints 20°, 35°, 70° Bedding 25-35°			
		Black. Siltstone (fine-grained) grades into argillite Distinguished by greater hardness (resistance to scratching) of siltstone. Fresh		570						
		Hard Laminated or finely banded from 557-558.7; elsewhere appears massive.		574.4						
		Shale and mudstone; minor Siltstone Fresh		578.4						
		Black; Cleaved. Local faint banding; generally massive. Fresh		580						
		Hard		582.6			Joints 20-25°, 40°; 65-70° Core broken 582.6-582.8 at close parallel joints, dipping 20° Bedding about 30° Contemporaneous deformation			
		Dolerite; concordant; hard		584.2						
		Shale and mudstone; minor Siltstone and graywacke Fresh		590						
		Black; indistinct Cleavage. Bands of fine-grained graywacke, 1/8" - 1", from 577.11 - 584.10 Fresh		595						
		Hard		600						

DRILL: MINDRILL E62 B
TYPE: Hydraulic
CORE: Triple tube
DRILLER: P. Grech
DURATION: 23-8-65
COMPLETED: 9-10-65
LOGGED BY: D.E. Gardner
VERTICAL SCALE: 1 inch = 10 feet

Joints of two ages, the earlier ones sealed with calcite; local minor solution. The later joints are generally tight, some coated with chloritic mineral; many have very thin coatings of sulphide.

WATER PRESSURE TESTS

DATE: _____
TIME: _____
WATER LEVEL: _____
WATER PRESSURE: _____
WATER TEMPERATURE: _____
WATER QUALITY: _____
WATER ANALYSIS: _____
WATER REFERENCE SYSTEM: _____
WATER ANALYST: _____

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION (COLOR, GRAIN, STRENGTH, HARDNESS, ETC.)	DEPTH & SIZE OF CORE	FRAC- TURE LOG	JOINTS, VEINS, SEAMS, FOLDS, PUSHED ZONES	WATER PRESSURE TEST LOG (in millions per minute per foot)
Silty shale or mudstone; passing to siltstone at 616'9 Fresh	Black Indistinct cleavage Hard Siltstone bleached (near dolerite)	609 611.10	N M L C	Joints 20°, 70°, 80° Bedding 20°-35°	20 40 80 120 160 200
Dolerite Fresh	Coarsely porphyritic Green grey Discordant Hard Inclusion of bleached siltstone 612'11 - 613'10	620 622.5			20 40 80
Shale; minor thin bands of siltstone Fresh	Black Hard	630		Joints 30°, 60°, 87° Bedding 30° Core broken along two intersecting, steeply dipping joints	20 40 80 120 160 200
Dolerite Fresh	As above. Irregular distribution of dolerite and siltstone 645'4 - 645'9	641.10 645.9		Bedding 35°	20 40 80 120 160 200
Silty shale and fine grained siltstone Fresh	Black. Not distinctly banded Hard	650		Joints 40°, 60°-80°	20 40 80 120 160 200
Dolerite	Fresh, hard.	660 662.3 663.10			20 40 80 120 160 200
Siltstone Shale Fresh	Dark grey Black Predominantly siltstone Not distinctly banded Hard	670		Joints 15°, 40°, 75°, 90° Bedding 25°-35°	20 40 80 120 160 200
Siltstone, shale, graywacke, (very fine grained) Fresh	Banded; Thickness of graywacke bands ranges from $\frac{1}{8}$ " - 1 inch, Commonly $\frac{1}{2}$ inch. A thicker band 693'10 - 694'7 Siltstone-shale bands range from $\frac{1}{8}$ " - 4", Commonly $\frac{1}{2}$ ". A thick band 686'3 - 689'2	680 690		Joints 20°, 30°, 80°-85° Bedding 25°-35° Core broken along two parallel steeply dipping joints.	20 40 80 120 160 200

MINDRILL F62B

Hydraulic

Triple tube

P. Grech

23-8-65

9-10-65

D.E. Gardner

1 inch 10 feet

NOTES

FRACTURE LOG - Number of fractures per foot of core. Zones of core loss are blocked -
BEDDING AND JOINT PLUNES - Angles are measured relative to a plane normal to the line of drill.

Early joints sealed with calcite. Later joints
tight, veneered with chloritic mineral and sulphide.
Minor solution of calcite on early joints

WATER PRESSURE TESTS

PACKER TYPE Mechanical NX

SUPPLY LINE AX Rising & N Rod

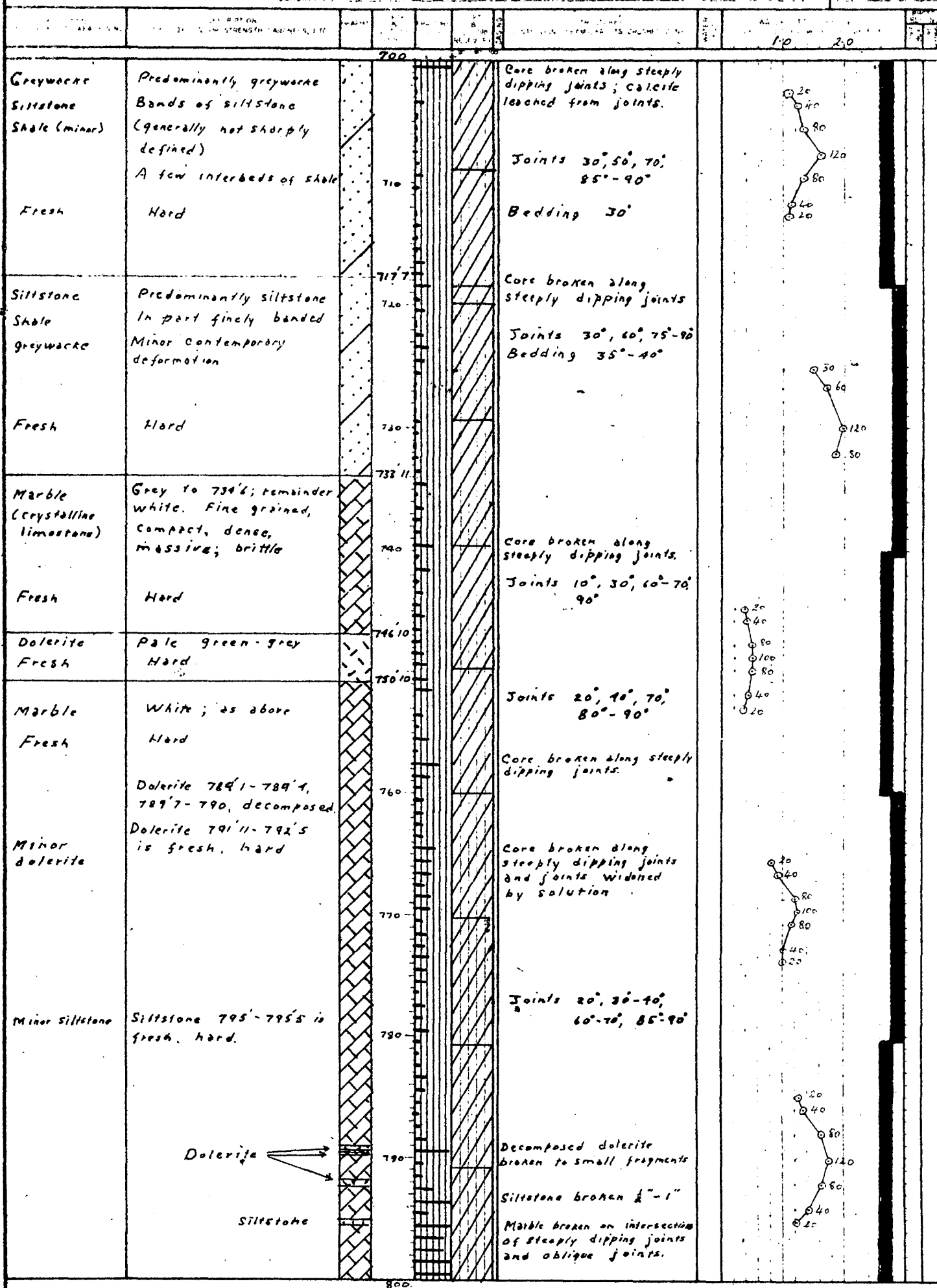
VERTICAL SCALE 1" = 200 p.s.i.

Figures given are gauge pressures.
Test sections are indicated graphically by blocked-in strips.

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

LOG OUR



DRILL: MEMINDRILL E62 B

Type: Hydraulic

DRILL BARNETT TYPE

Triple tube

DRILLER: P. Grech

COMMENCED: 23-8-65

TERMINATED: 9-10-65

LOGGED BY: D.E. Gardner

LOGGING SPEED: 10 feet

REMARKS: CALCITE LEACHED FROM JOINTS IN SILTSTONE, GREYWACKE AND SHALE BELOW 721'. NUMEROUS JOINTS IN MARBLE WIDENED BY SOLUTION, NOTABLY AT 734'5, 745', 751'-751'9, 754'5,

755'2-755'10, 757'-757'6, 760', 761'3, 773'3-774'7,

777'6, 781'-784'4, 787'10, 791', 792'6, 793'9-793'11,

795'4-795'8, 800'

WATER PUMP

Mechanical, NX

JULY 1965 AX Casing 4 N Rod

VERTICAL DISTANCE 1" = 200 ft

DRILLING LOG

DRILLING LOG

DRILLING LOG

DRILLING LOG

DRILLING LOG

DEPTH FEET	TYPE OF WEATHERING	DESCRIPTION OF ROCK AND MINERAL CONTENT	GRAIN SIZE	STRUCTURE	JOINTS	WATER PRESSURE TESTS
800						
801.4	Marble				Joints 10°, 20°-30°, 50°; 75°-90°	
803.3	Dolerite	Partly weathered; moderately hard				
808.7	Marble	White and pale grey				
810	Fresh	Hard				
814.8	Dolerite	Green grey. Appears porphyritic, with chilled margin. Very hard.				
818	Marble	Grey-white				
819	Fresh	Hard				
820	Dolerite	Very hard				
821.6	Marble	White and grey-white			Banding 823.6-824.6 dips 25°-35°; norm 30°	
822	Fresh	Fine grained. Compact Massive			Joints 10°, 25°-30°, 50°-60°; 75°, 80°-90°	
824.6						
825.1	Dolerite; slightly weathered, hard	As above				
826.2	Marble	White and grey-white				
827	Fresh	Fine grained Compact.				
828	Dolerite	Slightly weathered; hard				
830	Marble	White and grey-white				
831.4	Fresh	Fine grained Compact. Mainly massive; grey and grey-white banding, $\frac{1}{16}$ " - $\frac{1}{4}$ " from 857'-860', 861.4'-861.8', 867'-869'			Joints 10°, 20°, 30°; 50°, 65°, 75°-90°	
832					Banding 30°-40°; norm about 35°	
833.8						
834.6						
835.6						
837.4						
838						
839.8						
840						
841.4						
842.4						
843.6						
844.6						
845.6						
846.6						
847.6						
848.6						
849.6						
850						
851.4						
852						
853.8						
854.6						
855.6						
856.6						
857						
858						
859						
860						
861.4						
861.8						
867						
869						
870						
871.4						
872						
873.6						
874.6						
875.6						
876.2						
877						
878						
879						
880						
881.4						
882						
883.8						
884.6						
885.6						
886.6						
887.4						
888						
889						
890						
891.4						
892.4						
893.6						
894.6						
895.6						
896.6						
897.4						
898						
899						
900						

DRILL TYPE MINORILL F62B
WATER TYPE HydraulicCORE BARREL TYPE Triple tubeW. AS P. GrechW. AS 23-8-65W. AS 9-10-65W. AS D.E. GardnerW. AS Vertical scale 1 inch = 10 feet

WATER PRESSURE TESTS

WATER TYPE MechanicalWATER TYPE AX Casing & RodWATER TYPE 1" = 200 p.s.i.WATER TYPE Test pressure 100 p.s.i.WATER TYPE PHOTOGRAPH REFERENCEWATER TYPE BLACK AND WHITEWATER TYPE RECORDWATER TYPE RECORDWATER TYPE RECORDWATER TYPE RECORD

JOINTS AND BANDING: Joints widened by solution at 800'-801', 815'-816', 816'-817', 821'-823', 831'-832'(?), 834.8', 835.6'-835.11', 836.6'-837.4', 840'-840.4', 833.8', 833.8', 844.6'-850', 852'-855', 855.5', 856.11', 860', 876.2', 887.1'. Between about 800' and 887' the bedrock is cut by numerous intersecting joints; the carbonate banding has been leached out, and many joints widened by solution; excessive fragmentation of core at some open joints.

DD 21

SHEET 10 OF 12

MINIRILL F62.B. Hydraulic THE RESERVOIR TYPE Triple tube OR IN P. Grech 23-8-65 DATE FILED 9-10-65 RECORD BY D.E. Gardner TEST A SCALE / inch : 10 feet	NEED AREA TUBE CODE Number of fractures per foot of core (see 1.1) core has one placed in BONDING AND JOINT PLACEMENT Angles are measured at surface of plug (line normal to the core axis) Local incipient jointing parallel to bonding.	WATER PRESSURE TESTS PACKER TYPE Mechanical NX SUPPLY LINE 2 1/2" 150 lb. S. N. Rod VERTICAL SCALE 1" = 200 p.s.i. Figures given are gauge pressures Test sections are indicated graphically by the PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE COLOR
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ANGLE FROM HORIZONTAL -70° DIRECTION 358 magnetic
COORDINATES E 48 337 N 72 930 RL 397.3'

SHEET 11 OF 12

[illegible]

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT UPPER RAMU HYDRO-ELECTRIC SCHEME
LOCATION Intake Works, near access shaft, 11.5 feet from
DD19 on bearing 330° magnetic
ANGLE FROM HORIZONTAL -70° DIRECTION 330° magnetic
COORDINATES 43 05 8 E 788 33 N RL 9973'

DD21

SHEET 12 OF 12

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION THIN, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH & SIZE OF CORE	RECOVERY	JOINTS, VEINS, SLIPS, FOLDS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST LOSS in gallons per minute per foot
<i>Siltstone</i>	<i>Black</i>		1100		<i>Joint, 15° at 1107', slicken-</i> <i>sided, coated with 1/4 in.</i> <i>quartz & calcite.</i>		
<i>Fresh</i>	<i>Hard</i>		1110		<i>Joints 15°, 60°, 80°.</i>		
			1118		<i>Broken zone at intersection</i> <i>of joints at 1113-1115'.</i> <i>Fragments coated with calcite</i> <i>& minor pyrite.</i>		
<i>END</i>	<i>OF HOLE</i>		1120				
			1130				
			1140				
			1150				
			1160				
			1170				
			1180				
			1190				
			1200				

DRILL TYPE MINDRILL F62 B
FEED Hydraulic
CORE BARREL TYPE Triple tube
DRILLER P. Grech
COMMENCED 23-8-65
COMPLETED 9-10-65
LOGGED BY J.R.L. Read
VERTICAL SCALE 1 inch = 10 feet

NOTES

FRACURE LOG - Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis.

WATER PRESSURE TESTS

PACKER TYPE _____
SUPPLY LINE _____
VERTICAL SCALE _____
Figures given are gauge pressure.
Top sections are indicated approximately by dashed lines.
PHOTOGRAPH REFERENCE SYSTEM
BLACK AND WHITE _____
COLOUR _____

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

PROJECT

LOCATION

SCALE

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL

COORDINATES

UPPER RAMU HYDRO-ELECTRIC SCHEME

PROPOSED ACCESS SHAFT, RIGHT BANK

RAMU RIVER

-90°

DIRECTION

43011E 78629N

R.L. 3951.411

HOLE NO.

DD 22

SHEET 2 of 8

NO. OF FEET IN 10' INTERVALS	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	FRACTURE LOG	DEPTH & SIZE OF CORE	FRACTURE LOG	LIFT & CORE RECOVERY	STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST Loss in gallons per minute per foot
FRESH INTERBEDDED SILTSTONE AND SHALE	As above. Bedding at 112' 6" at 35° to com axis. 114' 0"		110				27/5/11	
FRESH TO HIGHLY WEATHERED DOLERITE	upper contact at 30° to com axis crossing bedding. Grey-green to grey-yellow mod. hard, mod. strong, fresh with highly weathered crush zones, medium grained microphyllitic dolerite. Rock is soft and weak in crushed zones. Pieces minute to 16" mod 6" Lower contact at 45° to com axis 142' 9"		120 130 140			Crushed zones at 114' 8"-115' 2", 118' 3"-121' 0", 122' 4"-124' 1", 131' 8"-131' 11", 138' 11"-139' 5", 142' 0"-142' 8". Sheared zone at 136' 2"-137' 1".		
FRESH TO HIGHLY WEATHERED AND BROKEN SILTSTONE AND SHALE	Light to dark grey, strong hard fresh siltstone and shale with broken and crushed zones containing weathered material. Bedding at 146' at 50° to axis. Pieces minute to 6", mod 1". 154' 3"		150			Joints at 30° to com axis also at 45°. Extremely broken 146' 0"-146' 3", 148' 2"-153' 10". Crushed and decomposed 148' 6"-152' 6".		
FRESH TO SLIGHTLY WEATHERED DOLERITE	upper contact at 45° to com axis, crossing bedding - sound. Fresh dolerite as above with several broken and weathered zones with soft, weak rock. Pieces minute to 15" mod 6". Lower contact crushed and decomposed. 189' 10"		160 170 180 190			Joints at 30° and 45° and at 144' 6" at 15° to com axis. Light clay coating on joints. Extremely broken 155'-158' 6", 177' 8"-178' 5". At 163' crush zone 6" wide at 30° to com axis. Moderately broken 182' 5"-183' 1". [HOLE DEFLECTED AND REDRILLED FROM 187 FEET] Crushed and decomposed 189' 4"-189' 10".		
FRESH SILTSTONE AND SHALE	Fresh, as above. Extremely broken zones with strong weathering between 189'-196'. Pieces 8"-16" mod 10".					Joint at 10° to com axis with some clay between 193' 8" and 196' 9". Extremely broken 189' 10"-195' 8".		

DRILL TYPE MINIPAL P628

PUMP HYDRAULIC

CORE BARREL TYPE NMLC

TUBE TYPE

DRILLER R. B. BROWN S.M.A.

COMPLETED 26.2.46

LOGGED BY S. P. MacGREGOR

REMARKS SCALE 1" = 10 feet

NOTES

FRACTURE LOG Number of fractures per foot of core. Zones of core types are bracketed in
bedding, and joint planes - Angles are measured relative to core axis - normal to the core axis

WATER PRESSURE TESTS

PACKER TYPE

SUPPLY LINE

VERTICAL SCALE

Figures given are gauge pressures.
Test sections are indicated graphically by shaded in design

PHOTOGRAPHY REFERENCE SYSTEM

BLACK AND WHITE

COLOUR

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT <u>UPPER RAMU HYDRO-ELECTRIC SCHEME</u>		HOLE NO. <u>DD22</u>	
GEOLOGICAL LOG OF DRILL HOLE		LOCATION <u>PROPOSED ACCESS SHAFT, RIGHT BANK</u> <u>RAMU RIVER</u>		SHEET <u>3</u> OF <u>8</u>	
ANGLE FROM HORIZONTAL <u>-90°</u>		COORDINATES <u>43011E 78429N</u>		DIRECTION <u>395141°</u>	
ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRAC- TURE LOG	LIFT & CORE RECOVERY
STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES		WATER LEVEL		WATER PRESSURE TEST Loss in gallons per minute per foot	
FRESH SILTSTONE AND SHALE	As above. Bedding at 202' at 70° to core axis. Siltstone bands up to 5" normally 1". Shale bands up to 1/2".		210		Thin irregular calcite veins.
FRESH DOLERITE	Sound contact - irregular fine-grained micro porphyritic strong and hard. Sound contact 209'10"		210		Joints clean
FRESH AND BROKEN SILTSTONE AND SHALE	Dark grey strong, hard, fresh undulating siltstone and shale. Shale massive and almost mudstone or claystone. Pieces 1/4" to 18" mode 3" Bedding at 215' at 60-65° to core axis. Bandings ranges from laminated to massive with bands up to 10" wide.		220		Joints at 30° and 45° to axis lightly coated with clay. Thin irregular calcite veinlets. Moderately broken 211'11"-216' 216'11"-217'3" 217'11"-218'4" 219'9"-220'9" 223'4"-227'9" 226'7"-226'11" 227'2"-227'9" Crushed zone 227'9"-228'1"
FRESH DOLERITE	Contact at 30° to axis - sound As above, coarse porphyritic to fine micro porphyritic. Pieces 1/2"-26" mode 6". contact at 65° to axis crossing bedding. 241'7"		240		Crushed zone 232'4"-232'9"
FRESH SILTSTONE AND SHALE	Light to dark grey, strong hard, fresh, fine-grained siltstone and shale. Bedding at 243' at 60° to axis. Pieces 1/4"-20" mode 8". Shale bands are laminated and siltstone bands reach 2" wide.		250		Irregular calcite vein up to 1/2" wide between 242'5" and 244'10". Several other minor calcite veinlets. Joints clean or thinly coated. Small crush zone in shale at 259'5"-259'7".
FRESH DOLERITE	Contact at 35° - sound Coarse porphyritic Contact at 15° - sound 276'4"		280		Numerous calcite veinlets in shale between 277' and 280'. Crushed zones 289'6"-289'8" 289'2"-294'2" Extremely broken 289'8" to 298'6".
FRESH GREYWACKE- SILTSTONE AND SHALE	As above with slightly coarser siltstone bands - greywacke. Bedding at 285' at 70° to axis Pieces minute to 18" mode 6" Rock highly broken below 289'6".		290		
FRESH DOLERITE	Porphyritic				Extremely broken 298'6"-300
DRILL TYPE <u>MINORILL F62B</u>		FEED <u>HYDRAULIC</u>		CORE BARREL TYPE <u>NMLC</u>	
DRILLER <u>P. GRECH-SMA</u>		COMPLETED <u>22.6.66</u>		LOGGED BY <u>J. P. MACGREGOR</u>	
VERTICAL SCALE <u>1"=10 feet</u>		NOTES FRACTURE LOG - Number of fractures per foot of core. Zones of core loss are blocked in. BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis		WATER PRESSURE TESTS PACKER TYPE _____ SUPPLY LINE _____ VERTICAL SCALE _____ Figures given are gauge pressures Test sections are indicated graphically by blocks in strip PHOTOGRAPH REFERENCE SYSTEM BLACK AND WHITE _____ COLOUR _____	

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT
LOCATION

ANGLE FROM HORIZONTAL
COORDINATES

UPPER RAMU HYDRO-ELECTRIC SCHEME
PROPOSED ACCESS SHAFT, RIGHT BANK
RAMU RIVER

-90°
43011E 78429N

DIRECTION
R.L.

3951411

HOLE NO
DD22

SHEET 4 OF 8

ROCK TYPE OR DEGREE OF WEATHERING	DESCRIPTION (MINERALOGY, COLOUR, STRENGTH, HARDNESS, ETC)	GRAPHIC SYMBOL	DEPTH IN FEET SIZE OF CORE	REMARKS LOG	LIFT IN FEET % CORE RECOVERY	CASTING	STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER PRESSURE TEST LOSS IN PSI PER MINUTE PER FOOT
FRESH DOLERITE	As above, coarse porphyritic broken in places Pieces 1/2"-12" mode 2" 305'6"						Joints at 20° and 35° to core axis. Light coating of clay. Slightly to moderately broken.	
FRESH GREYWACK- SILTSTONE AND SHALE	As above, greywacke is green and shale black. Bedding at 308' at 70° to axis. Bands laminae to 4" normally 1". 310'6"		310				Joints slightly coated.	
FRESH DOLERITE	As above, coarse porphyritic Broken contact. 314'9"						Moderately broken zone 310'10" - 311'7".	
FRESH AND BROKEN GREYWACK -SILTSTONE AND SHALE	As above. Bedding at 308' at 65° to axis. Banding varies from laminations to 2", normally 1/2". 335'0"		320				At 320' joint parallel to axis. Most joints at 35° to axis. Extremely broken zone 314'7" - 316'1" 316'9" - 318'7" 319'7" - 320'10" 321'4" - 322'0" Moderately broken at 325'1" - 326'	
FRESH SHALE AND CHAYSTONE	Black, strong, hard, fine-grained shale and claystone. Pieces 1/2"-6" mode 2". Bedding indistinct and irregular 352'6"		340				Joints at 20° and 35° to axis. Sparse, irregular, calcite veinlets. Moderately broken zones 338' - 340', 340'6" - 341'0", 344'8" - 345'0", 346'5" - 346'10".	
FRESH DOLERITE	Broken contact coarse porphyritic in part. Sound contact 356'9"		350				Irregular jointing sub-parallel to axis at 352' - 365'.	
FRESH GREYWACK SILTSTONE AND SHALE	As above, grey-green greywacke-siltstone and black shale. Bedding at 75° to axis Banding from laminations to 1/2", normally less than 1/2". 2" wide dolomite at 361'10" - 362'2" 391'6"		360				Calcite on joint at 35° to axis at 363'2". Extremely broken and brecciated 384' - 386'. Brecciated and sheared 386' - 388'.	
FRESH AND BROKEN SILTSTONE WITH MINOR SHALE	Light grey as above. Pieces mostly 1/2" to 4" mode 1" Extensively broken but still hard and strong.		380				Section of broken and sheared rock 384' - 388'.	
			390				50% recovery in sludge no fresh, angular siltstone and shale fragments. Rock broken throughout but no shearing.	

MINERALS F62B

SYNOPSIS

BASE: MMLC

TRIP TUBES

LOG: GREEN - SMA

LOG: 8" x 8"

LOG: 10' x 10'

LOG: 10' x 10'

REMARKS

NUMBER OF FRACTURES PER FOOT OF CORE. ZONES OF CORE LOSS ARE BLOCKED IN
 JOINTS AND JOINT PLANES - ANGLES ARE MEASURED RELATIVE TO HORIZONTAL PLANE TO THE CORE AXIS

WATER PRESSURE TESTS

PACKER TYPE: MX Mechanical

SUPPLY LINE: AX Casing

VERTICAL SCALE: 1" = 50 PSI

Figures given are gauge pressures

Test sections are indicated graphically by blocked in strips

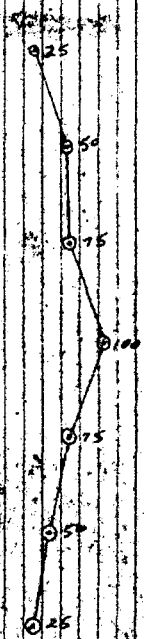
PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

COLOUR

GEOLOGICAL LOG OF DRILL HOLE

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC	GRAPHIC LOG	DEPTH SIZE OF CORE	FRAC/LIN LOG	LIFT % CORE RECOVERY	STRUCTURES JOINTS, FOLDS, BEARS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER REMARKS
BROKEN SILTSTONE WITH MINOR SHALE	As above 407' 0"					Moderately broken 400'-406' 401'10"-403'6". Joints sub-parallel to axis.		
FRESH INDURATED SHALE	Black, strong, hard, fresh fine-grained shale, thinly laminated, average width 1/2" but up to 1 1/2". Very minor amounts of siltstone. Pieces 1/4"-18" mode 8. Bedding at 420' at 70° to axis.		410 420 430 440 448' 0"			Joints at 15° and 45° to axis. Sub-parallel joint between 406'6" and 409'. Calcite on joints and in thin veinlets. Extremely broken 411'0"-412'10" 423'9"-424'2", 438'8"-440'0". Crushed zone 1/2 wide at 418", and 438'0"-438'8". Moderately broken - 407'-410' 425'3"-425'7", 428'7"-428'9".		
FRESH BROKEN SHALE WITH MINOR SILTSTONE	Dark grey & black as above laminated to massive. Bedding at 463' at 66° to axis. Pieces 1/2"-12" mode 2.		450 460 470 480 486' 0"			Joints calcite lined, sub-parallel to 10° to axis from 449'-446'. Calcite veinlets. Broken zones are related to parallel joints. Moderately broken 467'6"-470'6" 471'5"-471'10" 473'10"-474'0".		
FRESH INTERBEDDED SILTSTONE AND SHALE	As above thinly interbedded grey siltstone and black shale. Bedding at 489' at 65° to axis. Pieces 1/2"-12" mode 3.		490			Sheared zone 486'-486'5" minor calcite veinlets Extremely broken 441'10"-452'5".		



DRILL TYPE MINIRAIL FCB
PLED HYDRAULIC
CORE BARREL TYPE NMLC
TRIPLE TUBE
DRILLER P. GREEN - S.M.A.
COMMENCED 26.3.66
COMPLETED 22.8.66
WORKED BY J.P. MACDONALD
VERTICAL SCALE 1" = 10 feet

FRAC/LIN LOG - Summary of Fractures by depth of hole. Details of each fracture are given in the Fracture Log. Bedding and Joint Planes - Angles are measured relative to horizontal - negative to the left and positive to the right.

WATER RECOVERY LOG
PACER TYPE N.K. Macdonald
SAMPLE NO. PX 5000
VERTICAL SCALE 1" = 50 ft
PACER TYPE AX 5000
SAMPLE NO. PX 5000
VERTICAL SCALE 1" = 50 ft
PACER TYPE AX 5000
SAMPLE NO. PX 5000
VERTICAL SCALE 1" = 50 ft

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL

-90°

DIRECTION

COORDINATES

43011E 78429N

R.L.

3951.4 ft

SHEET 6 OF 8

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRACTURE LOG	LIFT & % CORE RECOVERY	STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST Loss in gallons per minute per foot
FRESH INTERBEDDED SILTSTONE AND SHALE	As above		510			Moderately broken 505'5"-508'8", 507'2"-507'8" 509'1"-509'7" Joint at 10° to axis 513'5"-514'8"		
FRESH DOLOMITE	Contact at 70° to axis - sound coarse, porphyritic. Contact crossing bedding at 65° to axis. Sound		520					
BROKEN SHALE	Fresh as above. Black, strong, hard.		525'6"			Extremely broken 522'-528'6" on parallel joint.		
FRESH DOLOMITE	Fresh, fine-grained, microporphyritic in places.		530			Calcite vein 1" wide at 529'1"		
FRESH SHALE	As above bedding at 533' at 60° to core axis		534'7"					
FRESH DOLOMITE	Contact at 70° - sound As above - fine-grained		539'6"					
FRESH SHALE	Contact at 50° - sound Dark gray strong, hard, fresh as above. Reces 1/2" to 1" mode 3" No clear banding.		540			Some calcite veining. Joints at 70° to core axis.		
			550					
			559'10"					
FRESH AND BROKEN INTERBEDDED SILTSTONE AND SHALE	Light to dark gray, strong, hard, fresh. Siltystone interbeds up to 3" wide usually 1/2". Bedding at 561' at 70° to core axis. Reces 1/2" to 10" mode 1" Siltystone content increases with depth. Rock is moderately weathered close to sheared core in upper limb may band between 584' and 587'6". Bedding at 592' at 70°		560			Trails clean on calcite lined predominantly at 60° to axis. Moderately broken 563'1"-565'9" 564'9"-565'6", 565'10"-566'1" 581'6"-583'0", 584'0"-584'10" 594'4"-606'0" Highly broken 567'1"-567'11", 568'7"-569'7", 571'8"-572'4" 597'2"-598'7" Sheared 584'10"-586'0" 588'3"-588'10" Reduced to clay 586'6"-586'9" 587'2"-587'6".		
			570					
			580					
			590					

MINDRELL F62B

HYDRAULIC

WATER

TRIPLE TUBE

P. GRESH - SMA

26.3.66

22.6.66

J.R. MCGREGOR

1" = 10 feet

NOTES

1. 28, C.F.E. 120. Number of fractures per foot of core. Zones of core loss are marked in
(a) 10% and (b) 20% PLACES. - Angles are measured relative to horizontal plane, to the core axis

WATER PRESSURE TESTS

WATER TYPE

SUPPLY LINE

WATER SCALE

- Pressures are gauge pressures
Test sections are indicated graphically by marked in stress

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

COLOUR

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS		PROJECT LOCATION		UPPER RAMU HYDRO-ELECTRIC SCHEME PROPOSED ACCESS SHAFT, RIGHT BANK RAMU RIVER		HOLE NO DD 22	
GEOLOGICAL LOG OF DRILL HOLE		ANGLE FROM HORIZONTAL		-90°		DIRECTION	
		COORDINATES		43011E 78429N		R.L. 3951.411	
MILE TYPE S DEGREE OF WEATHERING		DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC		GRAPHIC LOG		DEPTH SIZE OF CORE	
				FRACTURE LOG		LIFT % CORE RECOVERY	
				STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUMPLED ZONES		WATER LEVEL	
						WATER PRESSURE TEST LOSS IN PRESSURE PER MINUTE PER FOOT	
FRESH AND BROKEN INTERBEDDED SLTSTONE AND SHALE		As above, mostly siltstone in bands from 1/2"-6" wide - usually 1/2". Pieces 1/2"-1" wide 1". Bedding at 75° to axis at 607'6".		607'6"		Rock broken but little sign of shearing. Voids of calcite and calcite coating on joints. Highly broken 602'0"-602'10" 604'0"-605'0", 606'0"-606'10" 608'2"-611'0", 611'6"-612'0" moderately broken 606'7" 608'2", 612'0"-615'6".	
FRESH DOLERITE		coarse grained, porphyritic		616'6"		Joints clean	
FRESH, BROKEN AND SHEARED SLTSTONE AND SHALE		As above with a limy band between 617'10 and 618'6".		622'0"		Sheared zone 616'6"-617'10" moderately broken 618'6"-622'0"	
FRESH AND BROKEN MARBLE		white with occasional batches of gray impure marble, strong, hard, fresh with some slight signs of solution along joints. Contact with siltstone at 75° strong. Pieces minute to 1/2" mode 2. No clear banding. 3" wide dolomite at 331'6"-331'9" 2" wide dolomite at 334'7"-334'9".		656'6"		Calcite crystals in vein at 624'0". Joints at 15° and 60° to core axis. 1" wide shear with clay at 638'0". Highly broken 631'6"-631'9" 632'10"-633'6", 634'6"-635'0" 638'5"-639'6". Moderately broken 631'8"-632'0" 637'0"-638'6", 637'2"-637'8" 649'9"-650'6", 654'0"-656'6".	
SHEAR ZONE		From 656'6" to 657'5" sheared dolomite 1/2" to 662'8" sheared marble - crushed mostly to clay but contains some recognizable calcite fragments.		662'8"		All clay between 657'5" and 658'8" and between 659'6" and 662'8".	
FRESH MARBLE		As above white, strong		667'0"		Few joints. Broken zone 663'6"-663'7".	
FRESH DOLERITE		Contact at 45° strong. Fine-grained micro-porphyrific		670'0"			
FRESH BROKEN MARBLE		As above white, strong. Pieces 1/2"-8" mode 1". Slight solution markings		683'0"		Clay coating on some joints. Highly broken 670'0"-670'6". Moderately broken 373'4"-376'0" 380'6"-383'0".	
		Rods jammed in hole - deflected at 600 feet. New core from 610' on Sheet 7A.		690'			
DRILL TYPE MINDRILL #62B		FEEL HYDRAULIC		CORE BARREL TYPE NALC		TRIPLE TUBE	
DRILLER P. GRECH S.M.A.		COMMENCED 26.3.66		COMPLETED 22.6.66		LOGGED BY J.R. MACGREGOR	
ORIGINAL SCALE 1"=10 feet		FRACTURE LOG Number of fractures per foot of core. Zones of core loss are checked in. BEDDING AND JOINT PLANES - Angles are measured relative to horizontal normal to the core axis.		WATER PRESSURE TESTS		PACKER TYPE N.K. Mechanical	
						SUPPLY LINE A.X. Casing	
						VERTICAL SCALE 1"=100 feet	
						Fig. as given are gauge pressures. Test sections are indicated graphically. 1" mode 1 string.	
						PHOTOGRAPH REFERENCE SYSTEM	
						BLACK AND WHITE	
						COLOUR	

GEOLOGICAL LOG OF DRILL HOLE

ANGLE FROM HORIZONTAL

-90°

DIRECTION

COORDINATES

43011E 78429N

R. 3951-411

SHEET 7A OF 8

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	GRAPHIC LOG	DEPTH & SIZE OF CORE	FRAC- TURE LOG	LIFT & % CORE RECOVERY	STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER PRESSURE TEST Loss in gallons per minute per foot	REMARKS
	Hole wedged off at 600' New core from 610'							
FRESH BROKEN SLTSTONE AND SHALE	Dark grey as above Banding at 70°		610'			Moderately broken between 610'0"-611'2", 612'10"-615'0"		
FRESH DOLERITE	contact strong at 45° Coarse porphyritic		615'1"					
FRESH BROKEN AND SHEARED SLTSTONE AND SHALE	As above Lining band 619'4"-620'9"		620'			Seen at 5° & axis between 617'0"-618'6", highly broken 619'0"-619'9", 620'11"-621'4"		
FRESH BROKEN MARBLE	White strong with some signs of solution action		626'10"			Joints at 10-15°, 45° and 70° to com axis. Highly broken 622'10"-623'6"		
FRESH DOLERITE	Fine micro porphyritic		628'0"			Broken 626'10"-627'0"		
FRESH MARBLE	As above some signs of water action on joints Pieces 1/2"-10" mode 2". 3" wide dolomite at 631'9"-631'0" contact 45°. 2" wide dolomite at 634'10"-635'0"		630'			Slightly to moderately broken throughout. Joints at 15°, 45° and 70°		
			640'					
			650'					
FRESH DOLERITE	Coarse porphyritic		656'11"			Highly broken 656'11"-657'4"		
SHEAR ZONE	At 20° to axis containing both dolomite and marble fragments. Reduced to clay.		660'			Clay apart from marble fragments from 661'1"-661'4" Bottom contact at 60° to axis		
FRESH MARBLE	As above white, strong		667'4"			Few clean joints		
FRESH DOLERITE	Fine-grained micro porphyritic		671'3"			Moderately broken 670'3"-671'2"		
FRESH BROKEN MARBLE	As above		680'			Sheared at 60° to axis 671'3"-671'7" Moderately broken 671'1"-673'0", 680'9"-681'8" 682'2"-682'11", 685'9"-687'0" 688'0"-690'0"		
FRESH DOLERITE	Fine micro porphyritic Lower contact at 60°		690'			Shown 690'0"-690'9"		
FRESH MARBLE	As above 1" wide dolomite at 695'8" & 695'10"		696'10"			Broken 693'0"-693'4"		
FRESH DOLERITE FRESH MARBLE	Coarse porphyritic As above 4" dolomite at 698'1"-698'5"		697'10"			Contacts 60° & 70° to axis		

DRILL TYPE: MERRILL

FEED: HYDRAULIC

CORE BARREL TYPE: NMIC & BMLC

TRAP-TUBE

DRILLER: P. GREGG, S.M.N.

COMMENCED: 26.3.66

COMPLETED: 22.6.66

LOGGED BY: J.P. MacGREGOR

VERTICAL SCALE: 1" = 10 feet

NOTES

FRACTURE LOG - Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLACES - Angles are measured relative to axis, measured to the core axis

WATER PRESSURE TESTS

PACKER TYPE: Bx Hydraulic

SUPPLY LINE: AX Casing

VERTICAL SCALE: 1" = 100 PSI

Figures from air-gauge pressures.
Test sections are indicated graphically by shaded columns

PHOTOGRAPH REFERENCE SYSTEM

BLACK AND WHITE

COLOUR

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICSPROJECT
LOCATIONUPPER RAMU HYDRO-ELECTRIC SCHEME
PROPOSED ACCESS SHAFT, RIGHT BANK
RAMU RIVER

HOLE NO

DD 22

GEOLOGICAL LOG OF DRILL HOLE

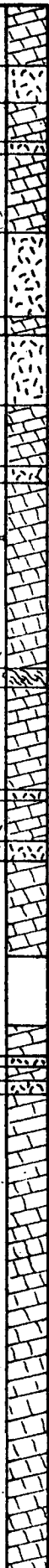
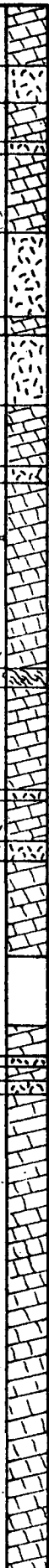
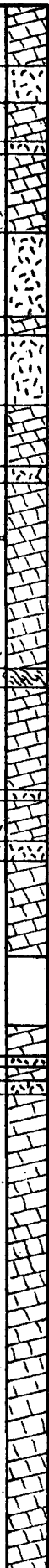
ANGLE FROM HORIZONTAL -90°

DIRECTION

COORDINATES 43011E 78429N

R.L. 3951.411

SHEET 8 OF 8

ROCK TYPE OR DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC	GRAPHIC LOG	DEPTH IN FEET OF CORE	FRACTURE LOG	LIFT IN FEET % CORE RECOVERY	STRUCTURES JOINTS, VEINS, BEDS, FAULTS, CRUSHED ZONES	WATER PRESSURE TEST Loss in gallons per minute per foot
FRESH MARBLE	As above 703' 10"		BMLC				
FRESH DOLomite	Coarse porphyritic 706' 2"					Contacts at 60° and 70°	
FRESH MARBLE	As above 708' 9"						
FRESH DOLomite	As above 709' 2"						
FRESH BROKEN MARBLE	As above 714' 2"					Some shearing 710' 6" - 711' 3" Highly broken 709' 2" - 709' 10"	
FRESH DOLomite	714' 2" - 715' 8" coarse porphyritic not fine-medium grained microphyritic 719' 8"					Broken 717' 9" - 718' 3"	
FRESH MARBLE	As above 720' 10"						
FRESH DOLomite	Coarse porphyritic 725' 2"						
FRESH MARBLE	As above 728' 0"					Shear 727' 6" - 727' 7"	
FRESH DOLomite	Fine microphyritic 730' 0"					Broken	
FRESH MARBLE	As above banding at 733' at 70° to 60° to axis		BMLC			Broken and sheared 731' 2" - 731' 7"	
FRESH DOLomite	Fine microphyritic 730' 0"						
FRESH MARBLE	As above 741' 10"					Broken 741' 3" - 741' 10"	
SHEAR ZONE	Calcite and Dolomite frags. 742' 10"					All clay	
FRESH MARBLE	As above 749' 2"					Broken 746' 0" - 747' 4"	
FRESH DOLomite	Fine microphyritic 750' 0"					Broken	
FRESH MARBLE	As above 752' 7"						
FRESH DOLomite	Coarse porphyritic 753' 10"						
FRESH BROKEN MARBLE	As above 766' 2"					slightly broken no sign of shearing.	
FRESH DOLomite	Fine microphyritic 766' 2"						
FRESH MARBLE	As above 787' 9"		BMLC				
FRESH DOLomite	Fine microphyritic 768' 8"						
FRESH BROKEN MARBLE	As above. Pieces minute to 4" max 1" Banding at 783' at 45° to axis.					Highly broken 776" - 777' 6" 778' 6" - 782' 3", 786' 6" - 787' 6" Rest slight to moderately broken	
FRESH MARBLE	As above 787' 9"						
FRESH DOLomite	Fine microphyritic 768' 8"						
FRESH BROKEN MARBLE	As above. Pieces minute to 4" max 1" Banding at 783' at 45° to axis.						
FRESH MARBLE	As above 787' 9"						
FRESH DOLomite	Fine microphyritic 768' 8"						
FRESH BROKEN MARBLE	As above. Pieces minute to 4" max 1" Banding at 783' at 45° to axis.						
FRESH MARBLE	As above 787' 9"						

END OF HOLE

DRILL TYPE MINDALL F 62 B
FEED HYDRAULIC
CORE BARREL TYPE BMLC
TRIESTE
DRILLER P. GRECH, J.M.A.
COMMENCED 26.3.66
COMPLETED 22.6.66
LOGGED BY J.P. MacGregor
VERTICAL SCALE 1"=10 feet

NOTES

FRACTURE LOG Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLANES - Angles are measured relative to a plane normal to the core axis.

WATER PRESSURE TESTS

PACKER TYPE 8 X Hydraulic
SUPPLY LINE AX Casing
VERTICAL SCALE 1"=100 feet
Figures given are gauge pressure
Test sections are not closed individually by spaced O-rings
PHOTOGRAPH REFERENCE SYSTEM
BLACK AND WHITE
COLOUR

APPENDIX 7

Method of Water Pressure Testing

Throughout the investigation the sections of drill holes close to proposed underground excavations were water pressure tested. During drilling the bottom section of the hole - usually about 20 feet - was sealed using either an hydraulic or mechanical packer connected by a supply line of AX casing fitted with a pressure gauge, through a flow meter to a Coventry Climax fire pump. Water was then pumped into the test section under varying pressures, care being taken to establish constant flow under each new pressure before readings of water flow were recorded. Normally at least three readings of water loss over a five-minute period were taken for each pressure but in cases of high loss the time to lose 100 gallons of water was recorded, to conserve water supplies. Tests were repeated for decreasing pressure values.

Knowing the static groundwater level in the drill hole and assuming full hydrostatic head the effective pressure on the test section consists of the gauge pressure plus the excess hydrostatic head in the supply line less the friction losses due to movement of water through the supply line and packer. Friction losses for the supply line are standard and each packer used was calibrated for pressure loss under different flows.

By calculating from these measurements the effective pressure in pounds per square inch and water loss in gallons per minute per foot of hole, it is possible to obtain an equivalent (fracture) permeability for the section in feet per year. It should be noted, however, that in deriving the formula used the assumption is made that the rock medium has a uniform permeability. As rock which possesses fracture permeability only is not uniformly permeable the result obtained is not a true indication of the rate of transmission of water through the rock. It is, however, useful for comparing the relative water tightness of bodies of similar rock.

As the rock fabric is almost impermeable at the Upper Ramu this permeability represents the movement of water through joints and cavities and a high loss may indicate either one large cavity or many small open joints.

APPENDIX 8

WATER PRESSURE TEST COMPUTATION SHEETS

DD 1

DD 1A

DD 1B

DD 1C

DD 18

DD 19

DD 20A

DD 21

DD 22

BUREAU OF MINERAL RESOURCES
UPPER RAMU HYDRO-ELECTRIC
WATER PRESSURE TEST RESULTS

DD1
DD1A Sheet 1

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)											
Drillhole No. DD1			Co-ordinates 42980E, 79567N						R.L. 3877 feet		Angle - 40°						
Packer B Hydraulic			Water supply - mindrill pump						Bearing 045° magnetic								
6.1.62	68	200	5	30	169.0	181.0	12.0	2.4	132	11	70'	5	0	1	34	0.020	20
			5	30	181.0	195.0	14.0	2.8			8'						
	65	200	5	50	252.0	290.8	38.8	7.76	135	11	70'	5	1	6	48	0.059	40
			4	50	290.8	322.1	32.3	8.07			8'						
Drillhole No. D.D.1A			Co-ordinates 43081E, 18194N						R.L. 3880 feet		Angle - 70°						
Packer N Hydraulic			Water supply - Mindrill Pump						Bearing 190° magnetic								
29.4.64	21	64	5	18	20.0	55.9	35.9	7.18	43	23	20'	10	0	1	27	0.17	
			5	18	64.0	103.4	39.4	7.88			AX						
			5	18	330.3	364.8	34.5	6.90			Casing						
			5	25	108.0	151.5	43.5	8.70					0	1	34	0.20	
			5	25	373.3	419.4	46.1	9.22									
			5	27	424.6	467.3	40.7	8.14									
			5	28	161.5	211.1	49.6	9.92					0	1	36	0.22	200
			5	27	220.0	266.4	46.4	9.28									
			5	27	274.4	319.7	45.3	9.06									
1.5.64	60	70	5	30	8.5	10.1	1.6	0.32	10	23	56'	10	0	0	40	0.024	
			5	30	10.1	11.1	1.0	0.20			AX						
			5	29	11.1	12.2	1.1	0.22			Casing						
			5	40	12.5	14.4	1.9	0.38					0	0	53	0.036	
			5	43	14.4	16.2	1.8	0.36									
			5	43	16.2	18.0	1.8	0.36									
			5	50	18.2	20.1	1.9	0.38					0	0	64	0.044	20
			5	54	20.1	22.5	2.4	0.48									
			5	54	22.5	24.7	2.2	0.44									
4.5.64	70	80	5	30	25.0	27.9	2.9	0.58	10	22	66'	10	0	0	40	0.058	
			5	30	27.9	30.8	2.9	0.58			AX						
			5	30	30.8	33.8	3.0	0.60			Casing						
			5	40	34.3	37.4	3.1	0.62					0	0	51	0.066	
			5	43	37.4	41.0	3.6	0.72									
			5	40	41.0	44.1	3.1	0.62									
			5	50	44.5	48.3	3.8	0.76					0	0	63	0.082	
			5	53	48.3	52.1	3.8	0.76									
			5	55	52.1	56.8	4.7	0.94									
			5	60	57.5	62.0	4.5	0.90					0	0	71	0.098	45
			5	61	62.0	67.0	5.0	1.00									
			5	61	67.0	72.0	5.0	1.00									
5.5.64	80	90	5	32	76.0	78	2.2	0.44	10	23	76'	10	0	0	42	0.016	
				32	78.2	78.3	0.1	0.05			AX						
				32	78.3	78.3	0.0	0.00			Casing						
				40	78.4	80.7	2.3	0.46					0	0	50	0.050	
				40	80.7	84.0	3.3	0.66									
				40	84.0	87.2	3.2	0.64									
				60	87.6	91.1	3.5	0.70					0	0	61	0.074	
				60	91.1	94.9	3.8	0.76									
				52	94.9	98.6	3.7	0.74									
				60	99.1	102.9	3.8	0.76					0	0	71	0.078	

DD1A Sheet 2
DD1B Sheet 1

200

DD1B Sheet 2
DD1C

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)											
Drillhole DD1B (cont.)																	
24.6.64	25' 6"	34' 6"	5	22	76.7	79.1	2.4	0.48	9	10	25'	4	0	0	26	0.050	
			5	22	79.1	81.2	2.1	0.42			AX						
			5	19	81.2	83.1	1.9	0.38			Casing						
			5	25	90.0	93.2	3.2	0.64				0	0	29	0.096		
			5	25	93.2	97.6	4.4	0.88									
			5	25	97.6	101.9	4.3	0.86									
			5	30	110.0	114.9	4.9	0.98			1	0	0	37	0.122	100	
			5	33	114.9	120.5	6.6	1.32									
			5	33	123.5	128.6	5.1	1.02									
26.6.64	34' 6"	45' 0"	5	30	145.5	147.0	1.5	0.30	10.5	10	35'	4	0	0	32	0.026	
			5	28	147.0	148.4	1.4	0.28			AX						
			5	28	148.4	149.7	1.3	0.26			Casing						
			5	35	150.4	151.9	1.5	0.30				0	0	38	0.028		
			5	34	151.9	153.4	1.5	0.30									
			5	34	153.4	154.7	1.3	0.26									
			5	40	155.1	156.6	1.5	0.30				0	0	44	0.031	25	
			5	40	156.6	158.2	1.6	0.32									
			5	40	158.2	159.8	1.6	0.32									
2.7.64	45	60	5	40	161.4	163.9	2.5	0.50	15	10	45'	4	0	0	44	0.033	
			5	40	163.9	166.2	2.3	0.46			AX						
			5	40	166.2	168.4	2.2	0.44			Casing						
			5	45	169.0	171.1	2.1	0.42				0	0	49	0.031		
			5	45	171.1	173.4	2.3	0.46									
			5	45	173.4	175.7	2.3	0.46									
			5	51	176.4	178.9	2.5	0.50				0	0	54	0.032	20	
			5	51	178.9	181.2	2.3	0.46									
			5	53	181.2	183.6	2.4	0.48									
Drillhole DD1C																	
Co-ordinates 43054E, 78545N R.L. 3898 feet Angle -70°																	
Packer - 'N' Hydraulic Water supply - Mindrill Pump Bearing 190° magnetic																	
16.7.64	10	30	5	12	142.4	146.3	3.9	0.78	20	Nil	10'	4	0	0	17	0.076	14' 0" - 23' 9"
			5	13	146.3	150.0	3.7	0.74	(has 10')		AX					Cement lined	
			5	14	150.0	153.8	3.8	0.76			Casing						
			5	20	155.5	160.2	4.7	0.94				0	0	22	0.086	100	
			5	18	160.2	164.3	4.1	0.82									
			5	18	164.3	168.5	4.2	0.84									
20.7.64	30	45	5	18	186.7	200.8	14.1	2.82	15	21	30'	9	0	0	27	0.186	
			5	18	200.8	214.5	13.7	2.74			AX						
			5	18	214.5	228.5	14.0	2.80			Casing						
			5	28	232.0	249.5	17.5	3.50				0	0	27	0.288		
			5	28	249.5	267.4	17.9	3.58									
			5	28	267.4	285.5	18.1	3.62									
			5	35	290.0	310.7	20.7	4.14				0	0	44	0.284	200	
			5	35	310.7	332.0	21.3	4.26									
22.7.64	40	49	5	28	359.2	363.1	3.9	0.78	9	21	40'	9	0	0	38	0.083	
			5	29	363.1	366.7	3.6	0.72			AX						
			5	30	366.7	370.4	3.7	0.74			Casing						
			5	36	371.3	375.4	3.9	0.78				0	0	46	0.089	60	
			5	37	375.2	379.2	4.0	0.80									
			5	37	379.2	383.2	4.0	0.80									
			5	37	383.2	387.1	3.9	0.78									

BUREAU OF MINERAL RESOURCES
UPPER RAMU HYDRO-ELECTRIC
WATER PRESSURE TEST RESULTS

DD18 SHEET 1

DATE	SECTION FROM (ft.)	TESTED TO (ft.)	TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS START (gallons)	FINISH (gallons)	WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH STANDING WATER (ft.)	LENGTH OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
Hole No DD18 Co-ordinates 41790E 86120N R.L. 3205 feet Angle from Horizontal -3½°																	
Packer:- N Hydraulic Supply line:- AX Casing Water Supply:- Mindill and Coventry Climax pumps. Bearing 181°15' True.																	
1-7-65	129'0"	176'7"	5	20	968	972.7	4.7	0.94	47.6	No G.W.L	125'	0	0	0	20	0.020	
			5	20	972.7	977.6	4.9	0.98			N rod						
			5	20	977.6	982.3	4.8	0.96									
			5	35	984	990.7	6.7	1.34					0	0	35	0.027	
			5	35	990.7	997.2	6.5	1.30									
			5	35	997.2	1003.7	6.5	1.30									
			5	50	100.8	1017.1	9.1	1.82					0	0	50	0.038	
			5	50	1017.2	1026.2	9.1	1.82									
			5	50	1026.2	1035.3	9.1	1.82									
			5	60	1040	1056.25	16.25	3.25					0	0	60	0.068	≡ Permeability 40ft/year
			5	60	1056.25	1072.6	16.35	3.27									
			5	60	1072.6	1088.8	16.2	3.24									
			5	50	1094.0	1110.1	16.1	3.22					0	0	50	0.067	
			5	50	1110.1	1126.1	16.0	3.20									
			5	50	1126.1	1142.1	16.0	3.20									
			5	35	1146	1162.8	16.8	3.36					0	0	35	0.067	
			5	35	1165	1180.9	15.9	3.18									
			5	35	1180.9	1196.8	15.9	3.18									
			5	35	1196.8	1212.6	15.8	3.16									
			5	20	1218	1233.5	15.5	3.10					0	0	20	0.066	
			5	20	1233.5	1249.1	15.6	3.12									
			5	20	1249.1	1264.7	15.6	3.12									
3-7-65	176'0"	206'9"	5	25	1450	1462.5	12.5	2.50	30.7	No G.W.L	171'	0	0	0	25	0.081	
			5	25	1462.5	1474.9	12.4	2.48			N rod						
			5	25	1474.9	1487.2	12.3	2.46									
			5	50	1543.0	1509.4	12.4	2.48					0	0	50	0.081	
			5	50	1509.4	1521.6	12.2	2.44									
			5	50	1521.6	1534.1	12.5	2.50									
			5	65	1543	1556.2	13.2	2.64					0	0	65	0.085	
			5	65	1556.2	1569.2	13.0	2.60									
			5	65	1569.2	1582.1	12.9	2.58									
			5	80	1597.2	1610.1	12.9	2.58					0	0	80	0.084	≡ Permeability 40ft/year
			5	80	1610.1	1622.7	12.6	2.52									
			5	80	1622.7	1635.6	12.9	2.58									
			5	65	1640	1653.1	13.1	2.62					0	0	65	0.086	
			5	65	1653.1	1666.2	13.1	2.62									
			5	65	1666.2	1679.2	13.0	2.60									
			5	50	1684	1696.4	12.4	2.48					0	0	50	0.081	
			5	50	1696.4	1708.7	12.3	2.46									
			5	50	1708.7	1721.1	12.4	2.48									
			5	25	1726	1731.9	11.9	2.38					0	0	25	0.077	
			5	25	1737.9	1749.6	11.7	2.34									
			5	25	1749.6	1761.5	11.9	2.38									
6-7-65	205'0"	226'3"	5	35	1770.0	1779.3	9.3	1.86	21.3	No G.W.L	209'	0	0	0	35	0.082	
			5	35	1782.0	1790.9	8.9	1.78			N rod						
			5	35	1792.0	1800.3	8.3	1.66									
			5	55	1818	1827.3	9.3	1.86					0	0	55	0.088	
			5	55	1828	1837.6	9.6	1.92									
			5	55	1838	1847.2	9.2	1.84									
			5	75	1871	1880.3	9.3	1.86					0	0	75	0.088	

DD 18 SHEET 2

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)											
Hole No. D.D. 18 (cont.)																	
6-7-65	205' 0"	226' 3"	5	75	1881	1890.2	9.2	1.84	21.3	No G.W.L.	209'						
			5	80	1891	1900.3	9.3	1.86			N rod						
			5	103	1914	1923.4	9.4	1.88				0	0	0	103	0.088	≡ Permeability 30ft/year
			5	103	1924	1933.3	9.3	1.86									
			5	103	1934	1943.4	9.4	1.88									
			5	75	1953	1961.9	8.9	1.78				0	0	75	0.080		
			5	75	1962	1970.5	8.5	1.70									
			5	75	1971	1979.5	8.5	1.70									
			5	55	1993	2001.9	8.9	1.78				0	0	55	0.084		
			5	55	2002	2010.9	8.9	1.78									
			5	55	2011	2020.0	9.0	1.80									
			5	30	2030	2038.8	8.8	1.76				0	0	30	0.082		
			5	30	2040	2048.8	8.8	1.76									
5	30	2049	2057.7	8.7	1.74												
8-7-65	224' 6"	244' 8"	5	30	2040	216.9	12.9	2.58	20.2	No G.W.L.	227'	0	0	0	30	0.128	Mindred Pump
			5	30	217.0	230.0	13.0	2.60			N rod						
			5	30	230.0	242.9	12.9	2.58									
			5	65	267.0	278.6	11.6	2.32				0	0	65	0.112		
			5	65	274.0	290.3	11.3	2.26									
			5	65	291.0	302.3	11.3	2.26									
			5	90	366.0	378.9	12.9	2.58				0	0	90	0.127		
			5	90	380.0	392.8	12.8	2.56									
			5	90	393.0	405.8	12.8	2.56									
			5	110	424.0	436.9	12.9	2.58				0	0	110	0.128	Country Clinic Pump	
			5	110	427.0	450.1	13.1	2.62								≡ Permeability 40ft/year	
			5	100	451.0	463.8	12.8	2.56									
			5	90	479.0	491.2	12.2	2.44				0	0	90	0.121		
			5	90	492.0	504.2	12.2	2.44									
			5	65	533.0	544.6	11.6	2.32				0	0	65	0.115		
			5	65	545.0	556.6	11.6	2.32									
			5	65	557.0	568.6	11.6	2.32									
			5	30	582.0	592.8	10.8	2.16				0	0	30	0.107		
5	20	595.0	605.8	10.8	2.16												
5	30	606.0	616.9	10.9	2.18												
10-7-65	243' 5"	267' 7"	5	30	747.0	758.8	11.8	2.36	24.2	No G.W.L.	249'	0	0	0	30	0.092	
			5	30	760.0	771.1	11.1	2.22			N rod						
			5	30	772.0	782.8	10.8	2.16									
			5	70	796.0	805.0	9.0	1.80				0	0	70	0.074		
			5	70	806.0	814.9	8.9	1.78									
			5	70	816.0	824.9	8.9	1.78									
			5	95	887.0	845.1	8.1	1.62				0	0	95	0.067		
			5	95	846.0	854.1	8.1	1.62									
			5	95	856.0	864.1	8.1	1.62									
			5	120	879.0	886.7	7.7	1.54				0	0	120	0.061	≡ Permeability 25ft/year	
			5	120	887.0	894.3	7.3	1.46									
			5	120	895.0	902.4	7.4	1.48									
			5	95	923.0	931.4	8.4	1.68				0	0	95	0.069		
			5	95	932.0	940.3	8.3	1.66									
			5	95	941.0	949.2	8.2	1.64									
			5	70	962.0	972.2	10.2	2.04				0	0	70	0.083		
5	70	973.0	983.0	10.0	2.00												

DD18 SHEET 3

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)											
Hole No. 12D18 (cont.)																	
10-7-65	243' 5"	267' 7"	5	70	984.0	993.9	9.9	1.98	242	No G.W.L.	248'						
			5	30	1008.0	1018.7	10.7	2.14			Horod	0	0	0	30	0.088	
			5	30	1019.0	1029.9	10.9	2.18									
			5	30	1031.0	1041.7	10.7	2.14									
13-7-65	263' 9"	291' 8"	5	35	1138.0	1154.5	16.5	3.30	27.9	No G.W.L.	269'	0	0	0	35	0.118	
			5	35	11155.0	1171.4	16.4	3.28			Horod						
			5	35	1172.0	1188.5	16.5	3.30									
			5	80	1213.0	1225.8	12.8	2.56					0	0	80	0.097	Pressure Sange fnctration
			5	80	1229.0	1243.3	14.3	2.86									
			5	80	1244.0	1257.8	13.8	2.76									
			5	80	1259.0	1272.5	13.5	2.70									
			5	80	1274.0	1287.5	13.5	2.70									
			5	105	1302.0	1313.9	11.9	2.38					0	0	105	0.082	Pressure fnctration
			5	105	1314.0	1325.0	11.0	2.20									
			5	105	1326.0	1337.4	11.4	2.28									
			5	105	1339.0	1350.5	11.5	2.30									
			5	130	1365.0	1377.7	12.7	2.54					0	0	130	0.065	Pressure fnctration ≡ Permeability 20ft/year Pushed packer out 3"
			5	130	1379.0	1391.8	12.8	2.56									
			5	130	1393.0	1403.7	10.7	2.14									
			5	130	1405.0	1414.2	9.2	1.84									
			5	130	1415.0	1424.1	9.1	1.82									
			5	130	1425.0	1434.0	9.0	1.80									
			5	105	1448.0	1458.4	10.4	2.08					0	0	105	0.075	
			5	105	1459.0	1469.2	10.2	2.04									
			5	105	1470.0	1480.5	10.5	2.10									
			5	80	1496.0	1508.9	12.9	2.58					0	0	880	0.093	
			5	80	1510.0	1523.0	13.0	2.60									
			5	80	1524.0	1536.9	12.9	2.58									
			5	35	1557.0	1573.3	16.3	3.26					0	0	35	0.116	
			5	35	1574.0	1590.1	16.1	3.22									
			5	35	1591.0	1607.0	16.0	3.20									
14-7-65	292' 0"	309' 1"	5	40	1745.0	1757.6	12.6	2.52	17.1	No G.W.L.	290'	0	0	0	40	0.149	
			5	40	1759.0	1771.9	12.9	2.58			Horod						
			5	40	1773.0	1785.7	12.7	2.54									
			5	90	1821.0	1834.4	13.4	2.68					0	0	90	0.156	
			5	90	1835.0	1848.3	13.3	2.66									
			5	90	1849.0	1862.2	13.2	2.64									
			5	110	1880.0	1893.5	13.5	2.70					0	0	110	0.158	
			5	110	1894.0	1907.5	13.5	2.70									
			5	110	19080	1921.4	13.4	2.68									
			5	140	1940.0	1954.4	14.5	2.90					0	0	140	0.168	≡ Permeability 40ft/year
			5	140	1955.0	1969.4	14.4	2.88									
			5	140	1970.0	1984.3	14.3	2.86									
			5	110	2000.0	2013.5	13.5	2.70					0	0	110	0.158	
			5	110	2014.0	2037.5	13.5	2.70									
			5	110	2028.0	2041.5	13.5	2.70									
			5	90	2057.0	2070.4	13.4	2.68					0	0	90	0.156	
			5	90	2071.0	2084.3	13.3	2.66									
			5	90	2085.0	2098.1	13.1	2.62					0	0	40	0.150	
			5	40	2119.0	2131.9	12.9	2.58									
			5	40	2133.0	2145.1	12.7	2.54									
			5	40	2147.0	2159.2	12.8	2.56									

DD 18 SHEET 4

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Hole No. DD 18 (cont.)																	
24-7-65	309'0"	336'8"	5	40	3986.0	4080.5	94.5	18.90	27.7	No GW.L	307'	0	1.8	4.8	33.4	0.668	
			5	40	4099.0	4195.6	96.5	19.30			AX						
			5	40	4228.0	4319.8	91.8	18.36			Casing						
			5	40	4338.3	4430.5	92.2	18.44									
			5	40	4559.5	4652.0	82.5	16.50									
			5	60	4894.5	5005.7	111.2	22.24					2.4	7.0	50.6	0.805	
			5	60	5000.7	5117.0	111.3	22.26									
			5	60	5117.0	5228.5	111.5	22.30									
			5	80	5485.6	5622.0	136.4	27.28					3.3	10.5	66.2	0.986	Gauge unsteady
			5	80	5622.0	5751.0	129.5	25.90									unable to maintain
			5	80	5751.5	5888.8	137.3	27.46									pressure at 80 p.s.i.
			5	75	5961.7	6104.5	142.8	28.56					3.6	11.6	59.8	1.029	≡ Permeability 600ft/year
			5	75	6104.5	6247.8	143.3	28.66									
			5	75	6247.8	6389.2	141.4	28.28									
			5	60	6519.2	6646.0	126.8	25.36					3.0	9.0	48.0	0.914	
			5	60	6646.0	6772.3	126.3	25.26									
			5	60	6772.3	6899.2	126.9	25.38									
			5	40	7047.5	7150.5	103.0	20.60					2.1	6.0	31.9	0.742	
			5	40	7150.5	7253.2	102.7	20.54									
			5	40	7253.2	7356.0	102.8	20.56									
27-7-65	330'6"	336'8"	5	40	2187.0	2219.0	32.0	6.40	6.2	No GW.L	336.1	0	0	0	40	0.935	
			5	40	2219.0	2250.0	31.0	6.20									
			5	40	2250.0	2279.7	29.7	5.94									
			5	40	2311.3	2340.5	29.2	5.84									
			5	40	2340.5	2369.0	28.5	5.70									
			5	80	2420.0	2460.4	40.4	8.08					0	0	80	1.308	
			5	80	2460.4	2499.9	39.5	7.90									
			5	80	2499.9	2540.3	40.4	8.08									
			5	80	2540.3	2581.6	41.3	8.26									
			5	120	2639.0	2698.4	58.4	11.68					0	1.5	118.5	1.881	≡ Permeability 500/year
			5	120	2697.4	2754.2	56.8	11.76									
			5	120	2754.2	2810.9	56.7	11.74									
			5	120	2810.9	2866.8	55.9	11.18									
			5	120	2866.8	2922.8	56.0	11.20									
			5	80	2968.2	3013.0	44.8	8.96					0	0	80	1.442	
			5	80	3013.0	3058.1	45.1	9.02									
			5	80	3058.1	3102.5	44.4	8.88									
			5	80	3102.5	3147.5	45.0	9.00									
			5	80	3147.5	3191.9	44.4	8.88									
			5	40	3223.0	3255.7	31.8	6.36					0	0	40	0.984	
			5	40	3255.7	3287.0	31.3	6.26									
			5	40	3287.0	3317.9	30.9	6.18									
			5	40	3317.9	3348.2	30.3	6.06									
			5	40	3348.2	3378.5	30.3	6.06									
30-7-65	336'8"	350'7"	5	40	3428.0	3432.8	4.8	0.96	13.9	No GW.L	335'	0	0	0	40	0.068	
			5	40	3433.0	3437.7	4.7	0.94									
			5	40	3439.0	3443.5	4.5	0.90									
			5	100	3464.0	3473.5	9.5	1.90					0	0	100	0.141	
			5	100	3474.0	3484.2	10.2	2.04									
			5	100	3485.0	3494.7	9.7	1.94									
			5	120	3512.0	3525.1	13.1	2.62					0	0	120	0.186	
			5	120	3526.0	3538.9	12.9	2.58									

DD-18 SHEET 5

DD18 SHEET 5

Pressure 105-110 psi
≡ Permeability 6000 ft/year

DD 18 SHEET 6

[illegible]

BUREAU OF MINERAL RESOURCES
UPPER RAMU HYDRO-ELECTRIC
WATER PRESSURE TEST RESULTS

DD19 SHEET 1

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)											
Hole No. D.D19			Co-ordinates:- 43060E, 78822N.					R.L. 3971 feet			Angle from Horizontal: - 90°						
Packer:- NX Hydraulic			Water supply:- Coventry Climax Fire Pump.														
29.6.65	81'8"	131'8"	5	10	679	687	8	1.6	50.0	90.0	84' N rod	35.5	0	0	45.5	0.032	Very good seal
			5	10	687	695	8	1.6									
			5	10	695	703	8	1.6									
			5	15	711	719	8	1.6					0	0	50.5	0.032	
			5	15	719	727	8	1.6									
			5	15	727	735	8	1.6									
			5	25	744	752	8	1.6					0	0	60.5	0.032	
			5	25	752	760	8	1.6									
			5	25	760	768	8	1.6									
			5	30	727	785	8	1.6					0	0	65.5	0.032	≡ Permeability 15 ft/year
			5	30	785	793	8	1.6									
			5	30	793	801	8	1.6									
			5	25	809	816	7	1.4					0	0	60.5	0.028	
			5	25	816	823	7	1.4									
			5	25	823	830	7	1.4									
			5	15	838	845	7	1.4					0	0	50.5	0.028	
			5	15	845	852	7	1.4									
			5	15	852	859	7	1.4									
			5	10	865	873	8	1.6					0	0	45.5	0.032	
			5	10	873	881	8	1.6									
			5	10	881	889	8	1.6									
30.6.65	131'0"	182'0"	5	25	902	903	1	0.2	51.0	90.0	133' N rods	39.1	0	0	64.1	0.0038	good seal
			5	25	903	904	1	0.2									
			5	25	904	905	1	0.2									
			5	50	908	909.5	1.5	0.3					0	0	89.1	0.0057	
			5	50	909.5	911	1.5	0.3									
			5	50	911	912.5	1.5	0.3									
			5	65	914	916	2	0.4					0	0	104.1	0.0076	
			5	65	916	918	2	0.4									
			5	65	918	920	2	0.4									
			5	80	924	927	3	0.6					0	0	119.1	0.0114	≡ Permeability 3 ft/year
			5	80	927	930	3	0.6									
			5	80	930	933	3	0.6									
			5	65	936	939.5	3.5	0.7					0	0	104.1	0.0114	
			5	65	939.5	942.5	3	0.6									
			5	65	942.5	945.5	3	0.6									
			5	65	945.5	948.5	3	0.6									
			5	50	951	954	3	0.6					0	0	89.1	0.0114	
			5	50	954	957	3	0.6									
			5	50	957	960	3	0.6									
			5	25	962	964.5	2.5	0.5					0	0	64.1	0.0095	
			5	25	964.5	967	2.5	0.5									
			5	25	967	969.5	2.5	0.5									
2.7.65	183'10"	231'10"	5	30	1273	1276	3	0.6	48.0	90.0	188' N rod	39.1	0	0	69.1	0.0125	Difficulty in maintaining steady pressure on pump.
			5	30	1276	1279	3	0.6									
			5	30	1279	1282	3	0.6									
			5	55	1286	1290	4	0.8					0	0	94.1	0.0166	
			5	55	1290	1294	4	0.8									
			5	55	1294	1298	4	0.8									
			5	75	1301	1307.5	6.5	1.3					0	0	114.1	0.0270	

DD19 SHEET 2

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)											
Hole No. D.D.19 (cont.)																	
2-7-65	183' 10"	231' 10"	5	75	1307.5	1314	6.5	1.3	48.0	90.0	188'	39.1					
			5	75	1314	1320.5	6.5	1.3			N rod						
			5	100	1328	1334.5	6.5	1.3				0	0	139.1	0.0270	≡ Permeability 6 ft/year	
			5	100	1334.5	1341	6.5	1.3									
			5	100	1341	1347	6.5	1.3									
			5	75	1352	1355	3	0.6				0	0	114.1	0.0124		
			5	75	1355	1358	3	0.6									
			5	75	1358	1361	3	0.6									
			5	55	1363	1364.5	1.5	0.3				0	0	94.1	0.0062		
			5	55	1364.5	1366	1.5	0.3									
			5	55	1366	1367.5	1.5	0.3									
			5	30	1369.5	1370	0.5	0.1				0	0	69.1	0.0021		
5	30	1370	1370.5	0.5	0.1												
5	30	1370.5	1371	0.5	0.1												
6-7-65	230' 7"	280' 7"	5	40	1	3	2	0.4	50.0	85.0	233'	36.9	0	0	76.9	0.008	
			5	40	3	5	2	0.4			N rod						
			5	40	5	6.5	1.5	0.3									
			5	100	9	11	2	0.4				0	0	136.9	0.005		
			5	100	11	12.25	1.25	0.25									
			5	100	12.25	13.5	1.25	0.25									
			5	100	13.5	14.75	1.25	0.25									
			5	120	16	17.75	1.75	0.35				0	0	156.9	0.005		
			5	120	17.75	19	1.25	0.25									
			5	120	19	20.25	1.25	0.25									
			5	120	20.25	21.5	1.25	0.25									
			5	150	23	24.75	1.75	0.35				0	0	186.9	0.007	≡ Permeability 1 ft/year	
			5	150	24.75	26.5	1.75	0.35									
			5	150	26.5	28.25	1.75	0.35									
			5	120	37	38	1	0.2				0	0	166.9	0.004	1	
			5	120	38	39	1	0.2									
			5	120	39	40	1	0.2									
			5	40	41	41.5	0.5	0.1				0	0	76.9	0.003		
			5	40	41.5	42.25	0.75	0.15									
			5	40	42.25	43	0.75	0.15									
7-7-65	280' 4"	330' 4"	5	40	49	51.25	2.25	0.45	50.0	85.0	280'	36.9	0	0	76.9	0.009	
			5	40	51.25	53.25	2	0.4			N rods						
			5	40	53.25	55.5	2.25	0.45									
			5	100	59	70	11	2.2				1.0	0	135.9	0.044		
			5	100	70	81	11	2.2									
			5	100	81	92	11	2.2									
			5	120	103	115	12	2.4				1.0	0	155.9	0.048		
			5	120	115	127	12	2.4									
			5	120	127	139	12	2.4									
			5	150	152	166	14	2.8				1.0	0	185.9	0.056	≡ Permeability 10 ft/year	
			5	150	166	180	14	2.8									
			5	150	180	194	14	2.8									
			5	120	213	224	11	2.2				1.0	0	155.9	0.044		
			5	120	224	235	11	2.2									
			5	120	235	246	11	2.2									
			5	100	253	270	11	2.2				1.0	0	135.9	0.044		
5	100	270	281	11	2.2												
5	100	281	292	11	2.2												

BUREAU OF MINERAL RESOURCES
UPPER RAMU HYDRO-ELECTRIC
WATER PRESSURE TEST RESULTS

DD19 SHEET 3

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS												
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)																							
Hole No. D.D. 19 (Cont.)																													
7-7-65	280' 4"	330' 4"	5	40	298	302	4	0.8	50.0	85.0	280' N rods	36.9	0	0	76.9	0.016													
			5	40	302	306	4	0.8																					
			5	40	306	310	4	0.8																					
9-7-65	329' 10"	379' 10"	5	40	311	312.75	1.75	0.35	50.0	85.0	330' N rods	36.9	0	0	76.9	0.007													
			5	40	312.75	314.5	1.75	0.35																					
			5	40	314.5	316.25	1.75	0.35																					
			5	100	319	321	2	0.4																					
			5	100	321	323	2	0.4																					
			5	100	323	325	2	0.4																					
			5	120	328	330.5	2.5	0.5																					
			5	120	330.5	333	2.5	0.5																					
			5	120	333	335.25	2.25	0.45																					
			5	150	340	342.5	2.5	0.5																					
			5	150	342.5	345	2.5	0.5																					
			5	150	345	347.25	2.25	0.45																					
			5	150	347.25	349.25	2	0.4																					
			5	150	349.25	351.75	2.5	0.5																					
			5	120	354	355.5	1.5	0.3																					
			5	120	355.5	357	1.5	0.3																					
			5	120	357	358.5	1.5	0.3																					
			5	100	360	361.25	1.25	0.25					0	0	136.9	0.005													
			5	100	361.25	362.5	1.25	0.25																					
			5	100	362.5	363.75	1.25	0.25																					
			5	40	366	367	1	0.2																					
			5	40	367	368	1	0.2																					
			5	40	368	368.75	0.75	0.15																					
			12-7-65	380' 4"	430' 4"	5	40	421										422.25	1.25	0.25	50.0	105.0	383' N rods	45.6	0	0	85.6	0.005	
						5	40	422.25										423.25	1	0.2									
						5	40	423.25										424.5	1.25	0.25									
						5	100	427										428.25	1.25	0.25									
						5	100	428.25										429.75	1.5	0.3									
			5	100	429.75	431.25	1.5	0.3					0	0	145.6	0.006													
			5	120	437	438.25	1.25	0.25																					
			5	120	438.25	439.25	1	0.2																					
			5	120	439.25	440.25	1	0.2																					
			5	150	443	444	1	0.2																					
			5	150	444	445	1	0.2																					
			5	150	445	446	1	0.2																					
			5	120	448	449	1	0.2																					
			5	120	449	450	1	0.2																					
			5	120	450	451	1	0.2																					
						5	100	452										453	1	0.2					0	0	145.6	0.002	
5	100	456				453.5	0.5	0.1																					
5	100	453.5				454	0.5	0.1																					
5	40	454.5				455	0.5	0.1																					
5	40	455				455.5	0.5	0.1																					
5	40	455.5				456	0.5	0.1																					
19-7-65	430' 4"	537' 8"				5	40	1173	1174.5	1.5	0.3	107.3	92.8	432' N rods	40.3	0	0	80.3	0.0028	B. Packer									
			5	40	1174.5	1176	1.5	0.3																					
			5	40	1176	1177.5	1.5	0.3																					
			5	100	1179	1179.5	0.5	0.1																					

BUREAU OF MINERAL RESOURCES
UPPER RAMU HYDRO-ELECTRIC
WATER PRESSURE TEST RESULTS

DD19 SHEET 4

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Hole No. D.D. 19 (cont.)																	
19-7-65	430'4"	537'8"	5	100	1179.5	1180	0.5	0.1	107.3	92.8	402'	40.3					
			5	100	1180	1180.5	0.5	0.1			N rods						
			5	120	1182	1182.25	0.25	0.05					0	0	160.3	0.0005	
			5	120	1182.25	1182.5	0.25	0.05									
			5	120	1182.5	1182.75	0.25	0.05									
			5	150	1183	1183.25	0.25	0.05					0	0	190.3	0.0005	≡ Permeability < 1 ft/year
			5	150	1183.25	1183.5	0.25	0.05									
			5	150	1183.5	1183.75	0.25	0.05									
			5	120	1184	1184	0	0					0	0	160.3	0	
			5	120	1184	1184	0	0									
			5	120	1184	1184	0	0									
			5	100	1184	1184	0	0					0	0	140.3	0	
			5	100	1184	1184	0	0									
			5	100	1184	1184	0	0									
			5	40	1184	1184	0	0					0	0	80.3	0	
			5	40	1184	1184	0	0									
			5	40	1184	1184	0	0									
20-7-65	540'8"	588'4"	5	40	1140	1140.5	0.5	0.1	47.7	82.0	542'	35.6	0	0	75.6	0.0126	
			5	40	1140.5	1143.5	3	0.6			N rods						
			5	40	1144	1147	3	0.6									
			5	40	1147	1150	3	0.6									
			5	100	1154.5	1156.5	2	0.4					0	0	135.6	0.0084	
			5	100	1156.5	1159	2.5	0.5									
			5	100	1159	1161	2	0.4									
			5	120	1163	1164.5	1.5	0.3					0	0	155.6	0.0063	
			5	120	1164.5	1166	1.5	0.3									
			5	120	1166	1167.5	1.5	0.3									
			5	150	1170	1172.5	2.5	0.5					0	0	185.6	0.0105	≡ Permeability 2 ft/year
			5	150	1172.5	1175	2.5	0.5									
			5	150	1175	1177.5	2.5	0.5									
			5	120	1180	1182	2	0.4					0	0	155.6	0.0084	
			5	120	1182	1184	2	0.4									
			5	120	1184	1186	2	0.4									
			5	100	1187.5	1189	1.5	0.3					0	0	135.6	0.0063	
			5	100	1189	1190.5	1.5	0.3									
			5	100	1190.5	1192	1.5	0.3									
			5	40	1193	1193	0	0					0	0	75.6	0.0010	
			5	40	1193	1193.25	0.25	0.05									
			5	40	1193.25	1193.5	0.25	0.05									
21-7-65	588'4"	641'10"	5	40	1250	1250	0	0	53.5	82.0	588'	35.6	0	0	75.6	0	
			5	40	1250	1250	0	0			N rods						
			5	40	1250	1250	0	0									
			5	100	1251	1251	0	0					0	0	135.6	0	
			5	100	1251	1251	0	0									
			5	100	1251	1251	0	0									
			5	120	1251	1251	0	0					0	0	155.6	0	
			5	120	1251	1251	0	0									
			5	120	1251	1251	0	0									
			5	150	1251	1251	0	0					0	0	185.6	0	≡ Permeability < 1 ft/year
			5	150	1251	1251	0	0									
			5	150	1251	1251	0	0									
			5	120	1251	1251	0	0					0	0	155.6	0	

UPPER RAMU HYDRO-ELECTRIC

WATER PRESSURE TEST RESULTS

DD19 SHEET 6

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION LOSSES		EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS			
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)							SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)						
Hole No. DD19 (cont.)																				
26.7.65	694' 8"	704' 8"	5	120	1850.5	1860.5	10	2.0	10.0	No G.W.L.	697' N rods	302.5					B Packer			
			5	120	1860.5	1872	11.5	2.3												
			5	120	1872	1882.5	10.5	2.1												
			5	100	1895	1906.5	11.5	2.3					3.0	0	399.5	0.26				
			5	100	1908	1921	13	2.6												
			5	100	1921	1934	13	2.6												
			5	100	1934	1947	13	2.6												
			5	40	1987	1998.5	11.5	2.1					3.0	0	339.5	0.22				
			5	40	1998.5	2009.5	11	2.2												
			5	40	2009.5	2020.5	11	2.2												
29.7.65	704' 10"	743' 2"	5	40	3020	3132	112	22.4	38.3	No G.W.L.	705' N rod	306.0	86.0	351.0	225.0	0.574	B Packer			
			5	40	3132	3241	109	21.8												
			5	40	3241	3349	108	21.6												
			5	40	3360	3470	110	22.0												
			5	100	3550	3679	129	25.8					123.0	46.0	237.0	0.671		≡ Permeability 90ft/year		
			5	100	3679	3807	128	25.6												
			5	100	3807	3936	129	25.8												
			5	100	3936	4064	128	25.6												
			5	40	4080	4186	106	21.2					79.0	32.0	235.0	0.548				
			5	40	4186	4291	105	21.0												
			5	40	4291	4395	104	20.8												
			5	40	4415	4520	105	21.0												
			30.7.65	743' 2"	765' 0"	5	40	150					290	140	28.0	21.8		No G.W.L.	743' N rods	322.5
5	40	290				428	138	27.6												
5	40	428				558	130	26.0												
5	75	680				830	150	30.0	165.0	16.0	216.5	1.330								
5	75	830				970	140	28.0												
5	75	970				1120	150	30.0												
5	125	1230				1398	168	33.6	213.0	20.0	214.5	1.514	≡ Permeability 200ft/year							
5	125	1398				1558	160	32.0												
5	125	1558				1723	165	33.0												
5	75	1900				2050	150	30.0	152.0	15.0	230.5	1.284								
5	75	2050				2190	140	28.0												
5	75	2190				2330	140	28.0												
5	40	2440				2560	120	24.0	111.0	11.0	240.5	1.101								
5	40	2560				2680	120	24.0												
5	40	2680				2800	120	24.0												
2.8.65	765' 0"	785' 4"	5	40	2950	3040	90	18.0	20.3	440' approx	768' N rod	191.0	66.0	25.0	140.0	0.861	B Hydraulic Packer No accurate method of determining static water level at this depth.			
			5	40	3040	3128	88	17.6												
			5	40	3128	3216	88	17.6												
			5	40	3216	3298	82	16.4												
			5	100	3390	3491	101	20.2					76.0	30.0	182.0	0.985				
			5	100	3491	3589	98	19.6												
			5	100	3589	3691	102	20.4												
			5	100	3691	3790	99	19.8												
			5	120	3900	4006	106	21.2					89.0	33.0	189.0	1.069				
			5	120	4006	4118	112	22.4												
			5	120	4118	4226	108	21.6												
			5	120	4226	4335	109	21.8												
			5	150	4410	4520	110	22.0					104.0	38.0	199.0	1.133		≡ Permeability 200ft/year		
			5	150	4520	4634	114	22.8												

UPPER RAMU HYDRO-ELECTRIC

DD19 SHEET 7

WATER PRESSURE TEST RESULTS

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Hole No. DD 19 (cont.)																	
2-8-65	765' 6"	785' 4"	5	150	4634	4750	116	23.2	20.3	440'	768'	191.0					8 Hydraulic Packer
			5	150	4750	4865	115	23.0		approx	N Rod						
			5	120	4930	5036	106	21.2				86.0	33.0	192.0	1.049		
			5	120	5036	5141	105	21.0									
			5	120	5141	5250	109	21.8									
			5	120	5250	5357	107	21.4									
			5	100	5410	5510	100	20.0				76.0	30.0	185.0	0.985		
			5	100	5510	5610	100	20.0									
			5	100	5610	5710	100	20.0									
			5	100	5710	5811	101	20.2									
			5	40	5850	5934	84	16.8				56.0	22.0	153.0	0.837		
			5	40	5934	6020	86	17.2									
			5	40	6020	6102	82	16.4									
			5	40	6102	6187	85	17.0									
3-8-65	784' 6"	804' 6"	5	40	650	660.5	10.5	2.1	20.0	500'	785'	217.0	3.0	0	254.0	0.100	Nx Mechanical Packer
			5	40	661.5	672	10.5	2.1		approx	N Rod						
			5	40	672	680.5	8.5	1.9									
			5	40	680.5	689	8.5	1.9									
			5	100	702	712	10	2.0				2.0	0	315.0	0.090		
			5	100	712	721	9	1.8									
			5	100	721	730	9	1.8									
			5	100	730	739	9	1.8									
			5	120	746	757.5	11.5	2.3				3.0	0	334.0	0.105		
			5	120	757.5	768	10.5	2.1									
			5	120	768	778.5	10.5	2.1									
			5	120	778.5	788.5	10	2.0									
			5	150	800	810	10	2.0				3.0	0	364.0	0.090	Permeability 10 ft/year	
			5	150	810	819	9	1.8									
			5	150	819	828	9	1.8									
			5	150	828	836	8	1.6									
			5	120	847	855	8	1.6				1.0	0	336.0	0.075		
			5	120	855	862.5	7.5	1.5									
			5	120	862.5	869.5	7	1.4									
			5	120	869.5	877.5	8	1.6									
			5	100	884	890.5	6.5	1.3				0	0	317.0	0.060		
5	100	890.5	896.5	6	1.2												
5	100	896.5	902.5	6	1.2												
5	100	902.5	908.5	6	1.2												
5	40	910	914.5	4.5	0.9				0	0	257.0	0.040					
5	40	914.5	918.5	4	0.8												
5	40	918.5	922.5	4	0.8												
5	40	922.5	926.5	4	0.8												
4-8-65	804' 6"	823' 4"	5	40	3902	3906	4	0.8	18.8	400'	806'	173.6	0	0	213.6	0.032	Nx Mechanical Packer
			5	40	3906	3909	3	0.6		approx	N Rod						
			5	40	3909	3912	3	0.6									
			5	40	3912	3915	3	0.6									
			5	100	3922	3926.75	4.75	0.95				0	0	273.6	0.048		
			5	100	3927	3931.5	4.5	0.9									
			5	100	3931.5	3936	4.5	0.9									
			5	120	3939	3943.5	4.5	0.9				0	0	293.6	0.048		
			5	120	3943.5	3948	4.5	0.9									
5	120	3948	3952.25	4.25	0.85												

UPPER RAMU HYDRO-ELECTRIC

WATER PRESSURE TEST RESULTS

DD19 SHEET 8

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICITION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Hole No. DD 19 (cont.)																	
4-8-65	804' 6"	823' 4"	5	150	3956	3961	5	1.0	18.8	400'	806'	173.6	0	0	323.6	0.051	Nx Mechanical Packer ≡ Permeability 5ft/year
			5	150	3962	3966.75	4.75	0.95		approse	N Rod						
			5	150	3967	3971.5	4.5	0.9									
			5	150	3971.5	3976	4.5	0.9									
			5	120	3981	3985	4	0.8				0	0	293.6	0.043		
			5	120	3985	3989	4	0.8									
			5	120	3989	3992.75	3.75	0.75									
			5	100	3996	3999.5	3.5	0.7				0	0	273.6	0.037		
			5	100	3999.5	4003	3.5	0.7									
			5	100	4003	4006.5	3.5	0.7									
			5	40	4009	4011.5	2.5	0.5				0	0	213.6	0.027		
			5	40	4011.5	4014	2.5	0.5									
			5	40	4014	4016.5	2.5	0.5									
5-8-65	823' 4"	843' 7"	5	40	4071	4074.5	3.5	0.7	20.3	400'	825'	173.6	0	0	213.6	0.034	Nx Mechanical Packer
			5	40	4074.5	4078	3.5	0.7		approse	N. rod.						
			5	40	4078	4081.25	3.25	0.65									
			5	100	4088	4092.75	4.75	0.95				0	0	273.6	0.044		
			5	100	4093	4097.5	4.5	0.9									
			5	100	4097.5	4102	4.5	0.9									
			5	120	4106	4110.75	4.75	0.95				0	0	293.6	0.047		
			5	120	4116	4115.75	4.75	0.95									
			5	120	4116	4120.75	4.75	0.95									
			5	150	425	4130.5	5.5	1.1				0	0	323.6	0.052	≡ Permeability 5ft/year	
			5	150	4130.5	4135.75	5.25	1.05									
			5	150	4136	4141.25	5.25	1.05									
			5	150	4141.5	4146.75	5.25	1.05									
			5	120	4150	4154.75	4.75	0.95				0	0	293.6	0.047		
			5	120	4156	4159.75	4.75	0.95									
			5	120	4160	4164.5	4.5	0.9									
			5	100	4167	4171.25	4.25	0.85				0	0	273.6	0.042		
			5	100	4171.5	4175.75	4.25	0.85									
			5	100	4176	4180.25	4.25	0.85									
			5	40	4183	4186	3	0.6				0	0	213.6	0.030		
5	40	4186	4189	3	0.6												
5	40	4189	4192	3	0.6												

UPPER RAMU HYDRO-ELECTRIC

WATER PRESSURE TEST RESULTS

DD 20A, SHEET 1

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION LOSSES		EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)							SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)			
HOLE :- DD 20A.			Co-ordinates 81740 N, 42490 E.					R.L. 4230 feet.			Angle from horizontal :- 90°						
Packer :- N Mechanical			Supply line :- AX Casing					Water supply :- Coventry Climax fire pump.									
4.3.66	950	970	3.00	25	500	600	100	33.3	20	190	9484	82.5	15	37	56	1.675	
			3.00	25	600	700	100	33.3			AX Casing						
			2.57	25	700	800	100	33.9									
			2.30	50	900	1000	100	40.0					22	43	68	1.995	
			2.30	50	1000	1100	100	40.0									
			2.31	50	100	200	100	39.7									
			2.17	75	300	400	100	43.8					27	47	84	2.190	
			2.17	75	400	500	100	43.8									
			2.17	75	600	700	100	43.8									
			2.7	100	700	800	100	47.2					30	50	103	2.340	≡ Permeability 700ft/yr.
			2.12	100	800	9900	100	45.5									
			2.6	100	900	1000	100	47.6									
			2.18	75	100	200	100	43.5					27	47	84	2.180	
			2.15	75	200	300	100	44.4									
			2.20	75	300	400	100	42.9									
			2.47	50	500	600	100	35.9					20	42	71	1.905	
			2.30	50	600	700	100	40.0									
			2.36	50	700	800	100	38.5									
3.00	25	900	1000	100	33.3					17	38	53	1.735				
2.58	25	1000	100	100	33.7												
2.42	25	100	200	100	37.0												
5.3.66	970	990	5	25	500	548	48	9.6	20	190	968'	82.5	2	13	93	0.495	
			5	25	550	600	50	10.0			AX Casing						
			5	25	600	650	50	10.0									
			5	50	700	760	60	12.0					2.3	16	114	0.610	
			5	50	760	820	60	12.0									
			5	50	820	883	63	12.6									
			5	75	900	975	75	15.0					3.5	19	135	0.760	
			5	75	975	1060	85	17.0									
			5	75	1080	1155	75	15.0									
			5	75	160	230	70	14.0									
			5	100	250	340	90	18.0					4.7	22	156	0.875	≡ Permeability 200ft/yr.
			5	100	340	420	80	16.0									
			5	100	420	510	90	18.0									
			5	100	510	600	90	18.0									
			5	75	620	700	80	16.0					3.7	19	135	0.785	
			5	75	850	925	75	15.0									
			5	75	1930	2010	80	16.0									
			5	50	2050	2115	65	13.0					3.4	16	113	0.645	
5	50	120	185	65	13.0												
5	50	190	253	63	12.6												
5	25	270	320	50	10.0					1.6	13	93	0.505				
5	25	320	372	52	10.4												
5	25	375	425	50	10.0												
9.3.66	990	1010	5	25	600	770	170	34.0		190	988	82.5	17	37	54	1.685	
			5	25	770	935	165	33.0			AX Casing						
			5	25	935	1105	170	34.0									
			5	50	400	580	180	36.0					20	40	73	1.835	
			5	50	580	765	185	37.0									
			5	50	0	185	185	37.0									
			5	75	550	735	185	37.0					21	42	95	1.915	

DD 20A, SHEET 2

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION LOSSES		EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)							SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)			
DD20 A cont.																	
9.3.66			5	75	735	930	195	39.0									
			5	75	0	195	195	39.0									
			5	100	250	450	200	40.0					23	44	116	2.000	≡ Permeability 500 ft/yr
			5	100	450	650	200	40.0									
			5	100	650	850	200	40.0									
			5	75	0	185	185	37.0					21	41	96	1.865	
			5	75	400	585	185	37.5									
			5	50	800	970	170	34.0					17	38	78	1.700	
			5	50	50	220	170	34.0									
			5	75	400	560	160	32.0								1.600	
			5	75	560	720	160	32.0					15	36	57		
11.3.66	1010	1030	2.35	25	800	900	100	38.7	20	190	1008	82.5	21	41	46	1.905	
			2.40	25	800	1000	100	37.5			AX						
			2.38	25	0	100	100	38.0			Casing						
			2.25	50	200	300	100	41.4					25	44	64	2.075	
			2.23	50	300	400	100	42.0									
			2.26	50	400	500	100	41.1									
			2.10	75	600	700	100	46.2					32	50	76	2.370	
			2.05	75	700	800	100	48.0									
			2.05	75	800	900	100	48.0									
			1.55	100	0	100	100	52.2					38	53	92	2.585	≡ Permeability 900 ft/yr
			1.57	100	100	200	100	51.3									
			1.56	100	200	300	100	51.7									
			2.10	75	600	700	100	46.2					32	50	76	2.375	
			2.02	75	700	800	100	49.2									
			2.07	75	800	900	100	47.2									
			2.20	50	100	200	100	42.9					26	45	62	2.13	
			2.20	50	200	300	100	42.9									
			2.23	50	300	400	100	42.0									
			2.40	25	600	700	100	37.5					21	41	46	1.885	
			2.40	25	700	800	100	37.5									
			2.38	25	800	900	100	38.0									
11.3.66	1027	1047	3.13	25	100	200	100	31.1	20	190	1025	82.5	14	34	60	1.525	
			3.20	25	200	300	100	30.0			AX						

DD 21 sheet 1

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Hole N ^o D D 21			Co-ordinates 43058 E, 78833 N.					R.L. 3973 feet.			Angle from horizontal - 70°						
Packer - 1N Mechanical.			Supply line - AX Casing, & N Rods.					Water Supply - Coventry Climax & Mindrill pumps.					Bearing 338° Magnetic.				
14.9.65	600' 5"	620' 5"	5	20	4295	4305	10	2.0	20	100	598'	43.4	0	0	63	0.100	
			5	20	4305	4315	10	2.0			N Rod.						
			5	20	4315	4325	10	2.0									
			5	40	4336	4348	12	2.4					0	0	83	0.120	
			5	40	4348	4360	12	2.4									
			5	40	4360	4372	12	2.4									
			5	80	4390	4404.5	14.5	2.9					0	0	123	0.122	
			5	80	4405.5	4418	13.5	2.7									
			5	80	4418	4428.4	10.4	2.08									
			5	80	4428.4	4440.2	11.8	2.36									
			5	80	4440.2	4450.7	10.5	2.1									
			5	120	454.3	4561.3	18.3	3.66					0	0	163	0.183	≡ Permeability 40 ft/year
			5	120	4561.3	4579.4	18.1	3.62									Pressure Fluctuation 105-135 psc
			5	120	4579.4	4597.5	18.1	3.62									
			5	60	4889	4906.5	17.5	3.5					0	0	103	0.177	
			5	60	4906.5	4924.2	17.7	3.54									Extreme fluctuation at 80 psc
			5	60	4924.2	4941.5	17.7	3.54									
			5	40	4745	4762	17	3.4					0	0	83	0.160	
			5	40	4764	4780.5	16.5	3.3									
			5	40	4782	4795.2	13.2	2.64									
			5	40	4796	4812.5	16.5	3.3									
			5	40	4812.5	4829	16.5	3.3									
			5	20	4835	4850.5	15.5	3.1					0	0	63	0.155	
			5	20	4850.5	4866	15.5	3.1									
			5	20	4866	4881.5	15.5	3.1									
16.9.65	620' 5"	641' 1"	5	30	7600	7850	250	150	20.7	259	410'	112.4	71.1	48	23	2.415	
			5	30	7850	8100	250	50			AX						
			5	30	8100	8350	250	50			208						
			5	40	8400	8650	250	50			N rod.		71.1	48	33	2.415	
			5	40	8650	8900	250	50									
			5	40	8900	9150	250	50									
			5	60	9200	9470	270	54					84	56	32	2.608	≡ Permeability 2500 ft/yr.
			5	60	9500	9770	270	54									
			5	60	9770	10040	270	54									
16.9.65	641' 1"	660' 9"	5	20	5126.5	5126.5	0	0	19.7	249	410'	108	0	0	128	0	
			5	20	5126.5	5126.5	0	0			AX Casing						
			5	20	5126.5	5126.5	0	0			229						
			5	40	5126.5	5126.5	0	0			N rod.		0	0	148	0	
			5	40	5126.5	5126.5	0	0									
			5	40	5126.5	5126.5	0	0									
			5	60	5225	5277.6	26	0.52					0	0	168	0.029	≡ Permeability 6 ft/yr.
			5	60	5227.5	5230.5	2.9	0.58									
			5	10	5230.5	5233.5	3.0	0.60									
			5	80	5235	5237.8	2.8	0.56					0	0	188	0.024	
			5	80	5237.8	5239.7	2.9	0.58									
			5	80	5239.7	5242	2.1	0.42									
			5	80	5242	5244	2.0	0.40									
			5	80	5244	5245.8	1.8	0.36									
			5	60	5246	5247.8	1.8	0.36					0	0	168	0.016	
			5	60	5247.8	5249.4	1.6	0.32									
			5	60	5249.4	5250.8	1.4	0.28									

DD 21 sheet 2.

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICITION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Hole No. DD 21 (cont.)																	
16.9.65	641' 1"	660' 9"	5	40	5254.5	5255.6	1.1	0.22	19.7	249	410'	108	0	0	148	0.013	
			5	40	5255.6	5256.9	1.3	0.26			AX						
			5	40	5256.9	5258.3	1.4	0.28			229						
			5	20	5259	5260.4	1.4	0.28			N rod						
			5	20	5260	5262	1.6	0.32					0	0	128	0.017	
			5	20	5262	5263.8	1.8	0.36									
			5	20	5263.8	5265.5	1.7	0.34									
17.9.65	658' 7"	678' 7"	5	20	527.6	527.6	0	0	20	249	410'	108	0	0	128	0.002	
			5	20	527.9	528.2	0.3	0.06			AX						
			5	20	528.2	528.5	0.3	0.06			246						
			5	40	529.4	529.7	0.3	0.06			N rod		0	0	148	0.003	
			5	40	529.7	530.0	0.3	0.06									
			5	40	530.0	530.3	0.3	0.06									
			5	80	530.5	530.9	0.4	0.08					0	0	188	0.0035	Permeability < 1 ft/yr.
			5	80	530.9	531.2	0.3	0.06									
			5	80	531.2	531.5	0.3	0.06									
			5	80	531.5	531.9	0.4	0.08									
			5	120	532.1	532.4	0.3	0.06					0	0	228	0.0034	
			5	120	532.4	532.8	0.4	0.08									
			5	120	532.8	533.1	0.3	0.06									
			5	80	533.2	533.5	0.3	0.06					0	0	188	0.003	
			5	80	533.5	533.8	0.3	0.06									
			5	80	533.8	534.1	0.3	0.06									
			5	40	534.2	534.5	0.3	0.06					0	0	148	0.003	
			5	40	534.5	534.8	0.3	0.06									
			5	40	534.8	535.1	0.3	0.06									
			5	20	535.3	535.5	0.2	0.04					0	0	128	0.002	
			5	20	535.7	535.9	0.2	0.04									
			5	20	535.9	536.1	0.2	0.04									
19.9.65	678' 7"	698' 11"	5	20	5425	5503	122	24.4	20.3	268	410'	116.3	12.7	5.4	118	0.860	
			5	20	5503	5580	77	15.4			AX Case						
			5	20	5580	5655	75	15.0			267'						
			5	20	5655	5730	75	15.0			N rod						
			5	40	5760	5841	81	16.2					11.2	4.7	140	0.803	
			5	40	5841	5923	82	16.4									
			5	40	5924	6005	81	16.2									
			5	80	6060	6182	122	24.4					21.2	9.5	166	1.128	
			5	80	6182	6293	111	22.2									
			5	80	6294	6408	114	22.8									
			5	80	6409	6520	111	22.2									
			5	120	10300	10440	140	28.0					28	13	195	1.330	Permeability 220 ft/yr.
			5	120	10440	10570	130	26.0									
			5	120	10570	10705	135	27.0									
			5	120	10705	10840	135	27.0									
			5	80	6570	6688	118	23.6	23.4				21.8	10	165	1.158	
			5	80	6690	6808	118	23.6									
			5	80	6801	6925	116	23.2									
			5	40	6980	7086	106	21.2					17.9	8	130	1.041	
			5	40	7086	7194	108	21.6									
			5	40	7200	7303	103	20.6	21.1								
			5	20	7330	7425	95	19.0									
			5	20	7425	7521	96	19.2					15.1	6.5	114	0.941	
			5	20	7521	7617	96	19.2									

BUREAU OF MINERAL RESOURCES
UPPER RAMU HYDRO-ELECTRIC
WATER PRESSURE TEST RESULTS

DD 21 sheet 4

DATE	SECTION TESTED FROM (ft.)	TO (ft.)	TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS START (gallons)	FINISH (gallons)	WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
Hole No. DD 21 (cont.)																	
22.9.65	740' 1"	760'	5	20	8600	8638	38	7.6	20	250		108.5	0	1	128	0.380	
			5	20	8638	8676	38	7.6									
			5	20	8676	8714	38	7.6									
23.9.65	760'	780' 5"	5	20	17220	17305	85	17	20.5	250	410'	108.5	14.8	5	109	0.829	
			5	20	17305	17390	85	17			Ax Case						
			5	20	17400	17485	85	17			3x8'						
			5	40	17500	17595	95	19			N rod		18.4	6.5	124	0.927	
			5	40	17600	17695	95	19									
			5	40	17700	17795	95	19									
			4:0.2	80	17830	17930	100	24.98					30.1	11	147	1.208	
			4:15	80	17930	18030	100	24.33									
			4:0.3	80	18030	18130	100	24.97									
			3:45	100	18200	18300	100	26.67					32	12	165	1.262	Permeability 250 ft/yr.
			3:53	100	18300	18400	100	25.53									
			3:56	100	18400	18500	100	25.42									
			4:24	80	18550	18650	100	22.73					92.2	11	148	1.180	
			4:0.4	80	18650	18750	100	24.96									
			4:0.8	80	18750	18850	100	24.92									
			4:25	40	18870	18970	100	22.65					24	8.5	116	1.063	
			4:42	40	18970	19070	100	21.28									
			4:40	40	19070	19170	100	21.43									
			5	20	19200	19295	95	19					18.4	6.5	104	0.927	
			5	20	19300	19395	95	19									
			5	20	19400	19495	95	19									
24.9.65	780' 5"	800' 8"	3:40	20	0	100	100	27.27	20.2	250	410'	108.5	34.5	12	82	1.285	
			4	20	100	200	100	25.00			Ax Case						
			3:50	20	200	300	100	25.57			3x8'						
			3:40	40	450	550	100	27.27			N rod		38	14	97	1.371	
			3:35	40	550	650	100	27.91									
			3:35	40	650	750	100	27.91									
			3	80	800	900	100	33.3					54.7	20	114	1.650	
			3	80	900	1000	100	33.3									
			3	80	1000	1100	100	33.3									
			2:40	120	1200	1300	100	37.50					63.3	24	141	1.784	Permeability 400 ft/yr.
			2:50	120	1300	1400	100	35.30									
			2:50	120	1400	1500	100	35.30									
			3	80	1600	1700	100	33.3					54.7	20	114	1.650	
			3	80	1700	1800	100	33.3									
			3	80	1800	1900	100	33.3									
			3:20	40	1950	2150	100	30.0					44.1	16	88	1.438	
			3:30	40	2050	2250	100	28.57									
			3:30	40	2150	2350	100	28.57									
			4:10	20	2300	2400	100	24.0					31.6	11	86	1.223	
			4	20	2400	2500	100	25									
			4	20	2500	2600	100	25									
25.9.65	799' 4"	819' 4"	5:02	20	22700	22800	100	19.87	20	250	410'	108.5	22.4	6.8	99	0.984	
			5:07	20	22800	22900	100	19.54			Ax Case						
			5:06	20	22900	23000	100	19.60			3x8'						
			4:25	40	23010	23110	100	22.65			N rod		27.8	9	112	1.116	
			4:27	40	23110	23210	100	22.47									
			4:35	40	23210	23310	100	21.81									

DD 21 sheet 6

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICITION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Hole No. DD21 (cont.)																	
27.9.65	836' 9"	857' 3"	5	40	2300	2380	80	16	20.5	250	410'		15.5	4.4	129	0.780	
			5	40	2380	2460	80	16			AX Case						
			5	40	2460	2540	80	16			424'						
			5	20	2600	2670	70	14			N rod.	12.2	3.4	113	0.683		
			5	20	2670	2740	70	14									
			5	20	2740	2810	70	14									
28.9.65	857'	877'	5	20	8834	8857	23	4.6	20	250	410'	108.5	0	0	129	0.222	
			5	20	8858	8880	22	4.4			AX Case						
			5	20	8880	8901.5	21.5	4.3			445'						
			5	40	8925	8948.5	23.5	4.7			N rod.	0	0	149	0.230		
			5	40	8949	8972	23	4.6									
			5	40	8972	8995	23	4.6									
			5	80	9024	9053	29	5.8				0	0	189	0.290		
			5	80	9053	9082	29	5.8									
			5	80	9082	9111	29	5.8									
			5	120	9144	9178	34	6.8				0	0	229	0.337	Permeability 50 ft/yr.	
			5	120	9178	9212	34	6.8									
			5	120	9212	9245	33	6.6									
			5	80	9276	9305	29	5.8				0	0	189	0.290		
			5	80	9305	9334	29	5.8									
			5	80	9334	9363	29	5.8									
			5	40	9388	9413	25	5.0				0	0	149	0.265		
			5	40	9413	9438	25	5.0									
			5	40	9438	9462.5	24.5	5.9									
			5	20	9486	9508.5	22.5	5.5				0	0	129	0.270		
			29.9.65	877'	897'	5	20	9566	9568.7	2.7	0.54	20	250	410'	108.5	0	0
5	20	9569				9571.5	2.5	0.50			AX Case						
5	20	9572				9576	4	0.80			465'						
5	40	9582				9586	4	0.80			N rod.	0	0	149	0.037		
5	40	9586				9589.5	3.5	0.70									
5	40	9590				9593.4	3.4	0.68									
5	80	9599				9602.8	3.8	0.76				0	0	189	0.039		
5	80	9603				9606.9	3.9	0.78									
5	80	9607				9610.8	3.8	0.76									
5	120	9617				9621	4	0.80				0	0	229	0.043	Permeability 6 ft/yr.	
5	120	9621				9625.5	4.5	0.90									
5	120	9626				9630.3	4.3	0.86									
5	80	9635				9638.8	3.8	0.76				0	0	189	0.037		
5	80	9639				9642.6	3.6	0.72									
5	80	9643				9646.5	3.5	0.70									
5	40	9649				9652	3	0.60				0	0	149	0.030		
5	40	9652				9655	3	0.60									
5	40	9655				9658	3	0.60									
5	20	9661				9663.5	2.5	0.50				0	0	129	0.025		
5	20	9664				9666.5	2.5	0.50									
5	20	9667	9669.5	2.5	0.50												

DD 21 sheet 7

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICITION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS	
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)												
Hole No. DD 21 (cont.)																		
30-9-65	897'	917' 4"	5	20	9694	9695.4	1.4	0.28	20.3	250	410'	108.5	0	0	129	0.012		
			5	20	9695.4	9696.7	1.3	0.26					AX Case					
			5	20	9696.7	9697.7	1.0	0.20					485'					
			5	40	9698	9699.2	1.2	0.24					N rod	0	0	149	0.012	
			5	40	9699.2	9700.4	1.2	0.24										
			5	40	9700.4	9701.6	1.2	0.24										
			5	80	9702	9703.3	1.3	0.26						0	0	189	0.012	
			5	80	9703.3	9704.5	1.2	0.24										
			5	80	9704.5	9705.7	1.2	0.24										
			5	120	9706.5	9707.9	1.4	0.28						0	0	229	0.014	Permeability 2 ft/yr
			5	120	9707.9	9709.3	1.4	0.28										
			5	120	9709.3	9710.7	1.4	0.28										
			5	80	9711.5	9712.7	1.2	0.24						0	0	189	0.012	
			5	80	9712.7	9713.9	1.2	0.24										
			5	80	9713.9	9715.1	1.2	0.24										
			5	40	9715.5	9716.5	1.0	0.20						0	0	149	0.0098	
			5	40	9716.5	9717.5	1.0	0.20										
			5	40	9717.5	9718.5	1.0	0.20										
			5	20	9719	9719.5	0.9	0.18						0	0	129	0.009	
			5	20	9719.9	9720.8	0.9	0.18										
5	20	9720.8	9721.7	0.9	0.18													
31-9-65	917' 6"	937' 6"	5	20	9721	9725.5	4.3	0.86	20	250	410'	108.5	0	0	129	0.043		
			5	20	9726	9730	4.0	0.80					AX Case					
			5	20	9730	9734	4.0	0.80					505'					
			5	40	9737	9740.8	3.8	0.76					N rod	0	0	149	0.036	
			5	40	9741	9744.5	3.5	0.70										
			5	40	9745	9748.5	3.5	0.70										
			5	80	9754	9757	3.0	0.60						0	0	189	0.033	
			5	80	9758	9761.5	3.5	0.70										
			5	80	9762	9765.4	3.4	0.68										
			5	120	9769	9772.9	3.9	0.78						0	0	229	0.038	Permeability 6 ft/yr
			5	120	9773	9776.8	3.8	0.76										Pressure Fluctuation
			5	120	9777	9780.7	3.7	0.74										
			5	80	9784	9787.2	3.2	0.64						0	0	189	0.031	
			5	80	9788	9791	3.0	0.60										
			5	80	9791	9794.2	3.2	0.64										
			5	40	9798	9801.5	3.5	0.70						0	0	149	0.034	
			5	40	9802	9805.5	3.5	0.70										
			5	40	9806	9809.2	3.2	0.64										
			5	20	9814	9817.4	3.4	0.68						0	0	129	0.032	
			5	20	9818	9821.1	3.1	0.62										
5	20	9822	9825.1	3.1	0.62													
	937' 8"	957' 8"	5	20	9871	9877.3	6.3	1.26	20	250	410'	108.5	0	0	129	0.060		
			5	20	9878	9883.9	5.9	1.18					AX Case					
			5	20	9884	9889.8	5.8	1.16					526'					
			5	40	9897	9903.2	6.2	1.24					N rod	0	0	149	0.061	
			5	40	9904	9910	6.0	1.20										
			5	40	9910	9916	6.0	1.20										
			5	80	9925	9932	7.0	1.40						0	0	189	0.069	
			5	80	9932	9939	7.0	1.40										
5	80	9939	9945.7	6.7	1.34													

DD 21 sheet 8

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Hole No. DD 21 (cont.)																	
1-10-65	937' 8"	957' 8"	5	120	9953	9960.6	7.6	1.52	20	250	410'	108.5	0	0	229	0.076	Permeability 10 ft/yr.
			5	120	9961	9968.5	7.5	1.50			AK Case						
			5	120	9969	9976.5	7.5	1.50			526'						
			5	80	9983	9990	7.0	1.40			N rod.		0	0	189	0.067	
			5	80	9990	9996.6	6.6	1.32									
			5	80	9997	10003.4	6.4	1.28									
			5	40	10009	10014.4	5.4	1.08					0	0	149	0.053	
			5	40	10015	10020.3	5.3	1.06									
			5	40	10021	10026.2	5.2	1.04									
			5	20	10031	10035.5	4.5	0.90					0	0	129	0.044	
			5	20	10036	10040.5	4.5	0.90									
			5	20	10041	10045.3	4.3	0.86									
1-10-65	957' 8"	978'	5	20	56	58	2.0	0.40	203	250	410'	108.5	0	0	129	0.016	Permeability 3 ft/yr.
			5	20	58	59.5	1.5	0.30			AK Case						
			5	20	59.5	61	1.5	0.30			526'						
			5	20	61	62.5	1.5	0.30			N rod.						
			5	40	65	66.5	1.5	0.30					0	0	149	0.015	
			5	40	66.5	68	1.5	0.30									
			5	40	68	69.5	1.5	0.30									
			5	80	72	73.5	1.5	0.30					0	0	189	0.015	
			5	80	73.5	75	1.5	0.30									
			5	80	75.5	77	1.5	0.30									
			5	120	80	81.6	1.6	0.32					0	0	229	0.018	
			5	120	81.6	83.9	2.3	0.46									
			5	120	84	85.8	1.8	0.36									
			5	120	85.8	87.6	1.8	0.36									
			5	80	90	91.5	1.5	0.30					0	0	189	0.015	
			5	80	91.5	93	1.5	0.30									
			5	80	93	94.5	1.5	0.30									
			5	40	100	101.5	1.5	0.30					0	0	149	0.015	
			5	40	101.5	103	1.5	0.30									
			5	40	103	104.5	1.5	0.30									
			5	20	107	108.3	1.3	0.26					0	0	129	0.014	
			5	20	108.3	109.7	1.4	0.28									
			5	20	109.7	111.1	1.4	0.28									
			5	20	111.1	112.5	1.4	0.28									
9-10-65	620'	640'	5	20	380	455	75	15	20	250	410'	108.5	77	3.9	117	0.750	Permeability 180 ft/yr.
			5	20	460	535	75	15			AK Case						
			5	20	540	615	75	15			208						
			5	40	700	790	90	18			N rod.		9.9	5.2	133	0.863	
			5	40	700	875	85	17									
			5	40	880	965	85	17									
			5	40	970	1055	85	17									
			4:55	80	150	250	100	20.35					13.3	7.3	168	1.012	
			4:56	80	250	350	100	20.27									
			5	80	350	450	100	20									
			4:24	120	550	650	100	22.73					16.9	8.5	203	1.141	
			4:20	120	650	750	100	23.08									
			4:25	120	750	850	100	22.64									
			4:56	80	950	1050	100	20.27					13.3	7.3	168	1.008	
			5	80	1050	1150	100	20									
			4:57	80	1150	1250	100	20.20									

DD 21 sheet 9

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DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS	
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)												
Drill Hole No. D.D. 22			Co-ordinates 43011E 78429N			R.L.: 3951.7 feet			Angle from Horizontal: -90°									
Packer Type: NX Mechanical and BX Hydraulic Water Supply - Coventry Climax Fire Pump.																		
27-4-66	302	352	5	25	4150	4186	36	7.2	50	85	305'	37	0	5	57	0.148	NX Mechanical packer	
			5	25	4186	4223	37	7.4				AX						
			5	25	4223	4260	37	7.4				Casing						
			5	50	4300	4348	48	9.6					0	7	80	0.192		
			5	50	4348	4394	46	9.2										
			5	50	4394	4444	50	10.0										
			6	75	4500	4556	56	11.2					1	8	103	0.224		
			5	75	4556	4612	56	11.2										
			5	75	4612	4666	54	10.8										
			5	100	4730	4807	77	15.4					1	12	124	0.308		Permeability 80 ft/year
			5	100	4807	4884	77	15.4										
			5	100	4890	4967	77	15.4										
			5	75	5032	5095	63	12.6					1	9	102	0.252		
			5	75	5095	5158	63	12.6										
			5	75	5158	5220	62	12.4										
			28-4-66	352	403	5	25	5600				5692	92	18.4	51	90		355'
5	25	5692				5781	89	17.8	AX									
5	25	5781				5868	87	17.4	Casing									
5	50	800				900	100	20.0		2	16	71	0.392					
5	50	900				1000	100	20.0										
5	50	00				100	100	20.0										
4.15	75	200				300	100	23.5		3	20	89	0.461					
4.14	75	300				400	100	23.6										
4.14	75	400				500	100	23.6										
3.40	100	600				700	100	27.2		4	23	112	0.515	Permeability 150 ft/year				
3.50	100	700				800	100	26.1										
3.55	100	800				900	100	25.5										
5	75	00				100	100	20.0		2	16	94	0.392					
5	75	100				200	100	20.0										
5	75	200				300	100	20.0										
4-5-66	406'6"	456'6"				5	50	400	490	90	18.0	50	75	410'			32	
			5	50	470	580	90	18.0										
			5	50	580	670	90	18.0										
			5	25	800	885	85	17.0		2	13				49	0.334		
			5	25	900	985	85	17.0										
			5	25	985	1070	85	17.0										
			4.20	25	700	800	100	23.1		4	20				33	0.470		
			4.15	25	800	900	100	23.5										
			4.15	25	900	1000	100	23.5										
			3.12	50	100	200	100	31.2		6	27				49	0.620		
			3.13	50	200	300	100	31.0										
			3.14	50	300	400	100	30.9										
			3.00	75	600	700	100	33.3		7	30				70	0.667		
			3.00	75	700	800	100	33.3										
			3.00	75	800	900	100	33.3										

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS							
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)																		
Drill Hole: D.D.22 (cont)																								
4.5.66	406'6"	456'6"	2:30	100	100	200	100	40.0	50	75'	410'	32	10	38	84	0.828	≡ Permeability 300ft/yr							
			2:25	100	300	400	100	41.4										AX						
			2:25	100	400	500	100	41.4										Casing						
			3:00	75	700	800	100	33.3											7	30	70	0.667	After test was completed water flowed out top of casing at 10 g.p.m. for 10 minutes then reduced in flow until stopped at 30 minutes after test	
			3:00	75	800	900	100	33.3																
			3:00	75	900	1000	100	33.3																
			3:40	50	200	300	100	27.3											5	23	54	0.546		
			3:40	50	300	400	100	27.3																
			3:40	50	400	500	100	27.3																
			4:20	25	700	800	100	23.1											3	19	35	0.460		
			4:24	25	800	900	100	22.7																
			4:23	25	900	1000	100	22.8																
18.5.66	635'6"	655'6"	5	25	100	140	40	8.0	20	65	637'	28	1	6	46	0.40	NX Mechanical Packer							
			5	25	140	180	40	8.0										AX						
			5	25	180	220	40	8.0										Casing						
			5	50	250	310	60	12.0											2	9	67	0.60		
			5	50	310	370	60	12.0																
			5	50	370	430	60	12.0																
			5	75	450	540	90	18.0											3	14	86	0.90		
			5	75	540	630	90	18.0																
			5	75	630	720	90	18.0																
			4:40	100	750	850	100	21.4											4	17	107	1.06	≡ Permeability 300ft/yr	
			4:43	100	850	950	100	21.2																
			4:47	100	950	1050	100	20.9																
			5	75	200	285	85	17.0											3	13	87	0.85		
			5	75	285	370	85	17.0																
			5	75	370	455	85	17.0																
			5	50	500	550	50	10.0											1	7	70	0.50		
			5	50	550	600	50	10.0																
			5	50	600	650	50	10.0																
			5	25	670	700	30	6.0											0	4	49	0.30		
			5	25	700	730	30	6.0																
5	25	730	760	30	6.0																			
19.5.66	655'	674'	5	25	934.0	939.5	5.5	1.1	19	65	655'	28	0	0	53	0.058	NX Mechanical Packer							
			5	25	939.5	946.0	6.5	1.3										AX						
			5	25	946.0	951.5	5.5	1.1										Casing						
			5	50	955.0	963.0	8.0	1.6											0	0	78	0.084		
			5	50	963.0	971.0	8.0	1.6																
			5	50	971.0	979.0	8.0	1.6																
			5	75	985.0	996.0	11.0	2.2											0	0	103	0.116		
			5	75	996.0	1007.0	11.0	2.2																
			5	75	1007.0	1018.0	11.0	2.2																
			5	100	020.0	033.0	13.0	2.6											0	0	128	0.137	≡ Permeability 35 ft/yr	
			5	100	033.0	046.0	13.0	2.6																
			5	100	046.0	059.0	13.0	2.6																
			5	75	070.0	081.0	11.0	2.2											0	0	103	0.116		
			5	75	081.0	092.0	11.0	2.2																
			5	75	092.0	113.0	11.0	2.2																
			5	50	130.0	138.0	8.0	1.6											0	0	78	0.084		
			5	50	138.0	146.1	8.1	1.62																
			5	50	146.1	154.1	8.0	1.6																
			5	25	165.0	170.0	5.0	1.0											0	0	53	0.055		
			5	25	170.0	175.2	5.2	1.04																

DD 22 Sheet 3

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICTION SUPPLY LINE (p.s.i.)	LOSSES PACKER (p.s.i.)	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			START (gallons)	FINISH (gallons)											
Drill Hole No DD 22 (Cont.)																	
19. 5. 66	655'	674'	5	25	175.2	180.4	5.2	1.04	19	65	655' AX						
15. 6. 66	689' 6"	709' 6"	5	25	0	12	12	2.4	20	75	688' Casing	32	0	1	56	0.12	Bx Hydraulic Packer
			5	25	12	24	12	2.4			AX						
			5	25	24	36	12	2.4			Casing						
			5	50	50	66	16	3.2					0	1	81	0.16	
			5	50	66	82	16	3.2									
			5	50	82	98	16	3.2									
			5	75	110	130	20	4.0					0	2	105	0.20	
			5	75	130	150	20	4.0									
			5	75	150	170	20	4.0									
			5	100	180	206	26	5.2					0	3	129	0.26	≡ Permeability 60 ft/yr
			5	100	206	232	26	5.2									
			5	100	232	258	26	5.2									
			5	75	270	291	21	4.2					0	2	105	0.21	
			5	75	291	312	21	4.2									
			5	75	312	333	21	4.2									
			5	50	340	356	16	3.2					0	1	81	0.16	
			5	50	356	372	16	3.2									
			5	50	372	388	16	3.2									
			5	25	345	406	11	2.2					0	1	56	0.11	
			5	25	406	417	11	2.2									
			5	25	417	428	11	2.2									
15. 6. 66	709' 6"	729' 6"	5	25	280.0	282.0	2.0	0.4	20	75	710' AX	32	0	0	57	0.02	Bx Hydraulic Packer
			5	25	282.0	284.0	2.0	0.4			AX						
			5	25	284.0	286.0	2.0	0.4			Casing						
			5	50	287.0	289.2	2.2	0.44					0	0	82	0.022	
			5	50	289.2	291.4	2.2	10.44									
			5	50	291.4	293.6	2.2	0.44									
			5	75	294.0	296.5	2.5	0.50					0	0	107	0.025	
			5	75	296.5	299.0	2.5	0.50									
			5	75	299.0	301.5	2.5	0.50									
			5	100	303.0	305.5	2.5	0.50					0	0	132	0.027	≡ Permeability 8 ft/yr
			5	100	305.5	308.2	2.7	0.54									
			5	100	308.2	310.9	2.7	0.54									
			5	75	313.0	315.5	2.5	0.50					0	0	107	0.025	
			5	75	315.5	318.0	2.5	0.50									
			5	75	318.0	320.5	2.5	0.50									
			5	50	322.0	324.2	2.2	0.44					0	0	82	0.022	
			5	50	324.2	326.4	2.2	0.44									
			5	50	326.4	328.6	2.2	0.44									
			5	25	330.0	332.0	2.0	0.40					0	0	57	0.020	
			5	25	332.0	334.0	2.0	0.40									
			5	25	334.0	336.0	2.0	0.40									
16. 6. 66	729' 6"	746' 9"	5	25	3.0	5.5	2.5	0.50	17.25	80	727' AX	35	0	0	60	0.029	Bx Hydraulic Packer
			5	25	5.5	8.1	2.6	0.52			AX						
			5	25	8.1	10.4	2.3	0.46			Casing						
			5	50	2.0	4.7	2.7	0.54					0	0	85	0.033	
			5	50	4.7	7.5	2.8	0.56									
			5	50	7.5	10.4	2.9	0.58									
			5	75	1.4	4.0	3.6	0.72					0	0	110	0.042	
			5	75	4.0	7.5	3.5	0.70									
			5	75	7.3	11.2	3.7	0.74									

DD 22 Sheet 4

DATE	SECTION TESTED		TIME OF TEST (min.)	GAUGE PRESSURE (p.s.i.)	WATER METER READINGS		WATER LOSS (gallons)	LEAKAGE RATE (g.p.m.)	LENGTH OF SECTION (ft.)	VERTICAL DEPTH OF STANDING WATER (ft.)	LENGTH & SIZE OF SUPPLY LINE	WATER COLUMN PRESSURE (p.s.i.)	FRICITION	LOSSES	EFFECTIVE TEST PRESSURE (p.s.i.)	WATER LOSS (g.p.m. per ft.)	REMARKS
	FROM (ft.)	TO (ft.)			SUPPLY LINE (p.s.i.)	PACKER (p.s.i.)											
Drill Hole No. D.D. 22 (cont.)																	
16.6.66	729'6"	746'9"	5	100	5.0	9.1	4.1	0.82	17.25	80	727'	35	0	0	135	0.043	≡ Permeability 10 ft/year
			5	100	9.1	13.0	3.9	0.78			AX						
			5	100	13.0	17.2	4.2	0.84			Casing						
			5	75	8.0	11.0	3.0	0.60				0	0	110	0.032		
			5	75	11.0	14.1	3.1	0.62									
			5	75	14.1	17.1	3.0	0.60									
			5	50	8.4	10.7	2.3	0.46				0	0	85	0.024		
			5	50	10.7	13.2	2.5	0.50									
			5	50	13.2	15.4	2.2	0.44									
			5	25	6.0	8.0	2.0	0.40				0	0	60	0.021		
			5	25	8.0	10.0	2.0	0.40									
			5	25	10.0	12.1	2.1	0.42									
17.6.66	746'9"	770'	5	25	0.0	0.5	0.5	0.10	23.25	80	745'	35	0	0	60	0.004	BX Hydraulic Packer
			5	25	0.5	1.2	0.7	0.14			AX						
			5	25	1.2	1.7	0.5	0.10			Casing						
			5	50	2.4	3.3	0.9	0.18				0	0	85	0.009		
			5	50	3.3	4.3	1.0	0.20									
			5	50	4.3	5.3	1.0	0.20				0	0	110	0.013		
			5	75	6.0	7.5	1.5	0.30									
			5	75	7.5	9.7	1.7	0.34									
			5	75	9.2	10.6	1.4	0.28									
			5	100	12.0	14.1	2.1	0.42				0	0	135	0.018		
			5	100	14.1	16.2	2.1	0.42									
			5	100	16.2	18.3	2.1	0.42									
			5	75	19.0	20.4	1.4	0.28				0	0	110	0.013		
			5	75	20.4	22.1	1.7	0.34									
			5	75	22.1	23.6	1.5	0.30									
			5	50	24.0	25.0	1.0	0.20				0	0	85	0.009		
			5	50	25.0	26.0	1.0	0.20									
			5	50	26.0	27.0	1.0	0.20									
5	25	27.4	28.1	0.7	0.14				0	0	60	0.004					
5	25	28.1	28.6	0.5	0.10												
5	25	28.6	29.3	0.7	0.14												
21.6.66	770	800	5	25	497.0	500.0	3.0	0.60	30	108'	773 ft	47	0	0	72	0.020	BX Hydraulic Packer
			5	25	500.0	503.5	3.5	0.70			AX						
			5	25	503.5	507.0	3.5	0.70			Casing						
			5	50	513.0	519.0	6.0	1.20				0	0	97	0.043		
			5	50	519.0	525.5	6.5	1.30									
			5	50	525.5	532.0	6.5	1.30									
			5	75	533.0	540.0	7.0	1.40				0	0	122	0.053		
			5	75	540.0	548.0	8.0	1.60									
			5	75	548.0	556.0	8.0	1.60									
			5	100	557.0	567.0	10.0	2.00				0	0	147	0.067		
			5	100	567.0	577.0	10.0	2.00									
			5	100	577.0	587.0	10.0	2.00									
			5	75	595.0	603.0	8.0	1.60				0	0	122	0.053		
			5	75	603.0	611.0	8.0	1.60									
			5	75	611.0	619.0	8.0	1.60									
			5	50	624.0	630.0	6.0	1.20				0	0	97	0.040		
			5	50	630.0	636.0	6.0	1.20									
			5	50	636.0	642.0	6.0	1.20									
5	25	650.0	654.0	4.0	0.80						0	72	0.027				
5	25	654.0	658.0	4.0	0.80												
5	25	658.0	662.0	4.0	0.80												

APPENDIX 9

RECOMMENDATIONS FOR CONTRACT PROVISIONS

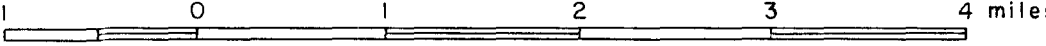
In order to facilitate the geological supervision of construction and to minimize the need for special arrangements or agreements during construction of the Upper Ramu Scheme it is recommended that consideration be given to the inclusion of the following clauses in the contract:

1. that reasonable access as required should be provided to the geologist to all rock faces for the purpose of geological examination;
2. that provision should be made for either (a) contractor to clean and wash down exposures as required by the geologist, the cost of such services to be part of the contract price, or (b) the contractor to quote per hour (or area) for cleaning and washing down as required by the geologist;
3. that a price be included in the contract for the installation of extensometers, flat jacks and such other instrumentation as may be considered desirable by the Supervising Engineer;
4. that the contract should specify that the contractor should take all due care to avoid damage to survey and scientific instruments, and shall replace without cost any that are damaged;
5. that access shall be provided to all survey and scientific instruments, as required;
6. that a price should be included in the contract for the sinking of costeans and pits for the geological investigation of rock conditions during construction;
7. that feeler holes, of at least $1\frac{1}{2}$ inch diameter are to be drilled ahead of underground working faces as required by the Supervising Engineer with the location, direction and length as specified by him. Price for feeler holes, per foot, to be quoted;
8. the contract should provide that the contractor shall bear the cost of controlling, and disposing of, all inflows of water into underground workings up to a total of X-thousand gallons per hour of free-draining water and Y-thousand gallons per hour of pumped water; he shall quote a price for disposing (a) by pumping and (b) by free-draining, of all water in excess of the specified rates. If at any point water inflow exceeds Z-thousand gallons per hour the cost of control measures shall be subject to negotiation. (It may be necessary to distinguish between initial inflow and sustained inflow).

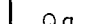
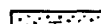
UPPER RAMU HYDROELECTRIC SCHEME
REGIONAL GEOLOGY OF THE KAINANTU AREA

ADAPTED FROM
THE GEOLOGY OF THE KAINANTU GOLDFIELDS T.N.G.
(Dow and Plane 1965)

Scale



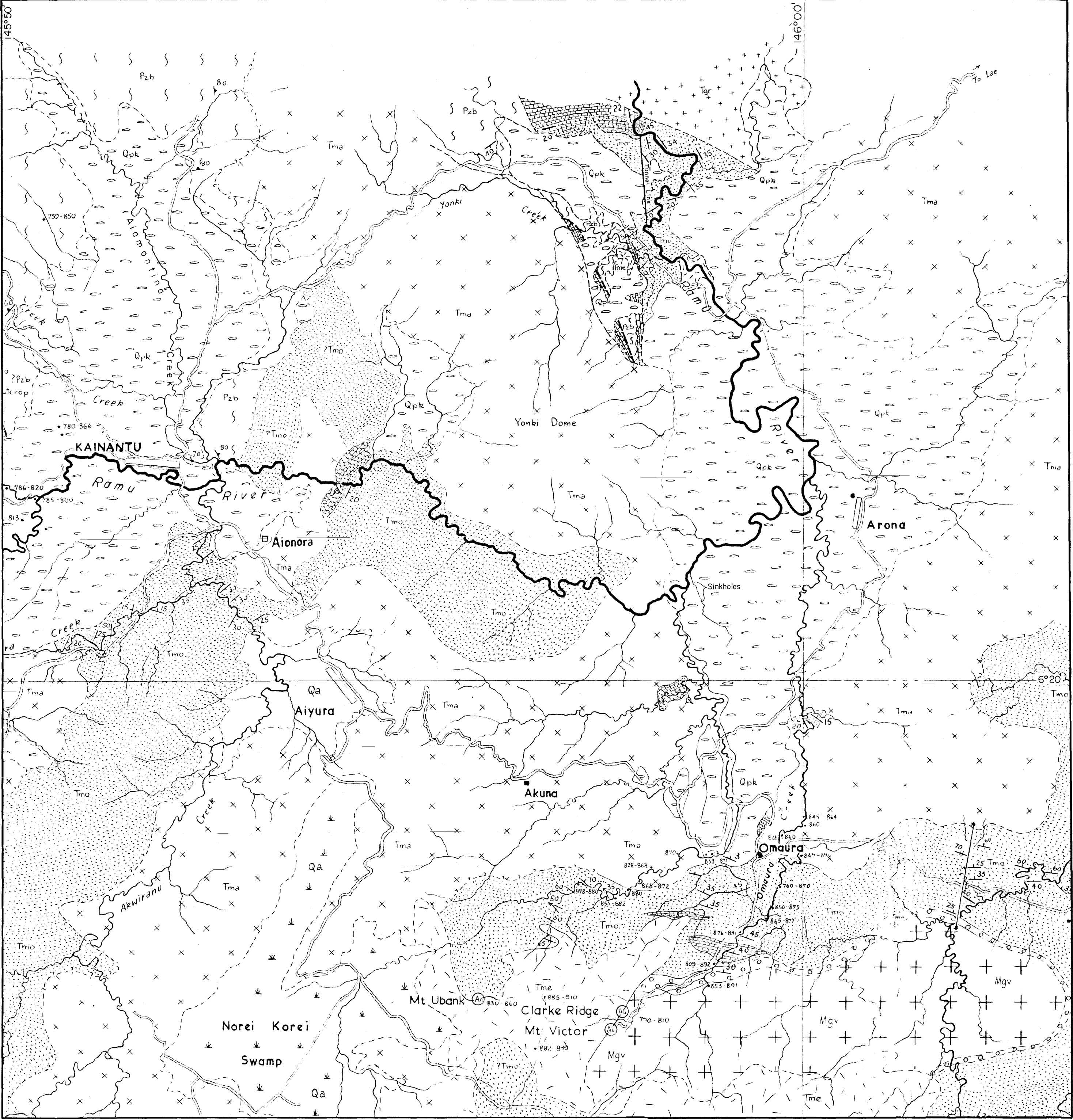
REFERENCE

QUATERNARY	{		Undifferentiated		<i>Clay, silt, sand, gravel, and boulder beds</i>		
		Pleistocene	Kainantu Beds		<i>Clay, sand, gravel, and conglomerate</i>		
TERTIARY	{	Lower Miocene	e-stage	{	Omaura Greywacke		<i>Greywacke and siltstone with limestone arkose, and pebble conglomerate limestone (marble)</i>
					Nasananka Conglomerate		<i>Conglomerate, arkose, and minor greywacke</i>
?PALAEOZOIC	TQ	?MESOZOIC	Bena Bena Formation		<i>Schist, gneiss, quartzite</i>		

IGNEOUS ROCKS

TERTIARY	Miocene	f ₁₋₂ stage	Elendora Porphyry	Andesite porphyry, microgranodiorite
			Akuna Dolerite	Diorite, gabbro and peridotite
			Tgr	Granodiorite (Ramu Gorge area)
MESOZOIC			Mgv	Granodiorite, quartz diorite

- Established boundary - position accurate
- Established boundary - position approximate
- Inferred, probable of indefinite boundary
- Inclined
- Vertical
- Strike and dip of foliation
- Plunge of minor fold
- Fault - position approximate
- Microfossil locality
- Measured section
- Minor mineral occurrence
- Unworked deposit
- Gold fineness
- Road
- Walking track
- Village



N
Grid

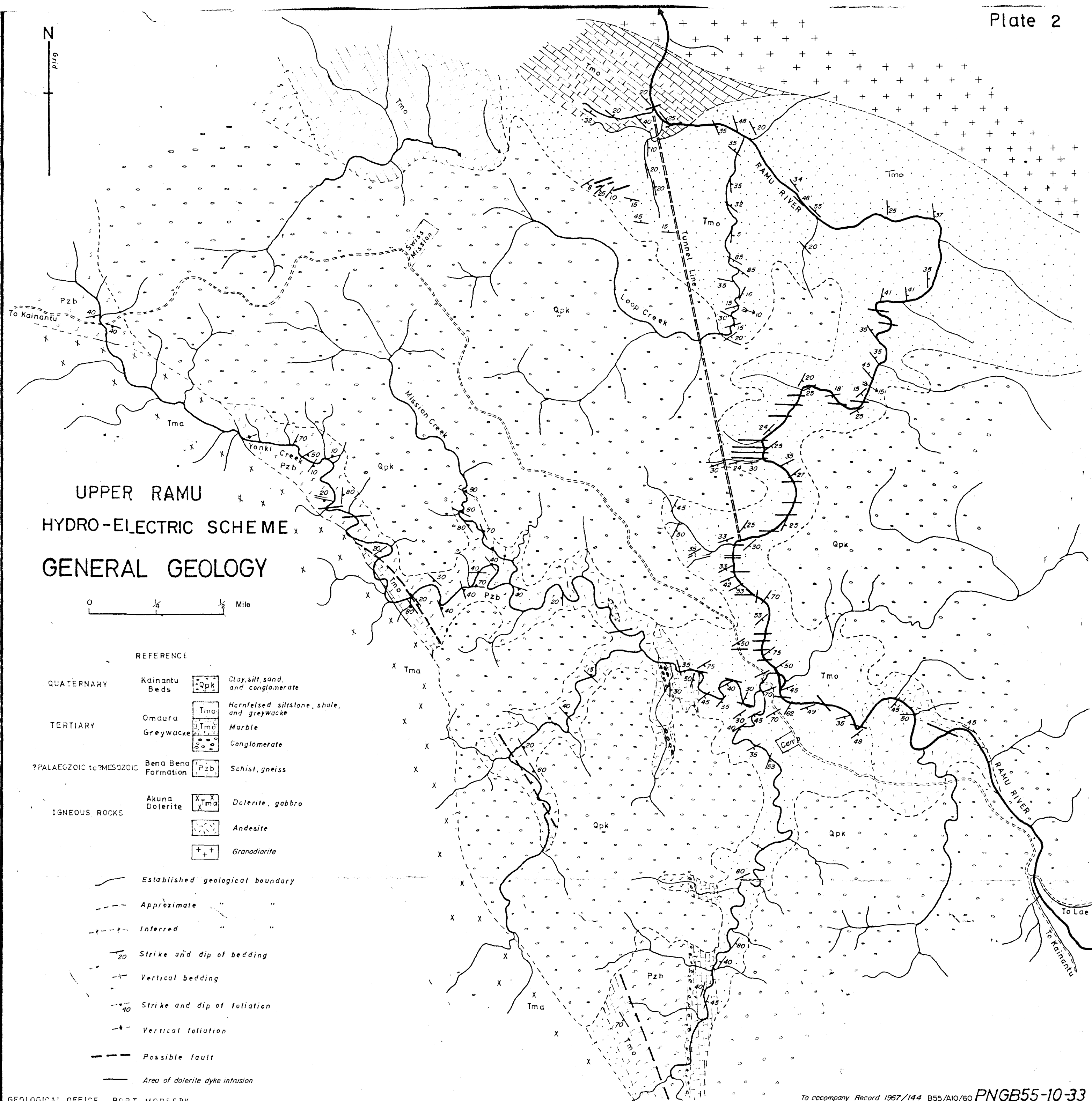
UPPER RAMU HYDRO-ELECTRIC SCHEME GENERAL GEOLOGY

0 1/4 1/2 Mile

REFERENCE

QUATERNARY	Kainantu Beds	Qpk	Clay, silt, sand and conglomerate
TERTIARY	Omaura	Tmo	Hornfelsed siltstone, shale, and greywacke
	Greywacke	Tmc	Marble
			Conglomerate
?PALAEOZOIC to ?MESOZOIC	Bena Bena Formation	Pzb	Schist, gneiss
IGNEOUS ROCKS	Akuna Dolerite	X Tma	Dolerite, gabbro
			Andesite
		++	Granodiorite

- Established geological boundary
 - - - Approximate " "
 - - - - - Inferred " "
 20 Strike and dip of bedding
 + Vertical bedding
 40 Strike and dip of foliation
 + Vertical foliation
 - - - Possible fault
 — Area of dolerite dyke intrusion



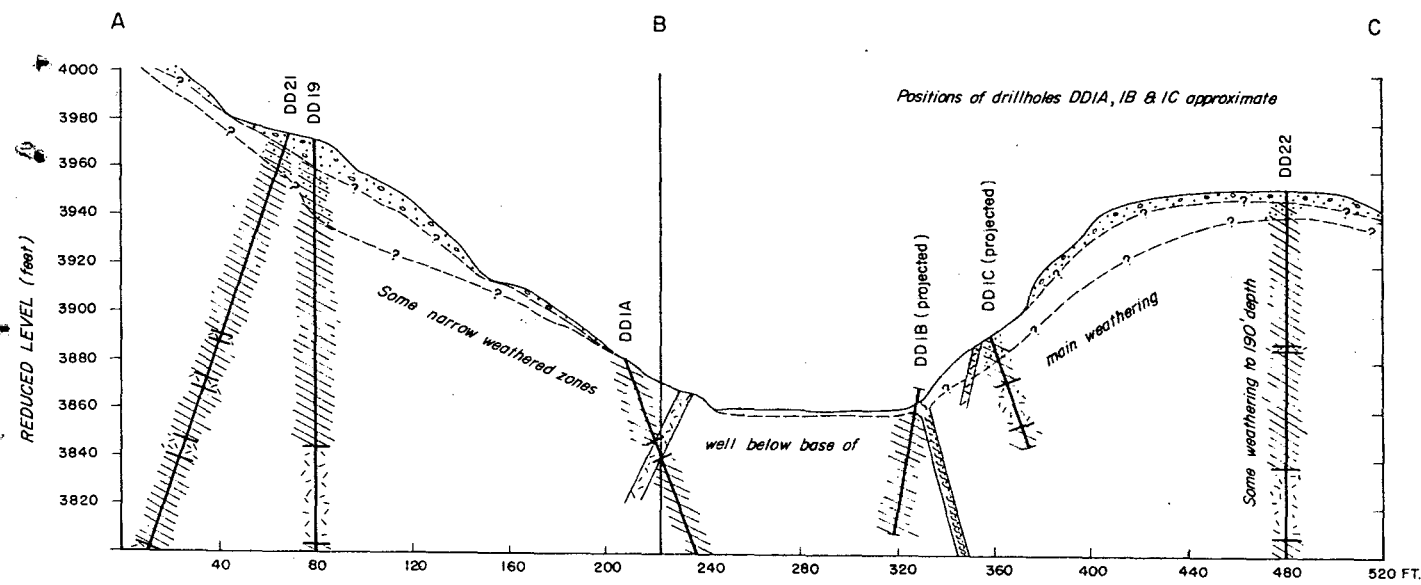


To Accompany Record 1967/144

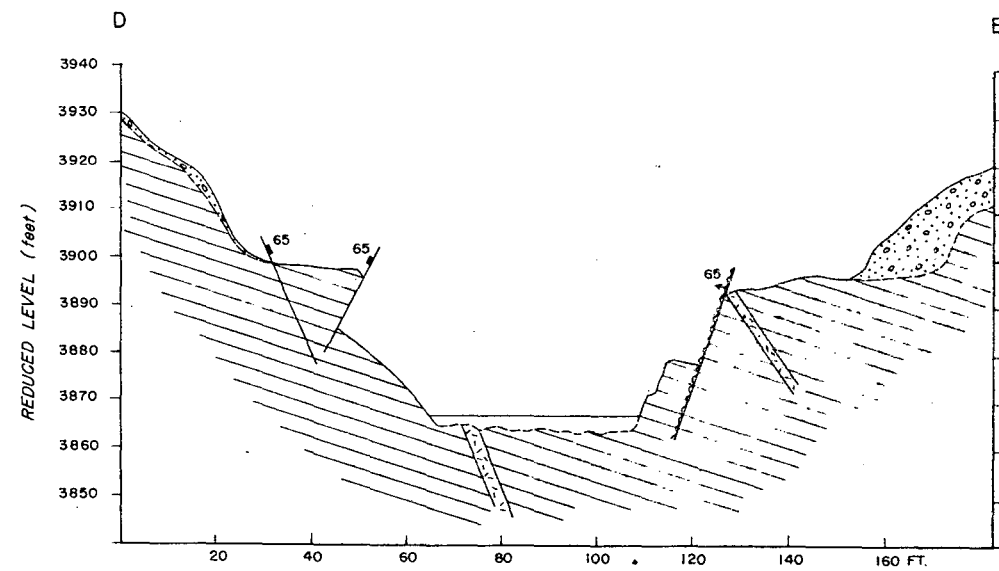
B55/A10/61

GEOLOGICAL SECTIONS THROUGH WEIR SITES Nos 1, 2. and GEOLOGICAL PLANS OF COSTEANS Nos 3, 4. UPPER RAMU HYDRO-ELECTRIC SCHEME

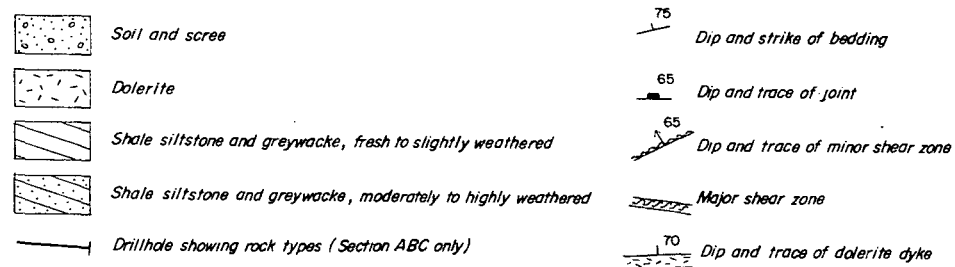
PLATE 4



WEIR SITE No. 1 Cross section ABC, looking downstream
SCALE 1 INCH to 80 FEET

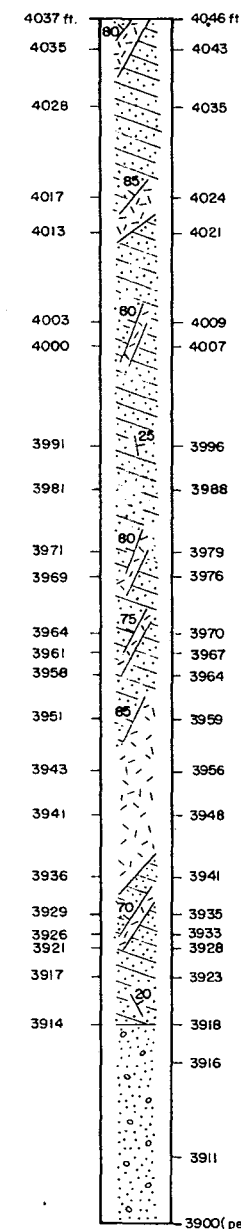


WEIR SITE No. 2 Cross section DE, looking downstream
SCALE 1 INCH to 40 FEET



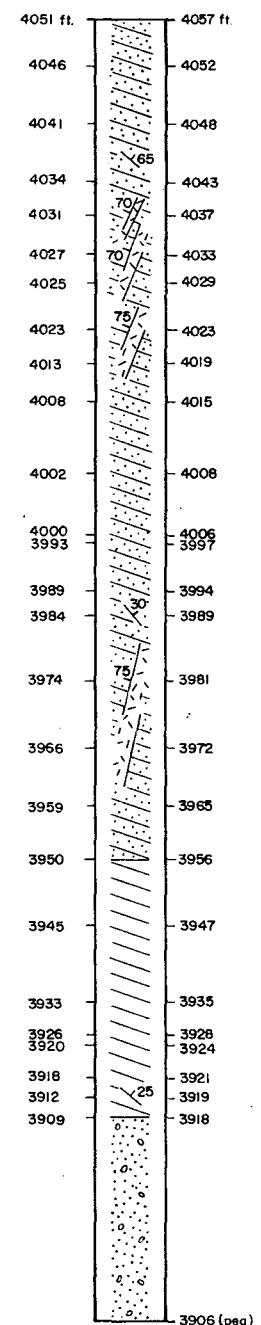
Note — See Plate 3 and Fig. 13 for locations of weir sites and costeans

REDUCED LEVEL OF BEDROCK REDUCED LEVEL OF NATURAL SURFACE



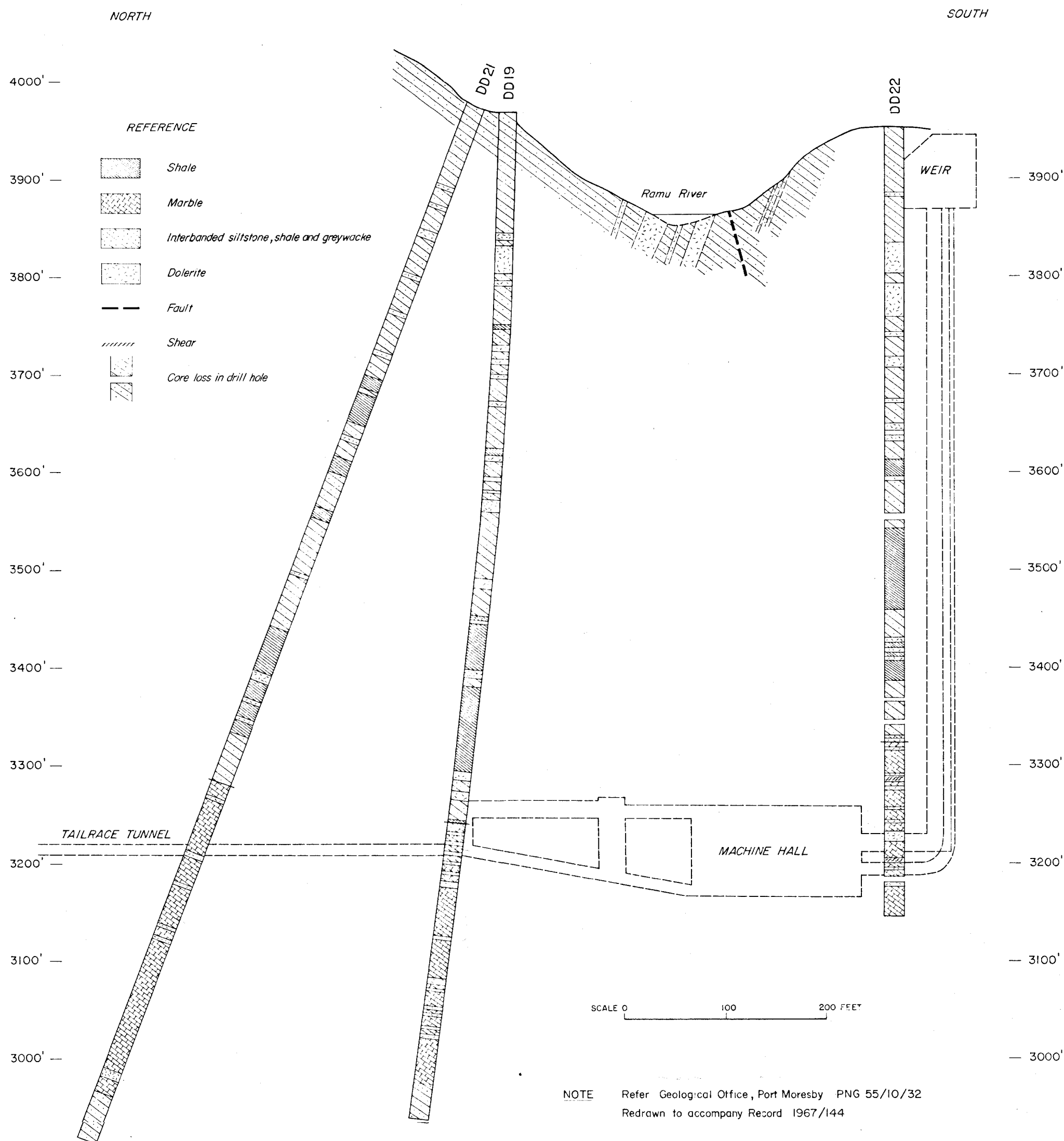
FLOOR PLAN, COSTEAN No. 4
Bearing 073°

REDUCED LEVEL OF BEDROCK REDUCED LEVEL OF NATURAL SURFACE

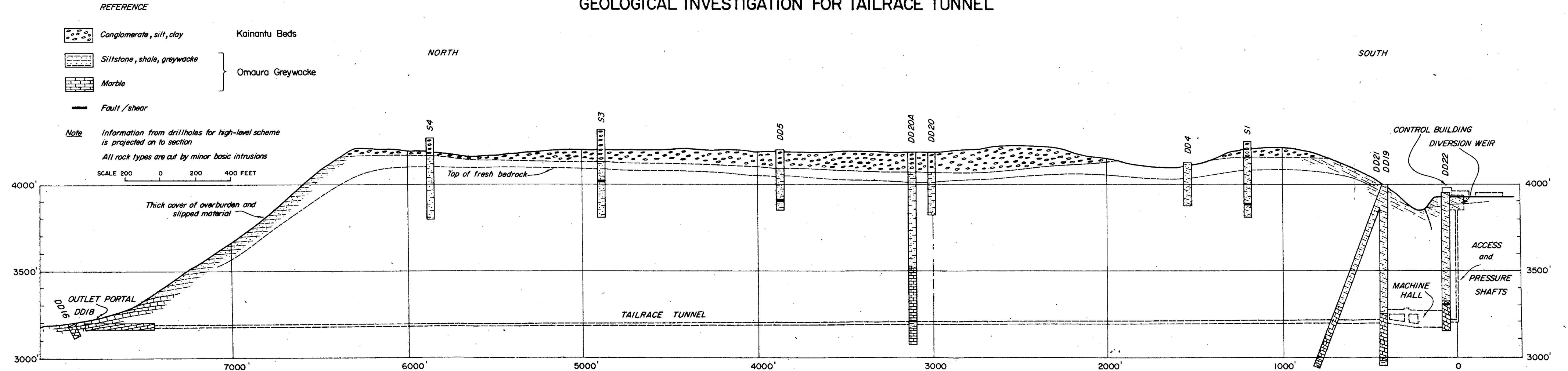


FLOOR PLAN, COSTEAN No. 3
Bearing 089°

UPPER RAMU HYDRO-ELECTRIC SCHEME GEOLOGICAL INVESTIGATION FOR UNDERGROUND WORKS AT INTAKE



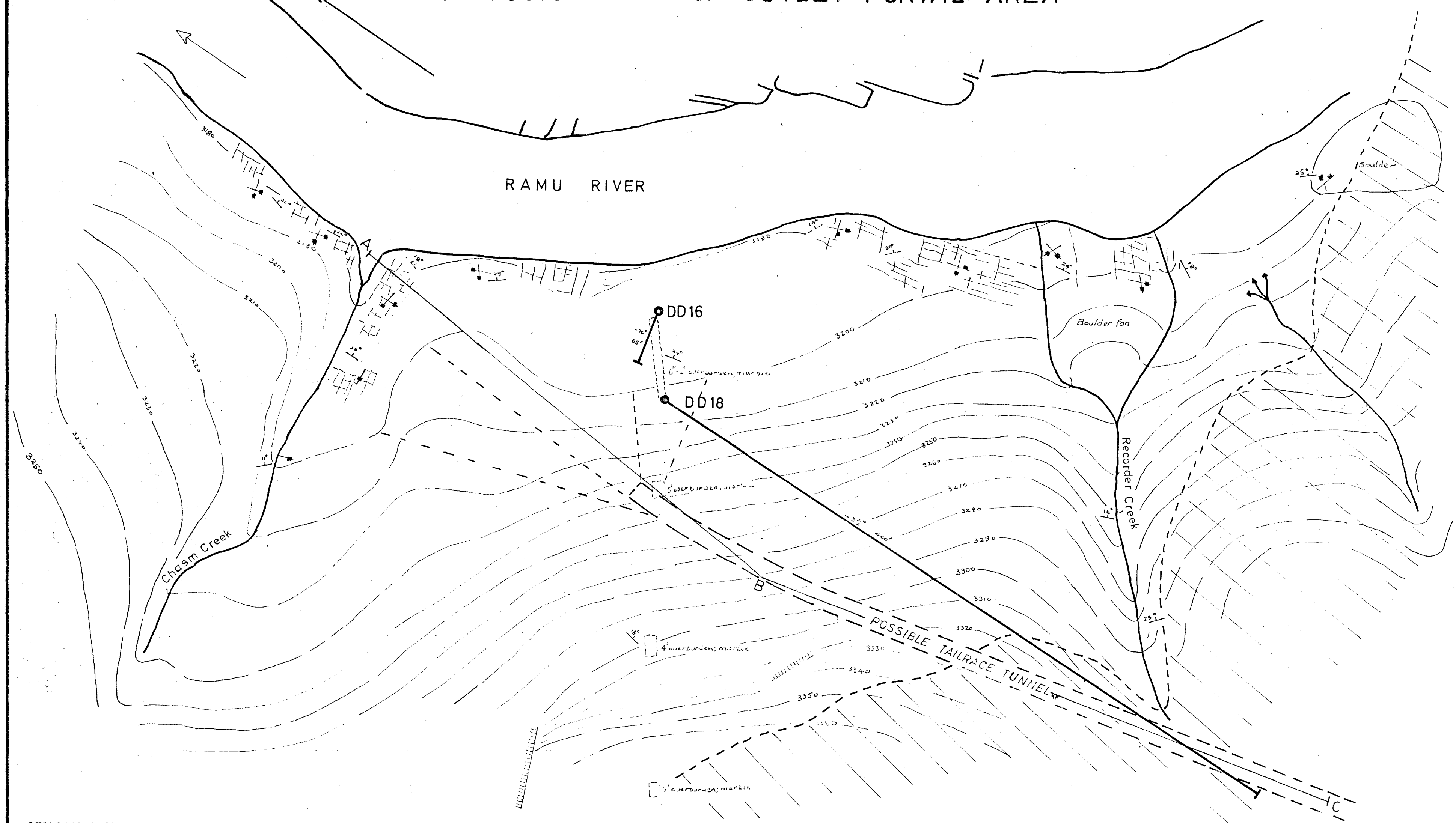
UPPER RAMU HYDRO-ELECTRIC SCHEME GEOLOGICAL INVESTIGATION FOR TAILRACE TUNNEL



Draft - Geological Office, Port Moresby PNGB55-10-43
Redrawn - B.M.R. To accompany Record 1967/144

UPPER RAMU HYDRO-ELECTRIC SCHEME GEOLOGICAL MAP OF OUTLET PORTAL AREA

PLATE 7



REFERENCE

- Dip and strike of bedding
- Trace of top of marble (inferred)
- Trace of joint pattern
- Strike of joints
- Cliff or near vertical slope
- Costean
- Diamond drill hole
- Marble
- Metasediments-siltstone, shale

Based on drawing PNG 7e/9 by J.K.Hill



UPPER RAMU HYDRO-ELECTRIC SCHEME GEOLOGICAL SECTION THROUGH OUTLET PORTAL (A-B-C on PLATE 7)

PLATE 8

