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## GEOLOGICAL INVESTIGATION OF THE PROPOSED LUFA-CHUAVE ROAD

by

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## SUMMARY

An investigation to determine the geological feasibility of the Lufa-Chuave road, Territory of New Guinea, which has been proposed to by-pass the existing road across the Daulo Pass, was carried out in May, 1966.

The oldest rocks exposed along the proposed alignment consist of greywacke, siltstone, mudstone and shale of the Upper Cretaceous Chim Group which occur between Chuave and Kurmu. From Kurmu to the Goroka Basin east of the Asaro Pass the Chim Group is overlain by a thick sequence of Tertiary limestone, shale, greywacke, sandstone and conglomerate, and in the Goroka Basin there are extensive deposits of Pleistocene piedmont gravels and lake sediments and Recent soil, scree, slopewash and river gravels.

Much of the terrain over which the road will pass is unstable and subject to landslide activity. The instability is due to a combination of factors, notably youthful topography, soft unconsolidated sediments, deeply weathered bedrock and a high rainfall.

It is concluded that the construction of a permanent, all-weather road is geologically feasible provided further investigation, particularly soils investigation, is carried out along the entire length of the proposed road before a final design is prepared. It is recommended that side-cut and box-cut embankments in overburden should not exceed a vertical height of 20 feet or have a slope steeper than $1\frac{1}{2}$:1. Embankments in cuts 20 feet or more deep should be benched. All traces of unstable material should be removed from areas which are to be filled and suitable steps should be taken to prevent base failure, by sinking or spreading of fills, in areas of swampy ground or lake sediment deposits. Adequate drainage should be provided.

Supplies of construction materials are sparse. The most readily available sources of aggregate are the Chimbu Limestone and borrow pits in the Kami and Tua River areas.

## INTRODUCTION

The section of the Highlands Highway between Goroka and Mount Hagen crosses the Bismarck Range from the Asaro Valley into the Wahgi Valley, via the Daulo Pass near Mount Gesigga (Plate 1). In the Daulo Pass area the highly dissected topography underlain by deeply weathered rocks has produced unstable slope conditions which are aggravated by the rains in the wet season (see Appendix 1). As a result numerous landslips often close the road to all traffic.

The Lufa-Chuave roadway has been proposed as an alternative to the Daulo Pass route. The investigation line for this route diverges from the existing Kainantu-Goroka road at the Lufa turn-off, 12 miles from Goroka along the roadway at present under construction. From this point the investigation line, generally, follows the existing road to Lufa Patrol Post, where it turns to follow the eastern side of the Hogabe Valley to the Tua River, thence to Chuave via Kurmu, Gogo and Keu on the western side of Mount Elimbari. A possible alternative route between Kurmu and Keu along the eastern side of Mount Elimbari has been proposed by the Commonwealth Department of Works.

At the request of the Director, Commonwealth Department of Works, Port Moresby, an investigation to determine the geological feasibility of the proposed alignment, including the alternative route, was carried out in May, 1966.

## GEOLOGY

### STRATIGRAPHY

The main geological units found in the area can be tabulated as follows:-

| Lithology | Rock Unit | Stage | Epoch | Period |
|---|---|---|---|---|
| Clay, silt, sand and gravel | Goroka Beds | | Pleistocene | Quaternary |
| Conglomerate | Asaro Conglomerate | f1-f2 | Miocene | Tertiary |
| Hornblende - feldspar porphyry | Daulo Volcanics | f1-f2 | Miocene | Tertiary |
| Peridotite, gabbro and serpentinite | | | Miocene | Tertiary |
| Sandstone, shale and greywacke | | e | Miocene | Tertiary |
| Sandstone, shale and conglomerate | | e | Miocene | Tertiary |
| Banded chert | | e | Miocene | Tertiary |
| Limestone | Chimbu Limestone | | Oligocene and Eocene | Tertiary |
| Shale, slate and limestone | | a-b | Eocene | Tertiary |
| Greywacke, siltstone, mudstone and shale | Chim Group | | Cretaceous | Mesozoic |

(After McMillan and Malone, 1960, and Rickwood, 1955)

The oldest rocks in the stratigraphic succession are greywacke, siltstone, mudstone and shale of the Upper Cretaceous Chim Group which occur in the western half of the alignment between Chuave and Kurmu. The Chim Group is conformably overlain by the Chimbu Limestone of Eocene and Oligocene age which forms the main peak of Mount Elimbari and the prominent Elimbari escarpment between Mount Elimbari and the Tua River. At Mount Elimbari the limestone is at least 1500 feet thick but it thins southward to a thickness of a few hundred feet at the Tua River.

Conformably overlying the Chimbu Limestone is a sequence of brown, medium-grained sandstone, shale and green, pebble conglomerate which is exposed from Kurmu to the Tua River and between Nambyufa and Keu, along the alternative route on the eastern side of the Elimbari escarpment. The sequence is repeated in the upper part of the Hogabe River Valley where it is in turn overlain by a sequence of greywacke, shale, sandstone and boulder conglomerate which extends to the Goroka Basin east of the Asaro Pass.

Insufficient field data are available to correlate these sediments with the stratigraphic succession compiled for the eastern Central Highlands by McMillan and Malone (1960). Probably there is a disconformity between the Oligocene Chimbu Limestone and the overlying sediments (Rickwood, 1955), which are presumably Miocene. The sequence of sandstone, shale and green, pebble conglomerate which occurs immediately above the limestone is similar to the succession exposed along the road between Chuave and Kenangi, beneath the f1-f2 stage sediments (Tmf1-f2) mapped by McMillan and Malone between Kenangi and Daulo Pass; it is therefore correlated with the e-stage sediments (Tme) of McMillan and Malone. The sediments above the green, pebble conglomerate east of Lufa are correlated with the Tmf1-f2 sediments. However, the boulder conglomerate at Asaro Pass has no equivalent within, or above, the Tmf1-f2 sediments near Kenangi and is tentatively regarded as the stratigraphic equivalent of the f1-f2 stage Asaro Conglomerate (Tma).

Lack of outcrop along the road east of the New Tribes Mission masks the relation between the succession and the sediments mapped by McMillan and Malone near Kami. The sediments are covered by extensive deposits of recent soil, scree, slopewash and river gravels which, north of the Kami River, merge with the Pleistocene piedmont gravels and lake sediment deposits of the Goroka Beds in the Goroka Basin.

## STRUCTURE

All outcrops conform to a single structural pattern of northerly strike and easterly dip.

At the Tua River the sediments are displaced along a transcurrent fault parallel to the Hogabe and Kuaribo Valleys. The Chim Group/Chimbu Limestone sequence is repeated on the eastern side of these valleys.

## ENGINEERING GEOLOGY

The engineering geology is described in sections based on road alignment chainages. The chainages are in feet. Where chainages are unknown, or unmarked, peg numbers as used by the survey investigation parties are referred to. The sections described are as follows (see Plate 1):

1. Lufa Junction, 55,000 to the New Tribes Mission, 00.

2. New Tribes Mission, 74,000 to Lufa, 33,800.

3. Lufa, 33,800 to the Tua River, 00.

4. Tua River, 00 to Kurmu, 38,407.

5. Kurmu to Chuave, via Gogo and Keu; 00 to 55,000 and Investigation Peg 383.

6. Nambyufa to Keu via the eastern side of Mt Elimbari.

## 1. Lufa Junction, 55,000, to the New Tribes Mission, 00.

The new alignment follows the existing road from the Lufa turn-off to the New Tribes Mission, south of Kami.

From 55,000 to the Kami River the alignment crosses lake sediments and piedmont gravels of the Goroka Beds. Beyond the Kami River minor outcrops of siltstone and shale occur in the small valleys near the bridge sites at 21,833 and 16,115, but otherwise the alignment is located on river terrace gravels, slope-wash and black, silty and organic soil. The terrain is generally flat, steepening only at stream or creek cuts and gullies to a maximum of 25 degrees.

The piedmont gravels are well drained and stable but the lake sediments contain silty layers within the horizontally bedded gravels, sands and clays, and are prone to failure by sliding along these layers. The slopewash and soils beyond Kami are not well drained, and are boggy when wet. They are prone to superficial slide and soil creep, and gullies along side-slopes are filled with unstable slide debris.

## 2. New Tribes Mission, 74,000, to Lufa, 33,800.

The alignment leaves the flat country close to the New Tribes Mission and rises across the Asaro Pass at 63,000 to follow the existing road to the Lufa Patrol Post at the head of the Hogabe Valley.

Two investigation lines have been pegged for part of the section between the New Tribes Mission and the Asaro Pass. Both leave the existing road at 73,600 and cross slopes above the road as far as 70,000. From 70,000 one line drops down to rejoin the road at survey investigation peg 11 and the other continues upslope to rejoin the road at peg 19, about $\frac{3}{4}$ mile above peg 11.

Between 73,600 and 70,000 the line crosses several areas of unstable ground. Two deeply incised creeks with thick deposits of slide and slope-wash material over the valley shoulders are located between 72,700 and 72,450 and from 72,000 to 71,800. Deposits of slide material, of unknown thickness, are located in gullies between 71,400 and 71,150, 71,050 and 70,950 and from 70,850 to 70,700. Between 72,400 and 72,000 there is a thick deposit of poorly drained swampy material which is slipping down a gentle slope.

The bottom line cuts through a spur at 70,000 before crossing flat stable ground and rejoining the Lufa road. The upper line cuts through the same spur at peg 10, and crosses a previous landslide upslope from pegs 10 and 11 before side-cutting along a 30 to 35 degree slope above the Lufa

Between 73,600 and peg 11, brown, gritty sandstone with strongly developed spheroidal weathering, siltstone and shale are exposed in cuts along the existing road. These are overlain by residual clay, unstable silty soil and slide debris. Sample LC02 from residual clay close to chainage 73,600 has a liquid limit of 78.2 and a plasticity index of 56.0 - U.S. soil classification CH (see Appendix 2).

Beyond peg 11 brownish black, interbedded medium-grained sandstone and siltstone are exposed in existing road cuts. The sequence changes at peg 21 to boulder conglomerate which extends to about 250 feet from the top of the pass. At the pass the boulder conglomerate is overlain by a residual clay of unknown origin. Sample LC07 from this residual clay has a liquid limit of 66.5 and a plasticity index of 33.4, (MH). Neither the sandstone nor the boulder conglomerate are extensively weathered. The sediments are moderately hard and strong, and are capable of supporting vertical cuts, but are overlain by unstable soil and scree. The strata strike normal to the road alignment and dip moderately to the east. The slopes below the alignment are up to 35 degrees, and are covered with unstable material, especially at the head of the gully which leads to the pass.

The thick cover of residual clay extends on the western side of the pass as far as 62,500, where the boulder conglomerate reappears. Side-slopes between the pass and the conglomerate outcrop are up to 35 degrees and show considerable signs of landslide activity.

The boulder conglomerate extends to 60,300 where it is underlain by pebbly conglomerate and brown, gritty sandstone as far as 58,250. Slopes in this section are steep (up to 45 degrees), but except between 60,300 and 59,400 the conglomerate and sandstone are only slightly weathered, are moderately strong, and able to support vertical cuts. The dip of the strata is into the hillside. The depth of soil and scree material overlying bedrock may not be more than 10 feet and slides which have occurred are superficial; but between 59,400 and 60,300 weathering is more intense and there is an increase in the depth of unstable slope material.

From 58,250 to 54,650 the road will be formed on brown, coarse-grained and gritty sandstone, calcareous sandstone, siltstone and shale. The intensity of weathering varies from slight to high, and generally there is a variable thickness of residual clay between weathered bedrock and overburden. Sample LC06 from residual clay at 57,300 has a liquid limit of 72.0 and a plasticity index of 20.3 (MH). Side-slopes vary between 25 and 30 degrees, and up to 20 feet of unstable overburden rests on residual clay and weathered bedrock. The weathered sediments maintain their original structure and texture, and there is little evidence of embankment failure.

From 54,650 to the sawmill at 43,800 highly to completely weathered siltstone and shale are overlain by a thick cover of slopewash and scree and deep red to yellow, residual clay. Sample LC05 from the residual clay at 47,540 has a liquid limit of 77.6 and a plasticity index of 39.4 (MH). Side slopes, up to 35 degrees in places, average 25 degrees and there tends to be a well-formed interface between overburden and residual clay roughly parallel to the land surface. A number of failures along the interface have initiated movement of overburden over residual clay in this section.

Between the sawmill and the end of the section at 33,800 bedrock is moderately to completely weathered siltstone, green pebbly conglomerate and medium-grained, brown, gritty sandstone with interbeds of siltstone. As far as 37,400 side-slopes range from 25 to 40 degrees but, where the road enters the head of the Hogabe Valley, they flatten out to less than 15 degrees. Overburden is thick and numerous slides of scree and soil over residual clay have taken place. Sample LC04 from 40,600 and sample LC03 from 36,000, both of residual clay, have liquid limits of 64.4 and 91.8, and plasticity indices of 34.1 and 44.4, respectively (both MH). The broad gullies beyond 37,400 contain extensive areas of poorly drained silty and organic soil.

3. Lufa, 33,800, to the Tua River, 00.

In this section the alignment descends the eastern side of the Hogabe Valley to the Tua River. Bedrock consists of green pebbly conglomerate, siltstone, shale, mudstone and greywacke, exposed only in stream outtings and creek beds. Throughout the valley there is a thick cover of poorly drained black, silty and clayey soil, thickened at the lower levels by soil creep and slide material. Sample LC01 which is typical of the black soil, has a liquid limit of 62.2 and a plasticity index of 44.7, (CH).

The sides of the valley slope at about 20 degrees although variations from 10 to 35 degrees occur in places near creeks. The overburden is unstable and soil creep, slumping and shallow-seated sliding are common. Nearly all the gullies and depressions are filled with slide debris. Construction of a permanent roadway in this section will be difficult.

The proposed route utilising two bridge sites across the Hogabe River north and south of 1502.5TP is preferred to that on the eastern side of the river between investigation pegs 18 and 5. (Public Works plan No. 9-150). The eastern route involves deep cuts into overburden and soft sediments on an unstable 45 degree slope, whereas the western route is mostly across flat river terraces and requires less earthworks and changes in grade. It is important that both bridge abutments be adequately piled and protected against any possible river erosion.

The abutments of the Tua River bridge are located on river terrace gravels and slopewash underlain by mudstone in the centre of a straight stretch of river. The two shallow bends in the river upstream and downstream of the bridge site do not show signs of excessive erosion.

4. Tua River, 00, to Kurmu, 38,407.

From the Tua river bridge the new alignment follows the river west for about 7,000 feet and then turns north up the eastern side of the Kuaribo Valley before crossing the Kuaribo River at 14,660. (There is a chainage shift before the Kuaribo River where 18,248 becomes 13,109). After crossing the river the road again turns west and rises over the dip slope east of the Elimbari scarp to cross the scarp at 31,000, and carries on towards Kurmu over scree material which has accumulated beneath the scarp.

Between 00 and 7,000 the road will be formed on thick deposits of overburden overlying mudstone, siltstone and shale. The depth of the overburden, which consists of slopewash and residual clay, is unknown but is expected to be considerable especially beyond 4,500, where the alignment is in the main Kuaribo Valley. A massive slip which has occurred at about 5,000 is about 300 feet wide and drops away at about 15 degrees to the river below; it indicates the unstable nature of the ground.

From 5,000 to the Kuaribo River extensive deposits of overburden, derived from slopewash material carried down the valley, overlie eastward-dipping sandstone, siltstone and shale. The thickness of the deposits is not known but the occurrence of numerous shallow-seated slides, slumps and soil creep indicates that the ground is unstable.

Deposits of poorly drained silty and organic clays occur along the approaches to the Kuaribo bridge from 14,000 to 13,109 (18,200), and to the bridge site at 14,660. Similar deposits also occur beyond the river, particularly in the gullies, as far as 17,000. Hard sandstone is exposed in the river banks at the bridge site and little difficulty should be encountered in siting the abutments in sound ground. Beyond 17,000 the road crosses the dip-slope of the Elimbari escarpment. The strata dip to the east of 25 to 30 degrees and consist of a thin layer of soil on top of calcareous sandstone which in turn overlies Chimbu Limestone. From 27,000 there is an increased thickness of overburden, which includes a number of limestone boulders derived from the Elimbari scarp. Several sink holes occur between 27,000 and the crest of the escarpment.

The road crosses the scarp at 31,000 and from there to the end of the section at Kurmu village it crosses detrital material heaped below the scarp. The detritus forms a massive deposit of black to red silt and clay with numerous large boulders of limestone. The deposit is poorly drained but only minor slide and slump areas were found on this section of the route.

5. Kurmu to Chuave, via Gogo and Keu: 00 to 50,000 and Investigation Peg 383.

The section commences at Kurmu village close to the existing road between Nambyufa, Kurmu, Gogo and Chuave and crosses numerous parallel ridges and gullies which extend south-west from the face of the Elimbari scarp.

Between 00 and 10,000 the alignment repeatedly crosses the existing road along the fringe of the detrital deposits beneath the excarpment. Side-slopes vary between 10 and 35 degrees and superficial slides, soil creep and infilling of gullies by overburden have taken place. Drainage is not good.

At 10,000 the alignment diverges most of the existing road as far as investigation peg 215. From the start of the diversion it follows the southern side of a minor ridge system before cutting through the ridge in a box-cut at 15,250. Although there are a few deposits of poorly drained swampy ground, and minor areas of soil creep and shallow-seated slides, there are no areas of major instability.

Beyond the box-cut at 15,250 the alignment traverses a wide gully to a ridge box-cut at 17,650, crosses a short gully between 17,650 and 20,000, and then turns south-west to follow the southern side of a long ridge as far as 30,000. Overburden consists of red, silty and clayey soil and slopewash, overlying deep red, residual clay and weathered sediments. There are few exposures of bedrock and the precise thickness of the individual layers is not known. However, in general there appears to be about 10 to 15 feet of overburden and up to 8 feet of residual clay overlying the sediments. The overburden is prone to failure by sliding over residual clay and bedrock, and most gullies on the sides of ridges are filled with slide debris.

From 30,000 the alignment descends along the north side of the ridge to a small creek at 38,000, then crosses a low ridge before descending again to a second stream crossing at 50,000. This bridge site marks the end of the pegged chainages, the next mark being investigation peg 180. From the bridge site the alignment traverses a 40 degree side-slope around the end of a spur, crosses a mass of escarpment detritus between the spur and a box-cut at peg 192, and then traverses shallow side-slopes before rejoining the existing road at peg 215. The terrain is similar to that in the section between 15,250 and 30,000. Several shallow slides of overburden over residual clay can be seen, but no major landslides have taken place. Depth of overburden appears to be from 10 to 15 feet and the thickness of the residual clay layer between the overburden and weathered bedrock about 3 to 4 feet.

Beyond peg 215 the alignment follows the general line of the existing road to Chuave Patrol Post; numerous cuts and fills are planned to increase the radii of curves and flatten the gradient. The road crosses a succession of gullies, ridges and short spurs which consist of escarpment detritus, soil and scree overlying residual clay and weathered bedrock. Bedding planes in the bedrock range in attitude from horizontal to a slight easterly dip. Samples LC11 and LC12 of residual clay from peg 200 and peg 234 have liquid limits of 69.9 and 81.9, and plasticity indices of 43.3 and 45.5, CH and MH respectively. Side-slopes vary from 10 to 35 degrees and the thickness of overburden varies from a few feet to upwards of 30 feet.

The gullies contain extensive deposits of overburden and many are poorly drained. Deposits of escarpment detritus are located between pegs 214 and 220, 229 and 234, 251 and 253, 267 and 270, 278 and 283 and 291 to 328. Extensive swampy deposits are located between pegs 235 and 237 and 238 and 240: there is an active slip area between pegs 261 and 265.

Between peg 328 (Keu), and peg 359 there is a considerable thickness of both overburden and residual clay. Sample LC13 from deep red, residual clay at peg 334 has a liquid limit of 81.9 and a plasticity index of 45.5 (MH). From peg 359 to the Mai River bridge site at peg 383 there is a thick cover of black, silty and organic soil, slopewash and escarpment detritus. Superficial sliding is evident and will provide a threat to the stability of the road on the steep descent to the bridge site.

6. Nambyufa to Keu via the eastern side of Mount Elimbari

This route of 13.7 miles follows the existing road between Nambyufa and Keu and was proposed by the Commonwealth Department of Works as an alternative to the alignment between Kurmu, Gogo and Keu.

Limestone crops out from Kurmu to 1 mile beyond Nambyufa from which parts it is overlain by east-dipping calcareous sandstone, siltstone and shale to 10.1 mile. At 10.1 mile the road is located under the high vertical bluffs of limestone east of Mount Elimbari and crosses thick deposits of scree before rising to the pass north of Mount Elimbari between 11.9 and 12.7 miles. The descent to Keu is also made across very thick deposits of silt, clay and limestone boulders.

The sediments between 1 mile and 10.1 mile are deeply weathered and are overlain by a considerable thickness of overburden and residual clay. Samples LC08 and LC09 from residual clay at 1.8 mile and 3.5 mile have liquid limits of 62.7 and 29.9, and plasticity indices of 29.9 and 16.2 respectively, (both MH). Sample LC10 of residual clay from 9.0 mile has a liquid limit of 62.5 and a plasticity index of 20.9, (MH). Considerable evidence of soil creep, slump and landslide activity can be observed, particularly between 6.2 mile and 10.1 mile where the terrain is closely dissected into numerous steep-sided ridges and spurs, and is particularly deeply weathered.

From 10.1 mile the road would have to cross the steeply sloped (35 to 40 degree), unstable detritus beneath limestone bluffs east of Mount Elimbari before reaching the pass. Similar conditions occur on the descent to Keu and construction of a permanent road in these sections would be very difficult.

## CONCLUSIONS

The proposed route of the Highlands Highway between Goroka, Lufa and Chuave has been chosen to avoid the Daulo Pass which is crossed by the existing road.

Much of the terrain over which the new road would pass is unstable and subject to landslide activity, particularly in the wet season. The instability is the result of a combination of factors common to all the Highland Districts and which have already been encountered during the design and construction of the Highlands Highway at Kassam Pass, and between Kainantu and Goroka. These include youthful topography, soft unconsolidated sediments, deeply weathered bedrock and high rainfall. (See Appendix 1).

However, provided additional investigation and other measures outlined in the recommendations are undertaken and the results incorporated in the final design of the highway, it is considered that construction to the standards required is geologically feasible. Because of the similarity of the problems encountered with those already experienced in construction of roads in other parts of the Highlands the recommendations made in this report are similar to those contained in reports on previous geological investigations carried out on other sections of the Highlands Highway (Read, 1966a and 1966b). The importance of these recommendations, particularly the need for detailed engineering investigation prior to design, cannot be over-stressed.

The route from Kurmu to Chuave via Gogo is preferred to the alternative along the eastern side of Mount Elimbari. In addition to the difficulty of obtaining a suitable grade, the terrain which would have to be traversed on the alternative alignment is much more unstable than that on the western side of the mountain. This is particulary so between 1 mile and 4 mile and from 6 mile to the pass at 11.9 mile.

## RECOMMENDATIONS

The following general and specific recommendations are made:

### EXCAVATIONS

A. Side-cut and box-cut embankments in overburden should not exceed a vertical height of 20 feet, nor have slopes steeper than $1\frac{1}{2}:1$. Embankments in cuts 20 feet or more deep should be benched; the width of the berm so formed should not be less than 10 feet wide. Where the side-slope is steeper than the recommended slope of the embankment the angle of the side-slope should be reduced. These recommendations are aimed at preventing two types of failure,

(i) failure of the ground above the cut due to removal of support from the toe of the slope in the cut. This type of failure is the predominant cause of landslides along the proposed alignment. In nearly all cases there is a definite interface, between overburden and firm ground, which is invariably aligned roughly parallel to the land surface. With the removal of support and, in the wet season, entry of water into the overburden and along the interface, failure occurs and the overburden slides over firm ground onto the roadway below.

(ii) embankment failure. The strength of the residual clays along the alignment - resulting from cohesion and internal friction - rapidly tends towards zero when the mass becomes saturated. Any increase in the vertical height or slope of an embankment over the limits given above should be made only if satisfactory results are obtained from tri-axial tests on undisturbed samples and if geological structures at the site are favourable.

B. Box-cuts should be avoided wherever possible; if required they should be kept to the minimum possible depth and length and be excavated in accordance with the recommendations given in section A, above. The preliminary design of the new alignment requires one major box-cut at the Asaro Pass and several along the section between Kurmu and Chuave. Careful investigation of the depth of overburden and the shear strength of the residual clays and weathered bedrock will be required at each location.

The cuts are through ridges which have low cross-slopes so that in each case there will be adequate room to allow benching to be carried out. It is also considered advisable to increase the road formation width in the cuts by up to double the normal width. The additional width will reduce the possibility of road blockage if a slide does occur.

## FILLS

C. Fills incorporated with side-cuts and fills in gullies on side-slopes will fail if placed on unstable ground composed of previous slide material or on slopes where the overburden is demonstrably slide prone. All traces of unstable material must be removed from the area to be filled, and on side-slopes it is recommended that the additional precaution of benching the foundation be carried out. Although valid for the whole of the new alignment this recommendation particularly applies to the Hogabe Valley and the section between the Tua River and the Kuaribo River crossing at 14,660.

D. Suitable steps should be taken to prevent base failure by either sinking or spreading of fills in areas of swampy ground or lake sediment deposits.

Lake sediment deposits are confined to the section between the Lufa turn-off at 55,000 and the Kami River but swampy ground occurs sporadically along the whole alignment, notably in the Hogabe and Kuaribo Valleys and between Kurmu and Chuave.

In all areas the depth of the lake deposit in swampy ground should be determined prior to design of the roadworks.

## DRAINAGE

The provision of adequate drainage is one of the most important aspects in the design of the new road. The part played by water in the creation of landslides is indicated by the fact that nearly all slips recorded in the Highland Districts have occurred during the wet season. The entry of water into overburden or along preferred slip planes reduces the cohesion and angle of internal friction to a value below the minimum required for stability. Equally important is the prevention of erosion of the alignment by volumes of uncontrolled storm-water run-off. Water cannot be released on fill material without disastrous consequences.

Culverts should be designed so that storm-water run-off can be cleared as quickly as possible. If a head of water is allowed to build up behind the culvert either through blockage or insufficient diameter of pipe, seepage into the fill could cause saturation or piping, leading to eventual failure of the fill.

Adequate drainage should be provided in swampy ground and areas of lake sediment deposits. The drains should be placed before construction begins to prevent increase in pore-water pressure during compaction of the fill, and also to provide permanent drainage after construction is finished.

## ADDITIONAL INVESTIGATION

Considerable additional investigation will have to be carried out before a final design for the new highway is prepared. The programme of investigation should provide information on:

(i) the depth of unconsolidated overburden, lake sediment deposits and swampy ground along the alignment

(ii) the natural drainage pattern at all sites of cuts and fills and

(iii) the moisture content and shear strength of residual clays and weathered bedrock in areas where embankments are to be formed.

Because of geological conditions it will be necessary to pay particular attention to changes in bedrock and residual clay types along the entire length of the alignment. Construction should not commence until results can be obtained, evaluated, and incorporated in the final design.

These results will also be needed in the calculation of the slopes of embankments and the amount of benching required to ensure that natural slopes above embankments remain stable. Drainage should be designed so that as far as possible storm-water run-off is directed towards, and retained within, the known natural drainage channels.

## CONSTRUCTION MATERIALS

Supplies of suitable construction materials are sparse. The most readily available source of aggregate for use as both sub-base and paving material is the Chimbu Limestone. This rock has been used extensively on the existing roads in the Chuave-Nambyufa area and appears to form a satisfactory aggregate.

Boulders of igneous rock were observed in several of the stream beds crossing the road between the Asaro Pass and Lufa, and a search for igneous rocks in the area around the foothills of Mount Michael may prove rewarding. Supplies of river gravel are confined to the Kami and Tua Rivers and it will be necessary to locate suitable borrow pits on these rivers. A large gravel flat is located on the left hand side of the Tua River immediately downstream of the bridge site and similar areas are probably located upstream of the bridge.

There is a large outcrop of rocks of the Daulo Volcanics close to the Lufa turn-off near the eastern end of the road. Although they crush to a very fine aggregate they have been successfully used as a paving material for light traffic in the Kami area.

It is unlikely that any of the sediments along the alignments will provide suitable aggregate. However tests on the sandstone in the vicinity of the Asaro Pass may prove it satisfactory and a search in the foothills of the Asaro Range west of Kami, between the Asaro Pass and the Tua River, may locate usable aggregate in that area.

## REFERENCES

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# APPENDIX 1

Rainfall figures from gauging stations
at Goroka and Chuave

## GOROKA

| | 1965 | 1964 | 1963 | 1962 | 1961 | 1960 | Average |
|---|---|---|---|---|---|---|---|
| January | 828 | 1352 | 106 | 472 | 826 | 1587 | 862 |
| February | 1013 | 878 | 113 | 870 | 773 | 1529 | 863 |
| March | 900 | 1107 | 859 | 704 | 544 | 964 | 864 |
| April | 488 | 587 | 438 | 896 | 805 | 1082 | 716 |
| May | 482 | 403 | 198 | 1454 | 769 | 297 | 600 |
| June | 328 | 111 | 380 | 171 | 378 | 451 | 303 |
| July | 24 | 104 | 170 | 500 | 158 | 35 | 165 |
| August | 181 | 136 | 458 | 414 | 773 | 226 | 365 |
| September | 845 | 345 | 1085 | 377 | 687 | 85 | 571 |
| October | 257 | 166 | 631 | 736 | 1121 | 676 | 598 |
| November | 225 | 885 | 370 | 446 | 780 | 1029 | 622 |
| December | 1259 | 458 | 506 | 1637 | 479 | 1099 | 906 |
| TOTAL | 6830 | 6532 | 5314 | 8677 | 8093 | 9060 | 7418 |

## CHUAVE

| | 1965 | 1964 | 1963 | 1962 | 1961 | 1960 | Average |
|---|---|---|---|---|---|---|---|
| January | 515 | 1196 | 419 | 511 | | | 660 |
| February | 1584 | 930 | 436 | 1041 | | | 998 |
| March | 1124 | 1165 | 1655 | 1242 | | | 1297 |
| April | 621 | 903 | 984 | 820 | | | 832 |
| May | 961 | 415 | 178 | 890 | | | 611 |
| June | 463 | 83 | 408 | 434 | | | 347 |
| July | 222 | 285 | 368 | 583 | | | 365 |
| August | 231 | 507 | 596 | 502 | 729 | | 513 |
| September | 503 | 1266 | 1635 | 1327 | 1079 | | 1162 |
| October | 452 | 315 | 568 | 1205 | 1094 | | 727 |
| November | 1199 | 1468 | 430 | 617 | 1512 | | 1045 |
| December | 1175 | 287 | 494 | 1231 | 614 | | 760 |
| TOTAL | 9050 | 8820 | 8171 | 10403 | 5028 | | 9316 |

## APPENDIX 2

Results of Mechanical Soils Tests carried out by Public Works Soils Laboratory, Port Moresby.

LUFA-CHUAVE ROAD PROJECT

MATERIALS LABORATORY -DEPARTMENT OF PUBLIC WORKS, PORT MORES

## SUMMARY OF TEST RESULTS

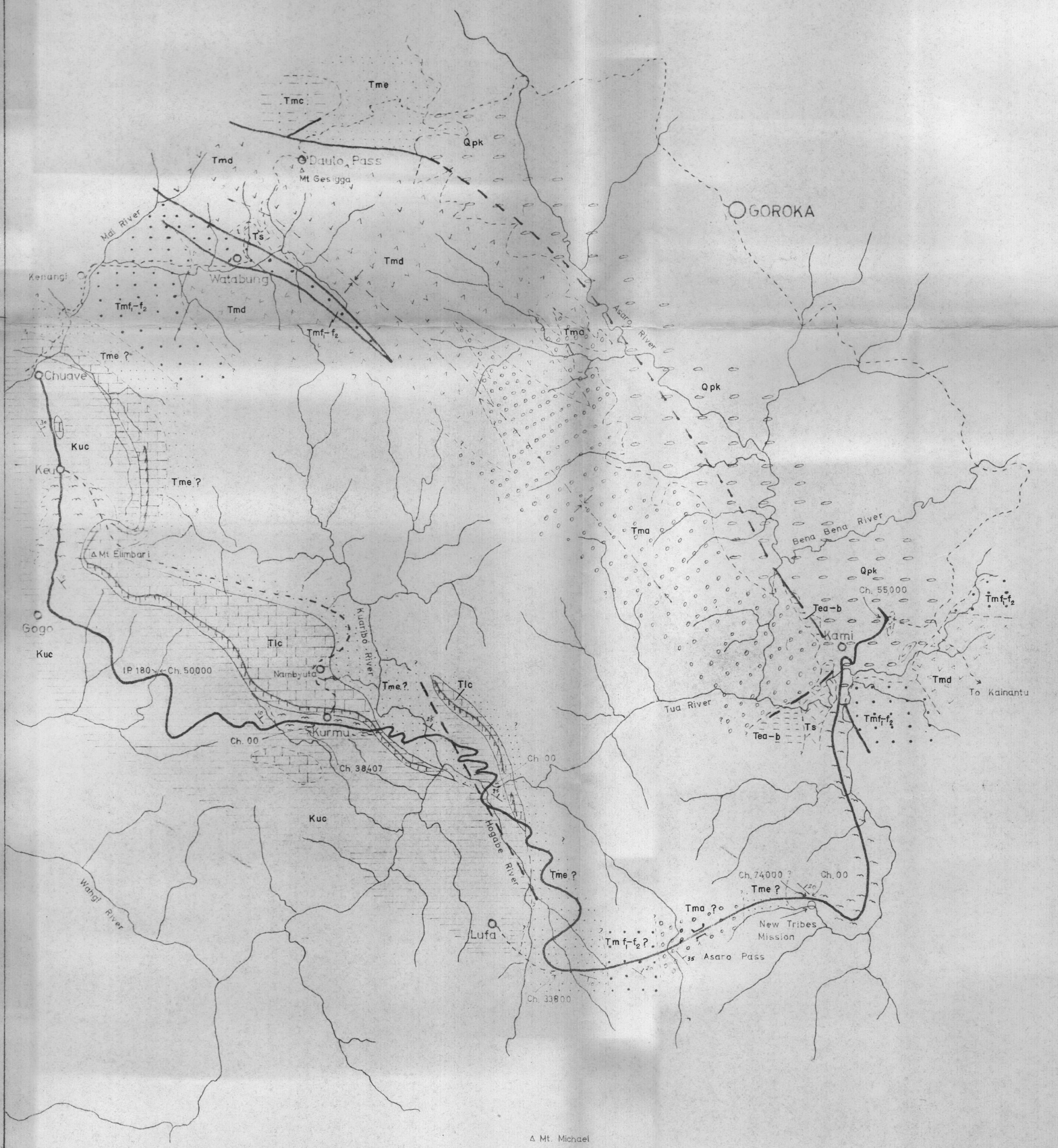
| Sample No. | P.W.D. Lab. No. | B.S. Sieve Size - Per cent passing | | | | | | Hydrometer Analysis - % | | | | | Summary | | | Atterberg Limits | | | Classification* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3/8" | 3/16" | 14 | 52 | 100 | 200 | .04 | .02 | .01 | .006 | .002 | % Sand | % Silt | % Clay | Liquid Limit | Plastic Limit | Plastic Index | |
| LC01 | 910 | 100 | 99 | 98 | 96 | 95 | 93 | 89 | 81 | 75 | 65 | 45 | 7 | 48 | 45 | 62.2 | 17.5 | 44.7 | CH |
| LC02 | 911 | | | 100 | 99 | 99 | 99 | 98 | 95 | 91 | 86 | 68 | 1 | 31 | 68 | 78.2 | 22.2 | 56.0 | CH |
| LC03 | 912 | | 100 | 97 | 94 | 86 | 78 | 74 | 70 | 63 | 58 | 48 | 22 | 30 | 48 | 91.8 | 47.4 | 44.4 | MH |
| LC04 | 913 | | | | 100 | 96 | 74 | 66 | 58 | 52 | 45 | 33 | 26 | 41 | 33 | 64.4 | 30.3 | 34.1 | MH |
| LC05 | 914 | | 100 | 99 | 96 | 82 | 73 | 69 | 61 | 52 | 45 | 30 | 27 | 43 | 30 | 77.6 | 38.2 | 39.4 | MH |
| LC06 | 915 | | | 100 | 99 | 86 | 74 | 62 | 53 | 44 | 36 | 24 | 26 | 50 | 24 | 72.0 | 51.7 | 20.3 | MH |
| LC07 | 916 | | | | 100 | 92 | 81 | 72 | 62 | 52 | 40 | 20 | 19 | 61 | 20 | 66.6 | 33.2 | 33.4 | MH |
| LC08 | 917 | | | 100 | 97 | 88 | 76 | 64 | 57 | 48 | 41 | 28 | 24 | 48 | 28 | 62.7 | 32.8 | 29.9 | MH |
| LC09 | 198 | | | | 100 | 98 | 90 | 82 | 71 | 62 | 54 | 41 | 10 | 49 | 41 | 72.6 | 56.4 | 16.2 | MH |
| LC10 | 919 | | | 100 | 96 | 85 | 78 | 72 | 64 | 54 | 47 | 30 | 22 | 48 | 30 | 62.5 | 41.6 | 20.9 | MH |
| LC11 | 920 | | | | 100 | 98 | 96 | 93 | 87 | 78 | 63 | 40 | 4 | 56 | 40 | 64.3 | 28.9 | 35.4 | MH |
| LC12 | 921 | | | | 100 | 99 | 91 | 84 | 78 | 70 | 62 | 44 | 9 | 47 | 44 | 69.9 | 26.6 | 43.3 | CH |
| LC13 | 922 | | | | 100 | 99 | 98 | 97 | 94 | 88 | 81 | 58 | 2 | 40 | 58 | 81.9 | 36.4 | 45.5 | MH |

* Classification is according to the United States Unified Soil Classification.

# GOROKA - CHUAVE HIGHWAY

PLATE 1

## GEOLOGICAL MAP SHOWING LOCATION OF EXISTING AND NEW ALIGNMENTS




REFERENCE

| | | | | |
|---|---|---|---|---|
| | Soil, slopewash ¢ scree | | Recent | QUATERNARY |
| Qpk | Clay, silt, sand ¢ gravel | Goroka Beds | Pleistocene | |
| Tma | Conglomerate | Asaro Conglomerate | | TERTIARY |
| Tmd | Hornblende - feldspar porphyry | Daulo Volcanics | $f_1 - f_2$ stage Miocene | |
| Ts | Peridotite, gabbro ¢ serpentinite | | | |
| $Tm f_1 - f_2$ | Sandstone, shale ¢ greywacke | | | |
| Tme | Sandstone, shale ¢ conglomerate | | e stage Miocene | |
| Tmc | Banded chert | | | |
| Tlc | Limestone | Chimbu Limestone | Eocene and Oligocene | |
| Tea-b | Shale, slate ¢ limestone | | Eocene | |
| Kuc | Greywacke, siltstone, mudstone ¢ shale | Chim Group | Upper Cretaceous | MESOZOIC |

Bedding. Strike ¢ Dip

Synclinal axis

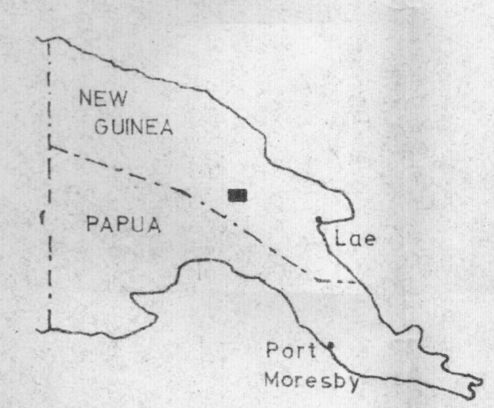
Established fault

Inferred fault

Escarpment

Existing road

Proposed alignment




Locality Map

0 1 2 4 8

Miles

N

Geological Office, Port Moresby J.R.L. Read 1·8·66 To accompany Record 1967/[redacted] 55

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