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REPORT ON EXPLORATORY DRILLING, UPPER RAMU HYDRO-ELECTRIC PROJECT, JUNE 1963

by

J.K. Hill

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INTRODUCTION

This report has been prepared as a result of a brief visit made to the project from 24th May to 8th June 1963. It contains a summary of drilling completed by the beginning of June, geological conclusions, an outline of a modified drilling programme and a proposed seismic survey, and recommendations concerning improved drilling equipment for future work.

RESULTS OF DRILLING COMPLETED BY 8.6.63.

D.D.1 (previously U.R.1) was completed in 1961 and the core has now been examined in detail. Good correlation has been found with the surface geology, and the gabbro dykes shown in Plate 4 of Record 1962/95 are now known to occupy much of the bed of the river. These rocks are mainly hard and strong and would make a satisfactory foundation for a low dam. However, the major fault mapped on the surface near station JG (on Plate 4) also continues along the river, as shown by the sheared and faulted bed of incompetent shale penetrated by D.D.1 from 7'6" to 31'6", the zones of core loss from 38' to 56', and the traces of fault gouge and breccia associated with the latter. The fault itself is estimated to lie at 48' in the hole. The incompetent shale bed would not provide a satisfactory foundation or abutment for a low dam, and excavation and anchorage difficulties in the right abutment would be increased by the presence of the fault itself. Because of the lack of an obviously favourable alternative site, it is felt that the present site should not be abandoned at this stage without first drilling D.D.1B to check the existence and extent of the shale bed in the abutment. The inclination of D.D.1B may be altered slightly. If D.D.1B reveals reasonably sound rock, D.D.1A should be drilled to complete the investigation of the site.

The water pressure test results have not yet been received for D.D.1.

Drilling was suspended on D.D.5 on 10th May because the depth at which permeability testing was scheduled to start had been exceeded without suitable storage tanks and pumps etc being available. The programme provided for permeability testing in 20 ft stages as the hole deepened from 300 to 400 feet. The hole has now reached 345 feet without testing being carried out. It is understood that it is planned to complete drilling and testing of this hole to 400 feet as soon as the necessary equipment has been installed. However, as far as can be ascertained, it appears that the hole is cased to 103 feet only, and it is very likely, for reasons outlined below, that the hole will have collapsed at 285 feet and minor caving taken place at any depth from 103 feet down. If this proves to be the case, it may be advisable to drill a fresh hole. Should it be necessary to suspend drilling of other holes until permeability testing can be commenced, it is recommended that the holes be temporarily cased to their full depth.

Core and sludge samples from D.D.5 show that the boulder bed described in Record 1962/95 extends from the surface to a depth of 101 feet. This is approximately 50 feet deeper than was estimated in the longitudinal section. The base of the boulder bed in the drill hole occurs at a level which agrees closely with the highest outcrop of metamorphic rocks found 600 feet to east in nearby Loop Creek, (about R.L. 4,120'). The R.L. of the tunnel at this point is about 3,855 feet. Running sands were encountered in the boulder bed immediately above the unconformity (i.e. bedrock) and at numerous other places in the formation.

From about 20 feet below the unconformity to a depth of 285 feet in the hole the formations consist of interbedded fresh silicified shales, sandstones, and siltstones intruded by basic igneous rocks (probably gabbro). Generally the thicker shale beds show a higher degree of fracuring than the more competent sandstones, siltstones and igneous rocks; the core from 101 to 159 feet is moderately sheared in places, but from 169 to 285 feet there is little evidence of faulting or weak rocks.

From 285 to 315 feet the hole passed through a major fault zone associated with an igneous intrusion. Core recovery was nil except for two short lengths of gabbro. The driller took samples of the sludge from this zone which consists of dark gritty sand. Previously it was thought that the sudden change from almost 100% core recovery to nil recovery was due entirely to the absence of rod grease causing excessive vibration of the drill rods, thus pulverizing the already closely jointed rock. It is now evident, after discussion with the native driller, Mr. B. James, that the sudden loss of core from 285 to 315 feet was <u>not</u> due to rod vibration but to the fact that the hole was penetrating a fault zone consisting mainly of dark blue-grey gouge, breccia and clay, and remnants of the intrusive gabbro. Fault gouge is readily dispersed by high velocity water at the bit face, and when sludge samples are taken only the coarser sand and grit fractions remain, the silt and clay size particles being removed by the circulating water.

Mr. James reported that for most of the interval from 285 to 315 feet, the formation was very soft and the average time taken to drill five feet was about 5 to 10 minutes. The time required to drill five feet in shale or sandstone elsewhere in the hole was usually 3 to 4 hours. In addition, as soon as the soft zone was encountered at 285 feet the drilling water changed from light grey to dark grey or black and remained that colour for the remainder of the hole.

There is no doubt that any vibration occurring at this stage would have helped to break down the fault gouge and to disperse the clay fraction in the drilling water, but the primary cause of nil core recovery from 285 to 315 feet is the existence of a large fault zone and the failure of the BX equipment to core it. The reasons for vibration are discussed later in this report.

The fault zone encountered in D.D.5 supports earlier evidence gained from surface mapping that the contact zones of the igneous intrusions are sometimes faulted. The short lengths of gabbro recovered in the middle of the zone are remnants of the intrusive rock. The constituents of the gabbro are susceptible, under great pressure, to chemical alteration to talc-like minerals which have low strength and are naturally greasy. They readily convert to fault gouge on shearing and crushing. The apparent thickness of the main fault zone is 30 feet; the true thickness is estimated to be about 20 feet. (These figures do not allow for the faulted bed of shale described below.) The remainder of the hole from 315 to 345 feet is in incompetent shale which shows much evidence of the proximity of the fault zone. In fact, three 5-foot intervals of nil or low recovery together with the presence of fragments of blue-grey gouge and breccia suggest that associated faults exist. If, on deepening this hole to 400 feet it is found that this is the case, it is recommended that the hole be continued to at least 500 feet to determine the extent of the faulted rock. Permeability testing should be carried out from 265 feet to bottom; the proposed programme will be altered to suit the geological conditions. On present indications the thickness of faulted rock which will be encountered in the tunnel at this point will be at least 50 feet.

D.D.6 was commenced on 1st April and reached a depth of 42 feet before being abandoned because of a spanner which was dropped down the hole. The hole was re-drilled about 2 feet away and eventually reached a depth of 81 feet before being again abandoned on my instructions. The hole encountered soil, fresh rock fragments, and weathered rock, underlain by what appears to be gritty sands and silts. Very little core was recovered, but sludge samples were taken. The hole was eventually abandoned because of continuous caving and jamming, and lack of sufficient power from the rig to drill-in NX or BX casing. Much of the trouble with D.D.6 was undoubtedly due to its proximity to the first hole drilled at this site.

The geological conditions encountered in D.D.6 are not those anticipated and present a problem which cannot be resolved until further holes are drilled in the vicinity and a seismic survey carried out. There are four possible geological interpretations which can be made on the evidence to date. Briefly these are as follows:-

1) D.D.6 is sited over a deep sub-surface valley in the metamorphic basement, filled with lacustrine or fluvial sediments and boulders.

2) D.D.6 has penetrated a thick mantle of landslide or slump material which has gravitated from the lacustrine deposits above.

3) D.D.6 is near a fault along which a block of lacustrine material has been moved to a lower level.

4) D.D.6 is in a fault zone in the metamorphic rocks and the sand recovered is residual material from fault gouge and breccia.

There is evidence to support each of these theories, but it will not be described here. It is obvious that, whichever theory is correct, the engineering geological implications have a considerable bearing on the scheme and investigations for it.

Should a deep sediment-filled subsurface valley exist near D.D.6, the inference is that such a valley could be found at other places along the tunnel line, possibly of sufficient depth to either reduce the thickness of solid rock above the tunnel to a dangerously low figure, or to be encountered by the tunnel. This question can only be resolved by a seismic survey supported by percussion and diamond drilling where necessary.

If a great thickness of landslide or slump material exists on the slopes adjacent to D.D.6 then conditions are unfavourable for constructing a tunnel portal and surface penstock. A seismic survey would give a continuous overburden-bedrock profile.

If D.D.6 is in a block of down-faulted lacustrine material then the implications are that either the fault or the lacustrine material could be encountered near the tunnel portal, and that such down faulted blocks could exist elsewhere in the scheme.

If D.D.6 is in a fault zone in the basement rocks, as suggested under 4) above, it is possible that the fault is a major one or that an extensive fault complex exists in the area, (evidence from costeans supports this). A seismic survey supported by diamond drill holes would be the best way of checking this possibility

A revised drilling programme to be undertaken in conjunction with a seismic survey is outlined in the next section.

Hole P.5 was commenced and reached a depth of about 30 feet when it was abandoned on my instructions. The drilling rig was moved to D.D.4, which has been re-located, and will be ready to spud-in about 12th June. (The rig from D.D.6 was moved to the new location for D.D.7 and is ready to commence drilling.) P.5 should not have been commenced at this stage as it is one of 6 holes contingent on the results of D.D.4, 5, and 6, which have not yet been completed.

REVISED DRILLING PROGRAMME

Because of the difficulties encountered so far in penetrating both overburden and lacustrine sediments, a modified drilling programme is proposed, aimed at reducing the amount of diamond drilling and at providing control for a seismic survey.

D.D.1A and D.D.1B should be drilled as originally proposed, except that the inclination may be changed slightly.

D.D.2, 2A, and 3 will be re-located because of a change in the alignment of the proposed tunnel at the intake structure, (see new specifications, sections and plans).

D.D.4 has been moved to chainage 1385' on the tunnel line with the object of eliminating drilling through the boulder bed. It will now be a vertical hole 320 feet deep. The new position and angle are less favourable geologically but this disadvantage will probably be more than offset by better drilling conditions and core recovery.

D.D.5 was drilled to 345 feet at which depth drilling was suspended. The hole has been cased to 103 feet only, and it is very likely that the hole has caved in at some depth below the bottom of the casing. If this is found to be the case, a decision as to whether the old hole should be drilled out or a new vertical hole drilled should be made by the Drilling Supervisor. If the existing hole is drilled out, it should be deepened until the faulted shale bed and associated fault zones have been penetrated. This may require drilling to a total depth of about 500 feet. The hole should be water pressure tested from 265 feet (just above the fault zone) to the bottom. Care should be exercised in selecting depths for and positioning the packer in this hole. If it is decided to drill a new vertical hole a site should be chosen well away from the existing one.

D.D.6 has been abandoned at 81 feet. It is not anticipated that any further attempts will be made to drill from this site.

A new site (chainage 6500') has been chosen for D.D.7, (see sections and plans). The new position is planned to be below the bottom of the sedimentary beds or away from the faulted zone, whichever interpretation is given to results from D.D.6. The hole will be vertical and it is expected that the only difficulties to be encountered will be in penetrating the soil and rock overburden which may be up to 40 feet thick. The hole is planned to extend 100 feet below the tunnel line to determine whether or not beds of crystalline limestone occur at this point.

D.D.8 has also been resited to chainage 6754' and deepened for similar reasons. It is not proposed to drill D.D.8A at this stage.

D.D.9 will be drilled as originally planned but will be extended to 100 feet instead of 50 feet.

It is not proposed to drill D.D.10, 11, 13, or 14. Only D.D.12 will be drilled as previously planned to provide control for the seismic survey down the penstock slope.

D.D.16 and 17 will be drilled as previously planned.

In addition to these holes, it is likely that several cased percussion holes will be required to investigate any critical zones revealed by the seismic survey. The percussion holes may be up to 400 feet deep and should be large enough to take NX size casing, which should be left in the holes until it is decided whether or not diamond drilling will be continued into bedrock. No delay will be caused while the services of a percussion rig are obtained, as the seismic survey has to be completed and plotted and there is ample work for the diamond drill rigs.

Diamond drilling now firmly proposed totals approximately 1,500 feet, about 600 feet less than before. Holes which may be drilled (or redrilled) depending on the results of the primary holes or seismic survey total about 500 feet, 600 feet less than before. Percussion holes might be expected to aggregate about 1,000 feet.

Specifications for new or relocated drill holes are attached to this report.

PROPOSED SEISMIC SURVEY

In order to delineate the surface of the metamorphic basement rocks and to establish the presence of any subsurface sediment filled valleys it is proposed that a seismic traverse be carried out along the tunnel line. It is also proposed that a seismic traverse be carried out down the penstock slope to provide a continuous soil/rock profile, (see attached plan). Results of these traverses will be of considerable assistance in interpreting the structure in the vicinity of D.D.6.

Because of other commitments the geophysical party will only have time to do a single traverse along each pegged line with one or two cross traverses in interesting areas. Traverses about 400 feet on each side of the tunnel line would have had the following advantages:-

1) a subsurface contour map could be drawn showing not only the position of any "valleys" but also their direction. The length of tunnel likely to be affected could then be determined more exactly;

2) an area would be defined within which the tunnel could be realigned to avoid any dangerous zones;

3) the two traverses would act as a check on each other.

However the single traverse as planned should provide sufficient information for geological interpretations at this stage.

DRILLING TECHNIQUE

The following comments are based on observations made during the visit, and are offered in the hope that drilling technique and equipment will be improved where necessary.

Boxing of Drill Core

Neither driller so far is marking the core lifts on both the core and box partition as recommended on page 44 of Record 1962/95. Unless this is done estimates of core recovery cannot be made for each lift. Wooden spacers painted red have only been used in place of lost core in D.D.1.

The heavy NX core boxes with hinged lids are excellent, but the BMLC core boxes with sliding lids are inconvenient to handle and often warp so that the lid does not fit. The sliding lids are easily jammed by protruding pieces of core which cannot always be pressed down.

The core shed is of excellent design but its capacity of 1,800 feet of NX or NMLC core will probably be exceeded towards the end of the investigation. There is a stock of 1,800 feet of NX or NMLC boxes, and 880 feet of BMLC boxes, but there are no BX boxes. Additional core boxes will probably not be required for the present phase of work.

BX core should not be put in BMLC boxes as has been done for D.D.5. Boxes so mistreated have bulged and split.

Drillers Log Sheets

Neither driller is filling in his daily report with sufficient information. In many cases there is no information recorded about the colour or quantity of returning drill water, about penetration rates, about diamond size and bit footage, or about the exact type of core barrel used. All this information is vital to the geologist when interpreting the core (e.g. fault zone in D.D.5) and should be carefully noted and recorded every day. Other information sometimes omitted from the daily report is depth to water table, exact time spent coring, running in or out of the hole, and length of core recovered. In some cases no distinction has been made between core and sludge samples, both being recorded as "Core Recovered". It is the Drilling Supervisor's responsibility to see that information requested on the report form or by the geologist is obtained without fail. The following list contains most of the items required daily:-

a) Colour and quality of return water and depth at which changes occur.

b) Quantity of drill water returning to surface and depth at which changes occur i.e. full return, partial return, no return.

c) Penetration rates and pressure on bit - the time (to nearest 5 mins) required to <u>drill</u> each run. Time spent running in or out of hole should not be included here.

d) Type, diamond weight, diamond size and footage obtained for each bit; also depths.

e) Size and exact type of core barrel used e.g.
5' NMLC double tube, stationary inner tube.
5' NMLC triple tube, stationary split inner tube.
10' BX double tube, stationary tube.
10' BMLC double tube, stationary split inner tube etc.

f) Depth to standing water table at start of each shift.

g) Length of core recovered.

h) Length of run drilled and depth.

i) Depth and size of casing.

j) Time spent coring, pressure testing, running casing or rods, standing, pulling casing, setting up, laying water line, rig shifting etc.

The daily report sheet at present in use is well laid out and provides ample space to record this information.

<u>Drilling Equipment</u>

Both drillers are seriously handicapped by lack of proper equipment, and the speed, cost, and geological results of the drilling programme are being adversely affected. The Drilling Supervisor has forwarded a list of items required, which I have discussed with him, and I strongly urge that this equipment plus spares be obtained immediately. Particular attention is drawn to lack of the following items:-

Drill rod clamps and casing clamps for both rigs - mainly NX and BX sizes.
Jaws for large Stilsons.
Core barrel wrenches, (Parmalee wrenches).
Socket and open end spanners and other hand tools.
Brazing and welding gear.
Pressure gauges and fittings for the hydraulic feed mechanism in both rigs.
Pressure gauges and fittings for the circulating pumps.
Cement for drill foundations and grouting.
Quick set additives for grouting.
Spare parts for all pumps.

In addition to these items of a general nature, there is, or will be in the near future, a shortage of all types of casing, especially if holes have to be completely cased while awaiting water pressure testing. The attached list gives stocks held at the beginning of June. There is an urgent need for short 1 and 2 foot lengths of NX and BX casing. Their absence is causing great difficulty in drilling-in casing and results in deterioration of the hole environs by caving which takes place in the long delay between drilling and positioning of casing.

With regard to bits, a list of those at present held in stock is attached. At present (June 8th) there are no NX casing bits available which means that neither rig will be able to spud in on the new sites until more arrive. The rig on P.5 was idle for about 8 days because no NX casing bits were available.

Stocks of suitable NMLC and NX bits are inadequate, as are NMLC, NX, and BMLC reamer shells.

All bits and reamer shells at present in stock have a diamond size of 30 or fewer diamonds per carat. Many are about 14 to 25 diamonds per carat. These diamonds are too large for economical drilling in the conditions prevailing, and it is recommended that all bits purchased in future have diamonds running not fewer than 50 to 60 per carat.

At present there is only one serviceable 5' NMLC triple tube stationary split inner tube core barrel on the site, and one similar 5' BMLC barrel. There is one serviceable 10' double tube stationary core barrel of each size, a serviceable 10' BMLC triple tube stationary barrel, a serviceable 5' BMLC double tube stationary split inner barrel, and various single tube core barrels. There should be two barrels (with spares) of the following to enable both rigs to drill with M-type equipment:-

5' NMLC	triple	tube,	stationary	split	inner	tube	core	barrel
5' BMLC	"	"	"	"	"	"	"	"
10' NMLC	"	"	"	"	"	"	"	"
10' BMLC	"	"	"	"	"	"	"	"

Triple tube barrels are preferred to the double type because of the better chance of recovering core in fault zones. As recommended in Record 1962/95, all drilling should be with bottom discharge "M" bits.

It is strongly recommended that suitable pressure gauges be fitted to both circulating pumps and hydraulic feed mechanism on the drill rigs. Their use will assist in obtaining good cores if fluctuations in pressure are carefully noted and responded to by the drillers.

Rod Vibration

During drilling of D.D.5 it was reported by the Drilling Supervisor that excessive vibration of drill rods was occurring and that core recovery had decreased from 100% to almost zero because of it. The vibration was thought to be due to the absence of rod grease in accordance with instructions contained in the report on permeability testing. However, discussions with the driller concerned revealed that he was not in the habit of using rod grease anyway, except when the drill rods had become rusty through standing over the weekend out of the hole. In addition, the onset of severe vibration apparently coincided with penetration of the major fault zone at 285 feet, and the sudden drop in core recovery is due as much to the clay and fault breccia encountered at this depth as it is to vibration pulverizing the core. The principal causes of rod vibration are probably lack of rod grease and the use of A-size drill rod in NX or BX hole. Rod grease should be used at all times during drilling except within 10 feet of proposed test sections. After a section has been tested rod grease can be used on the corresponding length of drill rod provided it is not within 10 feet of the next section to be tested. When 20-foot sections are being alternatively drilled and tested, the greatest length of core barrel and rod that needs to be free of grease is 30 feet. A short length such as this should not give rise to noticeable vibration in the drill string. The use of A-size rods in NX or BX hole is bad drilling practice and it is well known that the large annulus so created will permit the drill rods to "whip", causing the bit to pound up and down on the bottom of the hole and producing severe vibration. The effect becomes more pronounced in deep holes.

To avoid rod vibration in the remaining deep holes it is strongly recommended that enough N-size rods be obtained to permit both rigs to drill to about 200 to 300 feet with this size. Sufficient B-size rods should be provided to permit at least one rig to drill to 500 feet in this size. There is no doubt that core recovery in bad ground will be greatly improved if this is done.

Measurement of Standing Water Level

The drillers have no equipment to measure standing water levels at the start of each shift. Until now the depth to water has been estimated to the nearest 5 feet visually or by lowering a line. These methods may be satisfactory when the water level is near the surface but are not reliable for deep measurements. It is recommended that either an electric or sonic sounding device be provided for each drill rig so that daily measurements can be taken. Readings should be continued daily for about a month after the hole is completed, until equilibrium with the ground water table occurs.

Measurements of standing water level are not only of considerable use in estimating slope stability and in analysing weathering profiles, but they also play an important part in determining pressures to be used in permeability testing.

PERMEABILITY TESTING

Pressures for Permeability Testing

The test pressures given in Table 3 of the report on permeability testing are based on the assumption that the water table will be at or near the collar of most drill holes, as stated on page 9 of the report. A further assumption is made that the full theoretical head is exerted by the groundwater at any point below the water table. With regard to the first assumption, from the results of drilling to date it now appears that the water table will be at a considerable depth (about 80') below the surface in some areas at least. The specified test pressures would therefore be reduced accordingly, and the new pressures can be calculated using the formula on page 9 of the report.

The proportion of the full theoretical groundwater head that is assumed to act at a test section is a rather indefinite amount and should be arbitrarily chosen as a $\frac{1}{2}$ or $\frac{3}{4}$ etc. by the geologist depending on his rough estimate of the permeability of the rocks by inspection of drill core, i.e. whether joints appear to be tight or open, and on return of drilling water. In the case of D.D.5, open joints have been found in the drill core and it is felt that the ratio used should be about $\frac{3}{4}$, certainly not less than $\frac{1}{2}$.

As the drilling programme progresses, more water table levels and core will be obtained which will provide a basis for determining actual test pressures to be used. The pressures given in Table 3 are intended to demonstrate the type and extent of testing programme envisaged and the approximate magnitude of pressures required, so that suitable pumping equipment etc. may be brought to the site. In some, but not all, cases they will be the pressures actually used.

Results from D.D.5 show that the standing water level is approximately 70 to 80 feet from the surface, and that about $\frac{3}{4}$ of the full groundwater head might be expected to act at a test section. On this basis the highest effective test pressure required for the section 380 to 400 feet (yet to be drilled) will be about 100 p.s.i. (300 x 0.434 x 0.75) and not 190 p.s.i. as provisionally calculated. The gauge pressure required for an effective test pressure of 100 p.s.i. would be about 70 to 90 p.s.i. depending on the pipe friction. D.D.6 has been abandoned and will not be pressure tested. The only other holes requiring high test pressures are D.D.4 and the new D.D.7, but it is not possible to calculate the required gauge pressures until some water-table figures and drill cores have been obtained.

An accompanying map shows the proposed site of a water storage (B) tank near D.D.5, which will supply water for pressure testing to D.D.5 and D.D.4. In the case of D.D.5, the head available is approximately 195 feet, and if suitable low friction loss large diameter supply pipe (e.g. $1\frac{1}{2}$") is used between tank and hole it is possible that the required gauge pressures can be maintained without the use of pumps.

Test Pressures for D.D.5.

It is not possible to give a detailed testing programme for D.D.5 until the hole is re-opened and the depth to any caved sections is ascertained. As described earlier in this report, D.D.5 was drilled to 345 feet before drilling was temporarily suspended and the rig moved to P.5. Pressure testing in D.D.5 should have commenced at 300 feet and continued in approximately 20-foot sections (when safe to set packer) as the hole deepened. The situation is complicated by the existence of a major fault zone from 285 to 315 feet, possibly extending beyond the bottom of the hole. It would not be wise to set the packer in the fault zone because of the danger of jamming and the poor seal likely to result. This means that the section from 285 to 315 feet will probably have to be tested in one stage by setting the packer between 280 feet to 285 feet. It is very likely that the hole will have collapsed up to about 285 feet by the time pressure testing commences. If this is so, a 20-foot section from 265 to 285 feet should be tested in an attempt to establish the permeability of unfaulted rock. The hole should then be drilled through the fault zome to 315 feet and this section tested. Drilling and testing should then continue in approximately 20-foot stages until the zone affected by faulting is passed. Care should be taken in choosing setting depths for the packer in the bed of faulted shale from 315 feet to 345 feet.

The following table gives a tentative testing programme for D.D.5. It is based on the assumptions described above and may be altered to suit conditions. In the event of it being found impossible or dangerous to set the packer in faulted rock, pressure tests should be done with the packer set at a constant depth (say about 280 feet) as the hole is deepened in 20-foot stages.

Test Pressures for D.D.5

Distance from collar to test section (feet)	Gauge pressures P_G (p.s.i.)	Depth of packer (feet)
265 to 285	20, 25, 30, 35, 40	Between 260 to 265
285 to 315	25, 30, 35, 40, 45	Between 280 to 285
320 to 340	20, 30, 40, 50, 60	Between 315 to 320
340 to 360	25, 35, 45, 55, 65	Between 340 to 345

Tests below 360 feet will be determined by core recovered.

Hydraulic Packers

Enquiries have been made to Triefus Industries and Snowy Mountains Authority about safe pressures for hydraulic packers. S.M.A. officers advise that they have inflated the rubber sleeves at pressures up to 250 p.s.i. without ill effects, so it appears that there is an adequate safety margin for tests at the Ramu should sealing pressures of up to 200 p.s.i. be required.

This is, of course, providing the rubber sleeve is in good condition. It was pointed out by the S.M.A. that although the absolute pressure in a test section may be 300 to 400 p.s.i. an efficient seal can often be obtained when the packer has been inflated by a pressure of 50 to 100 p.s.i. only. At first sight this appears to be impossible until it is remembered that when the rubber sleeve is in the expanded position the water inside is completely entrapped, and the sleeve cannot be deflated by external pressure, no matter how great, unless the seals or sleeve binding fail . The actual pressure required in the sleeve to ensure a complete seal will vary according to the adhesion and friction forces between the sleeve and the sides of the hole. The drilling supervisor or engineering geologist should decide the sealing pressure after inspecting the core and taking into account the degree of fracturing at the chosen position. The effectiveness of the seal is checked by observing whether or not water flows from the collar of the hole during the initial 15 to 20 minute stabilising period.

It therefore appears likely that packers can be made to seal at pressures of about 100 p.s.i. and that they will not usually be required to withstand inflating pressures of the order of 200 p.s.i. at the Ramu project.

Another suggestion made by S.M.A. is that BX packers be used in N-size holes and AX packers be used in B-size holes, when there is a possibility of caving causing the packer to jam. There would be greater clearance between the deflated packer and side of hole with this arrangement and therefore less chance of fragments of rock being dislodged when lowering or raising the testing string.

Attached is a set of notes on the operation of hydraulic packers and a sectional diagram. The notes are copied from instructions supplied by Triefus Industries Ltd.

It is suggested that as conditions for water pressure testing at Ramu are likely to be difficult because of the thinly bedded and broken nature of the rock in places, it might be advisable to have two "cup" type packers available for testing isolated sections in some holes. This type of packer has been described in correspondence, but a further more detailed description is available if required.

Storage Tanks and Supply Lines

Proposed positions for storage tanks for pressure testing are shown on an accompanying map. Tank A will supply pressure water to holes D.D.7, 8, and 9, and to any other holes required in this area. Tank B will supply water to D.D.5 and D.D.4. All holes at the intake, weir, and powerhouse sites will be tested with water from the Ramu river.

Supply pipes to the tanks from nearby creeks can be any diameter compatible with the pumps employed. Delivery lines from the tanks to drill holes should have a nominal diameter not less than $1\frac{1}{2}$" to avoid friction losses at high flow rates. Quantities of pipe required can be measured approximately from the map.

Communication Equipment

In order to avoid moving the test pump to each hole in turn, it is suggested that it be located at the storage tank site. This will necessitate a two-way telephone system between the pump operator and person carrying out the testing at the drill hole. Otherwise quick regulation of flow rates and pressures may be impossible to achieve.

Other Equipment

Only one suitable pressure gauge (0-500 p.s.i.) is at present on the site. Other gauges required are described in the report on permeability testing. Besides the gauges used for tests, a set should be kept at the drillers' camp for calibration purposes. All pressure gauges and flow meters should be checked after each hole is completed.

The supply line in the hole for pressure testing should be either $1\frac{1}{4}$" or $1\frac{1}{2}$" wrought iron or steel pipe, or AX or EX casing. Reliable testing cannot be carried out using drill rods.

A possible source of water for drilling and testing holes on the penstock slope is at the limestone cave in Chasm Creek (see "cave" on map). Plentiful water is always available at the mouth of the cave. However, access to the cave is extremely difficult and it may not be possible to place a suitable pump and engine there. In this case it may be worthwhile to consider using a small hydraulic ram supplied and driven by water from higher up the creek which falls steeply at this point.

8.7.63.

J.K. HILL

Geologist, Grade 2.

APPENDIX 1

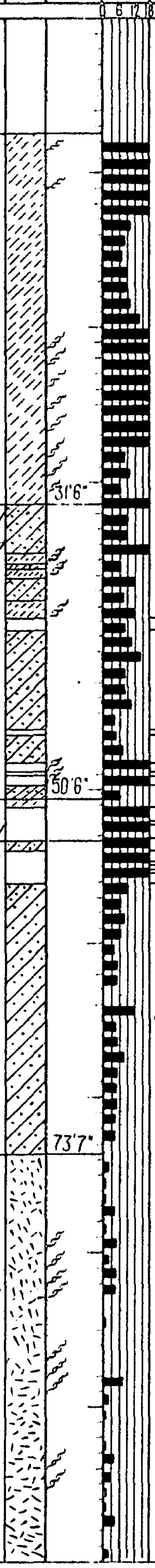
GEOLOGICAL LOGS OF D.D.1 AND D.D.5.

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 60 ft. upstream from Weir site. — ANGLE FROM HORIZONTAL: -40° — DIRECTION: 045° Mag.



Rock type	Description	Depth	Core recovery	Structures	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 5 mm. apart. Core very broken. Pieces minute to 6", mode 1".	31'6"	95% (Lifts not marked)	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", 20'1"-26'0", 29'0" to 31'6". The shale in these zones has been closely sheared and/or crushed.	
Fresh interbedded Greywacke and Shale	Light bluish grey, fresh, silicified, strong, very hard, very fine grained greywacke with thin shale interbeds (generally sheared or crushed). Pieces ¼" to 6", mode 2".	50'6"	0%	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. Frags (1" diam) of clay and brecciated rk. at 47'11"-48'8"	
Fresh Shale	A few badly ground 1" fragments of greyish-black, fresh, mod. ind., mod. strong, hard shale.		0%	No traces of gouge, clay or brecciated rock.	
Fresh interbedded Greywacke, Siltstone and Shale	Fresh, moderately indurated, strong, hard, thinly bedded or laminated rocks. Shale interbeds 1-10 mm. thick, 1-10 mm apart. Greywacke beds graded. Pieces ½" to 14", mode 3".	73'7"	0% / 100%	Many fracture surfaces coated with calcite and limonite. Some calcite veins up to 3 mm. 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'.		100%	Change from metamorphic rocks to igneous is gradational over distance of 5". Most joints clean, but a few thin Ca veinlets present. 2 mm. vein zeolite! at 88'8". Sections 79'-83', 86'-89', 93'-94' display well developed but irregular incipient closely spaced (≤5 mm) fractures. Possibly indicate rock has been stressed.	

Mindrill E 1000
Hydraulic Feed

NOTES:
1. Fracture log records number of fractures per foot of core. Zones of core loss are assumed to have been completely sheared or crushed.
2. ⌇ - indicates strongly sheared rock or other evidence of extensive faulting.
3. Mode - most common length of unbroken core.

LOGGED: J.K. Hill 29.5.63

VERTICAL SCALE: 10 feet : 1 inch.

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 / State of weathering	Description	Graphic Log	Depth	Fracture Log (0 6 12 18+)	Lift & core recovery	Casing	Structures: joints, veins, seams, faults, crushed zones	Water level	Water pressure test (Gallons per minute per foot loss)
Fresh Dolerite or Gabbro	Described above, pcs 1"-28", mode 8". (Diffuse boundary)		108'0"				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".		109'10"				Very soft fibrous talc/actinolite fills fracture at 109'3", 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.		132'6"		Lifts not marked		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 Dolerite or Gabbro	Described above. Pieces ½"-10", mode 5".		136'3"				Contact abrupt and unfaulted. Slickensides and talc on fracture at 138'0".		
Fresh interbedded Greywacke Siltstone and Shale	Described above. Pieces ¼"-6", mode 2".		149'6"		100%		Euhedral crystals of calcite and zeolite indicate open joints at 137', 148', 148'10". No slickensides observed, but smooth talc or serpentine-filled joints present. Off-set laminae present.		
Fresh Dolerite or Gabbro	Described above. Pieces ¼"-24", mode 12". Changes in grain size occur throughout.		190'4"				12" longitudinal joint filled with zeolite? and with 2mm wide cavities. Euhedral crystals at 155'. Slickensides present. Numerous thin veins of calcite and/or zeolite. Sheared zone 162'-163'. 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 (thinly). Slickensided fibrous fracture surfaces at 181'3".		
Fresh interbedded Greywacke Siltstone and Shale	Described above. Pieces 1"-16", mode 3". Bedding at 30° to core axis. Graded bedding indicates ↑ up		200'0"				Most fractures lined with quartz (or ? zeolite). Open joint at 198'2".		

END OF HOLE

Mindrill E 1000 Hydraulic feed

LOGGED J.K. Hill 29.5.63

VERTICAL SCALE 10 feet : 1 inch

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT: UPPER RAMU - Tunnel Line — HOLE NO: D.D. 5 — R.L.: 4200' approx.

LOCATION: 10 feet N. of peg 3705·50 on tunnel line — ANGLE FROM HORIZONTAL: -80 — DIRECTION: 158° Mag.

Rock type & degree of weathering	Description	Graphic Log	Depth & size of core	Fracture Log (0 6 12 18+)	Size % core recovery	Structures (joints, veins, seams, faults, crushed zones)	Water level	Water pressure test (Gallons per minute per foot loss)
Unconsolidated Sediments	No core or cuttings recovered.		30'0"		Bx			
Unconsolidated Sediments with boulders of Granodiorite and Shale	Coarse grained mottled (pale yellowish-orange to yellowish-grey) ferruginous, clayey sand with boulders of metamorphic and igneous rock.		NX			Granodiorite boulder. Boulders of silicified sandstone and greywacke.		
	Mottled coarse to very coarse sand with gravel.		NX			Gravel. Boulder of very weathered shale.		
	Yellowish grey coarse sand and silt with boulders.							
	Yellowish grey - pale olive coarse sand with boulders.		NX 100'		Lifts not marked	Boulder of pale-olive very weathered shale. Dolerite boulder. Dolerite or basalt boulders. Soft weathered dolerite boulder. Boulders of soft weathered granodiorite. Soft weathered shale fragments. Hard siltstone boulder. Soft weathered green dolerite fragments.		

DRILL NO. / TYPE: Mindrill E 1000 Hydraulic Feed

DRILLER:

COMMENCED:

COMPLETED:

NOTES:
1. Fracture log records number of fractures per foot of core. Zones of core loss are assumed to have been completely sheared or crushed.
2. ≈ Indicates strongly sheared rock or other evidence of extensive faulting.
3. Mode — most common length of unbroken core.

LOGGED: J.K. Hill

VERTICAL SCALE: 10 feet : 1 inch

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT: UPPER RAMU – Tunnel Line HOLE NO: D.D.5 R.L.: 4200' approx.

LOCATION: 10 feet N. of peg 3705·50 on tunnel line ANGLE FROM HORIZONTAL: –80 DIRECTION: 158° Mag.

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION	Graphic Log	DEPTH & SIZE OF CORE	Fracture Log	LIFT & CORE RECOVERY %	CASING	STRUCTURES: JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES	WATER LEVEL	WATER PRESSURE TEST Gallons per minute per foot loss
Uncons. Sediments			101'0"	0 6 12 18					
Slightly to moderately weathered interbedded Greywacke Siltstone and Shale	Medium light grey to dark grey, moderately strong, moderately hard, slightly weathered indurated siltstone, shale and fine grained greywacke with soft weak bands of moderately weathered shale. Beds laminated or thin, 1mm–5 cm thick. Pieces minute to 12", mode 1". Soft weathered shale and siltstone from 108'–109'4", 113'–119'.		NX; BMLC; 120'6"				Some fractures with 1–2 mm clay. Most fractures coated with either 1mm. clay, calcite or chlorite. Some zeolite present. Abundant sedimentary structures. Only a few joints with slickensides. Pyrite common on fracture surfaces. Graded bedding and other sedimentary structures common show ↑ up.		
Fresh interbedded Siltstone and Greywacke	Dark grey to black siltstone and light grey greywacke, hard and moderately strong, laminated to thinly bedded. Bedding at 60° to core axis.		136'0"				Calcite veins, developed in bedding planes with some recrystallisation.		
Fresh Shale	Dark grey, fresh, very hard, very strong, indurated shale. Pieces ½" to 5", mode 2". Rock thinly to thickly bedded.		BMLC; 159'4"				Calcite and chlorite very common on fractures and bedding planes, also pyrite. Slickensides fairly common. Open joints with euhedral crystals at 149', 152'3". Broken zones not due to weakness of rock, but to drilling difficulties or handling. Closely spaced joints with clay minerals in them @ 48° to core axis. Calcite and pyrite on joints. From 145'–150', two closely spaced sets of joints developed @ 60° + 30° to core axis and 90° to each other. 155'–153'2 high mineralized with calcite and pyrite. Some secondary crystallisation of calcite. Joint sets @ 60° and 30° to core axis persist to 160'.		
No core or cuttings	Core dropped and ground away in attempt to recover it.		169'5"						
Fresh interbedded Greywacke, Siltstone and Shale	As above, laminated or thin beds, 1mm.–8cm., Pieces 1"–24", mode 9".		180'0"				Pyrite very common on joints in radial fibrous aggregates and in disseminated form. Nearly all joints with slickensides. Open joints with euhedral crystals of calcite at 171'2", open 4mm. Numerous hairlike calcite or zeolite veins, some calcite veins up to 8mm thick. Bed offset 1" by calcite filled shear at 180'10". 1 2mm gouge on adjacent joint at 181'0".		
Fresh Hornfels	Medium light grey, very strong, very hard hornfels.		188'0"						
Fresh Dolerite or Gabbro.	Very hard and strong porphyry.		190'0"						
Fresh interbedded Greywacke Siltstone and Shale	Dark grey to black, moderately strong, mod. hard, very fine grained shale and interbedded hard and strong greywacke. Some small rock fragments in the siltstone-greywacke. Beds up to 6" thick. Pieces 2"–18", mode 9".		198'11"				Numerous sedimentary structures.— Slumping etc. Most joints calcite lined. Slickensides not common. Joints developed at 30° + 60° to core axis, and 90° to each other.		
Dolerite or fresh Gabbro.	Hard strong porphyry.				0 50 100				

DRILL NO. TYPE: Mindrill E 1000 Hydraulic feed

DRILLER:

COMMENCED:

COMPLETED:

LOGGED: J.K. Hill

VERTICAL SCALE: 10 feet : 1 inch

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT: UPPER RAMU - Tunnel Line HOLE NO: D.D. 5 R.L.: 4200' approx

LOCATION: 10 feet N. of peg 3705·50 on tunnel line ANGLE FROM HORIZONTAL: -80° DIRECTION: 158° Mag.

Rock / weathering	Description	Depth	Core size	Structure: joints, veins, faults, crushed zones	Water level	Water pressure test (gallons per minute per foot loss)
Fresh interbedded Siltstone Greywacke and Shale	As above, but greywacke and siltstone predominate. Beds up to 20" thick app. Pieces 1"-27", mode 10".	200'4" – 211'2"	BMLC	Joints lined with calcite, fibrous zeolites and chlorite. Slickensides present occasionally.		
Fresh Hornfels	Hard strong rock	214'8"				
Fresh Dolerite or Gabbro	Hard strong porphyry.	218'3"				
Unweathered Siltstone Greywacke & Shale	Greywacke predominant with narrow up to 4" thick beds of siltstone and shale, both hard and strong	222'0"				
Fresh Shale	Dark grey, fresh, very hard very strong indurated shale	269'0"	BMLC, BX	Open joints with euhedral calcite crystals at 222'. Most joints filled with calcite and zeolite. Veins common. Pyrite very common in fractures. Slickensides not common. Moderately devevloped joints from 60° to 70° to core axis. Calcite and pyrite on joints. Set of fine calcite veins @ 20° to core axis at 234'5". Calcite in openings 5mm. wide @35° to core axis at 235' and @ 20° to core axis at 238', pyrite in all breaks. Random hairthin stringers of calcite and qtz throughout this section. Open calcite crystal lined joint at 240'8". At 248'7" mass of fine calcite stringers. At 249'3" calcite has undergone solution and re-crystallisation. Core ground in places. Jointing better developed from 250' to 260' @ 30° to core axis and closely spaced. Open, calcite crystall-lined joints from 259' to 260'.		
Fresh interbedded Greywacke Siltstone and Shale	Predominantly greywacke, laminated to thinly bedded, hard, strong, light grey. Dark grey to black moderately strong, hard siltstone and shale. Core very broken from 275' to 277'. Pieces ½" to 18", mode 6".	280'0"		Calcite filled joints weakly developed. Vertical to bedding which is at 60° to core axis. No fine calcite stringers in this section and less pyrite.		
Fresh Dolerite or Gabbro	Hard strong porphyry	281'4"				
Fresh Greywacke Siltstone & Shale	Laminated to thin bedded as in section 269' to 280'.	285'0"				
No core	Cuttings dark grey to black sand and grit - represent coarse friction of fault gouge and breccia	290'0"		285' to 315' is major fault, associated with dolerite intrusion.		
Fresh Dolerite	Central core of faulted intrusion.	291'7"				
No core	Cuttings dark grey to black sand and grit - represent coarse friction of fault gouge and breccia.	300'		Driller recorded very soft drilling, 5 ft in 5 minutes. Water return black instead of usual light grey.		

Mindrill E 1000 Hydraulic feed

LOGGED: J.K. Hill

VERTICAL SCALE: 10 feet : 1 inch

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT: UPPER RAMU - Tunnel Line   HOLE NO: D.D 5   R.L: 4200' approx.

LOCATION: 10 feet N. of peg 3705·50 on tunnel line   ANGLE FROM HORIZONTAL: -80°   DIRECTION: 158° Mag

Rock type & degree of weathering	Description	Graphic Log	Depth & size of core	Fracture Log	Lift & core recovery %	Casing	Structures: joints, veins, seams, faults, crushed zones	Water level	Water pressure test: Gallons per minute per foot loss
No core			301'4"						
Fresh Dolerite Gabbro	Hard strong porphyry.		BX 305'0"						
No core			315'0"						
Fresh Shale	Dark grey, fresh, moderately hard, strong shale, very broken with much core loss.		BMLC 345'0"				Slickensided joints present. Core very fragmentary and ground in places. Calcite and zeolite veins are abundant. This bed of incompetent shale is faulted and could be considered part of the main fault from 285'-315'. Traces of gouge or breccia in fragments 340'-345'. Core badly ground.		
	Drilling						Suspended		

Fracture Log scale: 0 6 12 18+
Core recovery scale: 0 50 100

DRILL: Mindrill E 1000, Hydraulic feed
DRILLER:
COMMENCED:
COMPLETED:

LOGGED: J.K. Hill

VERTICAL SCALE: 10 feet : 1 inch

APPENDIX 2.

SPECIFICATIONS FOR NEW DRILLING

BUREAU OF MINERAL RESOURCES

GEOLOGICAL BRANCH

SPECIFICATIONS FOR DRILLING

PROJECT: Upper Ramu Hydro-electric Project.

DRILL HOLE No. D.D.2, (new location).

TYPE OF DRILLING: Diamond drilling with triple tube stationary split inner tube NMLC barrel.

LOCATION: Collar as shown on plan of intake structure.

OBJECTIVES OF DRILLING: To intersect proposed tunnel 100 feet from river and to extend 40 feet below invert.

SITE INDICATED BY: Not marked.

DRILL SITE PEG, CO-ORDINATES: --

METHOD OBTAINED --

R.L. OF GROUND SURFACE: 3,940 feet approx.

METHOD OBTAINED: From topographic map.

DIRECTION OF HOLE: -- INDICATED BY: --

REQUIRED SLOPE (ANGLE FROM HORIZONTAL): -90°

REQUIRED SIZE: MNLC

REQUIRED DEPTH (IN TERMS OF OBJECTIVES): To sample rock types in vicinity of intake structure; to detect any faults; and to determine soundness of rock by water pressure testing.

ANTICIPATED DEPTH: 120 feet.

ANTICIPATED DRILLING CONDITIONS (STRATA, STRUCTURES): Five to ten feet of overburden then hard strong silicified greywacke, siltstone with weaker beds of shale. Thinly bedded rock closely jointed. Dolerite dykes, possibly faulted, may be encountered. Any fault zones encountered will consist of soft blue gouge and broken rock.

WATER PRESSURE TESTING REQUIRED: Every 20 ft throughout the hole. Pressures used will be similar to those for original D.D.2, but will be finally determined by engineering geologist. Water level to be measured at start of each shift.

SPECIAL REQUIREMENTS: As for original D.D.2.

SITE SET OUT BY: Not marked. DATE 8.7.63.

J.K. HILL
Engineering Geologist

BUREAU OF MINERAL RESOURCES

GEOLOGICAL BRANCH

SPECIFICATIONS FOR DRILLING

PROJECT: Upper Ramu Hydro-electric Project.

DRILL HOLE No. D.D.3 and 3A, (new location).

TYPE OF DRILLING: Diamond drilling with triple tube stationary split inner tube NMLC barrel.

LOCATION: Collar as shown on plan of intake structure.

OBJECTIVES OF DRILLING: D.D.3 to intersect proposed tunnel 200 feet from river and to extend 40 feet below invert. D.D.3A depends on results of D.D.3 and should be drilled at direction of geologist.

SITE INDICATED BY: Not marked.

DRILL SITE PEG, CO-ORDINATES: Not surveyed.

METHOD OBTAINED: —

R.L. OF GROUND SURFACE: 3,965 ft. approx.

METHOD OBTAINED: From topographic map.

DIRECTION OF HOLE: 312° magnetic. INDICATED BY: Not indicated.

REQUIRED SLOPE (ANGLE FROM HORIZONTAL): -60°.

REQUIRED SIZE: NMLC.

REQUIRED DEPTH (IN TERMS OF OBJECTIVES): To test rock at point where dolerite dyke intersects tunnel line. Other objectives as for D.D.2.

ANTICIPATED DEPTH: 170 feet.

ANTICIPATED DRILLING CONDITIONS (STRATA, STRUCTURES):
As for D.D.2.

WATER PRESSURE TESTING REQUIRED: Every 20 feet throughout hole as for D.D.2.

SPECIAL REQUIREMENTS: As for D.D.2.

SITE SET OUT BY: Not marked. DATE: 8.7.63.

J.K. HILL
Engineering Geologist

BUREAU OF MINERAL RESOURCES

GEOLOGICAL BRANCH

SPECIFICATIONS FOR DRILLING

PROJECT: Upper Ramu Hydro-electric Project.

DRILL HOLE No. D.D.4, (new location).

TYPE OF DRILLING: Diamond drilling with triple tube stationary split inner tube NMLC barrel.

LOCATION: Collar at chainage 1,385 ft. (approx) on tunnel line.

OBJECTIVES OF DRILLING: To intersect tunnel line 1,440 feet from intake and to extend 50 ft. below it.

SITE INDICATED BY: White stake marked D.D.4.

DRILL SITE PEG, CO-ORDINATES: Not surveyed.

METHOD OBTAINED: ---

DRILL SITE PEG, R.L. OF GROUND SURFACE: 4,130 ft. approx.

METHOD OBTAINED: From topographic map.

DIRECTION OF HOLE: -- INDICATED BY: --

REQUIRED SLOPE (ANGLE FROM HORIZONTAL) -90°

REQUIRED SIZE: NMLC as deep as possible.

REQUIRED DEPTH (IN TERMS OF OBJECTIVES): The main objectives of this hole are:- to provide a continuous sample of the rock types which will be encountered in the tunnel from chainage 1000 to 1600 feet; to test the large igneous intrusion crossing the tunnel at this point for faulting; to detect any other faults; and to determine the soundness of rock around the tunnel at the point of intersection.

ANTICIPATED DEPTH: 320 feet.

ANTICIPATED DRILLING CONDITIONS (STRATA, STRUCTURES): A few feet of overburden and soft weathered rock, passing into strong hard thinly bedded greywacke, siltstone and weaker shale, with hard strong dolerite dykes except where faulted. Rock will be closely jointed in many places. Any fault zones encountered will consist of soft blue gouge and broken rock.

WATER PRESSURE TESTING REQUIRED: Every 20 ft from 220 to 320 feet according to the procedures described in the report on permeability testing. Pressures used will be determined by engineering geologist but will be approximately those in Table 3 of report on permeability testing. Water level to be measured at start of each shift.

SPECIAL REQUIREMENTS: Hole to be drilled with triple tube NMLC barrel as deep as possible. If bad ground encountered at tunnel line, hole to be deepened at direction of engineering geologist. Hole to remain fully cased on completion until instructions received to remove casing.

SITE SET OUT BY: J.K. Hill and
R. Campbell.

DATE: 5.6.63.

J.K. HILL
Engineering Geologist

BUREAU OF MINERAL RESOURCES

GEOLOGICAL BRANCH

SPECIFICATIONS FOR DRILLING

PROJECT: Upper Ramu Hydro-electric Project.

DRILL HOLE No. D.D.7, (new location).

TYPE OF DRILLING: Diamond drilling with triple tube NMLC barrel, with stationary split inner tube.

LOCATION: Collar 16 ft. north of peg 6483.72 on tunnel line.

OBJECTIVES OF DRILLING: To intersect proposed tunnel 500 ft from outlet portal and to extend 100 ft below it. The main objectives of the hole are:- to determine the depth of overburden and weak, weathered rock, to provide a continuous sample of rock types likely to be encountered in the tunnel in this area; to detect any fault zones; to determine the permeability and soundness of rock around the tunnel at this point; and to determine whether or not beds of permeable crystalline limestone are present.

SITE INDICATED BY: White stake marked D.D.7.

DRILL SITE PEG, CO-ORDINATES: Not surveyed.

METHOD OBTAINED: --

DRILL SITE PEG, R.L. OF GROUND SURFACE: 4,050 ft approx.

METHOD OBTAINED: From topographic map.

DIRECTION OF HOLE: -- INDICATED BY: --

REQUIRED SLOPE (ANGLE FROM HORIZONTAL): -90°

REQUIRED SIZE: NX to greatest possible depth.

REQUIRED DEPTH (IN TERMS OF OBJECTIVES): 100 feet below proposed tunnel line (at this point R.L. of tunnel is 3,850 ft). If bad rock conditions are encountered the hole should be deepened at the direction of the engineering geologist.

ANTICIPATED DEPTH: 300 feet.

ANTICIPATED DRILLING CONDITIONS (STRATA, STRUCTURES): Unconsolidated soil and rock overburden for first 20 to 40 feet, thence thinly bedded weathered metamorphic rocks passing into hard strong fresh silicified greywacke, siltstone and shale. Hard strong igneous intrusions will be encountered. Fault zones may be met with which will give rise to difficult drilling conditions.

WATER PRESSURE TESTING REQUIRED: Every 20 ft from 150 ft to bottom of hole, in accordance with procedures described in the report on permeability testing. Pressures to be used will be specified by geologist when depth to water table is known. Standing water level to be measured at start of each shift.

SPECIAL REQUIREMENTS: Every effort should be made to drill NX hole to the full depth. Triple tube stationary split inner tube barrels should be used at all times. Other requirements as for D.D.4. Hole to remain fully cased on completion until instructions are received to remove casing.

SITE SET OUT BY: J.K. Hill and R. Campbell. DATE: 5.6.63.

J.K. HILL
ENGINEERING GEOLOGIST

BUREAU OF MINERAL RESOURCES

GEOLOGICAL BRANCH

SPECIFICATIONS FOR DRILLING

PROJECT: Upper Ramu Hydro-electric Project.

DRILL HOLE No. D.D.8, (new location).

TYPE OF DRILLING: Diamond drilling with triple tube stationary split inner tube NMLC barrel.

LOCATION: Collar 31 ft north of peg 6722.61 on tunnel line.

OBJECTIVES OF DRILLING: To intersect proposed tunnel 250 feet from outlet portal and to extend 100 feet below it. Main objectives as for D.D.7.

SITE INDICATED BY: White stake marked D.D.8.

DRILL SITE PEG, CO-ORDINATES: Not surveyed.

METHOD OBTAINED: --

DRILL SITE PEG, R.L. OF GROUND SURFACE: 3,945 ft approx.

METHOD OBTAINED: From topographic map.

DIRECTION OF HOLE: -- INDICATED BY: --

REQUIRED SLOPE (ANGLE FROM HORIZONTAL) -90°

REQUIRED SIZE: NX to greatest possible depth.

REQUIRED DEPTH (IN TERMS OF OBJECTIVES): As for D.D.7.

ANTICIPATED DEPTH: 200 feet.

ANTICIPATED DRILLING CONDITIONS (STRATA, STRUCTURES): As for D.D.7.

WATER PRESSURE TESTING REQUIRED: Every 20 ft from surface of bedrock to bottom of hole. Other requirements as for D.D.7. Water level to be measured at start of each shift.

SPECIAL REQUIREMENTS:

SITE SET OUT BY: J.K. Hill and R. Campbell. DATE: 5.6.63.

J.K. HILL
ENGINEERING GEOLOGIST

BUREAU OF MINERAL RESOURCES

GEOLOGICAL BRANCH

SPECIFICATIONS FOR DRILLING

PROJECT: Upper Ramu Hydro-electric Project.

DRILL HOLE No. D.D.9.

TYPE OF DRILLING: Diamond drilling with triple tube stationary split inner tube NMLC barrel.

LOCATION: At proposed site of surge tank (chainage 7004) on tunnel line.

OBJECTIVES OF DRILLING: To test soundness of foundation rock.

SITE INDICATED BY: B.M. VI.

DRILL SITE PEG, CO-ORDINATES: Not surveyed.

METHOD OBTAINED: --

DRILL SITE PEG, R.L. OF GROUND SURFACE: 3,847 feet approx.

METHOD OBTAINED: Preliminary survey.

DIRECTION OF HOLE: -- INDICATED BY: --

REQUIRED SLOPE (ANGLE FROM HORIZONTAL) -90°.

REQUIRED SIZE: NMLC.

REQUIRED DEPTH (IN TERMS OF OBJECTIVES): To determine thickness of soil and rock overburden; thickness of soft weathered bedrock, and to detect any beds of possibly highly permeable crystalline limestone.

ANTICIPATED DEPTH: 100 feet.

ANTICIPATED DRILLING CONDITIONS (STRATA, STRUCTURES): Twenty to forty feet of soil and rock debris, thereafter weathered rock passing into hard strong silicified greywacke, siltstone and weaker shale. Crystalline limestone may be encountered.

WATER PRESSURE TESTING REQUIRED: Any beds of limestone encountered should be pressure tested as directed by geologist. Water level to be measured at start of each shift.

SPECIAL REQUIREMENTS: Driller to be on lookout for sudden losses of drilling water.

SITE SET OUT BY: C.D.W. Surveyor. DATE: 8.7.63.

J.K. HILL
Engineering Geologist

BUREAU OF MINERAL RESOURCES

GEOLOGICAL BRANCH

SPECIFICATIONS FOR DRILLING

PROJECT: Upper Ramu Hydro-electric Project.

DRILL HOLE No. D.D. 16 & 17 (New locations).

TYPE OF DRILLING: Diamond drilling with triple tube stationary split inner tube NMLC barrel.

LOCATION: Proposed powerhouse site (see Map 1 - Scheme Layout and Geological Plan).

OBJECTIVES OF DRILLING:

To determine soundness of foundation rock and degree of development of solution cavities and joints.

SITE INDICATED BY: Not marked.

DRILL SITE PEG, CO-ORDINATES: E N ---

METHOD OBTAINED: ---

DRILL SITE PEG, R.L. OF GROUND SURFACE: 3,195 ft.

METHOD OBTAINED: Preliminary survey.

DIRECTION OF HOLE: --- INDICATED BY: ---

REQUIRED SLOPE (ANGLE FROM HORIZONTAL): -90°

REQUIRED SIZE: NMLC

REQUIRED DEPTH (IN TERMS OF OBJECTIVES): To determine soundness of foundation rock beneath proposed powerhouse. Hole should be deepened if necessary to investigate any bad rock at direction of engineering geologist.

ANTICIPATED DEPTH: 50 ft.

ANTICIPATED DRILLING CONDITIONS (STRATA, STRUCTURES): Moderately hard and strong marble with two well developed joint systems. Drilling water losses are likely. Minor intrusions of hard strong dolerite may be encountered.

WATER PRESSURE TESTING REQUIRED: Every 10 ft. throughout holes in accordance with procedures in B.M.R. report on permeability testing.

SPECIAL REQUIREMENTS:

Driller to note any loss of water while drilling.

DATE: 10.7.63.

J.K. HILL
ENGINEERING GEOLOGIST

APPENDIX 3.

DESIGN AND OPERATION OF HYDRAULIC PACKERS

1. Introduction

In developing this packer the aim was to meet what is considered to be the essential requirements of a water pressure testing packer for use under various conditions encountered in both shallow and deep diamond drill holes. It is considered that these requirements are as follows:

(i) Be capable of being expanded against the wall of the drill hole over a length sufficient to prevent water which is being pumped into the test section from leaking past the seal into the hole above the test section.

(ii) Be capable of being readily moved to a sound or good sealing portion of the drill hole without the necessity of withdrawing the entire drill string.

(iii) Have ample clearance between the packer and the wall of the hole in the unexpanded position so that tearing of the expanding sleeve material cannot occur when lowering and raising the packer to and from the sealing location.

(iv) Have ample expansion of the sealing material so that slightly oversize portions of the drill hole may be sealed efficiently.

(v) Be tested thoroughly prior to use in a drill hole so that any defects may be detected and overcome. The packer should be tested in casing which is slightly greater in diameter than the hole and should be tested for long periods over the full range of pressures to be used.

(vi) Be as simple to operate as possible so that it may be used correctly by the average drill operator under all possible conditions.

(vii) Be as simple in design as possible to avoid the use of extraneous material which could be torn off or broken thus causing jamming of the packer or rods. An example of this is hose for the passage of compressed air or water.

2. General Description

The hydraulic packer utilises a three foot long rubber sleeve which is expanded by water under pressure, sufficiently to force the rubber sleeve outwards against the hole wall. Before the test is commenced the water inside the sleeve is trapped completely by isolating the water supply holes to the sleeve between a set of seals. At the same time another set of holes located below the rubber sleeve are opened to allow water to pass into the test section. Because the sleeve is held in the expanded position by entrapped water the sleeve cannot be deflated by outside pressure, no matter how great, unless the seals or sleeve binding fails.

Indications are that this packer should solve the problem of obtaining an efficient method of sealing drill holes under all conditions in both bedrock and overburden.

3. Principles of Design

The packer consists of :

(i) 3 feet long soft rubber sleeve $\frac{1}{4}$ inch thick $2\frac{3}{8}$ inch O.D. for 'N' holes and $1\frac{3}{4}$ inches O.D. for 'B' holes. This sleeve fits over the outer tube and is bound at either end.

(ii) An outer tube containing a plug at its lower end and N or B rod ferrules above and below the rubber sleeve. There are four holes $\frac{3}{8}$ inch diameter for the 'N' packer and $\frac{1}{4}$ inch diameter for the 'B' packer situated under the rubber sleeve. Below the lower ferrule are sixteen holes to permit water to enter the test section. These holes are $\frac{3}{8}$ inch diameter for the 'N' packer and $\frac{1}{4}$ inch diameter for the 'B' packer.

(iii) An inner tube which slides inside the outer tube. Four holes are located between two sets of seals and are opposite the four upper holes on the outer tube beneath the rubber sleeve. Another two sets of seals are located on the inner tube such that the sixteen holes on the outer tube are isolated between them when the packer is in the sealing or "DOWN" position. The upper end of the inner tube is threaded to take an adaptor coupling to the drill rods.

4. Principles of Operation

(i) The packer is lowered down the hole by means of drill rods attached to the inner tube which is in the "DOWN" position, that is the two sets of four holes are matching but the 16 holes on the outer tube are isolated between the lower sets of seals on the inner tube. At the same time the adaptor coupling on the inner tube is at the bottom limit of travel.

(ii) As the packer is lowered below the water table, the resistance of the packer ensures that the outer tube is kept forced up against the adaptor coupling.

(iii) When the packer reaches the desired sealing location the short drill rod containing the pressure gauge is added and the testing arrangement is attached to this short drill rod which has a sealed coupling on top.

(iv) The pulling plug is connected to the short drill rod and thus the drill string. The footclamp jaws are then removed and the drill rods are then supported by the winch rope.

(v) The pump is then started and the water allowed to bypass.

(vi) When ready to seal the packer the bypass valve is gradually closed.

(vii) The water then flows down the drill string and passes through the four matching holes, inclating the sleeve against the hole wall.

(viii) When a sealing pressure of from 30 to 100 p.s.i. is reached the drill string is raised a little more than seven inches until the pressure gauge registers a sudden drop in pressure, thus indicating that the sleeve is isolated and the lower sixteen holes are opened.

(ix) The sealing pressure used will depend on the hole conditions encountered and must be reviewed in each case.

(x) At stage (viii) the rubber sleeve grips the hole wall while the inner tube is raised and the four holes on the outer tube become isolated between two sets of seals on the inner tube and immediately the two sets of lower seals move upward beyond the sixteen holes of the outer tube below the sleeve.

(xi) At the limit of upward travel the sixteen holes in the outer tube permit water to flow out from the drill rod string into the hole below the sleeve.

(xii) The test can then be conducted by controlling the bypass valve in the usual manner. As the water inflating the sleeve is completely trapped, it cannot be deflated by outside pressure unless the seals or binding fail.

(xiii) When the test is complete all valves are left fully open and the drill string is lowered to the initial or "DOWN" position and the sleeve allowed to deflate over a period of a few minutes.

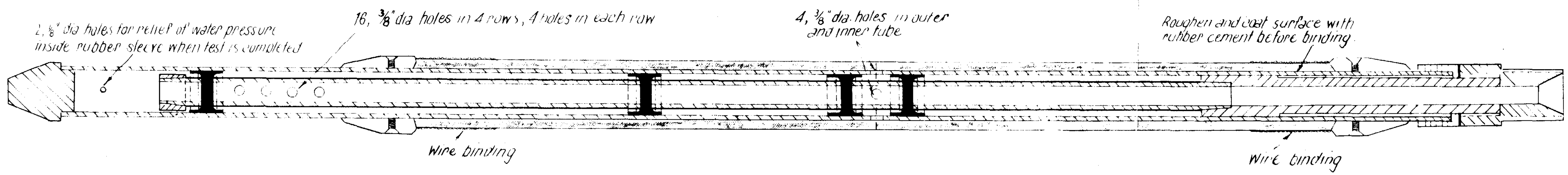
(xiv) The drill string and packer may then be withdrawn from the hole.

(xv) However, if at stage (xiii) with the packer in the "DOWN" position it is found that the depth to the ground water from the hole collar is greater than fifty feet, water should be pumped down the hole above the packer outside the drill string to within fifty feet from the top of the hole and maintained there while the packer is removed from the hole. This is because in the sealing position, that is the "DOWN" position, there is a trapped column of water inside the drill string which exerts a pressure on the inside of the sleeve. For the sleeve to deflate the resultant inside pressure must be less than 25 p.s.i. and therefore, the difference between the height of the column of water on the outside and above the sleeve must be less than approximately fifty feet for the sleeve to deflate and remain deflated during raising.

(xvi) Tests have shown that once the packer is assembled and tested adjustments are not necessary in the field. However, if the operation of the packer becomes in doubt at any time it is likely that either the leather seals or rubber sleeve are damaged and these may be replaced provided the necessary care is taken.

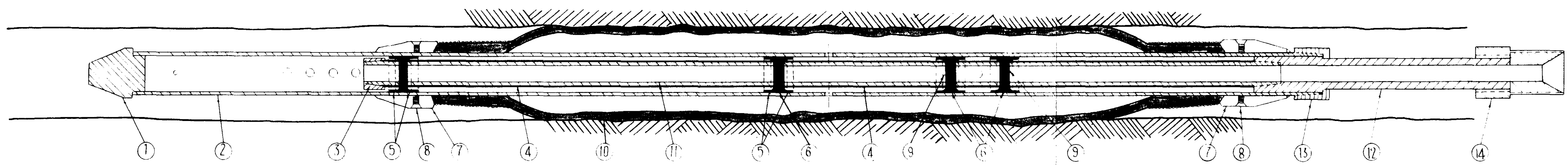
PACKER IN "DOWN" POSITION PRIOR TO SEALING

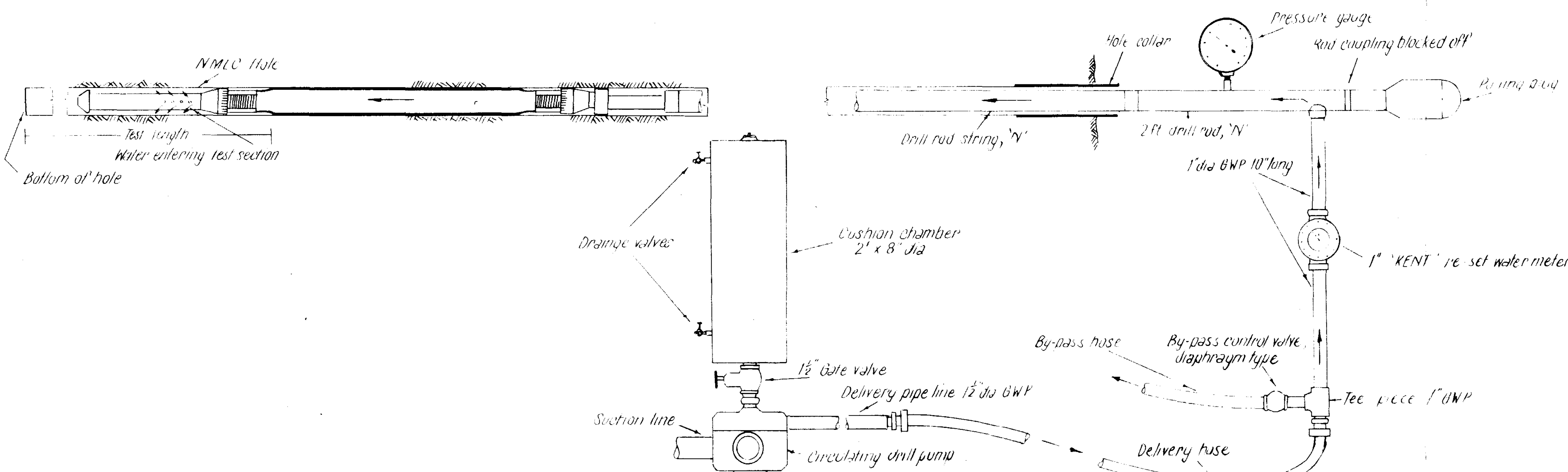
SCALE : QUARTER SIZE
Approximately



PACKER IN "UP" POSITION DURING TEST, RUBBER SLEEVE EXPANDED

SCALE QUARTER SIZE
Approximately





Item	Description	Material	No of
14	'N' Rod adaptor coupling	M.S	1
13	Guide collar	M.S	1
12	Connecting rod	M.S	1
11	Inner tube, 1" OD 10g	M.S.	1
10	Sleeve, 3 ft long 2¼" OD	Rubber	1
9	Washers, ⅛" wide	M.S	8
8	Set screws, ¼" dia	M.S	4
7	Tapered ferrule	M.S	2
6	Guide rings, ¼" wide, 1.61 OD	M.S	4
5	Cup seals, 1 9/16" OD	Leather	8
4	Spacer sleeves, various length	M.S.	5
3	Sleeve retainer nut	M.S.	1
2	Outer tube, 1⅞" dia	M.S	1
1	Tapered plug.	M.S	1

DIAGRAMMATIC LAYOUT OF ARRANGEMENT DURING TEST

PACKER IN "UP" POSITION

Note : Arrows indicate direction of water flow

Bureau of Mineral Resources, June 1963

After S.M.H.E.A drawing T.I.A. No 465

APPENDIX 4.

DRILLING EQUIPMENT IN STOCK AT RAMU AT 8TH JUNE 1963.

TYPE	STOCK	
CORE BITS		
NMLC	5	
NMLC (Step Face)	1	
NX	5	
BMLC	11	
BX	9	
AX	2	
CASING BITS		
NX casing core bits	0	
NX casing shoe bits	0	
BX casing core bits	8	
BX casing shoe bits	5	
REAMERS		
NMLC	4	
NX	2	
BMLC	3	
BX	6	
CORE BARRELS		
NMLC x 10' barrel	1	(2 unserviceable)
NMLC x 5' triple tube stationary barrel	1	
NX x 10' double tube stationary barrel	1	
NX x 10' single tube barrel	1	(inner tube missing)
BMLC x 10' triple tube stationary barrel	1	
BMLC x 10' double tube stationary barrel	1	
BMLC x 5' double tube (split inner) barrel	1	
BMLC x 5' triple tube stationary barrel	1	
BX x 10' barrel	2	
AMLC x 10' barrel	1	
AX x 10' barrel	1	
NX Starting barrel	1	

TYPE	STOCK
CASING	
H x 10'	9
H x 5'	2
H x 1'	1
NX x 10'	17
NX x 5'	4
NX x 3'	3
NX x 2'	1
NX x 1'	1
BX x 10'	61
BX x 5'	3
BX x 2'6"	2
AX x 10'	29
AX x 5'	1
DRILL RODS	
N x 10'	25
N x 5'	2
B x 10'	6
B x 5'	2
A x 10'	46
A x 5'	5
A x 3'	3
A x 1'	2
FLOW METERS	
DAVIES SHEPPARD	3
PRESSURE GAUGES	
0 to 500 p.s.i.	1
DRAG BITS	
	5
WATER PIPE	
$1\frac{1}{2}$" x 15	60
$1\frac{1}{4}$" x 15	41
1" x 15	39
$\frac{3}{4}$" x 15	-
PUMPS	
Mindrill 750 - 1200 Petrol	2 (1 unservicoable)
Mindrill 750 - 1200 Diesel	1
Ronaldson Tippet Type NAH No.40101	1
$1\frac{1}{2}$" Rex Centrifugal	1

FISHING TOOLS

Limited assortment in stock.

Upper Ramu Hydro-Electric Project

Geological Map and Longitudinal Section of Proposed Tunnel Line Showing Positions of New Drill Holes

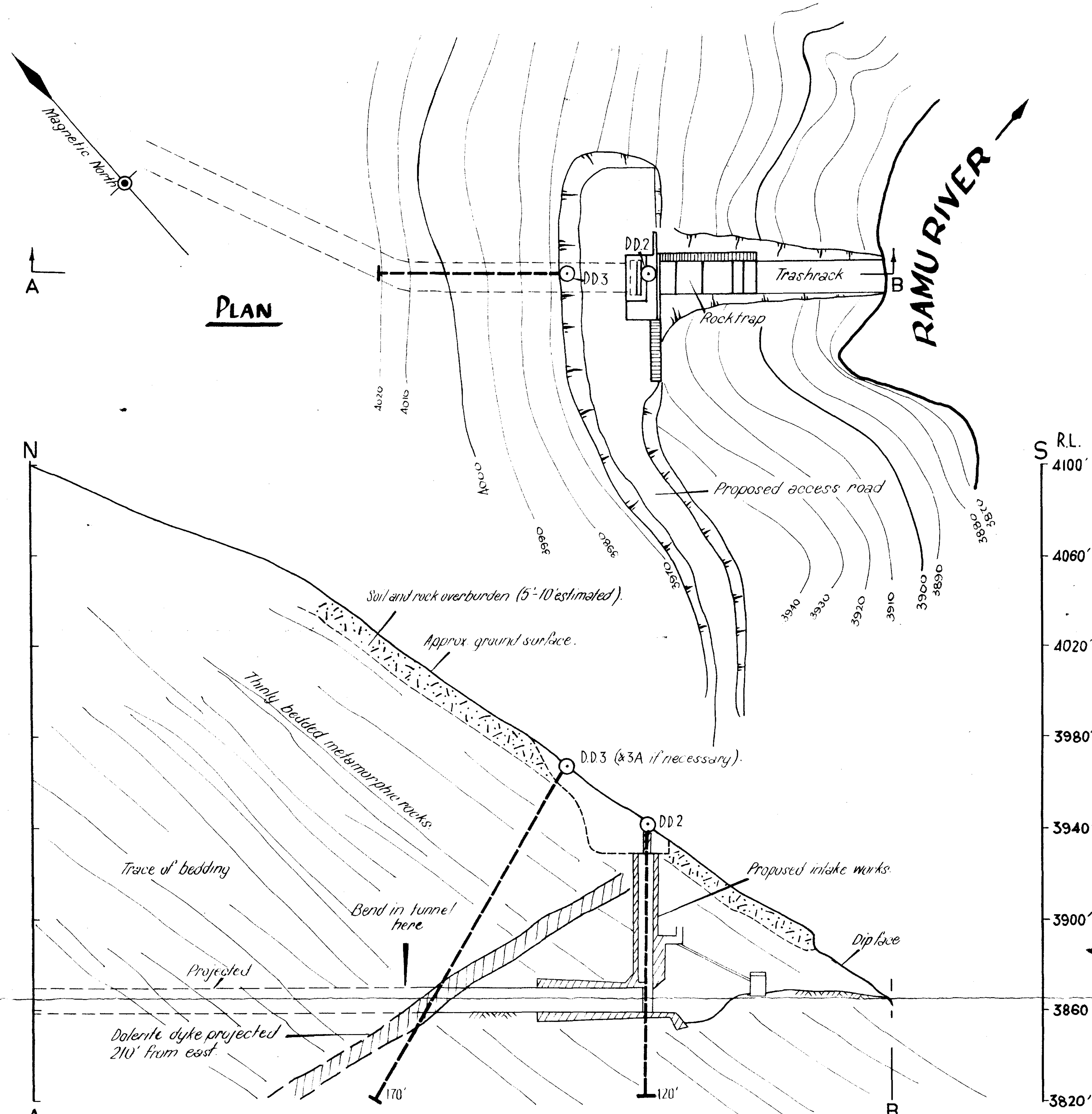
Section along Tunnel Line

Scheme Layout and Geological Plan

Bureau of Mineral Resources, July 1963.

After drawing supplied by C.D.W. Melbourne.

MAP 1



Upper Ramu Hydro-Electric Project

INTERPRETATIVE GEOLOGICAL SECTION AT INTAKE SHOWING PROPOSED DIAMOND DRILL HOLES

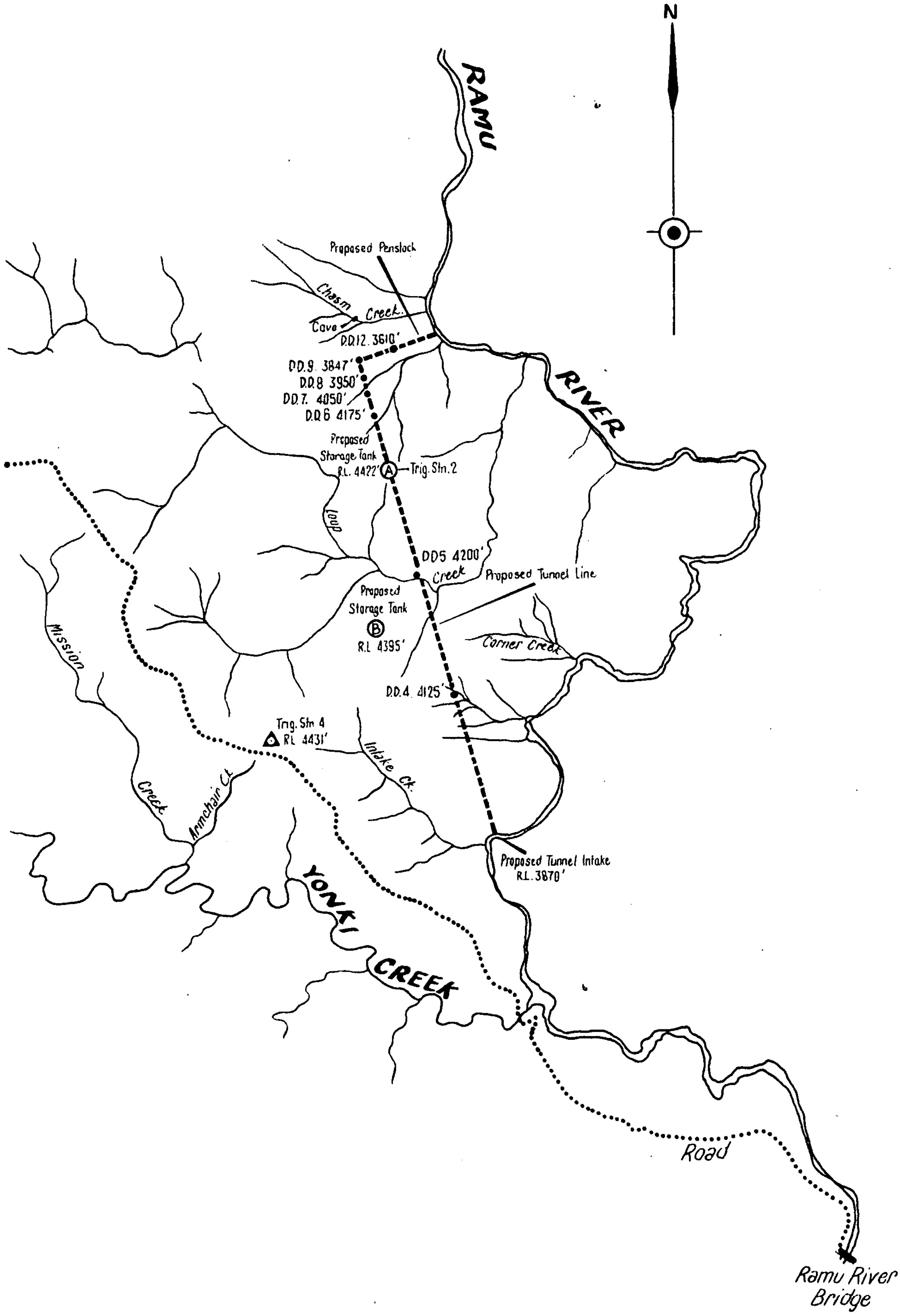
40 20 0 40 80 120 Feet

Scale

MAP 2

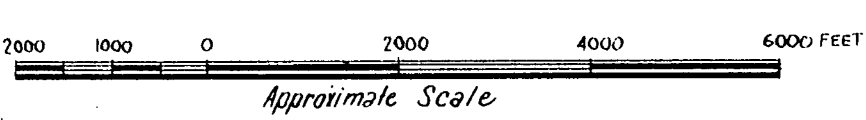
Bureau of Mineral Resources, July 1963.


RAMU RIVER
POWER STATION
WATER COURSE
CREEK
MAGNETIC NORTH
FUTURE No 2 PENSTOCK
No1 PENSTOCK
PROPOSED SEISMIC TRAVERSE ALONG PENSTOCK
SURGE TANKS & EMERGENCY SHUT OFF VALVES
TRAMWAY
ACCESS ROAD
SUB STATION
LOW PRESSURE TUNNEL
PROPOSED SEISMIC TRAVERSE ALONG EXISTING PEGGED TUNNEL LINE.
CREEK
DIVERSION & PONDAGE WEIR
RAMU RIVER
INTAKE WORKS
ACCESS ROAD
RE-ALIGNMENT OF TUNNEL (NOT PEGGED).
INTAKE CREEK
TO AIRONA KAISAM
TO KAINANTU
UPPER RAMU HYDRO-ELECTRIC PROJECT
TOPOGRAPHIC MAP SHOWING PROPOSED SEISMIC TRAVERSES
200 100 0 200 400 600 800 1000 FEET
SCALE
MAP 3
...u of Mineral Resources, Geological Branch, July 1963.



UPPER RAMU HYDRO-ELECTRIC PROJECT

TOPOGRAPHIC MAP SHOWING PROPOSED SITES OF STORAGE TANKS



Bureau of Mineral Resources, Geological Branch, July 1963.

MAP 4