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GEOLOGICAL RECONNAISSANCE OF THE TUMA RIVER HYDRO-ELECTRIC SCHEME, WESTERN HIGHLANDS, T.P.N.G. DECEMBER 1962

by

E.K. Carter

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SUMMARY

The Tuma River hydro-electric scheme is designed to provide electricity for the Mount Hagen area by diverting water from the Tuma River into the Nebelyer River.

Most of the works associated with the scheme would be founded in unconsolidated lake sediments, composed largely of redistributed volcanic debris. These may create some difficulties at the weir site and in support of a considerable length of the penstock, but would provide satisfactory race lines, for which lining should not be needed.

It is suggested that consideration be given to a larger scheme whereby water from the Tuma River would be raised over, or taken through a cut in, the ridge to the east of the Tuma River, and carried by penstock to the Nebelyer River 1500-2000 feet below.

INTRODUCTION

An inspection was made on Friday, 7th December 1962, of the site of a proposed hydro-electric project designed to harness the Tuma River to provide power for Mount Hagen district. The writer was accompanied by Mr. D. Ryan, Mr. V.A. Chadim and others of the Stream Gauging Section of the Commonwealth Department of Works. In addition to an examination of the geological aspects of a scheme proposed by Mr. J. Brett, Commonwealth Department of Works, Port Moresby (Departmental report 62/115, dated 8th June 1962), possible alternative schemes capable of greater power generation were considered.

LOCATION AND ACCESS

Mount Hagen township is the administrative centre of the populous Wahgi Valley and lies between the two headwater streams of the Wahgi River. It is in the Western Division of the Territory of New Guinea, 320 air-miles from Port Moresby and 85 air-miles from Goroka.

The Tuma River* is a small tributary of the Nebelyer River (which joins the Kaugel River and consequently is part of the Purari River system). It falls about 600 feet in 2 miles (direct distance) to the junction with the Nebelyer River (see Plate 1). It is proposed that this head should be used for power generation. The junction of the Tuma and Nebelyer Rivers is 10½ miles north of west from Mount Hagen township.

Access is via the formed, graded and roughly metalled road to Tambul and Wabag, which is left near the village of Melbor, a distance of 21 miles from Mount Hagen township. From Melbor, which is roughly 500 feet above the junction of the Tuma and Nebelyer Rivers, a steep foot track crosses the

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*Shown on National Mapping Division's map of Mount Hagen one-mile sheet as the Gogump River.

Nebelyer River to give access to the Tuma River. Owing to the steepness of the Nebelyer River valley at this point vehicular access to the Tuma River for construction purposes would be extremely difficult and it is considered that an easier crossing of the Nebelyer River would probably be found farther upstream; once the Nebelyer River valley is passed the headworks of the proposed scheme could be reached on easy gradients. Access is impossible from north and east of the Nebelyer River downstream of its junction with the Tuma River.

OUTLINE OF SCHEME

Plate 2 shows the layout of the proposed and alternative schemes and the elements of relief and stream pattern on which they are based. Mr. Brett's proposal is that the waters of the Tuma River should be picked up at a point about $\frac{3}{4}$ mile south of Bebeka village, near where the gradient of the stream begins to steepen, at RL 7250 (barometric height). At this point the river is incised into earth banks a depth of 35 - 40 feet. The water would be carried by an unlined race, along the left side of the river, to an open pondage above a saddle at the head of a steep spur. The spur leads down to the Nebelyer River a short distance upstream of its junction with the Tuma River. The race would also gather water from Kamoga Creek, which it would cross. From the pondage the water would be led by surface penstock down the spur to a surface power station. Alternative routes for the penstock, and consequently locations for the power station, have been considered. The surge tank would be placed at the head of the spur across the saddle from the pondage. Only barometric levels were available at the time of the inspection; these indicate an available head of about 550 feet. Detailed surveys may indicate the need for some modification.

GEOLOGY AND HYDROLOGY

GENERAL GEOLOGY

The Tuma River, including its tributary Kamoga Creek, has a catchment of about $18\frac{1}{2}$ square miles. The main catchment area is flat and is covered by kunai and other grasses. Near the Nebelyer River the former plane surface has been dissected into gentle ridges and spurs. The flat and dissected areas are rimmed to the east, south and west by continuous ridges of steep to moderately dipping Tertiary rocks. The northern end of what was formerly a lake has been cut through by the Nebelyer River, to the north of which rises the mass of Mount Hagen.

Rickwood (1955) shows large parts of the Wahgi, Baiyer, Nebelyer and Kaugel valleys, together with some rock masses such as Mount Hagen, as Pleistocene Volcanics, and the main ranges as Tertiary to Palaeozoic sedimentary, metamorphic and igneous rocks. Doubtless the valley floors are largely composed of volcanics and volcanic sediments, including lavas, pyroclastics and redistributed material (and flows or lahars and water-deposited volcanic material). The flat floor of the Tuma catchment is composed of unconsolidated redistributed volcanic debris, deposited under water. Apparently a flow or landslip dammed the existing river system either during or shortly after a volcanic eruption, and volcanic debris washed into the lake. Sections through the resulting sediment can be seen in the valleys of the Nebelyer and Tuma Rivers. The sediments are unstratified and form a compact yellow to dark grey-brown clayey soil in which shrinkage cracks form when dry. In places a tuffaceous texture, including weathered feldspar laths, may be seen. Studded through the fine soil matrix is a great number of generally well-rounded boulders of lava. They have a large size range but typically they are 1 - 2 feet in diameter. Boulders are completely absent in some exposures; in others, e.g. in the Tuma River near Bebeka village, parts of the section consist largely of boulders. Most of the boulders are fresh but some were observed to have completely decomposed in place without disruption of the rock texture.

The underlying basement rocks are exposed in the Nebelyer River where the track between Melbor and Bebeka villages crosses it. They are mainly well-bedded, dark-grey shale and claystone with a close polygonal-jointing but there are some coarser and more massive interbeds of greywacke and siltstone. Dips of from 15° to 30° south-west were measured. At the top of the ridge between the Tuma and south-flowing Nebelyer River similar sediments crop out or are represented by loose surface material*, and limestone was seen from the road farther south.

Mr. Brett states that there is evidence of old landslips in the area of the proposed power station. It is thought, however, that the area of level ground is an old river terrace and, apart from some very superficial stripping of soil from bedrock to expose dip slopes, no evidence of landslips was observed by the writer. Despite some very steep vegetation-covered slopes the lake sediments and derived soils appear quite stable; the sediments and soil must therefore have considerable cohesive strength.

SEISMICITY

No records of local seismic activity were obtained in the course of the visit. A map of the principal epicentres of earthquakes in Papua - New Guinea in the period 1910 - 1959, produced by the Port Moresby Geophysical Observatory, shows that seismically the Mount Hagen area is apparently one of the least disturbed areas in the Territory of New Guinea. However this may be due more to the lack of records from the area in pre-World War II years than to absence of earthquake activity. Enquiries about seismic activity should be made locally.

HYDROLOGY OF THE TUMA RIVER

The undissected part of the Tuma catchment appears to consist of a more-or-less water-saturated deep soil which should provide an excellent storage and should substantially even out run-off between wet and dry periods. No data are available yet on maximum and minimum flows in the Tuma River and Kamoga Creek. Mr. Brett reports that the average rainfall of the Temba - Tambu - Hagen area is of the order of 110 inches. He also estimated that a dry-period flow of 45 cusecs should be available for power generation. However gauging by officers of the Department of Works on the 6th and 7th December indicated that a considerably lower figure must be assumed and also revealed a surprisingly high recession. No rain fell between the two readings. Measurements obtained were:

	6/12/62	7/12/62
Tuma River, above junction with Kamoga Creek (Take-off site)	45 cusecs	36 cusecs
Kamoga Creek	8 "	6 "
	53 "	42 "

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* Three specimens collected from the ridge proved to be unfossiliferous.

ENGINEERING GEOLOGY

PROPOSED SCHEME (Brett's proposal)

Take-off from Tuma River

The point at which water would be diverted into a race has steep banks of yellow silt. The stream has a slight gradient and is very clear; bed load appears to be negligible as no sand or gravel banks have formed. The stream bed consists of rounded boulders of lava washed from the sediments. The thickness of the sediments is unknown but any weir and take-off works would certainly be in the silt. Water will have to be raised at least 20 feet from present river level to avoid the need for excessively deep channels. If a weir were constructed serious problems of scour may arise and it may possibly be cheaper to lift the water by pumping. The design of the take-off works will be determined by: Peak flood-flow of the Tuma River at this point.

Strength and permeability of the silt, both in the undisturbed and recompacted states.

Availability of material for rip-rap.

If peak flood flow is low and the silt proves to have suitable properties - high strength and low permeability - it may be possible to construct an earth weir, heavily protected by rip-rap, and so designed as to avoid turbulent flow. Alternatively it may be possible to turn the full flow into the take-off channel to avoid overtopping the weir, and to return excess flow into the river far enough downstream to prevent any scour affecting the weir.

With larger peak flows a concrete wall, deeply slotted into the silt; a concrete or steel stilling pond; and heavy rip-rap treatment, may be suitable.

Before a weir could be considered it will be necessary to establish the maximum flow likely to be experienced in the Tuma River, the load strength and shear strength of the silt, both in the undisturbed and disturbed states, over a range of water content, and the permeability of disturbed and undisturbed silt.

As Kamoga Creek is not so deeply incised as the Tuma River it should not present the same difficulties in diverting the flow as the Tuma River is likely to.

Race Line and Storage Pond

Mr. Brett states that the race line may be excavated and used without lining, as evidenced by native trenches up to seven feet deep and with vertical sides. I agree with this opinion. Provided walls and floor are kept smooth and that curves in the race line have large radii to reduce scouring very little maintenance should be necessary. Race lines should not, if it can possibly be avoided, be cut across steep slopes as saturation of the slope could initiate land slips. The danger of this happening can be better evaluated when strength and permeability figures are available for the soil and silt.

Some boulders would probably be encountered during excavation but it is not expected that substantial boulder beds would be met.

The brief examination of the terrain that was possible suggests that owing to the dissection as the Nebelyer River is approached the race line may be rather longer than that indicated by Mr. Brett.

The storage pond at the head of the penstock probably would not need to be lined provided adequate banks can be left. Width and batter of banks cannot be calculated until the strength and permeability of the soil and silt have been determined but it is considered that the material has a greater strength than that in which Rouna No.1 storage tank is constructed.

<u>Penstock</u>

On the foot track up the penstock spur (see Plate 2) rock crops out sporadically to a height of about 150 feet above the bed of the Nebelyer River. Up to this point soil and scree cover is generally only two or three feet thick. The rock exposed is a dark shale which dips roughly with the slope of the south-western face of the ridge; although not a very strong rock it should provide adequate foundations for the penstock supports. To the north of the spur, however, a river terrace of soil and random boulders possibly 70 or 80 feet above the river level conceals the rock. If the penstock were brought down on this line (which would give the greatest head and the least change of direction of the penstock but not the shortest length) a deep trench would have to be cut through the terrace to avoid sharp bends in the penstock at both edges of the terrace. No rock foundations are likely to be available across the river terrace.

Although the upper surface of the basement rock is probably irregular it is thought that it does not crop out significantly higher elsewhere on the spur than where seen on the track. The upper 400 feet or so (vertical measurement) of penstock would therefore have to be supported by clay and silt, which would also have to support the surge tank and other headworks. In order to determine their ability to do so, and to design appropriate footings for the penstock and surge tank supports, it is important that the sheer and load strengths of undisturbed silt and clay from the ridge be measured by laboratory tests. Although the slopes, which have an estimated gradient of greater than 30 degrees, appear to be stable the additional load of the penstock could cause local failure and damage to the penstock.

Three possible positions occur for the penstock, as indicated in Plate 2. Position B has the disadvantage that the penstock would have to be taken across the river terrace described above. Positions A and C appear to avoid the terrace and have shorter routes. They also would probably have rock footings for the whole of the lower 150 feet (vertically) but the penstock in either case would have a sharp bend and the total head available would be less than for position B.

<u>Power Station</u>

Time did not permit the examination of the power station sites but observation from the distance failed to reveal suitable level areas for a station at sites A or B; site C was not seen. At all these positions basement rock (siltstone, etc) which would provide satisfactory foundations is probably exposed or at a shallow depth. A site would probably have to be excavated in rock at positions A and C but could possibly be dug from the river terrace at position B.

Construction Materials

The possible use of silt and clay to construct a diversion weir is discussed above.

No sand or gravel suitable for concrete was observed in the course of the inspection and generally streams in the area have such steep gradients that sand, at least, is not likely to be found close at hand. Boulders of lava, mainly basalt, abound in the area and lava flows are reported by Rickwood (1955). These would provide excellent material for crushing for sand and concrete aggregate.

The abundant boulders of lava in the Tuma and Nebelyer Rivers should provide a suitable source of rip-rap. Although they are generally well-rounded probably enough of them are large enough to break into pieces to provide suitably shaped rip-rap. A boulder bed was observed in the bank of the Tuma River near a footbridge upstream of Bebeka village. If necessary these could be extracted by sluicing.

ALTERNATIVE SCHEME

Because of the difficulties in the scheme proposed by Mr. Brett, having regard to the likely output - lower minimum flow than expected, difficulties with the diversion from the Tuma River, absence of sound footings for the upper part of the penstock, and possible lack of a suitable power station site - some consideration was given to an alternative scheme suggested by Mr. Ryan, whereby the Tuma River would be diverted to a gap in the ridge east of the river and carried by penstock to a power station on the Nebelyer River 1500 - 2000 feet below (see Plate 2). This scheme would produce about three times the power of the scheme proposed by Mr. Brett. Mr. Brett states that the ridge to be crossed is at least 200 feet higher than the level of the Tuma River, but it is thought that the difference in level between the take-off point and the gap may be considerably less than this. The matter appears to be worth checking by an accurate survey. It is pointed out that if the vertical distance water has to be raised is of the order of only 50 feet the cost of pumping the water would be offset to some extent by economies in the take-off works if a weir could thereby be dispensed with.

An examination of air photographs shows that a spur leads down from near the gap in the ridge to the Nebelyer River just below a long deep gorge (see Plate 2). The ridge is believed to consist of shale, siltstone, greywacke and limestone, and should provide sound footings for the upper part of the penstock. The spur, however, is probably composed largely of soft volcanic material and may not provide any better footings than the lake sediments discussed above. The penstock would be about 6230 feet long, of which at least 5880 feet appears (by examination of air photographs) to lie over volcanic material.

A further possible difficulty is that as the race line, which would need to be about 3½ miles long, would traverse some fairly steep slopes it might require lining to prevent landslips produced by seepage. The scheme would be considerably more expensive than that proposed by Mr. Brett and could only be justified by its much greater capacity.

CONCLUSIONS AND RECOMMENDATIONS

The hydro-electric project proposed by Mr. Brett, which would be capable of producing about 1400 kilowatts, would be founded mainly in unconsolidated sediment of volcanic origin. The take-off works, race line and upper 400 feet of the penstock would all be in the sediment. The lack of foundations for the take-off works, where water must be raised at least 20 feet to the race line, may create some difficulties. The mechanical properties of the silt and the peak flood flow of the Tuma River must be determined before the take-off works can be designed.

The soil, silt and clay through which the race line would be cut appears to have considerable cohesive strength and should enable unlined races to be established with low construction and maintenance costs. The storage pond at the head of the penstock also probably would not need lining.

No evidence for lamdslips was observed in the penstock and power station areas. The lower 150 feet (measured vertically) of the penstock would probably be founded in fairly strong shale and siltstone if constructed in two of three possible positions; if placed down the north face of the spur the penstock would have to be carried across or entrenched into a river terrace of soil and boulders about 70 feet above the Nebelyer River. The mechanical properties of the soil, silt and clay in which the upper 400 feet (vertical length) of the penstock and the surge tank would be founded should be determined before design of the footings is undertaken.

Satisfactory foundations should exist for the power station.

ACKNOWLEDGEMENTS

The visit to the site of the proposed hydro-electric scheme was arranged by the Department of Works, Port Moresby, and Mr. Ryan provided transport, acted as guide, and provided information about the scheme. This assistance is gratefully acknowledged.

REFERENCES

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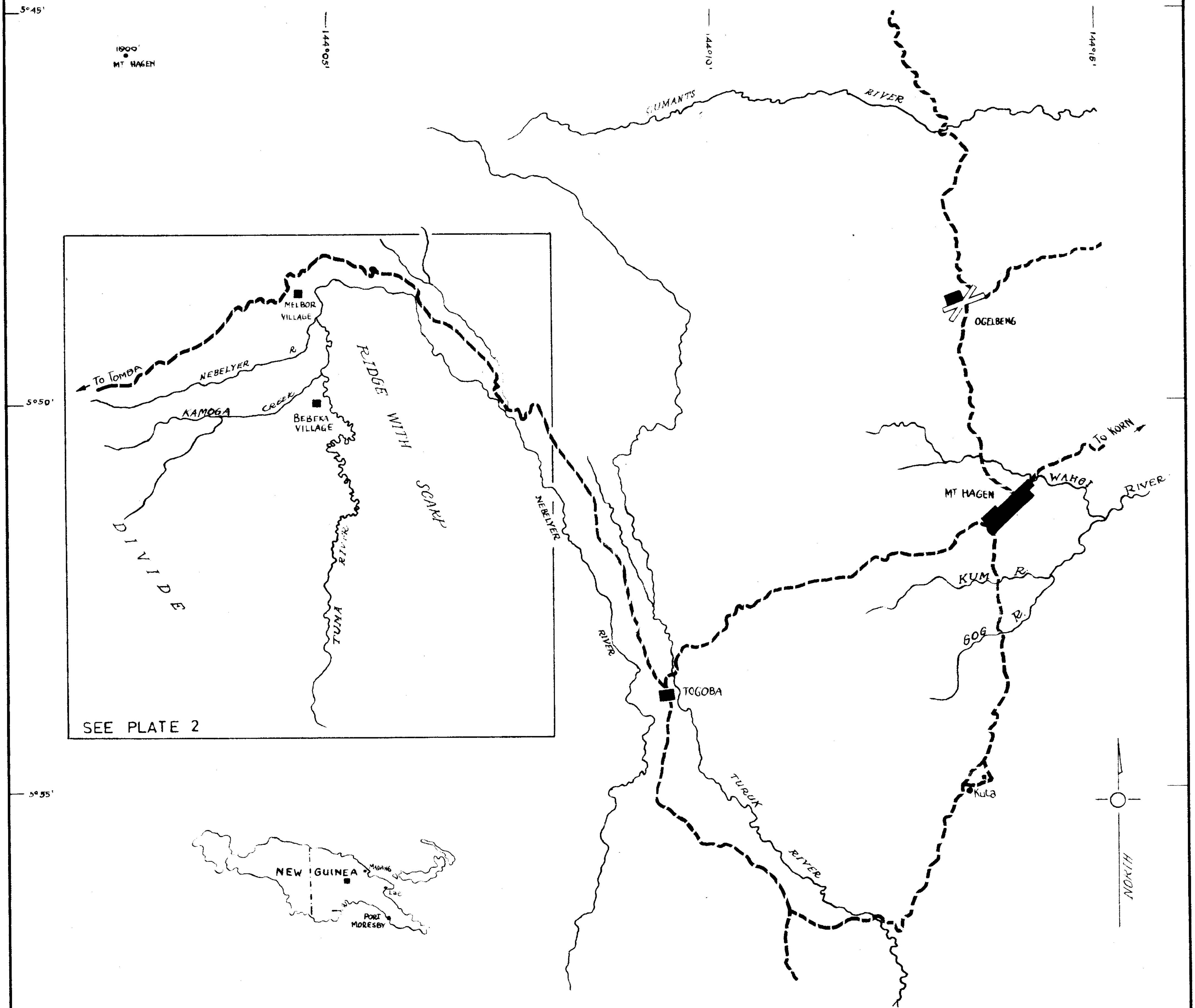


TUMA RIVER HYDRO-ELECTRIC SCHEME

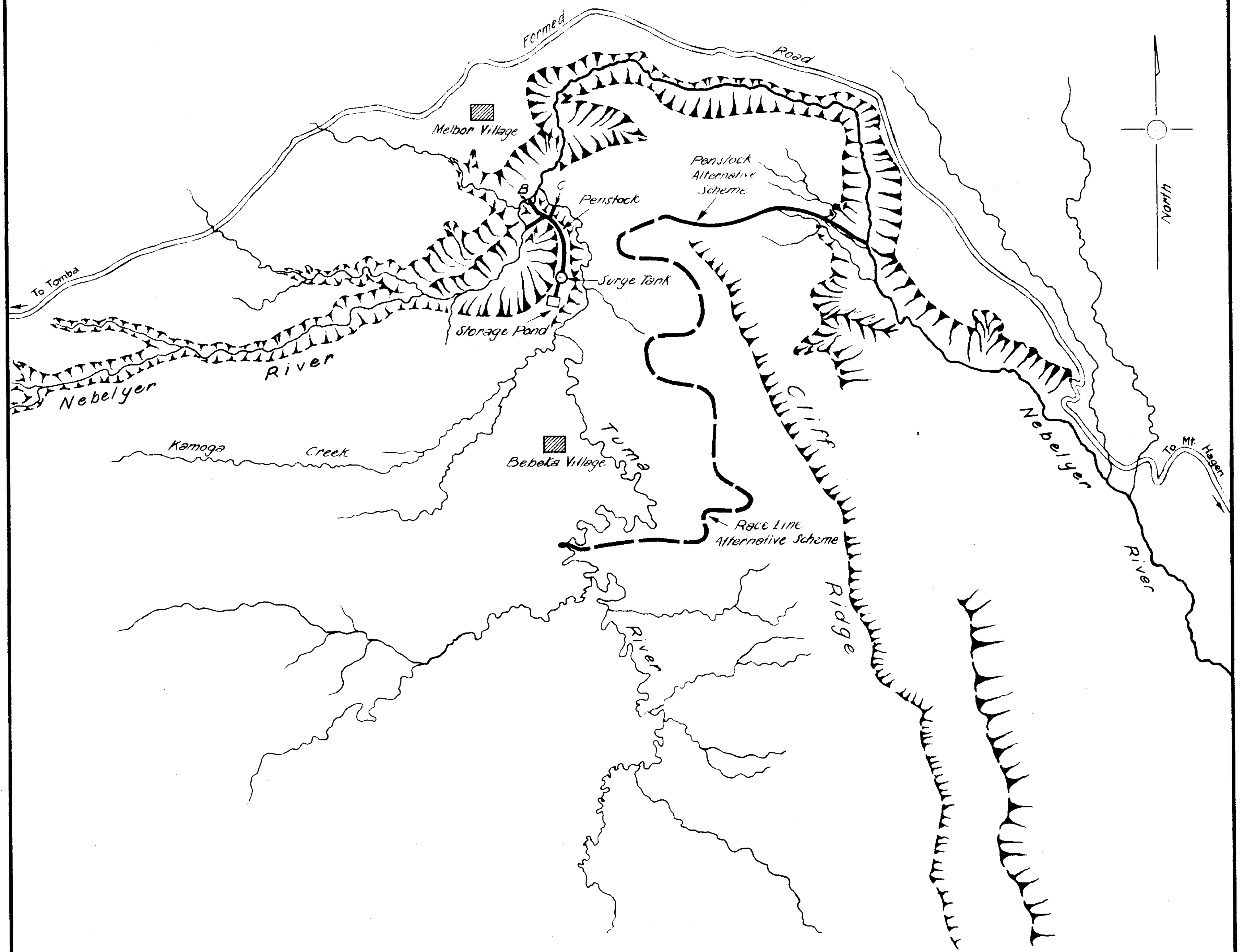
Mount Hagen District, T.N.G.,

Locality Plan

Bureau of Mineral Resources, Canberra, A.C.T. January 1963

To accompany Record 1963/41

PLATE 2



TUMA RIVER HYDRO-ELECTRIC SCHEME

Mount Hagen District, T.N.G.,

Showing possible Alternatives.

Steep Slope

Compiled, without ground control, from Air Photographs.

1 0.5 0 1 2

Approximate Scale in Miles

Bureau of Mineral Resources, Canberra, A.C.T. January 1963

To accompany Record 1963/41