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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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Upper Ramu
Hydro-electric Scheme, TPNG,
Geology of Possible Damsites
near the proposed intake area
for No.1 Power Station

by

E.K. Carter

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GEOLOGY OF POSSIBLE DAMSITES NEAR THE PROPOSED INTAKE AREA

FOR NO.1 POWER STATION

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FIGURE 1: Locality plan, Upper Ramu hydro-electric scheme. Scale 1 inch : 1600 feet.

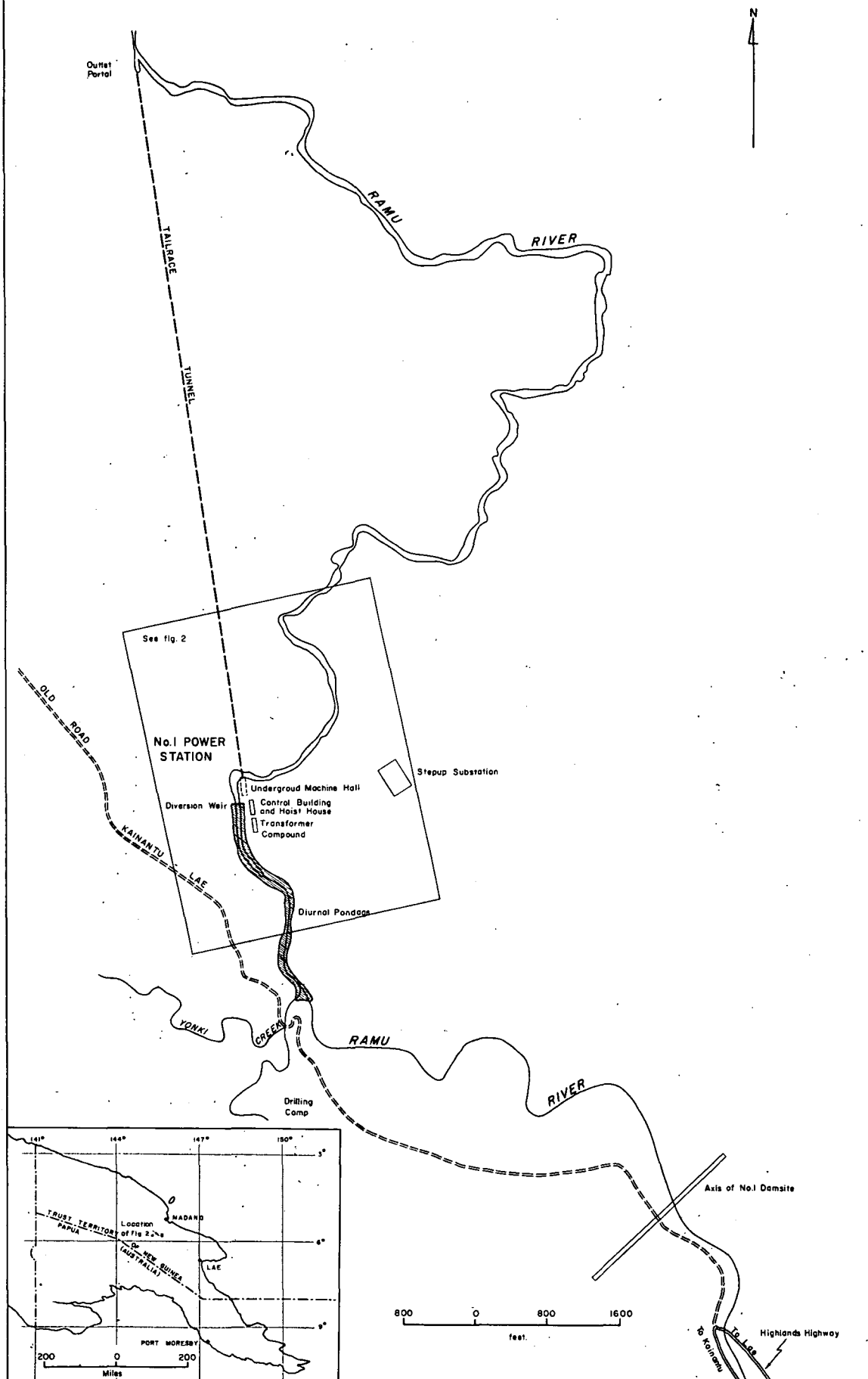
FIGURE 2: Area of possible sites for dams in the intake area, No.1 power station, Upper Ramu Gorge.

Scale: 1 inch : 400 feet.

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Fig 1.

LOCALITY PLAN UPPER RAMU HYDRO-ELECTRIC SCHEME



UPPER RAMU HYDRO-ELECTRIC SCHEME, T.P.N.G.

GEOLOGY OF THE POSSIBLE DAMSITES NEAR THE PROPOSED INTAKE AREA, FOR NO.1 POWER STATION

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INTRODUCTION

The location and proposed layout for Stage 1 of the Upper Ramu hydro-electric scheme - diversion weir, intake works, underground power station and tailrace tunnel - are shown in Figure 1.

Stage 2 of the scheme provides for a reservoir, with maximum water level possibly at about R.L.4136, upstream of the No.1 intake works, to provide firm flow for the scheme. Possible alternative sites for the dam to create the reservoir are: near the present Highlands Highway Bridge over the Ramu River, about one mile upstream of the intake area, or in the Ramu Gorge near the intake area. Because of the substantially greater height of dam needed in the gorge than near the bridge, to provide the storage needed, a dam in the gorge would probably be more expensive than one near the bridge. However, a dam in the gorge would provide a greater head of water for generation of power at the No.1 power station site. This report examines the suitability of the gorge sites in relation to geology, to assist in the economic evaluation of the alternative locations in the storage dam.

Gorge configuration and river fall appear to limit sites in the intake area to the section of gorge near point 1 and between points 3 and 4 in Figure 2. The profile at or near point 1 appears less attractive than that between 3 and 4. Height of dam required, for maximum water level at R.L.4136, appears to be between 270 and 330 feet, depending on the position in the river and assuming crest level of R.L.4145*.

GEOLOGY

Sources of Information

MacGregor (1967) describes the general geology and engineering geology of the No.1 power station project, including the intake area. Hill (1962) mapped in detail the intake area, to a point about 500 feet downstream of the bend at point 2 (Fig.2), and recorded observations based on a quick traverse down the river beyond that point. McDevitt (1969) presents the results of seismic traverses in the area, carried out in 1968, and records some geological observations. C.E. Maffi, of the Bureau of Mineral Resources, has made a photo-geological study of the area of Figure 2, using air-photographs taken

* These levels and heights are based on the Qasco 1 inch : 400 feet photogrammetric compilation.

in July, 1964; his observations are incorporated in this report. The sites of exploratory drill-holes are also shown in Figure 2.

Bedrock

The reader is referred to MacGregor (1967) and Hill (1962) for a detailed description of the geology of the intake area.

The bedrock in the area consists of well-bedded Miocene siltstone, greywacke, and sandstone (with some thin interbeds of shale and slate), and intrusive dykes and sills of basic rock. The sediments are generally slightly metamorphosed, and are hard and strong where fresh; the shale and slate are fairly soft. They are strongly to moderately folded; folding is complex but a major anticlinal axis lies a short distance to the north of the area of Figure 2. The fold plunges to the southeast; consequently the bedding in the left of the river bank generally dips parallel to the slope from point 2 to point 4.

The basic rocks include both gabbro and dolerite; intrusions are generally very irregular in outline, and many are lenticular. Some of the contacts between the intrusive rocks and the sediments are sheared but others are strong; some are gradational. Most of the dykes strike roughly east and many dip north. A dyke width of 35 feet has been measured, but most dykes and sills are a few feet to a few inches wide.

The bedrock is extensively faulted. A prominent shear strikes along the foot of the right bank of the river between points 2 and 3 and others can be seen at the surface. Shears and faults have been intersected at depth in drillhole DD22 and a fault was located by DD1. Correlations between drillholes DD19 and 22 show that some faults with large displacements must be present. McDevitt (1969) has interpreted the seismic record as indicating a probable fault on traverse D. The bare rock face forming the cliff above the south side of the watercourse at point 5 (Dyke Creek) probably is a fault face. A dolerite dyke is associated with the fault, and probably many of the dykes in the area are associated with faults and joints.

Most of the rocks are well-jointed; in places the joints are so closely spaced as to constitute sheeted zones. In general, surface joints are open above river level and have contributed to weathering and slope failure, but most joints are believed to be tight at depth.

The sediments of the bedrock are generally fresh to slightly weathered at river level but are very deeply weathered immediately below the overlying lake sediments (see below). Commonly the uppermost sediments are so profoundly altered (to clay) that it has proved difficult to identify the contact between the lake sediments and the bedrock. The seismic work has shown a low velocity zone between elevations of 4,000 and 4,160 feet (velocity range, other than for near-surface soil and scree 2,500-7,000 feet/second, generally

3,000-5,000 feet/second) ranging in vertical thickness from 120 feet to 8 feet on the left side of the river; the shallowest weathering, along traverse E and the southern end of traverse B, is in an area where recent landslips have occurred and which is topographically unattractive as a damsite. Below R.L.4,000 weathering is much shallower, ranging from 115 feet (but apart from traverse B, 75 feet) to zero. On the right side of the river the vertical depths are 140 feet to 56 feet between R.L's.4160 and 4000, and 77 feet to zero below R.L.4000.

The basic igneous rocks - dolerite and gabbro - tend to weather more deeply than the sediments. At river level basic rocks in fresh sediments are commonly moderately to completely weathered; gabbro in drillhole DD1A is partly weathered to 100 feet below river level.

All the drillholes in the area are outside of possible damsites but generally confirm the seismic results (see Table below).

Depth of Weathering in Drillholes

| Hole No. | R.L. Collar | Unconsolidated Material | completely weathered bedrock | slightly weathered bedrock |
|----------|--------------|------------------------------|------------------------------|--|
| S1 | 4250 approx. | ? | To approx. R.L.4120 | To approx. R.L.4075 |
| DD1 | 3877 | To R.L.3874 (River detritus) | Nil | Fresh from R.L. 3874 |
| DD1A | 3875 | Nil | Nil | Fresh from surface |
| DD1B | 3870 | To R.L.3863 (River gravel) | Nil | Fresh from 3863 |
| DD1C | 3900 approx. | Nil | Nil | To 3891 |
| DD2 | 3944 | (2' no core) | Nil | Fresh to slightly weathered from R.L.3942 |
| DD4 | 4130 | No core to R.L.4123 | To 4092 | Some moderately weathered rock, interbedded with fresh to 3900 |
| DD19 | 3971 | To R.L.3959(fill,etc.) | To 3940 | To 3921 |
| DD21 | 3973 | To R.L.3968 | To 3960 | To 3907 |
| DD22 | 3951 | To R.L.3947 | Nil | To 3882. Some slight weathering to 3761 |

Lake Sediments

The Miocene bedrock is overlain by horizontal, compact, but unlithified lake sediments of Recent (possibly Pleistocene) age. The sediments consist of silt, sandy and clayey silt, silty gravel and clay. In many places extensive boulder and cobble beds occur at the base of the succession; they do not appear to be present in the area under consideration, but large transplanted boulders of granodiorite occur in Intake Creek (Plate 2). In the absence of basal conglomerate, and because of the profound weathering of the upper surface of the bedrock it is difficult to establish accurately the level of the base of the lake sediments. The lake sediments of the region are believed to have been deposited on an irregular surface, with a relief of possibly several hundred feet, but no evidence has been found of deep ravines or similar abrupt changes in the pre-depositional surface which would, for example, cause permeable lake sediments to be present in possible dam abutments substantially below the general base level.

On the left side of the river, four drillholes (two of them - S2 and DD5 - north of the area under consideration) indicate the following probable levels for the base of the lake sediments:

- S1 - R.L. 4140-4150
- DD4 - above R.L. 4130 (lake sediments are not present in the hole)
- DD5 - 4100
- S2 - 4144 or lower

On the air-photographs lake sediments cannot be identified below about R.L. 4140. Geophysical work has failed to delineate the base of the lake sediments on the left side of the river, except for a possible value of R.L. 4125 on traverse AAl.

On the right hand side of the river, McDevitt (1969) shows a near-horizontal surface along traverse FF1 at about R.L. 4178-4190; this possibly represents the base of the lake sediments. Costean 4 (MacGregor, 1967, Plate 4) exposed bedrock to an elevation of 4051 feet, and bedrock is known to occur at a considerably higher elevation than the upper end of costean 4.

SLOPE STABILITY

Left Bank

Extensive slope failure has occurred on the left side of the river since systematic investigation of the scheme was started in 1961; evidence from drilling, photo-geological studies and the geophysical survey indicates that a number of older slips have occurred in the past and some are still active.

The attitude of the bedding in the bedrock, generally parallel to the land surface, has been the controlling factor in most of the

recent slips, three of which have been noted by McDevitt (1969, p.5). Movement has generally been along the soil-rock interface, at a depth of a few feet only, and most have probably been initiated by disturbance of the natural conditions in the course of the site investigations. These slips demonstrate the essential instability of the natural slopes. Between points 2 and 4, it is possible that frequent failure along dip slopes has protected the bedrock from more deep-seated failure - the geophysical results are not conclusive in determining whether deep slips have occurred, or are likely to occur, in the higher slopes. The slope of the lowest refractor is reminiscent of slip surfaces in some places, e.g., between chainages 500 and 700 on traverse CCl.

The concavity, in plan, of the slope above point 2 and that around point 8 are superficially suggestive of old, dissected slip surfaces from which the slipped material has been removed by erosion. However, the configuration could be produced by normal erosive processes, and C.E. Maffi (who made a photo-geological study of the area) is of the opinion that the slopes were not formed by major deep-seated slips.

North of an east-west line through point 4, the geological conditions are entirely different as the bedding dips either across or into the slope and the surface is controlled in part by failure along a steeply north-dipping dolerite dyke. In this area there is abundant evidence of deep-seated slope failure involving bedrock. The slip about point 6 is clear on the surface, being marked by a scar several feet high and free of vegetation; it matches the break in the bedrock profile at chainage 1780 feet on seismic traverse AAl. Drillhole S1 appears to be slightly uphill of the slip trace. It was drilled by percussion to 149 feet and considerable difficulties were experienced with tight casing and water. Below 149 feet, core was lost over several feet at depths of 150, 210, 220 and 300 feet; the core loss was associated with zones of broken rock. The fracture zones in rock are possibly of tectonic origin; nonetheless it was a common experience while drilling along the high-level tunnel line (the first project layout investigated) to find a great many more fracture and shear zones with evidence of movement in the upper part of the hole than in the lower part - a situation to be expected if the fractures and shears were partly due to near-surface slips. Proof of current landslip activity is given by the experience in drillhole DD4, in which substantial core loss, and adjoining broken core, occurred about 13, 68, and 82 feet depth, and the casing was sheared off when the hole was left standing for several months. McDevitt's interpretation of deep slips at the northeastern ends of seismic traverses B and C appears reasonable and, in conjunction with the evidence for deep slips about points 6 and 7, suggests that the whole slope above the face running west from the river through point 5 may be unsound.

Right Bank

The heavy tree cover on the right hand side of the river limits visual observation of evidence of landslips below the treeline. Abundant shallow slips from the upper slopes, possibly mainly from lake sediments, are apparent on the air-photographs. As bedding in the bedrock dips into the slope, shallow failures are not so likely to occur on the lower slopes as on the left side of the river - the high cliffs suggest that little modification by shallow slips has taken place. Nonetheless, the convexity of the profile along seismic traverse AAl, within 160 feet of the river, and the low velocity of the material forming the "bulge", indicate that substantial slips or rock-falls do occur.

Upstream of point 2, it is apparent from field observations that substantial masses of soil and rock have slipped from the ridge east and southeast of drillhole DD22. The irregular surface of the lowest refractor of seismic traverse FF1 suggests that some very deep-seated slips may be present.

Farther downstream, the deeply incised watercourse east of the river gorge may assist in draining, and thereby stabilizing, the upper slopes of the gorge, which presumably are formed of lake sediments with underlying highly weathered bedrock.

CONCLUSIONS

1. A damsite in the Upper Ramu gorge, near the proposed intake area for the No.1 power station, and with crest level at or about R.L. 4145, would have highly weathered to decomposed bedrock, with the mechanical properties of soil, in the upper part of both abutments. The top 0-40 feet would probably be of lake sediments.
2. Weathering, to vertical depths of over 100 feet in places, and the probable presence of lake sediments, would appear to preclude the construction of a concrete dam. Previous investigation for the Upper Ramu scheme suggest that materials suitable for either a rock or earth fill dam are available in the area.
3. As existing slopes in the gorge are generally unstable, or barely stable, any large-scale stripping or cuts in the lower parts of any dam abutments would probably initiate substantial slope failures at higher levels. Account would have to be taken of this fact in assessing excavation volumes and procedures.
4. Judging by the seismic results, a thorough investigation of the lower slope will be necessary to establish the distribution of slipped material in the lower abutments. Slipped material, possibly more than 100 feet thick (vertical depth), may be present in places and this would have to be either proved acceptable abutment material or removed.
5. The possibility of deep slips, extending below the lowest refractor of the seismic traverses, in any proposed abutments will have to be thoroughly investigated.

6. Any spillway cut in either abutment would be in soil-like materials in the crest area and probably for a considerable distance down the chute.
7. Any works on, or through, the slope between points 4, 5 and 6 (e.g. diversion tunnel, spillway, etc.) would probably involve a large segment of unstable ground and could prove technically difficult and expensive.
8. Any dam in the intake area would raise the water table of the area very substantially and would increase the instability of slopes. Substantial slips into the gorge section of the reservoir could be expected. It would therefore appear to be necessary to locate any intake works for the No. 1 power station downstairs of the dam embankment.

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