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Preliminary Investigation of the Geology of the Proposed Rouna No. 3 Hydro - Electric Power Station, Port Moresby, Papua

by

I.S. Cumming

PRELIMINARY INVESTIGATION OF THE GEOLOGY OF THE PROPOSED ROUNA No.3 HYDRO-ELECTRIC POWER STATION, PORT MORESBY, PAPUA

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SUMMARY

The proposed Rouna No.3 power station, near Port Moresby, Papua, is to be built adjacent to the existing Rouna No.1 power station. The new station is to harness the same fall of the Laloki River as No.1 power station, with the intake situated at the foot of the Rouna Falls.

A regulating pond is to be constructed upstream of the Rouna No.2 power station diversion weir above the Rouna Falls.

Geological conditions restrict the choice of a site for No.3 station. Upstream of No.1 station, there is a mass of very large boulders of agglomerate. Downstream, the site encroaches upon an area of river gravels originally chosen for the No.1 station site but which slipped soon after construction commenced. The downstream site can be used provided that it is thoroughly investigated to determine the design of foundations and that efficient drainage works are constructed on the slopes above the site.

The existing routes of the aqueduct from the intake and of the penstocks are the most satisfactory. The safety of the upper part of the penstocks can be increased by improvements to the main road to Sogeri; the existing drainage of the road is inadequate. Investigation of the sites for anchor blocks and supports for the lower end of the new penstocks is essential.

The site of the embankment for the regulating pond is in Astrolabe Agglomerate overlain by red clay. The bedrock profile has far less relief than at the diversion weir of the No.2 station and the depth of red clay is greater. Investigation by drilling and boring is necessary.

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INTRODUCTION

General:

With the increased regulation of the flow of the Laloki River, it is now possible to generate more hydro-electric power by utilising the same fall of the river that is harnessed by the existing Rouna No.1 power station. The proposed No.3 power station would be built next to the No.1 station. The site is restricted and unfavourable ground conditions appeared during construction of the existing station.

This report describes the findings of a preliminary geological investigation of the No.1 scheme and the proposed site for No.3 station. A brief description of the site for the Sogeri regulating pond upstream of the weir of Rouna No.2 power station is included.

Outline of the Port Moresby Hydro-Electric Scheme:

The development of the Laloki River to generate power for Port Moresby and Sogeri has taken place in four completed stages, the fifth is soon to be commenced and the sixth stage is proposed. The general layout of the scheme is shown in Plate 1.

1. Rouna No.1 power station, constructed 1954-57, comprises an intake near the foot of the Rouna Falls and an open flume $1\frac{1}{4}$ miles long, a steel penstock, and generating plant of 3 megawatt (Mw) capacity operating at a head of 380 feet and 130 cusecs flow.

2. Round No.1 power station was enlarged in 1961 by adding one generator of 2.5 Mw capacity; a 54 inch diameter concrete pipe aqueduct was laid downhill of the open flume; a diurnal storage pond and another steel penstock were constructed.

3. Sirinumu Dam, Stage 1, completed in 1962, was built across the Laloki River 6 miles south-east of the Rouna Falls to provide 77,000 acre-feet of storage.

4. Rouna No.2 power station, constructed 1965-68, is an underground scheme of 30 Mw capacity. Water is drawn from a diversion weir $\frac{1}{2}$ mile upstream from Rouna Falls and discharged at the foot of the Falls and upstream from the intake of No.1 Power Station.

5. Sirinumu Dam, Stage 2, construction of which will begin in July 1969, will increase storage of the reservoir to 280,000 acre-feet.

6. The proposed Rouna No.3 power station adjacent to No.1 power station and regulating pond upstream of the diversion weir of No.2 power station.

Location and Access.

Rouna No.1 power station is situated 15½ miles bearing N74°E from Port Moresby Post Office. The intake is 1¼ miles bearing S79°E from the power station.

Access is by the Port Moresby-Sogeri road. The power station road joins the main road 20 miles from Port Moresby. The private road does not go as far as the power station, which is reached by stairs and an inclined tramway down on the road. The access road to the intake joins the main road 22 miles from Port Moresby. Access to the aqueduct is gained only on foot.

Topography:

The Laloki River drains the Sogeri Plateau, which is undulating with scattered tors of agglomerate. The plateau rises to 3,300 feet above sea level along the southern margin which forms the Astrolabe Range. At the Rouna Falls the river plunges from 1,330 to 930 feet above sea level. Below the falls river flows for 4 miles westwards in a deep valley, widening downstream. The valley sides are for the most part dominated by vertical cliffs up to 500 feet high. The middle slopes of the valley are irregular and strewn with large boulders. In the valley bottom, the river flows in a gorge for much of its course. Vegetation on the valley sides is grass and scattered eucalypts except in the vicinity of the river, the Rouna Falls and tributary creeks, where there is tropical rain forest. Grass fires occur frequently during the dry season, April to December. From 4 miles west of the Falls, the river crosses an alluvial plain to flow north-westwards to the sea at Galley Reach, about 30 miles north-west of Port Moresby.

Previous Investigations:

Engineers of the Commonwealth Department of Works began investigations into the development of the Laloki River for power generation in the late 1940's and Condon (1949) made the first appraisal of geological factors. Edwards (1951) inspected the site chosen for the No.1 scheme and described the geology. During the construction, 1954-57, J.E. Thompson gave geological advice. During the investigations of weir sites for the Rouna No.2 scheme in 1958-62, Gardner and Noakes (1959) investigated two possible sites for the diversion weir at 1750 and 2450 feet upstream of the site adopted for construction.

Diamond Drilling:

Five holes were drilled in 1955 to investigate ground conditions following a slip near the proposed site for the No.1 power station. Drillholes Nos.1--4 were drilled to 60 feet and No.5 to 75 feet depth. Records of the results of this work have not been found.

Soils Investigations:

Some soils investigations were carried out for the site of the intake and in connection with the slip at the initial site of No.1 Power Station. A comprehensive investigation for soil to contruct the embankments of the diurnal storage pond was carried out. Records of these investigations are not kept in Port Moresby.

GEOLOGY

STRATIGRAPHY.

Detailed mapping of the area has not been completed. Much of the general information is obtained from the work of Carter and Brouxhon (1963) at Rouna No.2 Power Station, east of the site, and Yates and de Ferranti (1967) to the west of the site. The stratigraphy is summarised in Table 1. The known distribution of the strata in the vicinity of the site is as follows.

Sadowa Gabbro Complex:

Gabbro crops out in the beds of creeks on the south side of the Laloki Valley and forms much of the low ground south and west of the Sogeri Plateau. The subsurface of the gabbro beneath overlying beds is irregular. Traverses up tributary creeks found gabbro nearly 1,500 feet above sea level but at the No.1 Power house site, drilling reached 450 feet above sea level without meeting gabbro.

Siro Conglomerate

Both top and bottom of the Siro conglomerate are irregular so that thicknesses vary greatly from place to place. In the hillside south-east of No.1 power station, conglomerate or its gravel equivalent is exposed from 530 to 860 feet above sea level; this does not necessarily indicate a vertical thickness of 330 feet. At Rouna No.2 a drill hole penetrated 113 feet vertically without meeting the base of the succession. At Rouna Falls, the top of the formation is at 1,050 feet above sea level and conglomerate occurs in the river bed near the No.1 intake at 910 feet above sea level.

Both penstocks of No.1 Station rest on Siro conglomerate.

Astrolabe Agglomerate:

This formation forms the Sogeri Plateau. Near Rouna No.2 weir, a drillhole penetrated 520 feet to 915 feet above sea level without meeting the base. Allowing 500 feet for relief above the drillholecollar, the thickness thus exceeds 1,000 feet.

The bedrock of the Sogeri regulating pond will be Astrolabe Agglomerate, but no part of Rouna No.3 works is likely to be on this unit.

TABLE 1

SUMMARY OF STRATIGRAPHY

STRATUM	DESCRIPTION	THICKNESS (approximate)
Topsoil	Dark grey to black silty clay with stones. Thin on well-drained slopes: thick in swamps.	0 - 3 feet
Residual boulders and red clay.	Boulders almost entirely of agglomerate up to 1000 cubic yards in volume. Red or mottled brown and white clay derived from agglomerate.	0 - 50 feet
Laloki River gravels.	Interbedded silty sand and gravel with boulders of agglomerate, weathered lava pebbles and pebbles derived from Siro Conglomerate.	maximum thickness not known.
	UNCONFORMITY	
Scree and landslip breccia	Breccia of agglomerate fragments and large boulders.	0 - 500 feet (estimated)
	UNCONFORMITY	
Astrolabe Agglomerate	Dark grey agglomerate with andesite and basalt pebbles and boulders interbedded with lithic tuff.	up to 1000 feet proved.
	UNCONFORMITY	
Siro Conglomerate	Argillaceous sand and gravel locally cemented to greywacke and conglomerate; pebbles and boulders; of metasediments, igneous rocks, and rarely quartz, are well rounded.	up to 200 feet proved.
	UNCONFORMITY	
Sadowa Fabbro Complex	Mainly gabbro with minor dolerite and diorite.	plutonic

Scree and Landslip Breccia:

This unit includes all deposits consisting of boulders (many of them very large) of agglomerate with a matrix of angular fragments of agglomerate. The deposit is commonly so well-cemented that vertical faces occur. The deposits occupy much of the lower parts of the valley on both sides downstream from No.1 power station, including the bluff on which the transformer yard stands. Similar breccia occurs on the left bank upstream almost as far as the Rouna Falls.

Laloki River Gravels:

In the immediate vicinity of No.1 power station, including the slipped ground, there are patches of clayey gravel containing pebbles of weathered basalt and in one locality, a boulder of agglomerate. Because of the presence of the latter, the gravel must be younger than the Astrolabe Agglomerate; it is considered to represent remnants of old terraces of the Laloki River.

Residual Boulders and Red Clay:

Chemical weathering of the Astrolabe Agglomerate ultimately produces a firm to stiff red clay with scattered boulders of almost unweathered agglomerate included in it. Red clay occurs at the regulating pond site. Boulders residual from scree and landslip breccia are concentrated in creeks and along the banks of the Laloki River. In many places they are so abundant that the bedrock cannot be seen.

Topsoil:

Although the topsoil is usually thin and of no significance in engineering works, pockets of greater depth occur. Topsoil composed the natural debris of a slip that took place on the line of aqueduct in January, 1966.

STRUCTURE

The Sadowa Gabbro Complex was much deformed by orogenic movements and has abundant faults and joints.

In the Siro Conglomerate several joints and faults with clay filling were exposed in the competent rock at the western end of Rouna No.2 tailrace tunnel.

The bedding of the Astrolabe Agglomerate is sub-horizontal with dips up to 7° occurring locally. Well developed joints spaced at 10 - 100 feet occur throughout. Chemical weathering along joints has produced clay filling up to several feet wide. In the river bed above the Rouna Falls, the joints were found mostly to be tight within 10 feet of rock surface. Zones of shearing in the agglomerate have been observed in the vicinity of the Rouna Falls but none has been identified elsewhere.

ENGINEERING GEOLOGY

ENGINEERING PROPERTIES OF ROCKS AND SOILS.

Gabbro:

This rock is not expected to occur at shallow depth in the construction areas. The rock is deeply weathered in all outcrops.

Siro Conglomerate:

The lithology of this rock unit is extremely variable. The varying degrees of cementation of the Siro Conglomerate can be examined along the existing penstock line. Lenses of well-cemented conglomerate are interbedded with more weakly cemented gravel that can be dug with a pick. Natural slopes in the weakly cemented gravel stand at nearly 45°. There has been no settlement of the penstock supports and anchors, and erosion of the gravel is negligible. In the vicinity of Rouna No.1 power station, the visible Siro Conglomerate rarely contains pebbles more than 6 inches in diameter. In Rouna No.2 tailrace tunnel boulders up to 4 feet in diameter are abundant, and the part near the base of the Astrolabe Agglomerate has a highly sheared, argillaceous matrix.

No general statement of the soundness of the Siro Conglomerate as a bearing stratum can be made.

Astrolabe Agglomerate:

The agglomerate, in the fresh to mocerately weathered condition, is strong and provides a good foundation. The tuff is more deeply weathered than agglomerate, is generally more closely jointed, and is a much less satisfactory foundation material than the agglomerate.

Scree and Landslip Breccia:

These deposits, if coarse, are suitable for foundations. Their main disadvantage lies in the abundance of large boulders of fresh agglomerate in the scree and breccia. Many of the boulders are too large to push aside and are costly to break with explosives; as a result excavation tends to be difficult and expensive.

Laloki River Gravels:

A slip in these gravels at the originally selected site for No.1 power station led to the repositioning of the station. Because of the numerous pebbles of weathered basalt and the clay content, the gravel is considered to be unsuitable for foundations.

Red Clay:

The red clay, which is the end-product of the chemical weathering of agglomerate, is a fine to stiff silty clay which has been proved suitable for construction of earthworks.

No.3 POWER STATION SITE

Geological conditions restrict the choice of a site for the No.3 power station. Upstream of No.1 station, there is a steep bank of large boulders of agglomerate extending to the river's edge. The spaces between the boulders are partly filled with gravel and river water flows among the boulders. Stable foundations would be difficult to construct. The alternative is to site the No.3 station downstream of No.1 station.

The original site for No.1 station is about 100 feet west of the existing station. The slip which occurred at the end of 1954, soon after excavation began, extends from 50 feet to 100 feet from the west end of the building and up the slope to 200 feet from the river. The upper part of the slip was 20 feet wide until further movement in February, 1962 widened it to 60 feet and damaged the lower part of the concrete stairway to the power station.

Inspection of the slipped ground revealed that:

(a) the slip is in an area where four intermittent streams converge. The streams flow only during and immediately after heavy rain;

(b) at least one of the streams has a natural catchment extending above the main road. The system of drains for the road has beheaded the water course; the water is diverted westwards to another creek which is perennial. There has been some slipping of the road-fill where the road crosses the former course of the creek.

It is concluded that there is a considerable discharge of storm water over the abandoned site of No.1 station and that the gravel on the slopes becomes waterlogged during wet weather.

An inspection of the ground farther downstream yielded little information owing to the dense growth of vegetation there. The transformer yard is on a spur of landslip breccia. The north and east sides of the spur are steep, and vertical in places; on the north-west side the spur runs down to the Laloki River and on the west it slopes down to a creek strewn with large boulders of agglomerate. Farther downstream, the Laloki River flows in a gorge. Between the north side of the transformer yard spur and the Laloki, there is a flat area covered with tall kunai grass. This flat may be an old course of the river and if so, will be underlain by gravel and boulders. There could be flooding of this area during high floods.

In order to build No.3 Power Station, it is necessary to investigate not only the properties of the soils but also the hydrology of the area with the view to installing efficient drainage of the entire hillside above the site. Owing to the presence of large boulders, boring can be difficult and a seismic survey should help greatly to indicate the bedrock profile.

PENSTOCK ROUTE:

The foundations of the existing penstock have proved to be stable. There is instability in the slope below the main road near the surge tanks and a large disturbance of ground here could endanger the penstock. Defective drainage of the road at this point has caused minor slips in gravel fill.

For the penstock to No.3 station, investigation will be required as less stable ground is likely to occur in the lower part of the penstock route.

AQUEDUCT

The existing aqueduct comprises an open flume and a 54-inch-diameter concrete or steel pipe on the downhill side of the flume.

On 4th January, 1966, a slip in black soil occurred during heavy rain about 3600 feet upstream of the pipe outlet; 45 feet of the concrete pipe was left unsupported. The pipe did not break and the concrete flume was not affected. The slip carried away a retaining wall 8 feet high. Inspection showed that the drains under the flume and pipe had been blocked by grass and thatwater in the flume periodically spilled over the sides at this point. This incident calls attention to the vulnerability of existing works to damage by shallow slips and the need for adequate precautions to be taken in the design of future works.

REGULATING POND.

No construction difficulties are anticipated in the area of the regulating pond. Ground conditions are similar to those at Sirinumu Dam. Investigation of the thickness of red clay will be required.

SEISMICITY

The seismicity of the area is very low. The average number of felt shocks is one per year and felt intensities up to IV on the Modified Mercalli Scale have been reported. Structures of normal good design and construction, if founded on stable ground, would not be affected.

CONCLUSIONS

1. Owing to the presence of weak gravels and unsatisfactory drainage at the power station site, a comprehensive investigation of ground conditions and hydrology is required. Improvements to existing road works must be considered to ensure the safety of the power station and the penstock.

2. The stability of existing retaining walls and other structures along the aqueduct should be investigated.

3. Ground conditions at the regulating pond site are similar to those at Sirinumu Dam; investigation of the site should include boring to determine the depth of red clay and the bedrock profile.

4. Seismicity of the area is very low and special design for earthquake resistance of structures is not required.

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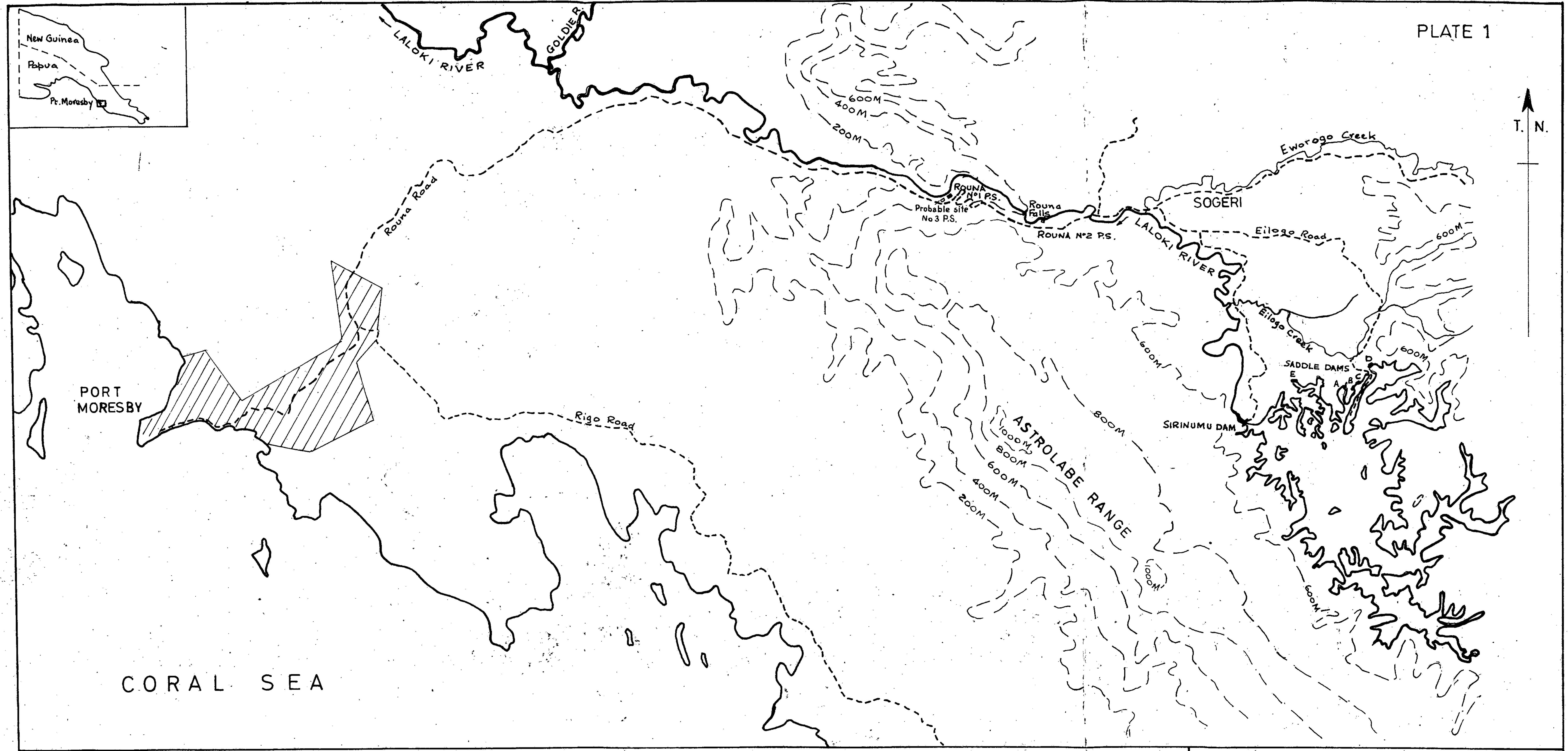


REFERENCE

200M — Contours, vertical interval 200 metres (656 feet)

Roads

Town area

SCALE

0 1 2 3 4 5 miles

PORT MORESBY HYDRO-ELECTRIC PROJECT

LOCALITY PLAN

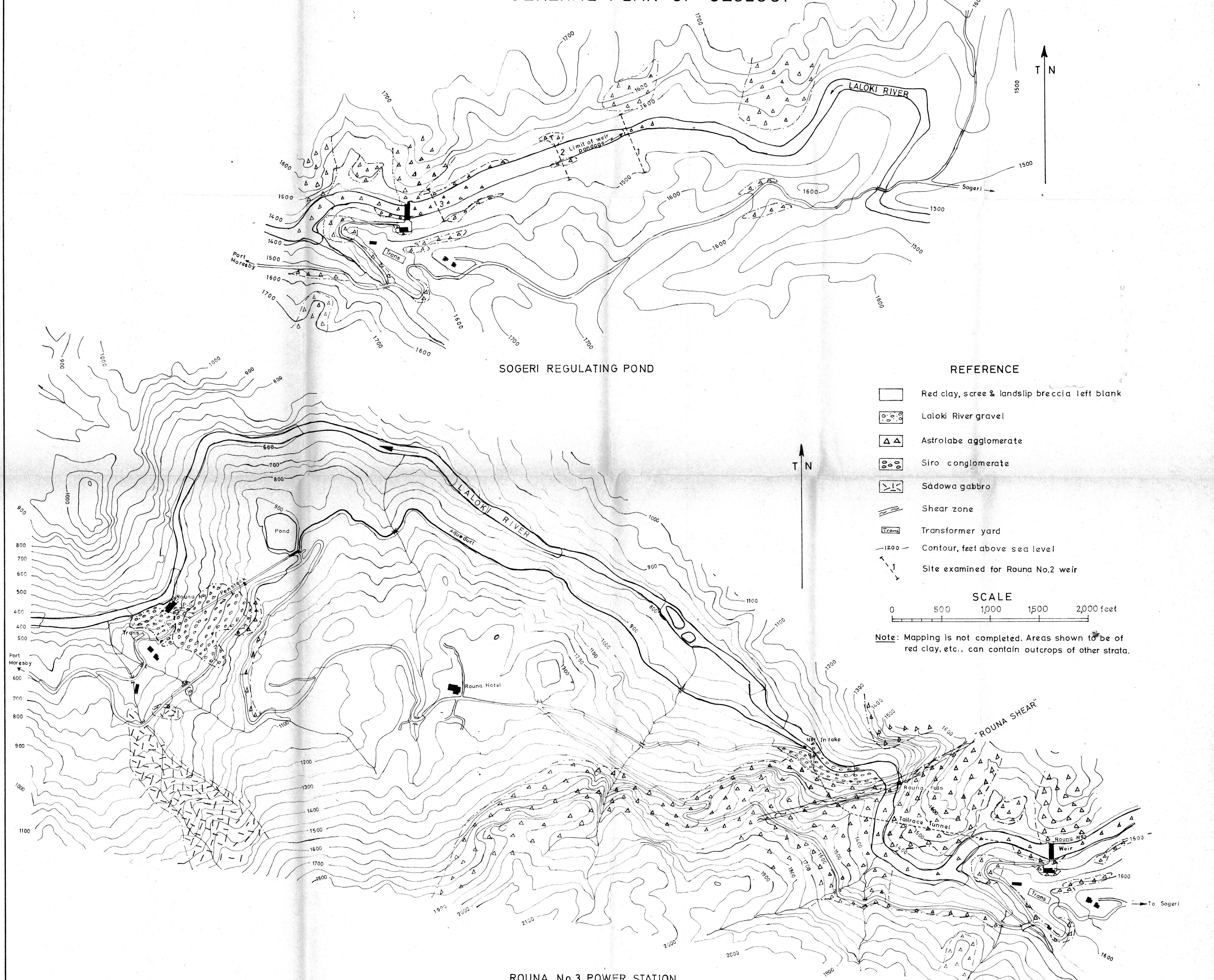
To accompany Records 1969/1 & 1969/106

Geological Office Port Moresby

C55/A7/39

PNG C55-7-21

ROUNA No.3 PROJECT
GENERAL PLAN OF GEOLOGY



ROUNA No.3 POWER STATION
Proposed pipeline route follows the existing aquiduct

I. S. Cumming Geological Office, Port Moresby To accompany Record 1969/106

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