COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

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1960/102

GEOLOGICAL REPORT ON DESIGN INVESTIGATION OF SIRINUMU DAM AND SPILLWAY AREA, UPPER LALOKI RIVER, NEAR PORT MORESBY, PAPUA.

by

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SUMMARY

Extension of the Port Moresby hydroelectric scheme, initially to a capacity of 15,000 kilowatts, and in a second stage to 24,000 kilowatts, will require the construction of a dam at the head of the Sirinumu Gorge. After preliminary investigation, including 617 feet of diamond drilling, a rock-fill dam with a crest 80 feet above river level in the first stage was proposed. The upstream face of the embankment will be sealed with a watertight, welded steel deck. High-level flood spill will be by way of a spillway channel cut through solid rock in the hill adjoining the right abutment. Rock-fill material for the main embankment will come from the spillway channel excavation.

The dam, the spillway and the entire storage will be on the Astrolabe Agglomerate, a thick sub-horizontal pyroclastic sequence, composed mainly of coarse, poorly sorted agglomerate in tuffaceous matrix, and narrow tuff interbeds.

In the dam and spillway area the formation dips south-west at 5° - 7°; this is probably a local depositional dip and has no tectonic implication. A section of about 380 feet, probably in the upper half of the Formation, was examined by diamond drilling or in outcrop. This section contains tuff members as thin interbeds, totalling about 8%, distributed through the agglomerate.

Weathering of the agglomerate at the spillway site was the subject of particular study in an endeavour to establish a basis for distinction between overburden and rock which would be acceptable as fill for the main embankment. A classification into three zones is proposed; namely "very weathered", "weathered" and "solid" rock. The "very weathered" zone can be penetrated by hand auger and cannot be recovered as core in diamond drilling; it should be regarded as overburden in all cases and can probably be removed with earth-moving equipment or by sluicing. The "weathered" zone is partially decomposed rock in situ which cannot be penetrated with an auger and yields only fragmentary diamond drill cores; it should be suitable as foundation for the rock-fill dam. The "weathered" rock will probably not be acceptable as rock-fill, therefore in the spillway channel cut it will have to be discarded as overburden, but may have to be quarried. The "solid" rock zone is mostly slightly weathered and fresh rock which will be suitable for rock fill. For field distinction of "solid" rock from the "weathered" category, colour and specific gravity will be the most useful properties. The fresh and slightly weathered rock of the "solid" zone is dark blue-grey, grading through purplish-brown to mid-brown and generally has a specific gravity greather than 2.0. The "weathered" material is generally light brown, may be crumbled by hand in places and has specific gravity less than 2.0.

Diamond drilling for design information totalled 1329 feet, of which 701 feet were drilled on the dam site and 628 feet on the spillway site.

This drilling provided information on -

1. Depth to solid rock along the line of a foundation cut-off wall.

2. Rock types below the dam foundation area.

3. Extent of overburden in the foundation area.

4. Subsurface conditions along the line of the diversion channel.

5. Quantity of overburden in the spillway area.

6. Quantity of "solid" rock in the proposed spillway cut.

7. Nature of spillway floor and walls.

8. Possible scour at the toe of the spillway.

Subsurface contours on the top of "solid" rock in the spillway area have been drawn so that a preliminary estimate can be made of rock and overburden. The contours should not be used as a basis for specifying rock acceptable as rock-fill. About 30,000 cubic yards of overburden will have to be removed from above the spillway channel; of this about two-thirds can probably be shifted with earth-moving equipment. The spillway channel cut will yield about 90,000 cubic yards of rock-fill against a required 85,000 cubic yards of rock-fill tentatively estimated by the engineers. Should additional rock-fill be required, a further 24,000 cubic yards could be obtained by widening the spillway channel 40 feet westwards.

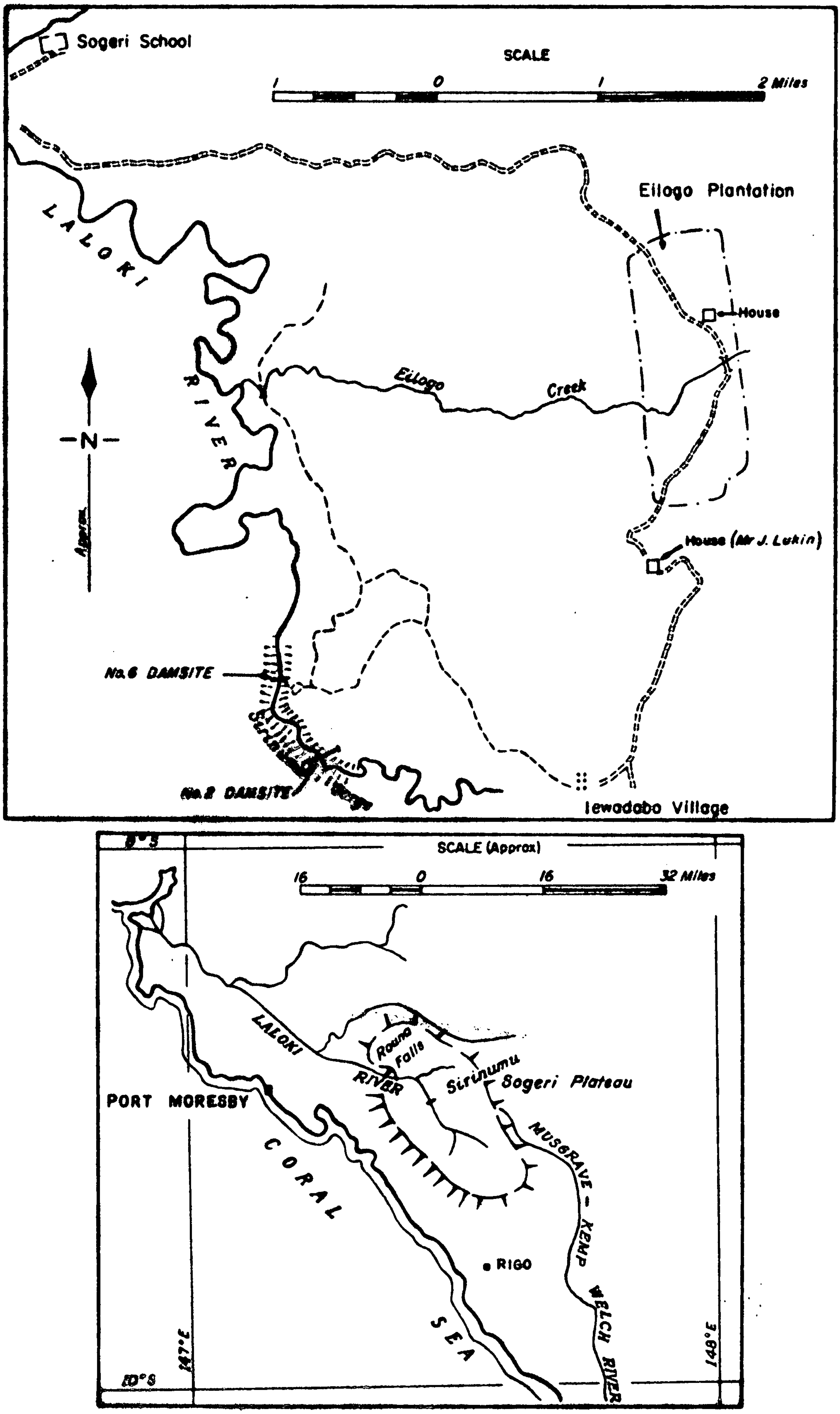
The spillway walls and floor will probably not need lining and the walls should stand safely at a steep angle. No scour problem at the toe of the spillway should arise in the first stage, but in the second stage, when the spillway is in permanent use, it may be necessary to remove a subsurface rock bar which is thought to lie at the eastern side of the spillway toe.

Deep weathering in the saddle east of the proposed spillway channel is probably related to the major tension joint which forms the steep [illegible] face of the right abutment hill and crosses the river at the deep pool just above the dam site. Leakage could occur through this deeply weathered zone, along the prominent joint, particularly in the second stage when the full storage level is raised to R.L. 1752. Opportunity should be taken during the excavation of the spillway channel to examine carefully this joint and its relationship to the deeply weathered zone.

Fig. 1

LOCALITY MAP - SIRINUMU AREA

TRACED FROM AERIAL PHOTOGRAPHS



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GEOLOGICAL REPORT ON DESIGN INVESTIGATION

OF SIRINUMU DAM AND SPILLWAY AREA,

UPPER LALOKI RIVER, NEAR PORT MORESBY, PAPUA.

INTRODUCTION.

This report reviews earlier work and recent diamond drilling planned to provide information on which to design and prepare specifications for a dam and spillway on the Upper Laloki River, which is to be part of a project to expand the hydroelectric power supply for Port Moresby.

The planned long-range expansion would ultimately provide, in two principal stages, an effective capacity of 24,000 kW. Although decision to take this scheme to full capacity will not be made until the demand trend can be predicted more precisely, the initial design of the dam and spillway will provide for later extension.

First, a rock-fill dam will be built with a crest at R.L. 1752*, about 80 feet above normal river level, to impound 33,000 acre feet of storage at R.L. 1724, and with provision for flood spill through a high level spillway channel at R.L. 1742. The dam and storage will, in the first instance, ensure flow to the existing Power Station and permit it to operate at its full 5,500 kW capacity. Later, with the installation of a second power house below Rouna Falls, a small dam above the falls, and a connecting pipeline and penstock, a capacity of 15,000 kW is anticipated.

The second stage of development will require the raising of the Sirinumu dam crest to R.L. 1766 and the spillway to R.L. 1752. With full storage level at R.L. 1752, the storage capacity would be about 128,000 acre feet which, when augmented by the natural flow from the rest of the Upper Laloki river system, would raise the potential of the system to 24,000 kW.

Geological mapping and the logging of most of the diamond drill cores was done by H. L. Davies of the Bureau of Mineral Resources' Resident Geological Staff, Port Moresby. The writer was in contact with the investigation from the early stages and logged the cores from the design drilling in the spillway area. L.C. Noakes of the Engineering Geology Section of the Bureau of Mineral Resources, Canberra, provided technical supervision for the geological work. Officers of the Commonwealth Department of Works, Port Moresby, were responsible for the drilling operations and topographic survey. Drilling locations were based on recommendations from the Department of Works Design Section, who were in liaison with Mr. Speedie, design consultant, and Mr. Noakes. As far as practicable these recommendations were carried out and some additional information was obtained. Progress results of the investigation were supplied to the Department of Works Design Section in Melbourne, through the Port Moresby Branch.

* Rouna datum.

PREVIOUS WORK.

In November-December, 1958, Gardner and Noakes (1959) made a preliminary geological investigation of the proposed power expansion scheme and examined several possible sites for the main dam in the Sirinumu area. Their recommendations did not include the site finally chosen, as its advantages only became apparent after an accurate topographic survey had been made.

H.L.Davies (1959) reported on the exploratory investigation of another dam site (No. 6) about ¾ mile downstream from the present site. This work, which included 617 feet of diamond drilling, yielded useful general information on the weathering and fracturing of the agglomerate. In particular, it indicated that fractures which appear at the surface as wide gashes generally close to insignificant width at shallow depth. This has also generally proved to be the case at the present site (No. 2).

The present report should be read in conjunction with that by Davies (1960) which describes the earlier phase of investigation, during which the decision in favour of a rock-fill dam was confirmed and attention drawn to very deep weathering in a saddle suitably located for a spillway. Davies' report contains an excellent description of the topographical and geological environment of the dam and spillway site and gives details, now relevant to design, on the lithology of cores from, and water pressure tests in, diamond drill holes 2S1 to 2S14, the locations of which are shown in Plate I of this report.

GEOLOGICAL ENVIRONMENT.

Regional.

The dam and entire storage area is wholly on the Astrolabe Agglomerate: a sub-horizontal volcanic formation composed of coarse basaltic agglomerate with thin, discontinuous interbeds and very rare augite basalt lava flows. The formation covers an oval area about 16 miles long and 5 miles wide, aligned north-westerly. The shape and alignment suggests that the volcanic succession has been deposited in a broad strike valley.

Bedding in the formation indicates spasmodic showers of roughly graded coarse and fine ejecta, probably deposited in shallow water. Apparently the initial vulcanism caused disruption of the drainage and damming of a valley to form a large shallow basin in which up to 1500 feet of agglomerate and tuff accumulated. At several stages in its history, this basin may have contained shallow lakes.

The Astrolabe Agglomerate has withstood erosion to a greater extent than the surrounding countryside during the Pleistocene; the Sogeri Plateau, between 1,200 and 2,000 feet above sea level, has formed as a result. Except for regional emergence and possibly slight tilting, the formation has not been tectonically disturbed since deposition, probably in late Pliocene time.

The surface of the Astrolabe Agglomerate has yielded to chemical weathering, rather than physical erosion, to produce a very thick clay and decomposed rock mantle that in places exceeds 100 feet. Differential deep weathering is responsible for the characteristic roundness of the hills and valleys of the Sogeri Plateau.

Local.

The investigations at the dam and spillway site have been concerned with about 380 feet thickness of typical Astrolabe Agglomerate - probably the upper half of the formation. Most of the section was intersected by diamond drill holes from which almost 100% core was recovered.

As illustrated in the composite stratigraphic column on Plate II, tuff beds up to 8 feet thick, distributed irregularly, comprise about 8% of the section. The remainder is agglomerate, with sub-angular components set in a matrix of fine tuffaceous mud. The inclusions are mainly of augite basalt, with subordinate andesite, and range in diameter from $\frac{1}{4}$ inch to 2 feet.

Coarse bedding, in which the large components of the agglomerate are roughly grouped, is apparent in large cliff faces, but in hand specimen and cores bedding cannot be detected in the agglomerate.

Lava flows do not occur in the dam and spillway section.

Typical agglomerate members of the section are composed of sub-angular fragments, in contact with one another, and tuffaceous matrix that completely fills the interfragmental spaces, and forms about 30% of the whole rock. Rarely, the fragments are completely isolated from one another in the tuffaceous matrix. At th other extreme, narrow zones of agglomerate with practically no matrix are commonly found. These zones are very permeable and the larger interfragmental cavities are generally lined or filled with clay near the surface and at depth are lined with powdery blue-grey or black films which look like sublimate deposits. The porous zones were formed by air, steam or gas pockets trapped immediately after ejection in the slowly cooling and solidifying volcanic sequence; as such they would be individually small and haphazard in distribution. Some of the major leakages in the water-pressure tested diamond drill holes of the 2S series may be attributable to these zones of porous agglomerate, particularly where they are linked by open tension joints.

In the abutment cliffs, particularly on the right bank, several small caves and scour holes have been formed by river erosion of loosely aggregated patches of agglomerate and tuff

The fresh, unweathered agglomerate, which was only seen in cores from the deeper drilling, is a dark grey, tough rock in which the components and matrix are about the same colour. Most of the agglomerate cores show incipient weathering manifested by a slight colour change of the matrix towards dark purplish-brown. This slight weathering does not seem to reduce seriously the compressive strength of the rock and most of the agglomerate described as "slightly weathered" in the drilling logs would be acceptable as rock-fill material. Weathering is discussed in greater detail under a separate heading later in this report.

The cementing material of the agglomerate has not been positively identified. Mr. P. J. Darragh, of the C.S.I.R.O., who examined typical agglomerate microscopically, considers that the matrix may contain volcanic glass. The impregnation of the tuffaceous matrix of the agglomerate with pervasive volcanic glass in a volatile state during, or shortly after, deposition could account for the cohesive strength of the rock, which cannot be adequately explained by normal compaction.

Well graded tuffs, composed of silt to sand-sized components, are interbedded with the agglomerate, and occupy about 8% of the section examined. The interbeds are generally a few inches to one foot thick, but range up to 7 feet. Most are lenticular or vary in thickness over short lateral distances. A tuff bed from 2 to 5 feet thick, exposed near the base of both abutment cliffs, has been eroded at a greater rate than the enclosing agglomerate, thereby forming small caves and nicks in the cliff profile.

As a general rule the tuff beds are not suitable for use as rock-fill because of their tendency to crumble and weather rapidly. However, some of the well-cemented tuffs may be acceptable.

Structure and Jointing.

Cliff exposures at the dam site show a 7° dip to the south-south-west. This dip probably represents deposition on a local sloping surface rather than structural deformation after consolidation of the agglomerate.

Vertical jointing is a striking feature of the dam site. It is widespread in the Astrolabe Agglomerate and has been attributed by Gardner & Noakes (1959) to a combination of jointing and tensional cracking, as a result of "unloading" at the surface. Drilling and water-pressure testing at the No. 6 dam site indicated that these joints tend to close at shallow depth and are greatly emphasized at the surface by weathering. However, clay fillings and linings in some of th joints intersected by drilling indicate some flow of water along joints, particularly near the surface.

The prominences, on both sides of the river, which provide the abutments for the dam are bounded by near-vertical joint faces and are cut into several rocky bluffs by valleys which have obviously developed along a fracture system that strikes about 050° magnetic.

On the right bank, three bluffs have intervening wide, steep-walled, clay and debris-filled valleys. On the left bank, erosion gashes filled with scree and clay separate four principal headlands. Surprisingly, this joint system cannot be traced through outcrop in the river bed - further evidence that the joints close at shallow depth. The very prominent joint which forms the upstream face of the right abutment hill strikes into the deeply weathered spillway saddle and crosses the river at the deep pool immediately above the dam site. The deep weathering on the eastern side of the spillway saddle and the zones of major leakage in diamond drill holes 2S1 and 2S4 are almost certainly related to this major fracture. At the spillway saddle the fracture may provide a leakage channel, particularly when full storage level is raised to R.L. 1752 in the second stage of development. Before this stage, and preferably during excavation of the spillway, the area should be closely examined. The fracture may require grouting, or a small dam and grout curtain across the narrow gully at the eastern upstream edge of the spillway channel may be warranted.

A small north-westerly striking fracture behind the upstream rock bluff on the right bank, may indicate a minor joint system parallel to the river. The possibility that a similar fracture might pass behind the right abutment should be examined when the trench for the cut-off wall is excavated.

Permeability.

Water-pressure tests during diamond drilling at the No. 6 site and in the early investigation of the present site have proved that the typical agglomerate with fine tuffaceous matrix is impermeable, even though some of the basalt components are very vesicular. Most cases of serious water loss were attributable to open joints, particularly in the transition zone between solid rock and the residual clay mantle. Some losses were related to "broken agglomerate" which in most cases represents narrow zones of the open agglomerate (see p. 3) fragmented during drilling.

The friable tuff beds intersected by drilling and seen in outcrop, are clearly more permeable than the enclosing typical agglomerate, but in no case has water-pressure testing proved seriously high permeability of the tuffs. The more advanced weathering of the tuffs compared with agglomerate at the same depth, as shown in drill holes, suggests freer movement of groundwater through the tuff than through the agglomerate.

WEATHERING.

General.

In the mature rolling country of the Sogeri Plateau, rock outcrops are rare. Road cuttings expose a thick, weathered mantle with red and orange, tight, homogeneous clays in the upper part grading downwards into a thick zone of lighter coloured plastic clays with a purplish tinge and distinct agglomerate fabric. In some places thin lateritic bands are developed near the surface and small residual agglomerate fragments high in the clay profile are partially replaced by gibbsite. Drilling, augering and pitting on the divide between Eilogo and Upper Laloki drainages near the homestead of Lukin's plantation have proved very deep weathering. One drill hole penetrated clay to 106 feet, then leached and decomposed rock to 129 feet before encountering reasonably solid agglomerate. Testing in this area has indicated that depth of weathering is very irregular and bears no apparent relationship to the surface configuration. Springs which emerge low on the Eilogo side of the Upper Laloki divide near Lukin's house suggest that the transition zone of decomposed rock between solid rock and clay is locally permeable.

Dam and Spillway Area.

At the dam site information for design purposes was required on:-

(1) depth of overburden (soil, clay, loose scree and alluvium) above suitable foundations for the rock-fill.

(2) depth to solid rock along the line of a foundation cut-off wall around the upstream edge of the embankment, into which the proposed water-tight steel deck of the upstream face could be embedded.

(3) depth to solid rock along the line of a proposed diversion channel to be cut, where possible, 15 feet into solid rock.

As it was proposed that rock for the rock-fill embankment should be obtained from the spillway excavation, a programme of augering and drilling was undertaken to determine depth of overburden and amount of rock in the proposed spillway channel cut. Diamond drill holes 2S4, 2S13 and 2S14 of the earlier investigation proved unexpectedly deep weathering on the north western side of the spillway saddle. A fairly close drilling and augering pattern was necessary to ensure that no other deeply weathered zones existed in the area. The results of the drilling are discussed later in the report.

For convenience in presenting results the weathered mantle or overburden above solid rock has been classified into "very weathered" and "weathered" zones.

The "very weathered" zone is that upper portion of the weathering profile which could be penetrated by hand auger and which could not be recovered as core in the diamond drilling. This zone comprises the surface humic layer of soil and the underlying plastic clay zone. It contains many residual unweathered boulders of agglomerate, particularly in the dam site area where scree boulders are common.

The "weathered" zone is decomposed, leached, rock in situ which was incompletely recovered as fragmentary cores in diamond drilling. It grades downwards into solid rock, characteristically has a low specific gravity, and is so friable that it may be readily broken by hand.

This classification will be of practical value to the contractor in that the "very weathered" zone can probably be stripped by earth moving equipment or by sluicing, whereas the "weathered" zone may have to be quarried along with the solid rock. Material of the "weathered" zone would not be desirable as rock-fill.

In many of the drilling logs cores have been described as "slightly weathered". This generally refers to solid agglomerate or tuff in which the matrix or components have changed from the bluish-grey of the fresh rock to dark or purplish-brown. In the vertical sections and the sub-surface contour plan (Plates II*, III and IV) the rock described as "slightly weathered" in the drilling logs is for the most part included in the solid rock zone. Many of the tuff bands are more

* The following correction to Plate II should be noted: Plate II, Fig. 3A - From a point about 15 feet upstream of SDD 18 to the right side of the figure the "very weathered" - "weathered" rock boundary should be less than 2 feet above the "solid" rock boundary.

susceptible to weathering than the typical agglomerate because of higher permeability, and "slightly weathered" tuff is commonly interbedded in unweathered agglomerate.

Localized deep weathering, along fractures, and the preferential deep weathering of some tuff beds prevents the specification of any particular horizon below which rock acceptable as fill for the main embankment could be guaranteed. For the purposes of preliminary estimates of quantities of overburden and solid rock, the rather arbitrary "solid" rock boundary on the sections of Plates II and III, and contoured in the spillway area (Plate IV) has been introduced. The sub-surface contours in the spillway area are based on data from widely-spaced drill-holes and accordingly are not sufficiently accurate to use to specify acceptable "solid" rock for rock-fill. The estimate of rock available from the proposed spillway channel cut given later in this report is based on the sub-surface contour plan with a liberal deduction of 10% to allow for deeply weathered or friable rocks

Difficulties may be experienced in establishing acceptance standards for rock-fill material but the best field guides are colour, specific gravity (or density), and toughness as indicated by a simple hammer-blow test.

The colour change with weathering, although gradational, is very marked. The fresh agglomerate and tuff is a dark blue-grey. The first weathering effect in the agglomerate is a colour change of the matrix to dark and purplish brown; this degree of weathering does not seriously affect the strength of the rock. The colour change spreads from the matrix to the agglomerate components as weathering progresses and the overall colour of the rock passes through mid-brown to red and yellow shades of light brown. Beyond the mid-brown stage the strength of the rock is seriously reduced and all the light brown rocks should be discarded as overburden. The well-cemented tuffs follow the same pattern of colour change with weathering, but throughout the colour scale they lag slightly behind the agglomerate in strength; accordingly these tuffs may not qualify as rock-fill material in the mid-brown weathered state. The classification of friable tuffs should be based on toughness irrespective of degree of weathering as indicated by colour.

Weathering is also accompanied by marked lowering of specific gravity, quite noticeable in the handling of specimens, particularly diamond drill cores. Five selected specimens of core from the spillway drilling, representing the agglomerate and tuff members in various stages of weathering, were tested by the Department of Works, Soils Testing Laboratory, Port Moresby, for density, specific gravity, moisture content in air, moisture content after 24 hours' immersion, and total absorption. The results, tabulated below, indicate a clear relationship between weathering and specific gravity. Specific gravity may be the most useful criterion for specifying rock acceptable for the rock-fill embankment.

Description	Drill Hole Depth	Density lb/cu.ft	Air Moisture Content %	Specific Gravity	Moisture Content after 24 hrs immersion %	Total Absorp--tion %
1. Weathered, yellow-brown, friable agglomerate.	SDS 15 26'	95.0	11.3	1.52	25.0	45.2
2. Slightly weathered solid agglomerate with dark--brown matrix.	SDS 8 24'2"	129.0	2.0	2.09	17.2	11.8
3. Fresh, solid, blue-grey agglomerate.	SDS 17 42'	144.0	2.3	2.48	38.2	5.9
4. Weathered, mid-brown tuff.	SDS 6 37'6"	96.5	4.5	1.36	19.1	23.4
5. Fresh, compact, grey tuff.	SDS 6 22'2"	146.0	0.13	2.32	6.4	2.0

Of the five specimens, the weathered agglomerate (1) and the weathered tuff (4) with specific gravities 1.52 and 1.36 respectively would be unsuitable for rock-fill. It is suggested that all rock of specific gravity greater than 2 might be regarded as acceptable. This would probably exclude the friable tuffs and loosely compacted agglomerate, but, if not, they could be excluded by special provision.

A simple toughness test using a standard hammer blow could be used as a basis for rejecting the friable tuffs or open agglomerate which might otherwise qualify for acceptance on the basis of colour or specific gravity.

PRELIMINARY INVESTIGATION.

In the first stage of the investigation, described by Davies, 1297 feet of diamond drilling was completed; 10 holes were drilled in the spillway section, two holes on the right bank at the dam site to test foundation conditions and two holes high on the left bank on a proposed quarry area which will probably not be used until the second phase of construction. In addition, twenty-eight auger holes were drilled in the dam foundation area, on both banks, to determine the depth of overburden. As a result of these investigations the original proposal for a rock-fill dam was confirmed and a decision was made to excavate a 200-foot wide spillway channel in solid rock in the abutment hill, north-west of the deeply weathered saddle.

PRELIMINARY DESIGN OF DAM AND SPILLWAY.

The preliminary design of the dam and spillway has provided for a rock-fill dam in the first stage with a crest at R.L. 1752, about 80 feet above river level, and about 250 feet thick at the base. Crest length of the dam will be about 300 feet, and will link solid rock abutments at the downstream end of the dam site. The upstream face of the embankment will be sealed with a watertight, welded steel plate embedded in a concrete cut-off wall founded in solid rock. A diversion channel 14 feet wide and 15 feet deep, excavated as far as possible in solid rock, on the right bank of the river will accommodate river flow during dam construction and will ultimately carry a 5-foot diameter steel outlet pipe. The diversion channel will be covered with a reinforced concrete roof on which the rock-fill will be laid.

Full storage level at R.L. 1724 is proposed and the estimated top flood level is R.L. 1747. A 200-foot wide channel with a floor level at R.L. 1742, excavated in solid rock through the north-eastern side of the right abutment hill, will provide for high-level flood spill. It is anticipated that sufficient rock for the main embankment of the dam will be obtained from the spillway excavation, so that the quarry site high on the left bank, which was proposed earlier, will not be required until the second stage of construction.

The approximate locations of the principal elements of the project are shown on Plate I.

PRINCIPAL AIMS OF THE DESIGN INVESTIGATION.

A programme of drilling and augering was drawn up to provide further information on the following aspects:

I. Dam Site.

(1) Depth to, and nature of, solid rock around the line of the foundation cut-off wall into which the steel deck of the upstream dam face is to be embedded.

(2) The geological section below the dam foundation and, in particular, to check for any weak or very permeable zones.

(3) Extent of overburden in the foundation area.

(4) Depth to solid rock and nature of rock along the line of the diversion channel to at least 5 feet below the channel floor.

II. Spillway Area.

(1) Extent and nature of overburden over the proposed spillway channel.

(2) The amount of rock, suitable for rock-fill, available from the proposed spillway excavation.

(3) The nature of rock at the level of the spillway channel floor.

(4) Depth of weathering and nature of rock at downstream toe of spillway for consideration of scour problems.

DESIGN DRILLING AND AUGERING.

Diamond drilling in the course of design investigations totalled 1329 feet, of which 701 feet were drilled on the dam site at locations SDD 1 to SDD 22, and 628 feet on the spillway site at locations SDS 1 to SDS 17 (see Plate I). All the design drill holes were vertical, and were not water-pressure tested as the principal objectives were depth of overburden and nature of underlying rock.

A Mindrill E 1000 plant using NMLC stationary split inner tube core barrels was used for all the diamond drilling. The drill was operated by J. Allis and native assistants.

Table I presents a tabulated summary of all diamond drilling in the area and gives depths and reduced levels of the base of the "very weathered" and "weathered" zones in each hole. The significance of this classification has been explained under "Weathering" earlier in the report. The approximate grid references given in the summary for the collar of each hole refer to the grid on Plate I. Principal geological features in each hole are noted in the last column of the tabulated summary.

Core recovery from the "very weathered" zone was negligible and improved only slightly in the "weathered" zone. Within solid rock core recovery was almost 100% throughout, with only small losses near fractures and in small patches of agglomerate without matrix.

Logging of cores from the 2S series of diamond drill holes of the earlier investigation and of the SDD series of the design drilling at the dam site was done by H. L. Davies. The cores from the SDS holes of the design drilling in the spillway area were logged by the writer. This will explain some minor differences in nomenclature between the logs of SDS drilling and the previous drilling. For the classification of the weathered mantle into "very weathered" and "weathered" zones, all the drilling was reviewed by the writer. The design drilling logs are appended to this report.

All the design drilling cores, together with those from the earlier drilling, have been stored at Rouna where they are available for inspection.

Further augering, particularly in the spillway area, was undertaken for information on the depth of overburden. The locations of all auger holes and their depths in feet are shown on Plate I. The auger hole information must be applied with caution because diamond drilling has shown that solid boulders which would block the progress of an auger, are commonly completely surrounded by weathered rock. The auger hole depths only indicate the minimum depth of readily removable overburden (the "very weathered" zone) and should not be interpreted to indicate the total depth of overburden. In most cases, except where some control is afforded by diamond drilling, solid rock has been assumed at 5 feet below auger limit. This assumption may have led to local misinterpretation, particularly at the dam site where scree boulders are abundant. The vertical sections on Plates II and III and the sub-surface contours on Plate IV therefore indicate only roughly the upper surface of solid rock.

RESULTS OF THE DESIGN INVESTIGATION.

I. Dam Site.

(1) Foundation Cut-off Wall.

On the left bank, diamond drill holes SDD 3, 4, 5 and 6 were located approximately along the line of the foundation cut-off wall. Depth to solid rock along this line is very irregular, ranging from 7 ft 6 ins in SDD 6 near the river, to 20 ft 6 ins in SDD 3 near the abutment. Excavation along this line should reveal horizontal benching and deep weathering along the principal joint planes. The probable positions of these joint planes are shown diagrammatically in the section (2a, Pl. II) through SDD 3, 5 and 6. It may be necessary to grout any open joints exposed in the foundation cut-off trench.

On the right bank, overburden is much deeper than on the left bank. This is illustrated by the section through diamond drill holes SDD 14, 9, 10, 11 and 12. SDD 9 passed through 25 feet of overburden and decomposed rock before encountering solid agglomerate and, nearby, a 21-foot hole was drilled with a hand auger. Excavation to locate solid rock along the line of the cut-off wall will almost certainly be hampered by water seepage as the top of solid rock at SDD 9 is near normal river level. This deep overburden, which seems to extend in a fairly narrow zone parallel to the river between the line of the proposed diversion channel and the base of the right abutment, may represent an old river channel. Diamond drill hole 2S6 of the preliminary investigation did not intersect any major fractures beneath this zone. Tension joints striking at 050° magnetic and in line with the steep joint faces of the abutment cliffs will be revealed when the foundation area is cleared, and where these intersect the line of the cut-off wall some grouting may be required.

(2) Geological Section Below River Level.

A vertical diamond drill hole, SDD 8, located on a rock platform in the river bed at the upstream toe of the dam was drilled t R.L. 1529, 145 feet below normal river level, to examine the section below the dam site for possible weak zones or very permeable beds. After intersecting fresh agglomerate for 24 feet the hole passed through a predominantly tuffaceous interval between 24 ft and 30 ft 10 ins containing three fresh, solid tuff beds 1 ft 3 ins, 4 ft 1 in. and 5 ft thick. Below 31 ft, to 145 ft, the section was mainly solid agglomerate with minor tuff beds.

The tuff beds between 24 ft and 30 ft 10 ins are compact and not weathered. Water-pressure tests in diamond drill hole 2S5 which traversed this tuffaceous section nearby did not indicate any marked permeability in the tuff.

At 37 ft and 59 ft, yellow, soapy clay occupies small cavities between agglomerate components and at 66 ft a steep fracture is filled by clay $\frac{1}{4}$ inch thick. Small fractures at 107 ft are lined with a fine grey powder which is possibly a volcanic sublimate. The clay at 37 ft, 59 ft, and 66 ft, suggests movement of water through narrow permeable zones or fractures.

This exploratory hole has eliminated the possibility of weak or highly permeable beds less than 140 feet below the stream bed.

Near the SDD 8 collar, the river flows through a channel 12 feet wide and 4 ft to 5 ft deep, between rock platforms. Fractures striking along the course of the river may extend from the bottom of this channel; they would be revealed when the river is diverted and can, if necessary, be grouted before the cut-off wall across the upstream toe of the dam is emplaced.

The vertical section across the dam site through the upstream toe and SDD 8 collar includes a generalized stratigraphic column which shows the principal tuff horizons.

(3) Extent of Overburden in the Foundation Area.

The partly decomposed rock of the "weathered" zone should be suitable as foundation for the laying of rock-fill; overburden therefore, will be the "very weathered" zone.

The thickness of overburden in the foundation area, as determined by diamond drilling, ranges from 3 ft to 18 ft 6 ins on the left bank, and from 4 ft to 23 ft on the right bank, with abrupt local variations on both banks. Hand augering, which could only indicate minimum thickness of overburden, did not extend the limits indicated by the diamond drilling.

Estimation of the quantity of overburden to be removed would be difficult because of irregularities in the "bedrock" surface and large boulders at and near the surface.

On the left bank, deepest overburden is at the base of the abutment cliffs, particularly near the principal joints. Diamond drill hole SDD 3, located over the large tension joint near the left abutment, passed through 18 ft 6 ins of overburden before entering the decomposed rock layer, and an auger hole nearby penetrated to 13 feet. Except near the base of the cliffs and over the deeply weathered joints, overburden ranges in thickness from 3 ft to 8 ft. Large slumped blocks of agglomerate are littered over the surface of the left bank foundation area.

On the right bank, overburden is generally thicker than on the left bank, and attains maximum thickness between 1700 and 1720 contours on the upstream side of the abutment. In this area, SDD 9 and SDD 10 were drilled through 23 ft and 15 ft 7 ins of overburden respectively, and auger holes penetrated to 22 ft. Along the line of the diversion channel the overburden is thinner, so it seems likely that the deeper "bedrock" between the diversion channel line and the base of the abutment cliffs may represent a former river channel now filled with silt, residual clay and soil.

(4) Diversion Channel.

Vertical diamond drill holes SDD 14, 15, 16, 17 and 18 were drilled along the axis of the proposed diversion channel line on the right bank to determine the "bedrock" profile and examine the underlying rock in which the channel will be cut. The inclined diamond drill hole 2S6, which was drilled during the early investigation to intersect a possible fracture, passed through the diversion channel line midway between SDD 14 and SDD 15.

The vertical section (3A on Plate II) along the axis of the channel shows the approximate relationship of the "bedrock" profile to the surface. The proposed diversion channel cannot be wholly contained within solid rock upstream from SDD 15 and will require special construction up to this point to prevent flooding or serious seepage into the excavation for the cut-off trench and into the area from which thick overburden will have to be removed.

Between diamond drill holes SDD 15 and SDD 16, the solid rock surface rises steadily until at SDD 16 the floor of the channel will be about 30 ft below the top of solid rock. Augering on the abutment side of the section line indicates deeper erosion or weathering; the north-eastern wall of the channel between SDD 15 and SDD 16 may therefore need some lining. From SDD 16 to SDD 18, the proposed channel can be cut into solid rock, but first it will be necessary to remove a number of large boulders between SDD 17 and SDD 18 which will threaten the channel if undercut.

Tension joints belonging to the prominent joint system, obvious in both abutments, will probably be revealed in the excavation of the diversion channel. Except in SDD 18 between 16 ft and 19 ft, they were not indicated by the diamond drilling along the axis of the proposed channel, but as the fractures and the drilling were vertical, intersections could not be expected. The most likely positions for these joints or joint zones has been indicated diagrammatically on the longitudinal section by projecting the strike of the major joint faces in the abutments. Weathering along the joint planes may cause local weakness in the channel wall.

A brown, compact tuff bed was intersected in SDD 15 between R.L. 1684 and R.L. 1682 but was not encountered in SDD 16, 70 feet farther downstream. This tuff will appear in the channel but, being compact, should not erode seriously.

II. Spillway Area.

Overburden in this area will include the material both of the "very weathered" and the "weathered" zones because the walls and floor of the channel must be in solid rock and the excavation is to be the main source of rock-fill for the dam.

The sections (Plate III) and the sub-surface contours on the solid rock surface (Plate IV) have been constructed from drill and auger hole information. The "solid rock" boundary shown is a diagrammatic representation of a transition zone, and should not be interpreted as a firm boundary.

The "solid rock" shown below this transition zone is not entirely "solid" as it contains many friable tuffs and some deeply weathered agglomerate near fractures.

With the qualifications set out above the "solid" rock boundary has been used as a basis for determining the approximate amounts of overburden and rock-fill material in the spillway area.

(1) Quantity of Overburden.

An estimated 30,000 cubic yards of overburden covers the site of the 200-foot wide spillway channel indicated on Plate I. The probable distribution of this overburden is shown in sections of Plate III and can be arrived at by superimposing the solid rock sub-surface contour plan over the topographic plan. Trimming of the overburden back from the solid rock walls of the spillway will slightly increase the amount of overburden to be removed.

Most of the overburden will be clay and will be easy to remove with earth-moving equipment but some, in the "weathered" category, may have to be quarried with the solid rock.

(2) Quantity of Solid Rock in Spillway Cut.

In the location shown on Plate I, a 200-foot wide spillway channel, with an upstream lip at R.L. 1742, floor slope of 1 : 100 (as suggested by engineers on the project), and vertical sides, will contain about 71,000 cubic yards of rock in situ, of which some friable tuff and locally deeply weathered rock will not be acceptable as rock fill. Allowing for a possible 10% rejection, the estimate of available rock fill becomes 64,000 cubic yards which, when broken and dumped will occupy about 90,000 cubic yards. The requirement of rock-fill in the main embankment has been tentatively estimated as 85,000 cubic yards. If required, additional rock-fill could be gained by widening the spillway channel westward. About 4,300 cubic yards of acceptable rock in situ would be gained per 10 ft westward advance of the channel wall over a total distance of 40 ft. Beyond this distance the rate of gain would decrease sharply. Thus an additional 17,000 cubic yards of acceptable rock in situ, or 24,000 cubic yards of rock-fill, could be obtained by widening the spillway channel to 240 feet.

Additional rock-fill could also be obtained from a quarry on the steep slope south of the spillway site, or from the rock bluffs at the upstream end of the damsite.

(3) Spillway Channel Floor and Walls.

Diamond drilling has indicated that the floor of the spillway channel will be in typical well-cemented agglomerate; this should adequately resist erosion.

Joints will undoubtedly strike across the spillway channel site but at the level of the floor they will probably be closed. Should open joints be exposed in the floor of the spillway cut, they would probably not require sealing until the second stage expansion when the spillway will be in permanent use.

Diamond drill holes SDS 3, 4, and 6 intersected a characteristically brown, slightly weathered tuff bed, ranging from 2 ft to 3 ft 8 ins in thickness, between R.L. 1752 and 1763. Intersections on this bed indicate a dip of about 5° to the south-west; this roughly conforms with dip seen in the abutment exposures. Tuff beds exposed in the wall of the channel may fret slightly but should not require special attention.

The spillway channel may be safely left with steep, unlined, rock walls as many natural escarpments attest the stability of the sub-horizontal agglomerate.

(4) Toe of the Spillway.

The downstream rock edge of the spillway coincides with a continuation of the major joint which forms the steep northern face of the abutment hill. Beyond this edge scree accumulation and weathering is deep.

Possible outcrop and shallow depth of bedrock in SDS 10 have suggested the presence of a narrow ridge below the toe of the spillway. Such a feature, if exposed by scouring during first-stage operation, may have to be removed if the spillway is later extended or modified. No serious scour problem is envisaged, however, during the first stage operation as the spillway will only carry water at rare times of high flood.

CONCLUSIONS.

1. The Sirinumu No. 2 dam site is suitable for a rock-fill dam.

2. Tension joints expressed at the surface as steep-sided gashes or valleys between prominent rock bluffs are expected to be closed at shallow depth. They will require some grouting around the line of the foundation cut-off wall, but the extent of grouting can best be determined after overburden has been removed.

3. As difficulty was experienced in distinguishing large slump blocks of agglomerate from "bedrock", no estimate of overburden in the dam foundation area was made. However, drilling and augering has indicated abrupt irregularities, with overburden thickness ranging from 3 to 23 feet, due principally to deep weathering and erosion around major joints and to horizontal benching in the bedrock. Thickest overburden, up to 23 feet,

occurs in a zone on the right bank of the river just east of the upstream half of the diversion channel. This zone may be a former narrow river channel now occupied by sediments and scree.

4. The sub-horizontal agglomerate formation continues for at least 145 feet beneath the dam site, and does not contain any weak or very permeable beds.

5. The proposed diversion channel will need lining for about the first 120 feet from the upstream end; farther downstream it should be in solid rock, but may require concrete plugs in tension joints (extensions of joints visible in the right abutment).

6. A very large tension joint which forms the upstream margin of the right abutment hill strikes into the deeply weathered area on the eastern side of the spillway saddle. This deeply weathered zone could be a leakage area, particularly in the second stage development when top water level is raised to R.L. 1752. The problem should be examined during the excavation of the spillway.

7. A 200-foot wide spillway cut into the right abutment hill, in the position indicated on Plate I, should provide about 90,000 cubic yards of placed rock-fill. The estimated amount required for the dam is 85,000 cubic yards. A further 24,000 yards of rock-fill could be obtained by widening the spillway channel by 40 feet westwards.

8. About 30,000 yards of overburden will have to be removed from a 200-foot wide spillway channel as indicated; two-thirds of which can probably be stripped with earth-moving equipment.

9. Lining of the floor and walls of the spillway will not be necessary. The channel walls in solid rock will safely stand almost vertically.

10. No serious scour problem at the spillway toe is envisaged in the first stage. In the second stage, and before the spillway is in permanent use at top water level of R.L. 1752, it may be necessary to remove a rock bar from the eastern side of the spillway toe, the presence of which was suggested by drilling.

ACKNOWLEDGEMENTS.

Most of the field work on which this report is based was carried out by H. L. Davies, who was not available to participate in the writing of the report. Acknowledgement of this work within the text would be repetitious and incomplete. Accordingly Mr. Davies' contribution is now acknowledged.

Liaison between engineers and geologists throughout the investigation has been excellent and most references in the report to proposed design features of the project have been obtained by discussion with the local engineers. This co-operation is gratefully acknowledged.

The driller, Mr. J. Allis, and his native assistants were thoroughly reliable throughout and the high core recovery reflects skill and care by the driller.

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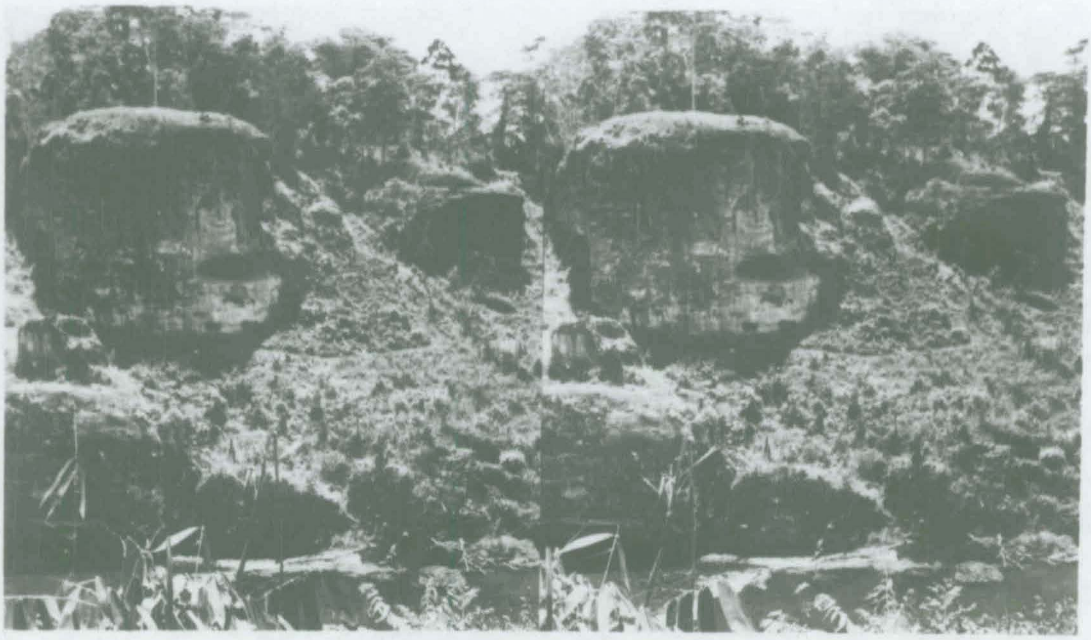


Fig. 2 . Stereo pair of photos showing right abutment for the dam .

Fig. 3. Stereo pair of photos showing left abutment for the dam.

Fig. 4. Steep gully in left bank upstream from the upstream toe of the proposed dam, formed by erosion of a joint.

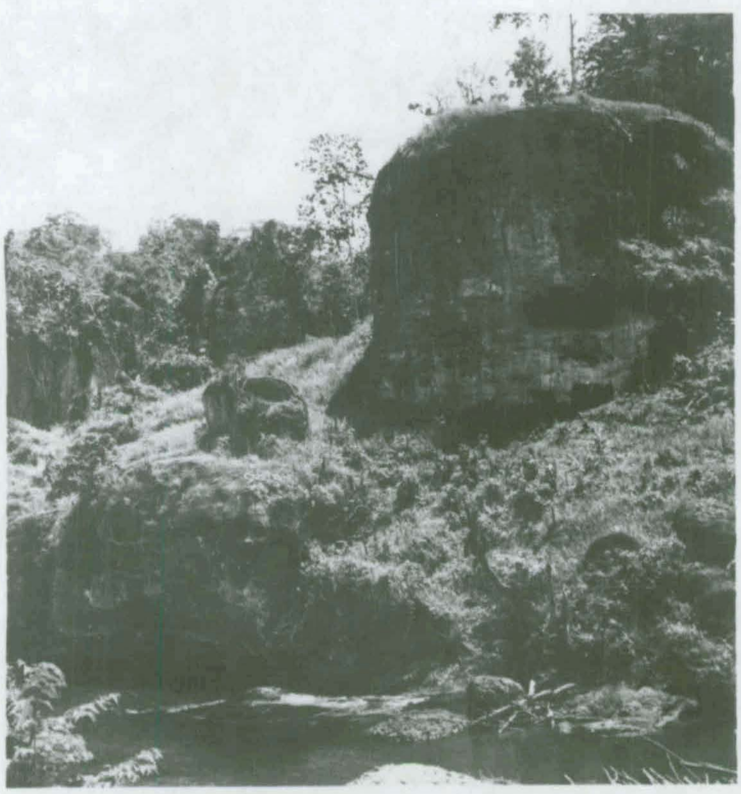


Fig. 5. Right abutment of the proposed dam showing scour holes in a tuff bed at the base of the cliff.

Fig. 6. Poorly-sorted coarse-grained agglomerate of the Astrolabe Agglomerate. Scale is indicated by the pen.

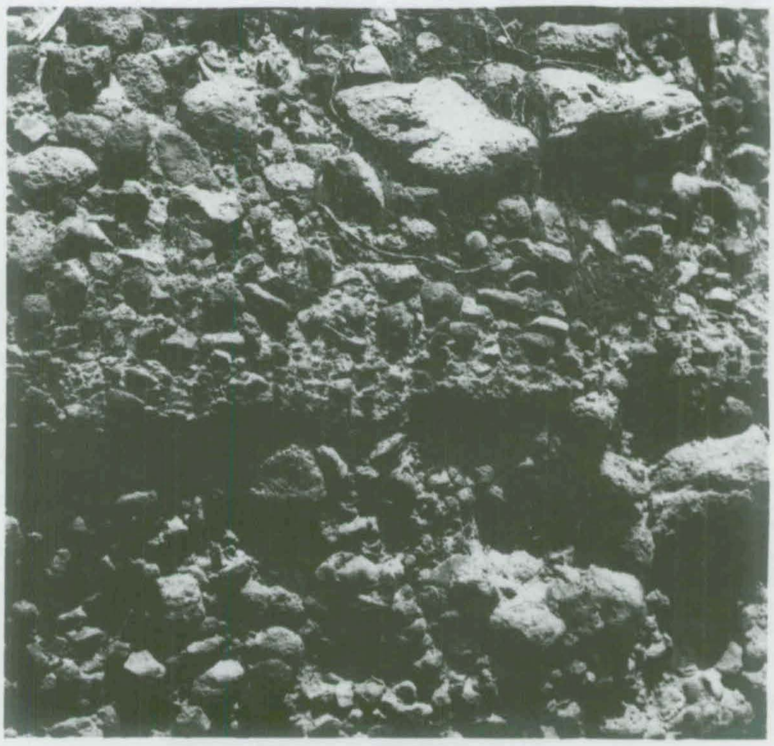


Fig. 7. Medium-grained Astrolabe Agglomerate. Note the relief produced by the preferential weathering of the matrix.

SIRINUMU DAM AND SPILLWAY

TABLE 1

DIAMOND DRILLING SUMMARY

HOLE	LOCATION – AREA	LOCATION – GRID REF. PLAN PH60/2178	R.L. OF COLLAR	① BASE OF "VERY WEATHERED" ZONE – FROM COLLAR	① BASE OF "VERY WEATHERED" ZONE – REDUCED LEVEL	② BASE OF "WEATHERED" ZONE – FROM COLLAR	② BASE OF "WEATHERED" ZONE – REDUCED LEVEL	TOTAL DEPTH – FROM COLLAR	TOTAL DEPTH – REDUCED LEVEL	GEOLOGICAL NOTES (DEPTHS FROM COLLAR)
DAM DESIGN DRILLING										
SDD 1	LEFT ABUTMENT DAM	350N 27E	1785·0	2'-7"	1782·4	4'-0"	1781·0	17'-8"	1767·3	4'0" – 17'8" matrix brown.
SDD 2	LEFT BANK CUT-OFF WALL	325N 76E	1753·7	2'-8"	1751·0	4'-5"	1749·3	17'-5"	1736·3	11'0" – 11'7" fractured with black lining. 12'8" – 12'11" clay in fracture. 10'7" – 11'11" 16'0 – 16'5" tuff.
SDD 3	LEFT BANK FOUNDATIONS	335N 135E	1726·0	18'-6"	1707·5	20'-6"	1705·5	33'-6"	1692·5	22'6" broken and weathered. 25'3" porous. 31'6" fractured, with light coloured clay fillings.
SDD 4		310N 165E	1714·0	10'-2"	1703·8	11'-6"	1702·5	24'-7"	1689·4	16'5" porous. 22'6" – 22'9" tuff.
SDD 5	LEFT BANK CUT-OFF WALL	270N 165E	1709·0	12'-8"	1696·3	15'-7"	1693·4	27'-6"	1681·5	18'4" clay in matrix. 27'0" – 27'4" tuff.
SDD 6		225N 195E	1694·0	6'-7"	1687·4	7'-6"	1686·5	21'-6"	1672·5	15'0' and 20'3" porous agglomerate.
SDD 7	LEFT BANK FOUNDATIONS	350N 177E	1700·0	3'-1"	1696·0	4'-10"	1695·2	18'-2"	1681·8	17'4" – 17'9" tuff.
SDD 8	RIVER BED UPSTREAM TOE	225N 290E	1674·2	0'	1674·2	0'	1674·2	145'-2"	1529·0	24'0"-25'3", 25'9"-25'10", 30'5"-30'10", 38'10"-39'9", 42'11"-43'3", 90'8"-91'4", 107'3"-107'7, 113'-114'6", 117'0"-117'9", 138'7"-140'4", 141'3-141'9" tuff beds. 37', 59', 66' clay in fractures.
SDD 9	RIGHT BANK CUT-OFF WALL	210N 407E	1700·0	22'-11"	1677·1	23'-2"	1676·8	33'-0"	1667·0	26'6" – 26'9" tuff.
SDD 10		245N 430E	1716·0	15'-7"	1700·4	18'-8"	1697·3	28'-9"	1687·25	20'8" porous agglomerate. 24'0" – 25'0" clay in matrix.
SDD 11		275N 462E	1735·0	10'-3"	1724·75	11'-7"	1723·3	24'6"	1710·0	19'1" – 19'5" broken, porous. 20'0" – 21'0" porous agglomerate.
SDD 12		294N 430E	1755·0	3'-9"	1751·25	5'-9"	1749·25	18'-7"	1736·4	15'9" open fracture. 17'10" – 18'7" tuff and fine agglomerate.
SDD 13	RIGHT ABUTMENT DAM	305N 535E	1774·0	11'-8"	1762·3	16'-6"	1757·5	31'-7"	1742·4	24'11" – 26'-0" weathered and broken. 30'11" – 31'5" fractures.
SDD 14	RIGHT BANK DIVERSION CHANNEL	168N 370E	1682·0	9'-5"	1672·6	12'-6"	1669·5	24'-3"	1657·25	22'8" – 23'0" tuff.
SDD 15		283N 380E	1700·4	3'-11"	1696·5	12'-4"	1688·1	34'-0"	1666·4	16'2" – 18'1" brown compact tuff. 26'3" fracture, clay filled.
SDD 16		355N 380E	1706·0	4'-0"	1702·0	6'-1"	1699·9	39'-2"	1666·8	15'1" fractured and porous.
SDD 17		412N 383E	1706·0	3'-9"	1702·25	3'-9"	1702·25	38'-11"	1667·1	21'8" – 21'11", 28'6" tuff.
SDD 18		312N 387E	1692·0	6'-3"	1685·75	6'-3"	1685·75	36'-1"	1655·9	16'6" – 18'10" weathered and broken agglomerate.
SDD 19	RIGHT BANK DOWNSTREAM	430N 470E	1736·0	10'-0"	1726·0	10'-3"	1725·75	24'-11"	1711·1	18'2" fracture with red clay.
SDD 20		500N 555E	1723·8	10'-4"	1713·5	10'-4"	1713·5	20'-5"	1703·4	14'9" – 16'3" tuff.
SDD 21	LEFT BANK FOUNDATIONS	363N 210E	1684·0	6'-3"	1677·75	7'-11"	1676·1	21'-4"	1662·7	18'5" – 18'7" tuff.
SDD 22		425N 177E	1699·0	5'-1"	1693·9	5'-1"	1693·9	20'-2"	1678·8	7'11" – 8'0", 18'6" – 18'9" tuff.
SPILLWAY DESIGN DRILLING										
SDS 1	SPILLWAY UPSTREAM EDGE	225N 753E	1780·7	5'-6"	1775·2	5'-6"	1775·2	45'-6"	1735·2	30'2" – 30'8" friable matrix. 35'2" – 35'6", 42'4" – 42'7" porous agglomerate. 43'6" – 44'0" brown tuff.
SDS 2		230N 862E	1760·6	3'-9"	1756·85	3'-9"	1756·85	18'-10"	1741·8	13'0" – 15'4", 16'4" – 17'4" poorly cemented agglomerate.
SDS 3	SPILLWAY STAGE II AXIS	300N 881E	1776·0	8'-11"	1767·1	11'-7"	1764·4	33'-10"	1742·2	13'0" – 16'8" brown tuff. 25'9" – 26'7", 27'2" – 32'-4" weathered matrix
SDS 4		310N 762E	1799·2	14'-1"	1785·1	14'-1"	1785·1	59'-4"	1739·9	17'-1" – 17'3", 28'10" – 29'1" 30'7" – 34'-4" clay in fractures and cavities. 34'4" – 35'6", 43'0" – 45'6", 46'0" – 46'6" brown tuff.
SDS 5	SPILLWAY APRON	430N 862E	1763·0	17'-0"	1746·0	33'-10"	1729·2	48'-9"	1714·25	36'2" – 36'4" slightly weathered.
SDS 6		395N 775E	1794·3	6'-7"	1787·7	6'-7"	1787·7	56'-7"	1737·7	21'5" – 22'5" slightly weathered tuff. 27'8" – 32'0" porous agglomerate. 35'0" – 38'4", 44'7" – 44'10" compact tuff.
SDS 7		495N 775E	1746·1	24'-11"	1721·2	24'-11"	1721·2	39'-7"	1706·5	29'8" – 32'8 clay in fractures and cavities.
SDS 8		510N 870E	1740·2	21'-4"	1718·9	26'-4"	1713·9	33'-10"	1706·4	33'10" – 36'3" weathered matrix.
SDS 9	SPILLWAY TOE	570N 820E	1715·5	7'-0"	1708·5	7'-0"	1708·5	22'-1"	1693·4	16'5" – 16'9" brown tuff. 20'7" – 20'9", 21'7" – 21'9" porous agglomerate.
SDS 10		545N 770E	1728·6	1'-6"	1727·1	1'-6"	1727·1	16'-6"	1712·1	12'8 – 15'4" bed of fine agglomerate.
SDS 11	SPILLWAY SCOUR	615N 800E	1708·1	8'-11"	1699·2	14'-2"	1693·9	33'-8"	1674·4	14'2" – 16'11", 19'10" – 22'3", 24'6" – 27'9", 30'3" – 30'9" steep, clay-filled fractures.
SDS 12		567N 708E	1707·6	16'-10"	1690·8	17'-10"	1689·8	30'-10"	1676·8	19'10" – 21'4", 25'0" – 26'-0" steep, clay filled fractures.
SDS 13		645N 730E	1717·3	11'-8"	1705·6	11'-8"	1705·6	26'-6"	1690·8	13'0" – 16'10" compact tuff except 15'10" – 16'2" friable.
SDS 14	SPILLWAY TOE	525N 745E	1731·6	16'-3"	1715·35	17'-1"	1714·5	31'-4"	1700·3	22'3" – 24'2" slightly weathered.
SDS 15	SPILLWAY EAST FLANK	380N 880E	1767·0	28'-3"	1738·75	29'-0"	1738·0	43'-3"	1723·75	30'4" – 30'7" tuff. 42'11" – 43'1" porous agglomerate
SDS 16		472N 930E	1738·0	21'-6"	1716·5	23'-4"	1714·7	41'-5"	1696·6	31'0" – 31'6" light brown tuff. 35'11" – 36'5" brown tuff. Slight weathering throughout suggests near fracture.
SDS 17		410N 935E	1753·0	26'-2"	1727·8	26'-2"	1727·8	46'-3"	1706·75	27'6" – 28'4" porous agglomerate. 29'2" – 29'5", 31'0" – 31'2" tuff.
③ **PRELIMINARY INVESTIGATION DRILLING ~ DAM, QUARRY & SPILLWAY**										
2S1	SPILLWAY SADDLE AXIS	275N 1037E	1765·1	5'-9"	1759·35	18'-1"	1747·0	97'-9"	1667·35	32'3" – 33'5" tuff. 34'0" – 34'6" broken. 47'6" – 48'2", 52'8" – 53'11", 60'5" – 61'6" 76'11" – 77'9", 91'3" – 94'9" tuff.
2S2	SPILLWAY SADDLE EAST	262N 1142	1773·7	29'-1"	1744·6	41'-1"	1732·6	73'-10"	1699·9	45'2" – 45'4" broken. 48'9" – 49'2" friable tuff. 59'2" – 60'0" compact tuff. 72'8" – 73'4" broken.
2S3	SPILLWAY SADDLE WEST	305N 930E	1770·3	18'-6"	1751·8	25'-0"	1745·3	76'-1"	1694·2	27'9" – 29'0" tuff. 61'10" – 66'1" compact tuff.
④ 2S4	SPILLWAY SADDLE	315N 1015E	1754·0	22'-2" Hole length	301N 1027E 1743·9	35'-2" Hole length	295N 1037E 1736·0	171'-2" Hole length	218N 1125E 1666·2	63'6" – 64'10", 66'10" – 69'8" tuff. 108'1" – 108'7" carbonaceous. 147'10" – 154'2" weathered. 160'3" – 161'2" tuff. 165'11" – 167'1", 169'1" – 170'10" tuff.
④ 2S5	RIGHT BANK CUT-OFF WALL	237N 318E	1675·0	0	1675·0	0	1675·0	114'-2" Hole length	147N 355E 1618·0	49'1" – 50'8" tuff. 75'2" – 75'5" "soapstone" in fractures.
④ 2S6		220N 360E	1688·3	13'-4" Hole length	226N 370E 1684·6	22'-2" Hole length	230N 376E 1682·3	82'-8" Hole length	249N 433E 1666·5	29'6" – 30'1" broken. 50'4" – 55'10" tuff. 61'7" – 61'9" clay filled fracture.
2S7	LEFT BANK STAGE II QUARRY AREA	Not on Works Plan PH60/2178	1891·6	7'-1"	1884·5	9'-6"	1882·1	130'-5"	1761·2	34'6" – 35'3", 40'3" – 40'7", 55'2" – 56'1", 73'9" – 80'0", 103'6" – 103'10", 110'-9" – 111'3", 118'11" – 119'5" tuff beds.
2S8		See PH59/155A L.B. Quarry Site	1860·6	6'-5"	1854·2	10'-9"	1849·85	100'-2"	1760·4	15'4" – 15'9", 20'9" – 21'6", 41'9" – 42'1", 45'5" – 55'10" compact. 81'3" – 81'11", 97'3" – 98'2" tuff beds.
2S9	SPILLWAY SADDLE WEST	267N 840E	1782·0	9'-9"	1772·25	16'-0"	1766·0	30'-0"	1752·0	16'6", 26'3" – 27'0", 27'6" porous agglomerate.
2S10	SPILLWAY SADDLE EAST	263N 1238E	1786·5	81'-9"	1704·75	Not encountered		106'-8"	1679·8	Weathered, soft throughout.
2S11		300N 1140E	1762·7	7'-9"	1755·95	13'-6"	1749·2	31'-6"	1731·2	30'8" – 30'10" broken.
2S12	SPILLWAY SADDLE WEST	358N 945E	1759·4	1'-2"	1758·2	14'-5"	1745·0	25'-4"	1734·1	16'3" – 16'10" weathered. 21'2" – 21'5" tuff.
④ 2S13	SPILLWAY SADDLE EAST	388N 1195E	1747·0	37'-6" Hole length	353N 1208E 1737·3	Not encountered		141'-0" Hole length	261N 1237E 1710·0	Except for "weathered" agglomerate at 55'0" – 92'0" remainder is "very weathered".
④ 2S14		155N 1195E	1737·8	71'-0" Hole length	218N 1220E 1719·5	Not encountered		116'-0" Hole length	261N 1236E 1706·8	"Very weathered" throughout.

① **"VERY WEATHERED" ZONE** : Regard as Overburden in all cases.

② **"WEATHERED" ZONE** : Decomposed Rock, probably not acceptable as rock fill material but suitable as foundation for rock fill.

③ **WATER PRESSURE TESTS** : Details of the Water Pressure Tests on the 2S series are contained in DAVIES' (1959) Report. The SDD and SDS series were not Water Pressure Tested.

④ **INCLINED HOLES** : Base of "Very Weathered" and "Weathered" Zones indicated by R.L. and Grid reference.

APPENDIX I

GEOLOGICAL LOGS OF DRILL CORE.

SDD series of diamond drill holes was logged by H. L. Davies.

SDS series was logged by J. E. Thompson.

All holes were vertical and core was NMLC size: except where indicated otherwise stationary split inner tube core barrel was used.

SDD 1

Location: Left bank of dam.

Commenced and completed: 9.6.60.

From	To	Core Description
0	2'7"	Not cored, soil and scree.
2'7"	4'0"	Agglomerate, slightly weathered, partly broken probably due to use of one-foot core barrel.
4'0"	17'8"	Agglomerate, slight to moderate weathering (matrix all has brown tint) but solid, few fractures.

END

Solid rock:- 4'0" (100% Core recovery below here).

SDD 2

Location: Left bank of dam.

Commenced and completed 10.6.60.

From	To	Core Description
0	2'8"	Not cored, soil and scree.
2'8"	4'5"	Agglomerate, slightly weathered, partly broken probably due to one-foot core barrel.
4'5"	17'5"	Agglomerate, slightly weathered most matrix has brown tint, mostly solid:- 11' - 11'7" 20° fracture with iron and manganese (?) (black, shiny) oxide staining. 12'8"-12'11" 30° fracture, irregular, with ¼" clay filling Tuff 10'7" - 11'11" and 16' - 16'5".

END

Solid rock: 4'5" (100% core recovery below here).

SDD 3

Location: Left bank of dam.

Commenced 15.6.60, completed 16.6.60.

From	To	Core Description
0	18'6"	Not cored, soil and scree.
18'6"	20'6"	Agglomerate, weathering moderate to bad, part broken.
20'6"	33'6"	Agglomerate, fresh and slightly weathered, solid except at 22'6" broken, white clay partly replaces matrix, shows some lamination.
		23'9" broken where matrix removed, no clay.
		31'6" irregular fracture, some matrix removed, some white and yellow clay and black manganese (?) wad.

END

Solid rock - 20'6" (100% core recovery below here).

SDD 4

Location: Left bank of dam.

Commenced 4.6.60, completed 6.6.60.

From	To	Core Description
0	10'2"	Not cored; soil and scree.
10'2"	11'6"	Agglomerate, moderately weathered, part broken.
11'6"	24'7"	Agglomerate, slightly weathered, few fractures. Matrix removed 16'5" Highly vesicular boulder 21'3" - 22'6"; Tuff 22'6" - 22'9".

END

Solid rock:- 11'6" (100% core recovery below here).

SDD 5

Location: Left bank of dam.
Commenced 4.6.60, completed 6.6.60.

From	To	Core Description
0	12'8"	Not cored, soil and scree.
12'8"	15'1"	Agglomerate, badly weathered and broken.
15'1"	15'7"	Agglomerate, moderately weathered, solid.
15'7"	27'6"	Agglomerate, fresh, solid, clay partly replaces matrix at 18'4". Tuff 27' - 27'4".

END

Solid rock - 15'7" (100% core recovery below here).

SDD 6

Location: Left bank of dam.

Commenced 2.6.60, completed 3.6.60

From	To	Core Description
0	6'7"	Not cored, soil and scree.
6'7"	7'6"	Agglomerate, moderately weathered (matrix brown).
7'6"	21'6"	Agglomerate, fresh and solid except at 15' and 20'3" where broken due to loss of matrix.

END

Solid rock 7'6" (100% core recovery below here).

SDD 7

Location: Left bank of dam.

Commenced and completed: 17.6.60.

From	To	Core Description
0	3'1"	Not cored; soil and scree.
3'1"	4'10"	Agglomerate; slightly weathered, partly broken probably due to one-foot core barrel.
4'10"	18'2"	Agglomerate; slightly weathered, solid.
		Tuff 17'4" - 17'9"

END

Solid rock: 4'10" (100% core recovery below here).

SDD 8 (Double tube core barrel)
Location: Foundation of dam.
Commenced 5.5.60, completed 11.5.60.

From	To	Core Description
0	5'0"	Agglomerate, fresh, broken owing to use of one-foot core barrel.
5'0"	24'0"	Agglomerate, fresh, few fractures.
24'0"	25'3"	Tuff, fresh, few fractures.
25'3"	25'9"	Agglomerate, fresh, few fractures.
25'9"	29'10"	Tuff, fresh, solid.
29'10"	30'5"	Agglomerate, fresh, solid.
30'5"	30'10"	Tuff, fresh, solid.
30'10"	145'2"	Agglomerate, fresh, few fractures, one component boulder of tuff at 31'1"; Tuff beds at 38'10" - 39'9", 42'11" - 43'3", 90'8" - 91'4", 107'3" - 107'7", 113'1" - 114'6", 117' - 117'9", 138'7" - 140'4", 141'3" - 141'9". Some matrix missing at 37' and at 59' where there is some soapy yellow clay filling (narrow). 30° fracture at 66' with up to ¼" thickness of clay filling which shows tuff matrix texture. 45° fractures with grey "paint" at 107'.

END OF HOLE. Total core recovery (99%).

SDD 9

Location: Right bank of dam.

From	To	Core Description
0	22'11"	No core; soil and scree.
22'11"	23'2"	Agglomerate, moderately weathered, broken.
23'2"	33'0"	Agglomerate, slightly weathered, mostly solid. Tuff 26'6" - 26'9".

END OF HOLE.

SDD 10

Location: Right bank of dam.

From	To	Core Description
0	13'10"	No core; soil and scree.
13'10"	15'7"	Agglomerate, badly weathered and broken.
15'7"	18'8"	Agglomerate, moderately weathered (all matrix brown) but mostly solid, few irregular fractures.
18'8"	28'9"	Agglomerate, slightly weathered, mostly solid, broken due to loss of matrix at 20'8", some matrix replaced by clay 24' - 25'.

END OF HOLE.

SDD 11

Location: Right bank of dam.

From	To	Core Description
0	10'3"	No core; soil and scree.
10'3"	11'8"	Agglomerate, moderately weathered (matrix brown), two irregular fractures.
11'8"	19'1"	Agglomerate, slightly weathered, mostly solid.
19'1"	19'5"	Agglomerate, broken and friable due to loss of matrix.
19'5"	24'6"	Agglomerate, slightly weathered, mostly solid, some matrix lost 20'-21'.

END OF HOLE.

SDD 12

Location: Right abutment of dam.

May 1960.

From	To	Core Description
0	3'9"	No core, soil and scree.
3'9"	5'9"	Agglomerate, slightly weathered, broken ½" - 3" fragments probably due to one-foot core barrel.
5'9"	17'10"	Agglomerate, mostly slightly weathered but moderately weathered (brown matrix) at 8'9" and 15'6" - 18'1" only 8 fractures, all irregular; water circulation lost completely near irregular open (due to clay removal) fracture at 15'9". Minor amounts of matrix lost, partly replaced by clay.
17'10"	18'7"	Tuff and fine agglomerate, moderately weathered to 18'1". Slightly weathered 18'1" - 18'7".

END OF HOLE.

SDD 13

Location: Right bank of dam.

Commenced 28.5.60.

From	To	Core Description
0	11'8"	Not cored; soil and weathered rock.
11'8"	16'6"	Agglomerate, badly weathered and mostly broken.
16'6"	24'11"	Agglomerate, slightly weathered, a few irregular fractures some with clay.
24'11"	26'0"	Agglomerate, badly weathered and partly broken.
26'0"	31'7"	Agglomerate, slightly weathered, few fractures except where broken at 30'11" - 31'5".

END

Solid Rock - 16'6" (100% core recovery below here).

Weak Zone:- 24'11" - 26'0".

SDD 14

Location: Diversion channel.

From	To	Core Description
0	9'5"	No core; clay.
9'5"	11'9"	Agglomerate, moderately weathered, matrix brown, three irregular fractures.
11'9"	11'11"	Agglomerate, broken.
11'11"	12'6"	Agglomerate, moderately weathered, solid.
12'6"	12'10"	Agglomerate, broken.
12'10"	24'3"	Agglomerate, slightly weathered, mostly solid; iron-stained fractures in vesicular boulder at 16'7" and 16'9", several other irregular fractures with grey "paint". Tuff 22'8" - 23'.

END OF HOLE.

SDD 15

Location: Diversion channel.

From	To	Core Description
0	3'11"	No core; clay.
3'11"	11'8"	Agglomerate, slightly weathered, solid except where broken by core barrel at 5'6".
11'8"	12'4"	Agglomerate with highly weathered (buff-coloured) tuff matrix, one irregular fracture.
12'4"	16'2"	Agglomerate, slightly weathered, solid.
16'2"	18'1"	Tuff, some graded bedding and irregular bedding planes, weathered brown but not friable, several irregular fractures and one at 30° at 17'.
18'1"	34'	Agglomerate, slightly weathered, mostly solid, broken at 26'3", some yellow clay filling in vesicles and fractures.

END OF HOLE.

SDD 16

Location: Diversion channel.

From	To	Core Description
0	4'0"	No core; clay.
4'0"	6'1"	Agglomerate, slightly and moderately weathered, broken into 3" and 6" lengths.
6'1"	39'2"	Agglomerate fresh and slightly weathered, mostly solid, matrix removed and irregular fracture at 15'1".

END OF HOLE.

SDD 17

Location: Diversion channel.

From	To	Core Description
0	3'9"	No core; clay.
3'9"	5'5"	Agglomerate, fresh, solid.
5'5"	5'7"	Agglomerate, fresh, broken by core barrel.
5'7"	19'10"	Agglomerate, fresh, solid, concentration of vesicular boulders at 17'.
19'10"	22'6"	Agglomerate, slightly weathered, some components brown, some matrix removed, broken at 20'1". Tuff 21'8" - 21'11", dips 5°.
22'6"	38'11"	Agglomerate, fresh, solid, one boulder 22", tuff at 28'6" bedded horizontally. Grey "paint" in some vesicles and fractures.

END OF HOLE.

SDD 18

Location: Diversion channel.

Commenced 26.4.60 and completed 28.4.60.

From	To	Core Description
0	2'6"	Not cored, soil.
2'6"	6'3"	Agglomerate, some fresh some badly weathered and broken.
6'3"	16'6"	Agglomerate, slightly weathered, few fractures, one weathered 30° fracture at 11'10".
16'6"	18'10"	Agglomerate, badly weathered and broken.
18'10"	36'1"	Agglomerate, fresh very few fractures.

END.

SDD 19

Location: Abutment of dam.

Commenced 30.4.60 completed.

From	To	Core Description
0	9'10"	Not cored, soil and scree.
9'10"	10'3"	Agglomerate, moderately weathered, broken.
10'3"	24'11"	Agglomerate, slightly weathered with slight increase in degree of weathering at bottom; few fractures, one at 18'2" irregular with red clay in vesicular boulder, high proportion of tuff matrix below 22'8".

END OF HOLE.

SDD 20

Location: Abutment of dam.

Commenced and completed 29.4.1960.

From	To	Core Description
0	10'4"	Not cored, soil and scree.
10'4"	20'5"	Agglomerate, slightly weathered, few fractures, tuff 14'9" - 16'3".

END OF HOLE.

SDD 21

Location: Left bank of dam.

Commenced and completed 18.6.60.

From	To	Core Description
0	6'3"	Not cored; soil and scree.
6'3"	7'11"	Agglomerate, badly weathered, broken.
7'11"	21'4"	Agglomerate, fresh and slightly weathered, solid. Tuff 18'5" - 18'7".

END.

Solid rock:- 7'11" (100% recovery below here).

SDD 22

Location: Left bank of dam.

Commenced and completed 20.6.60.

From	To	Core Description
0	5'1"	Not cored; soil and scree.
5'1"	20'2"	Agglomerate; slightly weathered, solid.
		Tuff 7'11" - 8'0" and 18'6" - 18'9".

END.

Solid rock:- 5'1" (100% core recovery below here.)

SDS 1

Location: Spillway of dam.

From	To	Core Description
0	5'6"	Clay with few small boulders.
5'6"	45'6"	Agglomerate. 13'6" to 13'9", friable matrix 30'2" to 30'8" " " 35'2" to 35'6" loosely compacted, large opening between agglomerate components, permeable. 42'4" to 42'7" loosely compacted 43'6" to 44'0", tuff fine, weathered brown.

45'6" End of hole, core recovery 99% from 5'6".

SDS 2

Location: Spillway.

From	To	Core Description
0	3'9"	Clay, not cored.
3'9"	13'0"	Agglomerate, well sorted, components up to 1", matrix compact.
13'0"	15'4"	Some cavities between agglomerate components.
15'4"	16'4"	Solid agglomerate.
16'4"	17'4"	Small cavities between agglomerate components.
17'4"	18'10"	Solid agglomerate.
	18'10"	End of hole, core recovery 99% below 3'9".

SDS 3

Location: Spillway.

From	To	Core Description
0	8'11"	Clay, not cored.
8'11"	11'7"	Weathered brown and broken agglomerate.
11'7"	13'0"	Solid agglomerate.
13'0"	16'8"	Tuff, weathered brown.
16'8"	25'9"	Solid agglomerate.
25'9"	26'7"	Friable tuff matrix, slightly weathered.
26'7"	27'3"	Large, solid agglomerate components.
27'3"	32'4"	Agglomerate components in partly weathered brown tuff.
32'4"	33'10"	Solid agglomerate.

SDS 4

Location: Spillway.

From	To	Core Description
0	14'1"	Clay, not cored.
14'1"	22'1"	Solid agglomerate except for cavities between components at 17'1" - 17'3".
22'1"	24'6"	Large vesicular basalt components in weak tuff matrix.
24'6"	25'4"	Large cavities between agglomerate components.
25'4"	28'10"	Solid agglomerate.
28'10"	29'1"	White clay in fractures and interstices in loosely compacted agglomerate.
29'1"	30'7"	Solid agglomerate.
30'7"	34'4"	Loosely compacted agglomerate, many small cavities between components containing clay between 32'3" and 33'3".
34'4"	35'6"	Brown, weathered tuff.
35'6"	36'0"	Cavities between agglomerate components.
36'0"	39'0"	Solid agglomerate.
39'0"	39'4"	Friable tuff matrix, small agglomerate components.
39'4"	43'0"	Agglomerate with large components loosely bound in tuff with porous zones at 40'4" and 42'4".
43'0"	45'6"	Brown tuff becoming coarser downwards.
45'6"	46'0"	Coarse components in slightly weathered tuff matrix.
46'0"	46'6"	Brown tuff.
46'6"	59'4"	Coarse components in brown tuff matrix becoming more compact (less tuff) towards bottom.
	59'4"	End of hole, 100% core recovery below 14'1".

SDS 5

Location: Spillway.

From	To	Core Description
0	17' "	Clay, not cored.
17'0"	33'10"	Leached, friable agglomerate, breaks easily in core barrel - treat as overburden.
33'10"	48'9"	Solid agglomerate, slightly weathered and broken zone, 36'2" to 36'4".
	48'9"	end of hole. Core recovery 99% from 17'0".

SDS 6

Location: Spillway.

From	To	Core Description
0	6'7"	Clay, not cored.
6'7"	19'0"	Solid agglomerate, no weak zones.
19'0"	21'5"	Vesicular boulders in loose tuff matrix.
21'5"	22'5"	Coarse tuff, slightly weathered.
22'5"	35'0"	Agglomerate with weak zones due to washing out or lack of tuff matrix at 27'8", 28'5", 29'5" and 32'0".
35'0"	36'6"	Compact, hard tuff becoming finer grained downward.
36'6"	38'4"	Light brown tuff, compact.
38'4"	56'7"	Solid agglomerate with tuff bed 44'7" to 44'10".

END OF HOLE.

Boundary of "weathered" and "slightly weathered" rock about 6'7".

SDS 7

Location: Spillway.

From	To	Core Description
0	24'11"	Clay, not cored.
24'11"	29'8"	Solid agglomerate, but matrix red-brown due weathering.
29'8"	32'8"	As above, but fractures and pore spaces filled or lined with light brown clay.
32'8"	39'7"	Solid agglomerate.
	39'7"	end of hole. Core recovery 100% below 24'11".

SDS 8

Location: Spillway.

From	To	Core Description
0	21'4"	Clay, not cored.
21'4"	26'4"	Agglomerate with tuff matrix, leached, brown.
26'4"	33'10"	Solid agglomerate.
33'10"	36'3"	Agglomerate with matrix leached, suggesting porous zones.
	36'3"	End of hole - 100% core recovery below 21'4".

SDS 9

Location: Spillway.

From	To	Core Description
0	7'0"	Clay, not cored.
7'0"	16'5"	Solid agglomerate.
16'5"	16'9"	Brown tuff.
16'9"	22'1"	Solid agglomerate except for loosely compacted zones at 20'7" - 20'9" and 21'7" - 21'9".

22'1" End of hole. 100% core recovery below 7'0".

SDS 10

Location: Spillway.

From	To	Core Description
0	1'6"	Clay, not cored.
1'6"	16'6"	Solid agglomerate, with zone containing small components from 12'8" - 15'4".

16'6" End of hole. 100% core recovery below 1'6".

SDS 11

Location: Spillway.

From	To	Core Description
0	8'11"	Clay, not cored.
8'11"	14'2"	Badly broken and weathered along numerous fractures.
14'2"	16'2"	Solid except for small clay-filled fault at 15'2".
16'2"	16'11"	Fractures, clay filled.
16'11"	19'10"	Solid agglomerate.
19'10"	22'3"	Strongly fractured with weathering and clay filling along fracture planes.
22'3"	24'6"	Solid agglomerate.
24'6"	27'9"	Very broken, steeply dipping, clay-filled fractures, about 60% recovery.
27'9"	33'8"	Solid agglomerate with steep fracture with ½" clay fillings between 30'3" and 30'9".

33'8" End of hole. 95% core recovery below 8'11".

SDS 12

Location: Spillway.

From	To	Core Description
0	16'10"	Clay, not cored.
16'10"	17'10"	Slightly weathered, brown agglomerate.
17'10"	30'10"	Solid agglomerate, with steep clay-lined fractures, between 19'10" and 21'4", 25'10" and 26'0".

30'10" End of hole. 90% core recovery below 16'10".

SDS 13

Location: Spillway.

From	To	Core Description
0	11'8"	Clay, not cored.
11'8"	13'0"	Fine agglomerate grading down to medium tuff.
13'0"	15'10"	Well-compacted, hard tuff.
15'10"	16'2"	Fine, friable tuff.
16'2"	16'10"	Hard, compact tuff.
16'10"	26'6"	Solid agglomerate.

26'6" End of hole. 100% core recovery below 11'8".

SDS 14

Location: Spillway.

From	To	Core Description
0	16'3	Clay, not cored.
16'3"	17'3"	Agglomerate with slightly weathered tuff matrix.
17'1"	22'3"	Solid agglomerate.
22'3"	24'2"	Agglomerate with slightly weathered tuff matrix.
24'2"	31'4"	Solid, unweathered agglomerate.

31'4" End of hole. 100% core recovery below 16'3.

SDS 15

Location: Spillway.

From	To	Core Description
0	28'3"	Clay and very weathered agglomerate, not cored.
28'3"	2 '0"	Weathered, brown agglomerate.
29'0"	43'3	Solid agglomerate with 3" tuff bed 30'4" - 30'7" and loosely compacted agglomerate at 42'11" - 43'1".

End of hole.

Boundary of "weathered" and "slightly weathered" rock about 28'3".

SDS 16

Location: Spillway.

From	To	Core Description
0	21'6"	Clay and weathered agglomerate, not cored.
21'6"	22'4"	Weathered agglomerate.
22'4"	23'4"	Slightly weathered agglomerate, tuff matrix, brown.
23'4"	31'0"	Solid agglomerate slight weathering of matrix from 29'0" to 31'0¼".
31'0"	31'6"	Light brown tuff.
31'6"	33'4"	Solid agglomerate, tuff matrix; some components slightly weathered brown.
33'4"	35'11"	Solid agglomerate.
35'11"	36'5"	Brown tuff.
36'5"	41'5"	Solid agglomerate, tuff matrix slightly weathered.
		Slight weathering throughout hole suggests nearness to open fracture.
		End of hole.

"Weathered" rock above 21'6"; "slightly weathered" 21'6" to 23'4"; "solid" rock below 23'4".

SDS 17

Location: Sp.llway.

From	To	Core Description
0	26'2"	Clay and weathered agglomerate, not cored.
26'2"	36'2"	Slightly weathered agglomerate with cavities between 27'6" and 28'4", and weathered tuff beds at 29'2" - 29'5" and 31'0" - 31'2".
36'2"	46'3"	Solid agglomerate.
		End of hole.

Boundary of "weathered" and "slightly weathered" rock about 26'2".

APPENDIX II

PETROLOGICAL DESCRIPTIONS OF SPECIMENS OF AGGLOMERATE

by

C. Gregory.

Specimen from Drill-hole SDS 7, 26 feet depth; Spillway.

Thin Section No. 5830.

In hand specimen the rock consists of poorly sorted to unsorted fragments, up to one inch across, of flow-lineated basalt set in a groundmass of altered porous basalt. The fragments show a wide range in porosity and form about half the rock.

The primary minerals in the thin section examined are a fairly calcic plagioclase (possibly labradorite), augite, hyperthene and magnetite. Secondary limonite and brown devitrified glass are common, and some clay, formed from feldspar, occurs. Most of the pyroxene, plagioclase and rock fragments are fresh. The fragments and groundmass are fairly well-bonded: fractures formed under load would probably cut across the fragments except where weathering is most advanced.

The groundmass contains an estimated 40% secondary material, 35% pore space and 25% pyroxene and plagioclase. Grainsize in the groundmass ranges from 1 mm. diameter to micro-size.

In the fragments the pore space averages less than 5%. The pores in the groundmass are isolated and therefore the rock is not likely to be permeable; they are irregular and are not lined with secondary minerals. Some of the pores and micro-fractures in the fragments, however, are lined or filled by opaline silica. Volcanic glass is uncommon where opaline silica occurs.

The rock is a basaltic agglomerate.

Specimen F 434, from the Dam site.

Thin Section No. 5831

The hand specimen is black, homogeneous, fine-grained and structureless, the fragmental nature of the rock being obscure.

In thin section the rock is clearly an agglomerate, composed of angular fragments of medium-grained flow-lineated basalt, set in a flow-lineated basaltic groundmass. The fragments are ill-sorted and range up to half an inch across. Fragments and groundmass are similar in composition, texture and grainsize, but the groundmass contains a much higher proportion of volcanic glass than the fragments.

The specimen is less weathered than the one described above and the bond between fragments and groundmass is strong.

Plagioclase (andesine-labradorite) forms about 35% of the rock, augite about 15%, volcanic glass 40%, primary iron oxide 1%, limonite 3% and chalcedony (in pore spaces) about 6%. Some of the pyroxene is altered to iddingsite.

All former pore spaces, which are very unevenly distributed but only occur in the groundmass, are filled by pale yellow-brown chalcedony.

The rock is a basaltic agglomerate.

PLATE I

LEGEND

10' Contours	Creeks
5' Contours	Diamond Drill Holes
1747 Contour (Flood level)	Auger Holes
1724 Contour (Top Storage level)	Rock outcrop and faces (some possibly boulders)
	Boulders

40 30 20 10 0 40 80 120
Scale of Feet

NOTES:

All outcrops in the area covered by this map belong to the Astrolobe Agglomerate formation, a thick sequence of coarse basaltic agglomerate with minor tuff bands. The formation dips South-West at 5°-7° in the dam and spillway area.

For Spillway Subsurface Contours see plan PH60/225 (Plate IV)

Grid Survey by G. KOLAROV.
Additional information by J.E. THOMPSON.

This Plan is reduced from Grid Plan PH60/115

To accompany Record 1960/102

C55/A7/46

AMD'T No.	DESCRIPTION	DATE	INIT.	DRG. No.	SUBJECT
				PH60/225	Sirinumu Spillway Subsurface Contours
AMENDMENTS				ASSOCIATED DRAWINGS	

COMMONWEALTH OF AUSTRALIA
DEPT. OF WORKS
PAPUA AND NEW GUINEA BRANCH

PORT MORESBY HYDRO-ELECTRIC SCHEME
SIRINUMU DAM & SPILLWAY SITE SHOWING DRILLSITES, AUGER HOLE LOCATIONS & SECTION LINES.

GEOLOGIST	SCALE: 40' to 1"	DRAWN / TRACED K.R.P. CHECKED
PRINCIPAL	DATE: 21·9·60	DRAWING No.
DIRECTOR OF WORKS	FILE	PH60/217 B P

Plate II
To accompany Record 1960-102

SIRINUMU Nº2 DAM SITE - VERTICAL SECTIONS

(See Plate I for Section Lines)

Sections by J. E. Thompson

GEOLOGICAL NOTES

The abutments and foundations are composed of a sub-horizontal succession of thick coarse volcanic agglomerate beds and thin tuff bands of the Astrolabe Agglomerate Formation. The Agglomerate components are subangular augite basalt and andesite boulders set in a fine well-bonded tuffaceous matrix. Some tuff bands (about 8% of the section examined) are friable and porous; these are generally more susceptible to weathering than the agglomerate.

WEATHERING

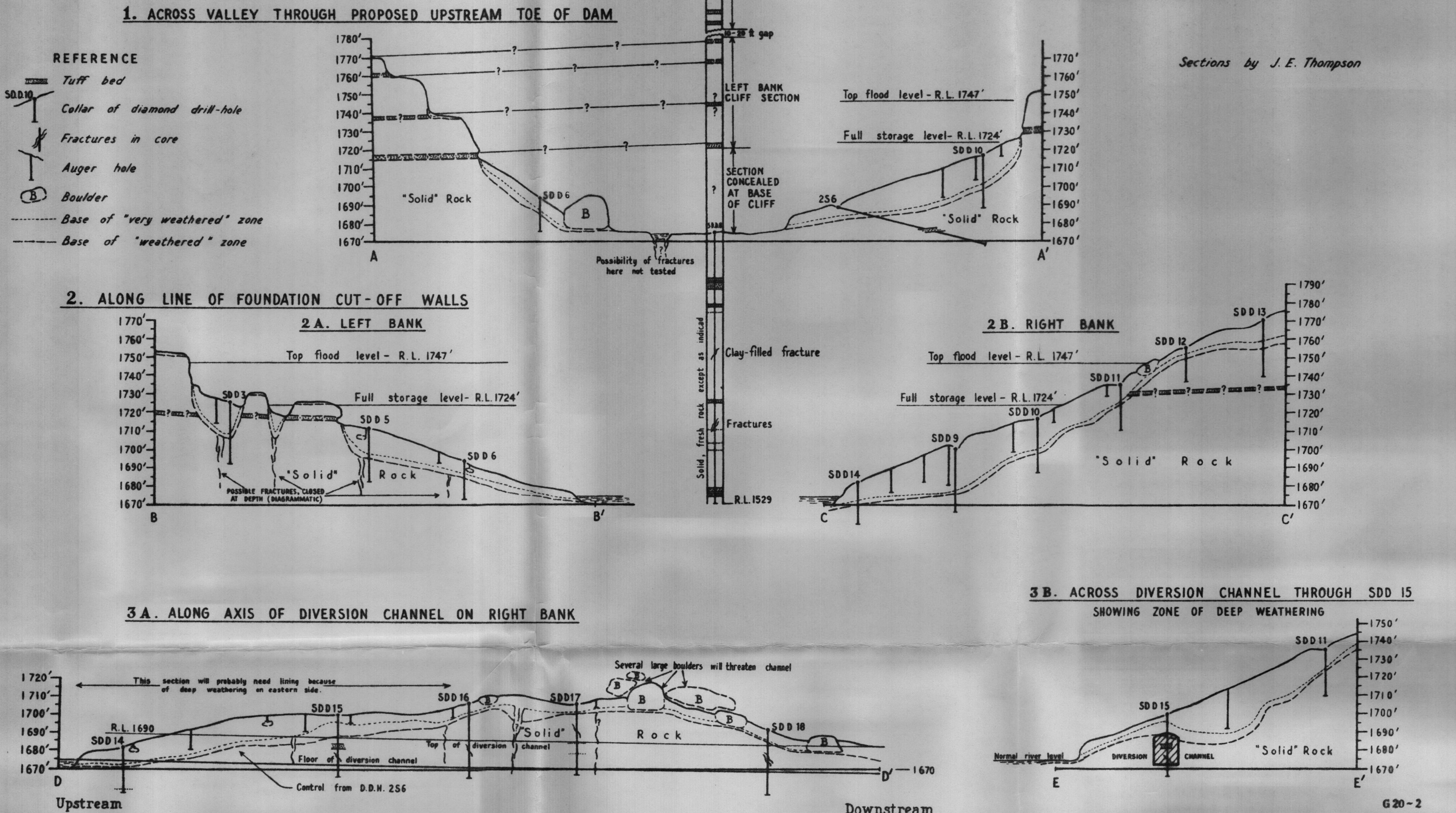
These sections illustrate diagrammatically the depth of weathering based on diamond drilling and augering. Two zones of weathering are represented.

The "Very Weathered" Zone which includes soil, scree, alluvium, and residual clay can probably be stripped with earth moving equipment or by sluicing and should be removed from the dam foundation area.

The "Weathered" Zone is mostly friable decomposed rock in situ which may serve as a base for rock-fill but not for anchoring cut-off walls or the steel deck.

"Solid" Rock implies rock acceptable for rock-fill and for solid foundations, with the exception of friable tuff bands and loosely compacted agglomerate.

The boundaries shown are not reliable enough for use in specifications.



Bureau of Mineral Resources, Geology & Geophysics. September, 1960.

G20-2
PNG 8C-13

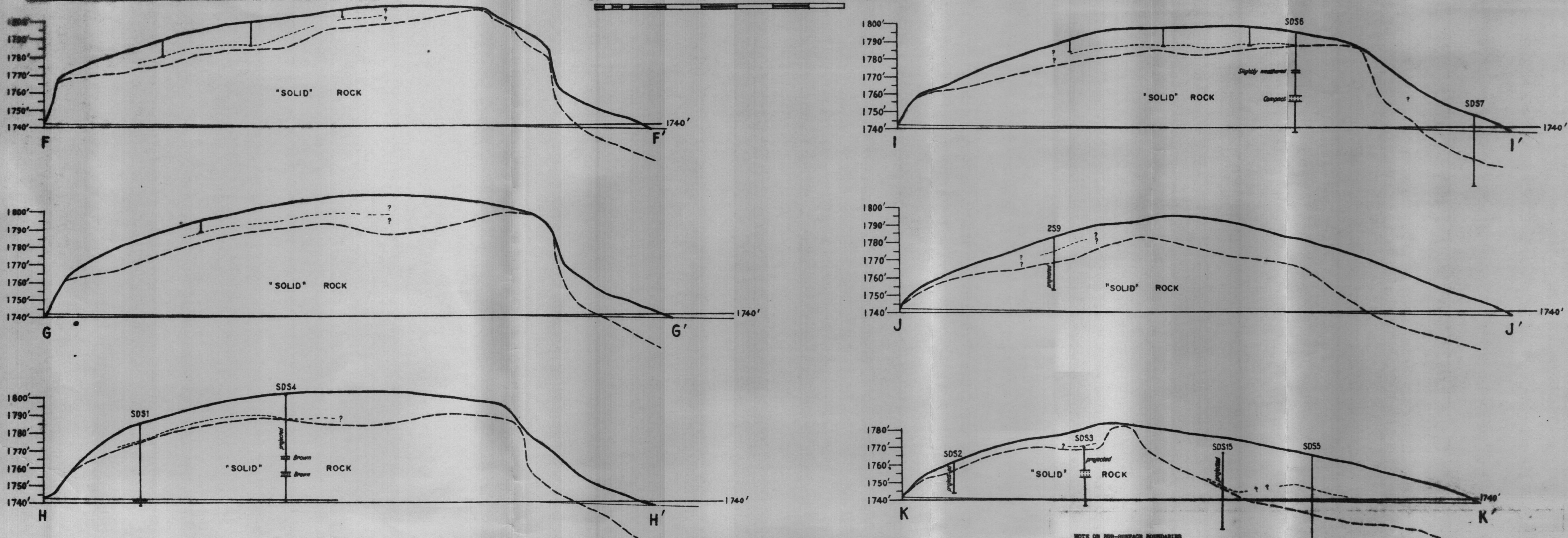
SIRINUMU № 2 DAM SITE - SPILLWAY AREA

See Plate I for Section Lines

HORIZONTAL & VERTICAL SCALE
20 0 40 80 120 Feet

Sections by J. E. Thompson

1. VERTICAL SECTIONS AT 40 ft. INTERVALS ALONG PROPOSED SPILLWAY CHANNEL

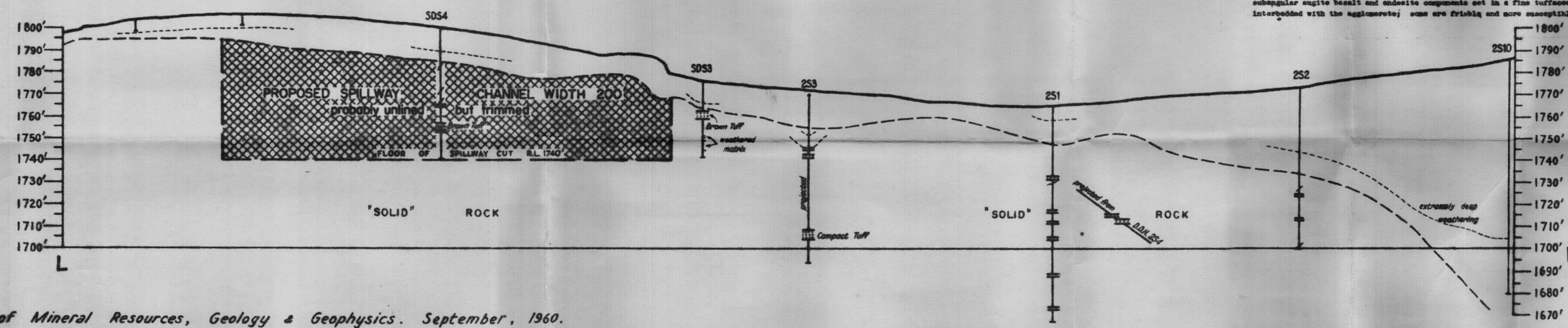


NOTE ON SUB-SURFACE BOUNDARIES

The boundaries between "Very Weathered", "Weathered" and "Solid" Rock are only approximate and should be used as a rough guide only. The "Very Weathered" Zone is mostly soil and clay and can probably be stripped by earth moving equipment. The "Weathered" Zone contains decomposed and leached rock which would probably not be acceptable as rock-fill for the Dam. The "Solid" Rock contains both slightly weathered and fresh agglomerate and tuff; it is acceptable as rock-fill, except for friable tuff. Poorly bonded agglomerate and weathered rock are localized near fractures.

The Astrolabe Agglomerate, which occupies the entire section, is a coarse, generally well bonded, volcanic agglomerate with subangular augite basalt and andesite components set in a fine tuffaceous matrix. Tuff beds up to six feet thick are interbedded with the agglomerate; some are friable and more susceptible to weathering than the typical agglomerate.

2. VERTICAL SECTION ACROSS PROPOSED SPILLWAY CHANNEL AND ALONG SPILLWAY SADDLE



REFERENCE

- Tuff bed
- SDD 10 — Collar of diamond drill-hole
- Fractures in core
- Auger hole
- Base of "very weathered" zone
- Base of "weathered" zone

G 20-1

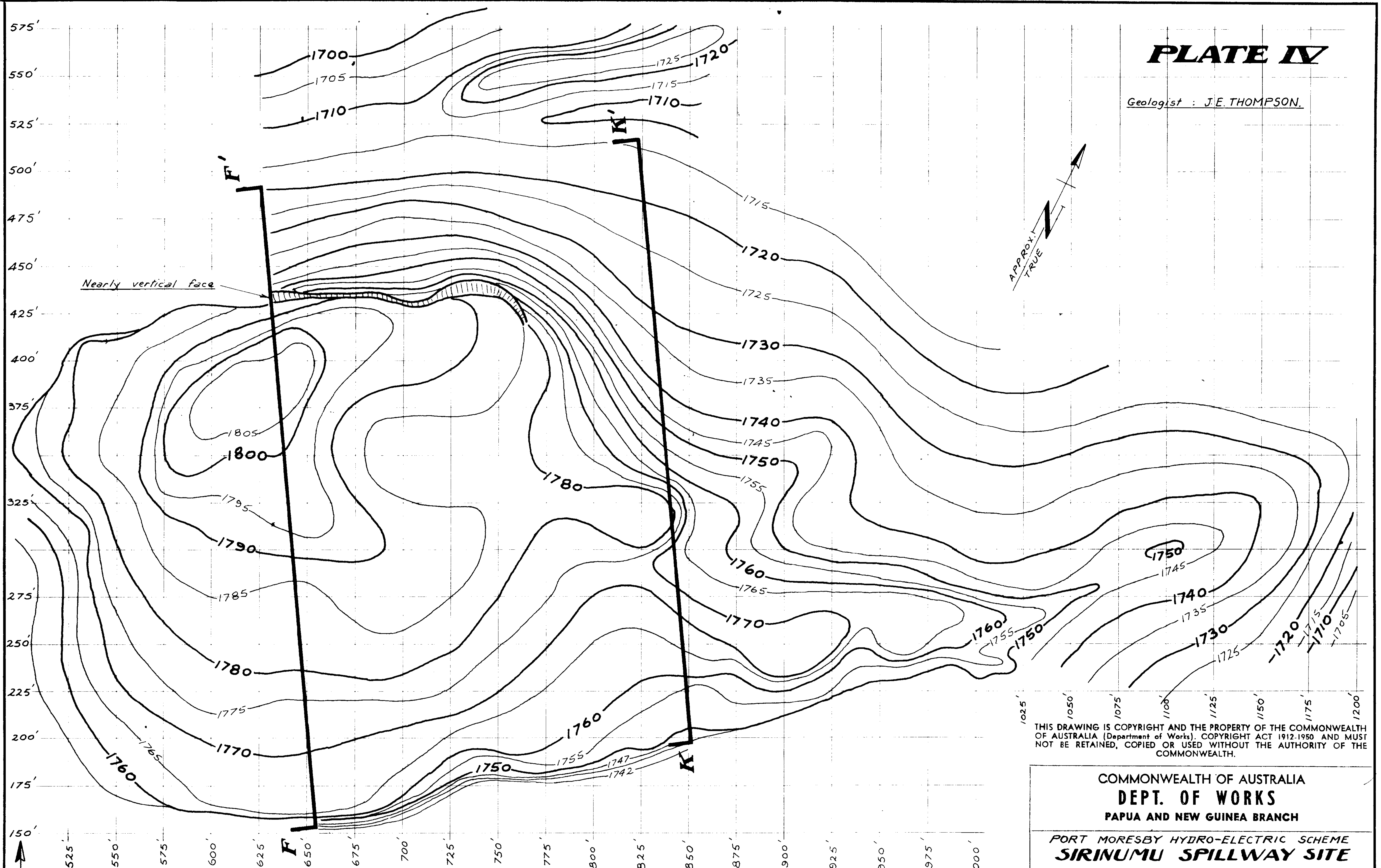
PNG 8C-14

H.F.D. & M.K.

Bureau of Mineral Resources, Geology & Geophysics. September, 1960.

PLATE IV

Geologist : J.E. THOMPSON.



COMMONWEALTH OF AUSTRALIA
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PORT MORESBY HYDRO-ELECTRIC SCHEME
SIRINUMU SPILLWAY SITE
SUBSURFACE CONTOURS

NOTE

These contours represent an interpretation of the surface of solid rock as inferred from limited drill hole evidence and should not be used as a basis for the specification of overburden or solid rock. This plan to be read in conjunction with PH60/217, (Plate I).

To accompany Record 1960/102 C55/A7/47

AMD'T No	DESCRIPTION	DATE	INIT.	DRG. No.	SUBJECT
				PH60/217	SIRINUMU DAM & SPILLWAY SHOWING DRILL-SITES, AUGER HOLES & SECTION LINES.
AMENDMENTS				ASSOCIATED DRAWINGS	

GEOLOGIST	SCALE: 40' to 1"	DRAWN TRACED KRP CHECKED
PRINCIPAL	DATE: 21·9·60	DRAWING No. PH60/225
DIRECTOR OF WORKS	FILE	D

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