APPENDIX A

APPENDIX A

ACCESS ROUTES TO OPHIR GORGE

A1. INTRODUCTION

The present access road to the Ophir Gorge has grades as steep as 1 in 3 in places and several tight corners. Access is therefore restricted to tracked vehicles and four wheel drive vehicles in good weather. The road is inadequate for any major construction work. An all weather access road to the gorge is needed for regular maintenance of the water race, to enable quick access in the event of disruption to water supplies, and would be essential for scheme refurbishment work.

Access to the gorge from downstream is physically restricted to the right bank, downstream of the end of tunnel 1. Three new access routes have been proposed and mapped out by Dunedin District Office (figure A1). Walk over surveys of the routes have been carried out by Head Office and District Office personnel and an engineering geologist from New Zealand Geological Survey. At this stage of investigations it has been assumed that access is needed throughout the Ophir Gorge from the desilter to the entrance of tunnel 2. All three proposed access routes therefore end at the presently existing platform just upstream of the entrance to tunnel 2 (figure A3). If the pumped weir option of scheme refurbishment is adopted, the destination of the access route may be different.

Access option 1 follows the old disused raceline from Chinky Gully along the river bank to the end of the present access track (figure A1). Option 2 uses the present access road to climb the hills, west of the gorge, then winds down along the side of the hills to meet the disused race about 100 m downstream of the entrance to tunnel 2. From here it follows the same route as Option 1. Option 3 uses the existing road to the top of the scarp above design sector D (see section 4 of this report). A cut is made through the scarp and the road traverses the top of the basal failure to the borrow pit (figure A6, plate A4). From here District Office originally proposed a cut section across the toe of the slip to the end of the present road. For geotechnical reasons an alternative to Option 3 was agreed upon after discussions between District Office and Head Office. This alternative, called Option 3A, is the same as option 3 down to the borrow pit and then uses the same route as the present access road. These options will be discussed in more detail in following sections.

The final choice of access route option will be based on the choice of option for upgrading the aqueduct, as well as on geotechnical and economic assessment.

AERIAL PHOTOGRAPHY

CONTOURS
Wild R.C.8 - 29th February 1976

PHOTO DETAIL
Zeiss R.M.K. 30/23 - 2nd March 1978

Origin of co-ords - Lindis Peak Meridional Circuit 700 000 m N 300 000 m E

Grid interval - 500metres

Level Datum Otago Datum (100m below M.S.L.)

REFERENCE

Contours

Depressions

Selected detail

Spot heights

COMPILATION NOTE

This sheet is a composite of photogrammetric contours and selected detail superimposed on a halftone enlargement from photography taken with a 12" focal length lens. As the 12" photography is not an orthogonal projection displacement of the image will occur, due to difference in ground elevation.

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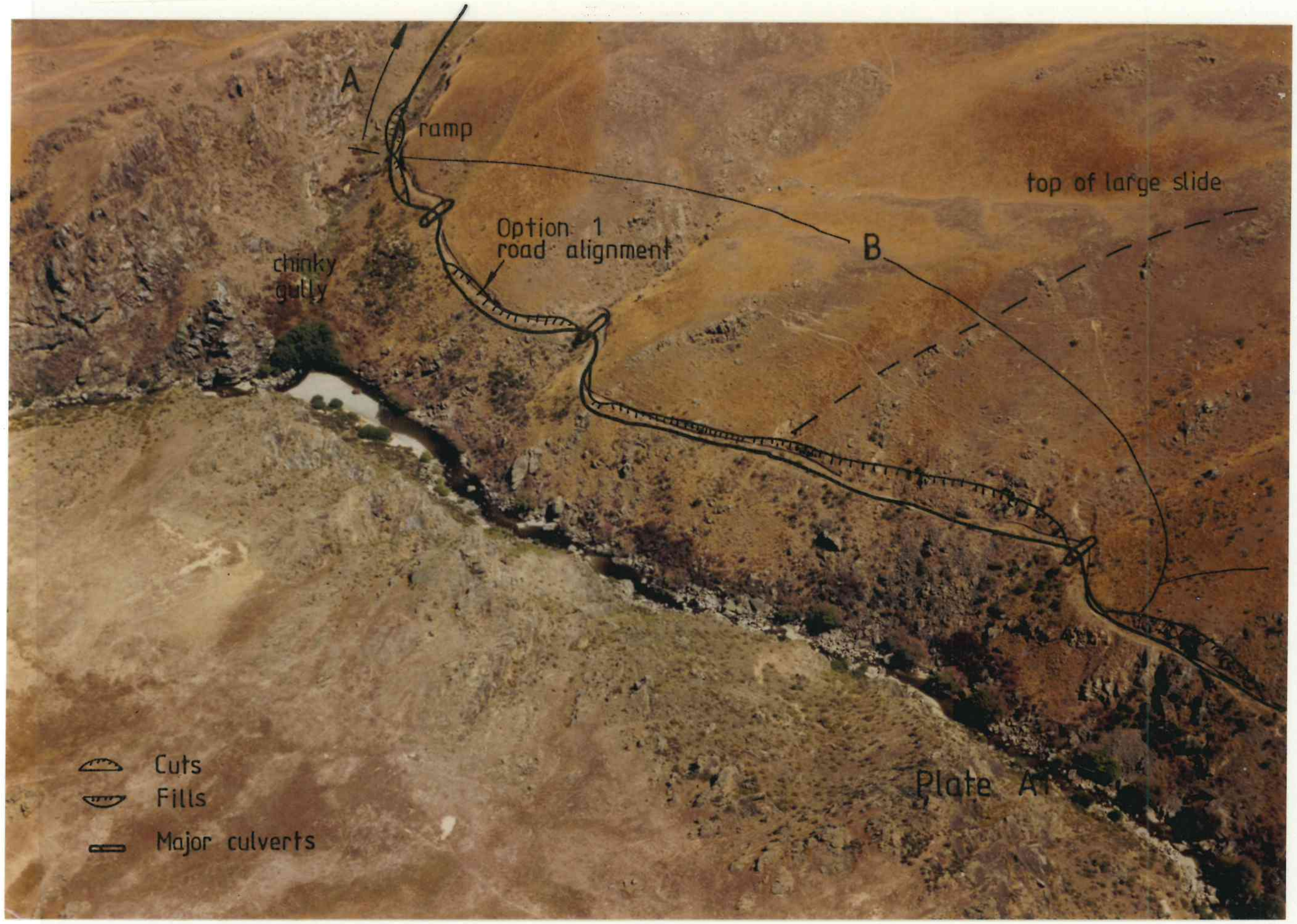


Option 1 : Design Sectors A and B

A2. GEOLOGY AND MATERIALS

The geology along the three alternative access routes has been described in an engineering geological report by B Paterson, who presents geological maps showing the extent of the various materials (reference 3). A summary of the geology along the three routes is given here and is shown in figure A3.

Options 1 and 2 enter the Ophir gorge from a downstream direction where the surface topography is generally more gentle than in the gorge proper. The main geological feature, traversed by option 2 and crossed at the toe by option 1, is a large basal slide (figure A1, plates A1, A2, A3). This landslide is delineated by an arcuate boundary extending to the top of the ridge above the disused race line. The landslide is apparently stable at present. The upper slopes of the landslide are undulating with an average slope of 18°-20°. There is a distinct change in slope about 50 m above the level of the disused race, with angles increasing to about 45°.

The materials within the landslide are landslide debris, colluvium, pockets of loess and ridges and mounds of schist blocks. At the oversteepened toe of the landslide there are slope failures of various magnitudes in all the materials present. Bluffs of relatively competent schist rock are exposed at the level of the old race. There is one large loess filled valley within the slide which would create problems for road construction (plate A3).

To the west of this large landslide the country is stable, consisting of schist rock overlain by colluvium. The upstream boundary of the landslide is marked by steep massive rock bluffs up to 50 m high. These bluffs appear to consist of insitu schist. Weathering of the rock has caused relaxation and some rock falls to occur.

The existing part of access road option 3 crosses schist rock terrain overlain by colluvium. The remainder of this option is within the Ophir gorge and the geology is described earlier in this report (section 4.3).

The gorge geology consists of a basal slide up to 50 m deep. The head scarp is relaxed insitu schist and the body of the slide consists of landslide debris. There is a distinct change in slope of the surface of the slide about 40 m above race level. Unravelling of schist blocks occurs from this oversteepened toe of the slide. Surface cracking indicates the presence of deeper seated failures within the toe.

The borrow pit (plate A4) is situated at the base of a depression filled with fine grained material. There is evidence of movement within the borrow pit and higher up slope.

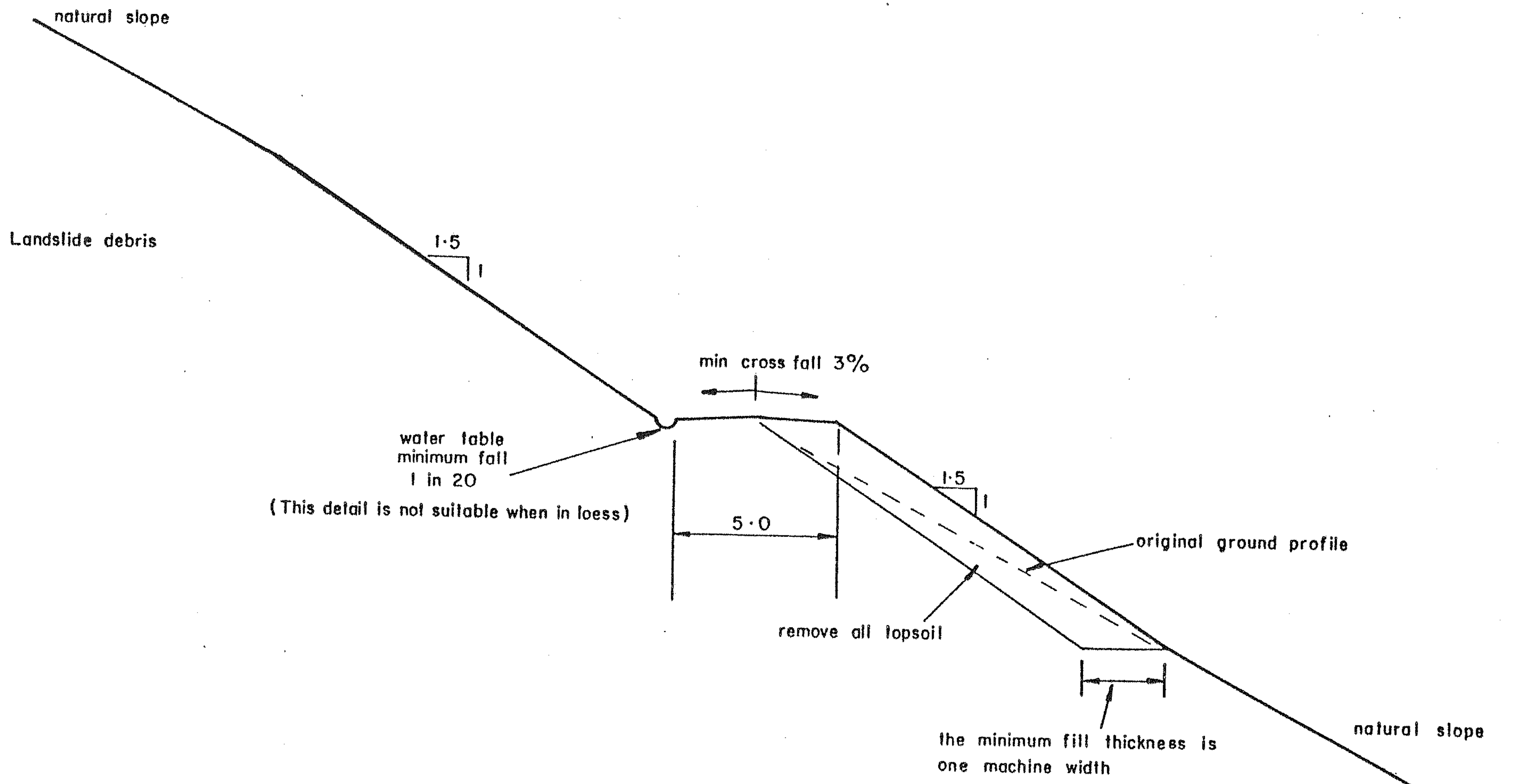


Figure A2 : TYPICAL CUT / FILL SECTION

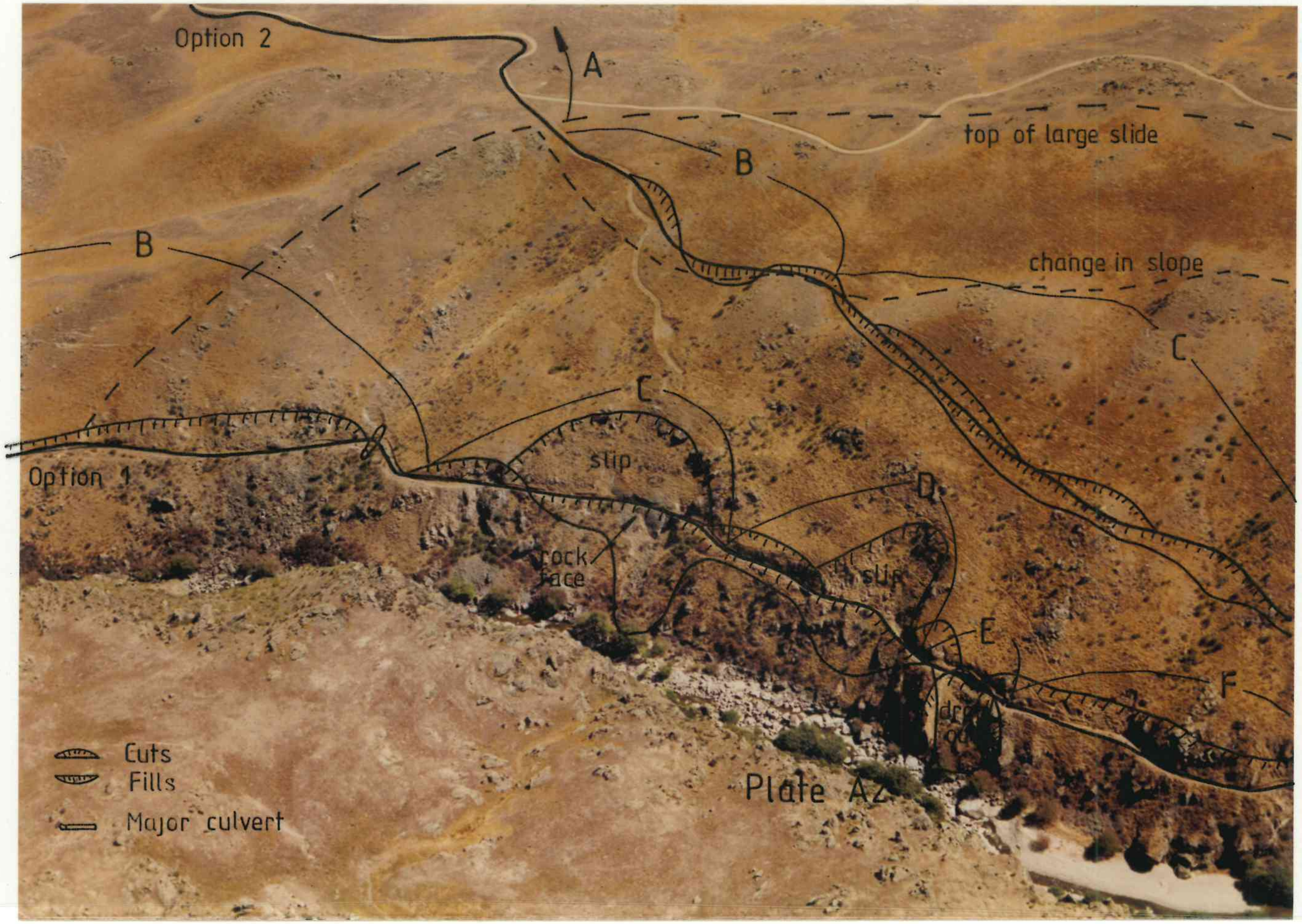


Plate A2

Option 1 : Design Sectors B-F

Option 2 : Design Sectors A-C

Section 3 of this report details the properties of the schist rock, landslide debris and colluvium. Option 1 and 2 cross a loess filled valley as well as areas of the other three materials. Loess is a fine grained wind-blown material which is susceptible to surface and tunnel gully erosion. This erosion potential makes it an unsuitable foundation material. Loess deposits may be in a loose state and loss of volume can occur, especially with dynamic loading.

As most of the slopes in the vicinity of the three access options are in a marginally stable condition, care must be taken when choosing borrow areas.

A3. PHILOSOPHY OF DESIGN

Dunedin District Office have prepared access route plans and cross-sections based on a maximum 8:1 grade, 6 m road width and 15 m outside turning radius. Due to the topography of the Ophir Gorge area, the marginal stability of the slopes which the various access options cross, and the large cuts and fills required for road construction, it has been agreed with District Office that a lower standard of road be accepted. A 5 m wide road formation is recommended, with passing bays where possible. The maximum grade of the road should be increased to 6:1. These two design alterations will result in reduced cut heights and volumes of earthworks. The benefits of relaxing the road design standard will be commented on where appropriate for each access option.

High factors of safety against failure of cut and fill batters are not economically possible in the Ophir gorge terrain. Falls of individual rocks onto the road and surficial slumping are likely to occur frequently. Maintenance of the road will be necessary at regular intervals.

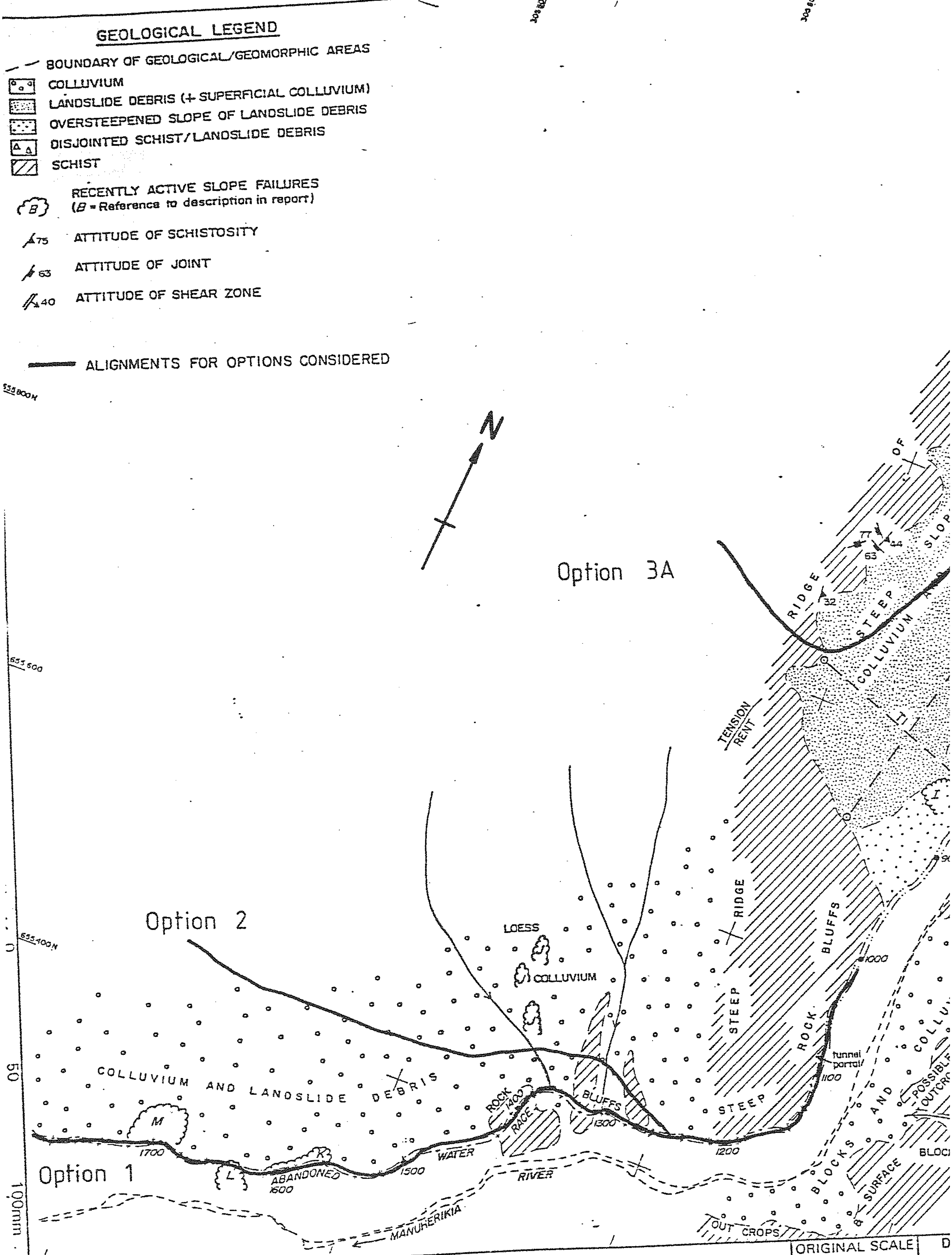
The design guidelines for batters for the various construction materials are given below. In certain difficult situations it is considered appropriate to lower the design standard to balance the risk/cost of failures against the cost of construction.

(i) Colluvium

Natural slopes of colluvium have been observed to be stable at 28°-33° cut batters in colluvium are therefore recommended at 2:1, corresponding to 28°.

(ii) Landslide Debris

Cuts in landslide debris have been designed in accordance with the stability chart (figure A7).



GRAPHIC SCALE	0 50 100 200 300 metres	ORIGINAL SCALE	
		Mapped	BRP
EXPLANATION	PLAN BASED ON NZAM P219 GEOMORPHIC BOUNDARIES ARE NOT CORRECTED FOR PHOTOGRAPHIC DISTORTION AND HENCE ARE APPROXIMATE ONLY	Dr.	BRP
		Tr.	LVL
		Ck.	

Option 1 : Design Sectors F-K

Option 2 : Design Sectors C-K

(iii) Rock Slopes

The cut batters in rock will be determined by the orientation and relaxation of the defects. Each rock cut should be inspected by a geologist and the design batter modified during construction if necessary. In the absence of information about defect orientation either rock cuts parallel to the existing natural slope or the following rock cut batters have been assumed.

0.25:1	competent, massive rock
0. 5:1	well jointed rock
0.75:1	relaxed jointed rock
1:1	very relaxed - loose well jointed rock.

(iv) Fills

1.5:1 fill batters constructed of schist and schist derived materials have been found to be stable in the past and are recommended for the design of the access road. Where fills extend below river flood level, rip rap toe protection should be placed.

The geotechnical aspects of the design of each of the access options will be discussed in following sections.

Figure A2 shows the proposed typical road cross section for cut/fill construction in landslide debris.

A4. OPTION 1

A4.1 Introduction

Access Route Option 1 enters the Ophir Gorge from a downstream direction (figure A1). The route begins at the Chinky Gully flume and continues along the gully floor before climbing up to the abandoned race platform just before Chinky Gully joins the Ophir River. From here the route follows the abandoned race for about 1.8 km to the inlet of tunnel 2 (plates A1, A2, A3). The route then follows the presently used race around a rock bluff to a platform at the end of the existing access road.

As the whole route follows a race line it will have a consistently gentle grade. The platform on which the old race is founded will in most places provide a good foundation for the road, and in some sections very little earthworks will be required for road construction. The existing platform is wide enough in some areas to provide passing bays.

The construction work required will involve removing the outer race wall and widening the race bench to form a roadway, easing tight corners and bridging gaps in the race bench caused by slope failures. Dunedin District Office have estimated $850,000 construction cost for this option.

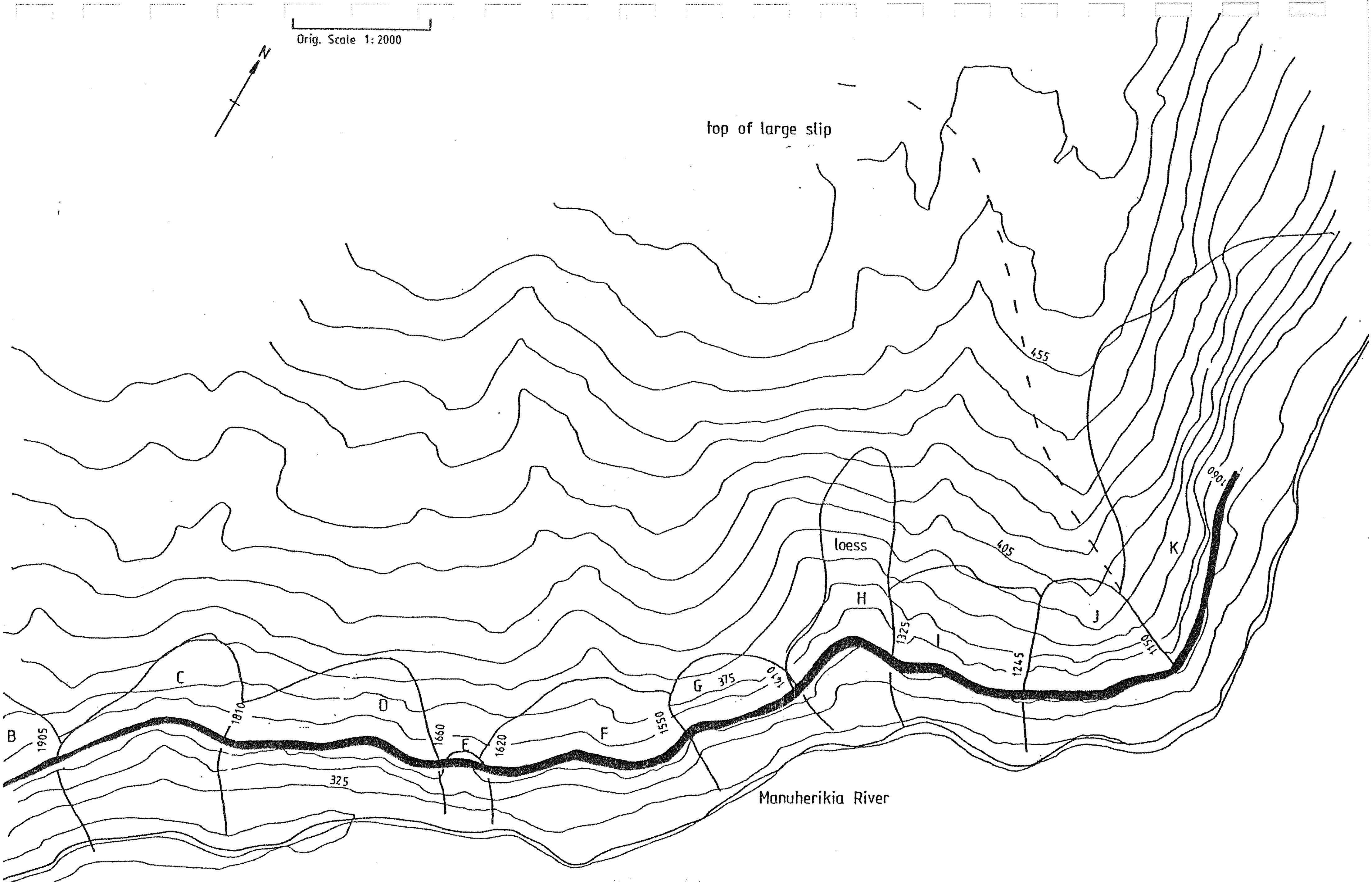
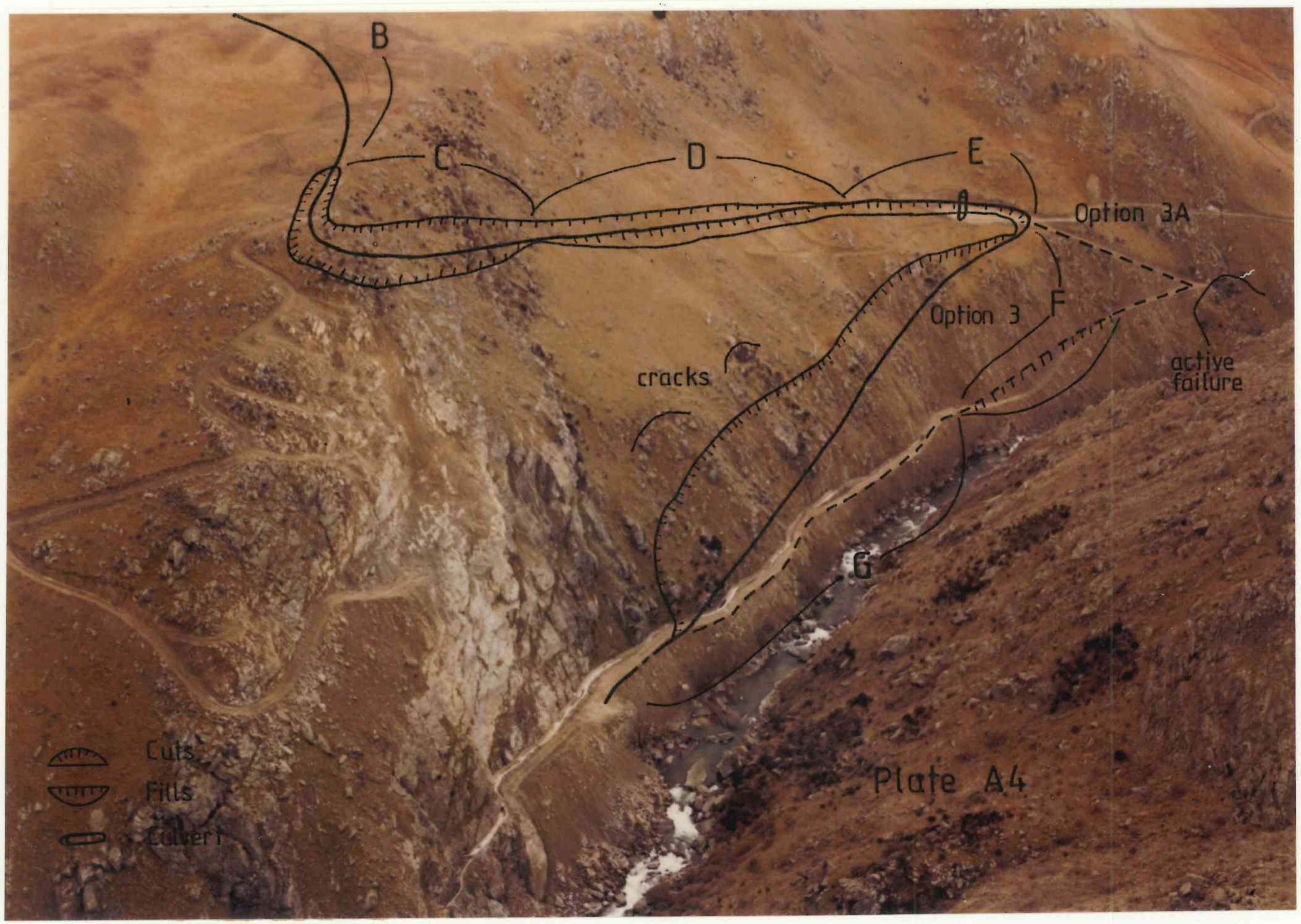


Figure A4 : Option 1 DESIGN SECTORS



Options 3 & 3A: Design Sectors B-G

A4.2 Geotechnical Aspects of Road Design

In this section comments will be made on the geotechnical aspects of road design and construction. The route will be divided up into sections of similar geotechnical properties, and traced from Chinky Gully flume to the present road platform upstream of tunnel 2. These sections are shown on figures A1 and A4, and on photographs A1, A2 and A3. Table 1 summarises the geology and design of this route.

Section A (Chinky Gully Flume to 2840 m)

The section of road in Chinky Gully requires only the construction of a road formation on the valley floor. The valley floor is generally dry however attention should be paid to drainage on both sides of the road formation.

Where the road leaves the valley floor to rise up to the old race level, a culvert may be needed under the embankment.

The road will rise up to race level on a cut/fill ramp along the valley side. Fill batters of 1.5:1 (1.5 horizontal to 1 vertical) and cut batters in colluvium of 2:1 are recommended.

Section B (2840 m - 1905 m)

This section of the route follows the old raceline in an area where there are no apparent stability problems. Road construction will involve cutting the slopes above the race to obtain the desired bench width. Cuts up to about 10 m will be required. Cut batters of 0.5:1 in rock and 2:1 in colluvium and landslide debris are recommended.

Controlled drainage should be maintained to prevent the initiation of failures below road level. Culverts will be needed in at least three valleys. These valleys may also be suitable for passing bays.

Section C (1905 m - 1810 m)

This section of the route crosses a fairly large slip delineated by an arc of exposed schist blocks above race level (plate A2). The material within this slip is actively unstable therefore a fill with 1.5:1 batter is recommended to avoid cutting into the face. At the upstream end of this section, a shear rock face steeply dipping towards the river is exposed above and below race level. Any fill here will have to extend to river level. A retained fill or simple bridge may be an economic alternative. Drainage of fill sections is important.

Section D (1810 m - 1660 m)

For the first 60 m of this section sidling cut/fill road construction is recommended. The rock slope above the race should

TABLE 1 : SUMMARY OF OPTION 1

Section	Geology/Topography	Problems	Recommended Design
A Chinky Gully flume to 2840 m	gently graded valley floor		Construct road formation cut/fill ramp to race level cut 2:1 fill 1.5:1
B 2840 m to 1905 m	gentle slopes of colluvium and landslide debris with some rock outcrops		cuts at 2:1 in colluvium 1:1 in landslide debris 0.5:1 in rock controlled drainage
C 1905 m to 1810 m	landslide debris and steeply dipping sheer rock face	active instability of landslide debris, rock face not suitable for cut or fill	fill 1.5:1 with possible use of retaining wall or bridge to cross sheer rock face
D 1810 m to 1660 m	steep schist rock bluff and landslide debris	active instability of landslide debris	cut/fill in rock. cut 0.5:1 fill 1.5:1 fill across land-slide debris 1.5:1 dip in road to reduce fill heigh
E 1660 m to 1620 m	small steep valley bounded by schist rock bluffs	large fill needed to cross valley	cut in rock 0.5:1 fill in valley 1.5:1 rip-rap protection of toe of fi
F 1620 m to 1500 m	35° slope of colluvium steep schist rock bluffs	active instability of colluvium, unfavourable rock defects	cut in colluvium 1.25:1 cut in rock 0.75:1 costly maintenance of colluvium cut will be needed
G 5000 m to 1410 m	steep bluffs of relaxed schist rock tunnel through more competent schist rock	active fretting of schist blocks from bluffs	fill 1.5:1 cut in relaxed rock 1:1 cut in competent rock 0.5:1

OPTION 1

Section	Geology/Topography	Problems	Recommended Design
H 1410 m to 1325 m	Steep, stable schist rock slope. 35° Loess slope sheer rock face below race dipping towards river	Active failure and tunnel gully erosion of loess. Instability of fill on sheer rock face.	Rock cut parallel to existing face, fill across loess 1.5:1 drainage under fill and upslope. Costly maintenance will be required.
I 1325 m to 1245 m	Schist rock spurs. Slopes of landslide debris	Small scale instability of landslide debris slopes	Cuts in rock 0.5:1 Cuts in landslide debris 1.1:1
J 1245 m to 1150 m	Two rocky slope failures separated by rock spur. 2-3 m colluvium above failure scarps	Oversteepened rock faces in head scarps of failures	Cut in rock parallel to existing face. Cut in colluvium 2:1
K 1150 m to 1084 m	Steep bluffs of competent schist rock up to 50 m high	Some fretting of schist blocks	Cuts 0.25:1 Difficult construction Maintenance will be required

be cut at 0.5:1 and a 1.5:1 fill batter used. The remainder of this section traverses another slope failure and road design should be the same as for section C. A dip in the road level could be used to reduce fill volumes.

Section E (1660 m - 1620 m)

In this section the route crosses a small valley bounded by two steep, apparently stable, rock bluffs (plate A2). Cut batters up to 20 m high, at 0.5:1, are needed to form a road bench. A 1.5:1 fill in the valley may need to extend to river level.

Section F (1620 m - 1500 m)

Approximately 60 m or 1620-1560 of this section is across the toe of a 35° colluvium slope. There is instability of this slope where it has been oversteepened by race construction. As the slopes below the race are too steep for a fill foundation, cutting into the colluvium at 1.25:1 (40°) is recommended. Shallow failures in the colluvium will continue to occur resulting in high maintenance costs.

The remainder of this section is around some rock bluffs. The rock in these bluffs appears to have a shallow angle of defect orientation dipping in an unfavourable direction. A 0.75:1 cut batter is therefore recommended.

Section G (1500 m - 1410 m)

In section G the race follows the base of some rock bluffs and then passes through a short tunnel (about 10 m long) with about 10 m rock cover, at the upstream end of the section. There is active fretting of schist blocks from the bluffs, whereas the rock which the tunnel passes through appears to be more competent.

For 60 m or 1620-1560 of this section it is recommended the road be built on fill at 1.5:1 batter. Major cuts of the rock bluffs and removal of the tunnel will be required in the remainder of the section. Recommended cut batters are 1:1 in the actively fretting rock bluffs and 0.5:1 in the rock over the tunnel. Cuts up to 35 m high will result when these batters are used.

Section H (1410 m - 1325 m)

45 m or 1620-1560 of this section is below a stable rock slope. A road bench should be formed by cutting back the rock parallel to the existing face. In the remainder of section H a 35° slope of loess has formed in the valley above race level (plate A3). There is evidence of tunnel gully erosion through this material and active instability at race level and above. Below race level there is a 26° slope of various materials and below this a sheer rock face dipping towards the river. It has been assumed that the road will be formed on fill across the toe of the loess

slope. Analysis of the stability of the fill overlying the sheer rock face is needed.

Drainage under the fill and upslope will be very important to prevent undermining of the fill foundations and reduce surficial failures. Costly maintenance would still be required on this section due to the active instability of the loess slope.

Section I (1325 m - 1245 m)

This section of the route consists of a series of rocky spurs and slopes of landslide debris. The slopes below race level are too steep to support a fill, therefore the road in this section would be formed by cutting back into the hillside. A 0.5:1 batter has been assumed for cuts in the steeply standing rock spurs and 1.1:1 for cuts in landslide debris. Cuts up to 35 m high would result from the use of these batters.

Section J (1245 m - 1150 m)

This section contains two rocky slope failures separated by a rock spur (plate A3). Oversteepened, rock scarps occur in both failure areas. A 2-3 m layer of fine grained material overlies the rock above the first failure area. The recommended road construction procedure is to cut rock batters parallel to the present face and batters in the fine grained material at 2:1.

Section K (1150 m - 1065 m)

Over this section the disused race is confined to a narrow ledge with steep rock faces above and below. The rock above the race is up to 50 m high, massive and stable except for the fretting of the odd schist block. At this stage, without detailed geological information, a 0.25:1 cut batter with no benching is recommended for this section.

Construction of this section of road will be difficult due to the restricted access and probable need to use explosives. Care must be taken to ensure a clean cut face to reduce further rock fall problems. Between the entrance to tunnel 2 and the end of the existing road it will be necessary to pipe the race water under the new road. A convenient turning area at the end of the new road is provided by an existing platform (plate A3).

A4.3 SUMMARY OF OPTION 1

The use of the existing bench of the old race as a road foundation initially sounds promising. However the old race was abandoned for several reasons. These include dropouts of the race from slope failures below race level and cracking and blocking of the race by upslope failures. These same problems have to be overcome for road construction.

After approximately 500 m of relatively easy construction along the old race line there is about 1300 m of construction made difficult by various types of slope instability. During road construction it would be necessary to avoid initiating slope failures or accelerating existing slope failures in colluvium and landslide debris. In some sections of the road this means the road must be supported on large fills or on a retained fill or bridge structure. Road construction also requires many rock cuts, some up to 35 m high, in rock with varying degrees of relaxation and defect orientations.

Each of these rock cuts requires individual assessment and design.

The design of this access route will therefore require quite extensive investigations. Construction would be difficult in some areas and large volumes of rock would need to be excavated.

The construction methods recommended will not result in a reliable access as the cost of providing a totally reliable access is prohibitive. The proposed access route is likely to be blocked or washed out by colluvium slides and some rock falls. Heavy rainfall will trigger many of these events. However it should be possible to restore access within 2-3 days for most events.

A5. OPTION 2

A5.1 Introduction

Access Route Option 2 utilises the existing access road that climbs onto the main ridge north of the river. From here it branches off the existing road (figure A1) and sidles around the hillside to meet the Option 1 route about 150 m downstream of the entrance to tunnel 2. From this point the route is the same as Option 1 (figure A5, plates A2, A3).

The grade of the road proposed by Dunedin District Office varies between 1 in 10 on the upper slopes to 1 in 8 towards the Option 1 route. The majority of the construction work will involve cutting and filling to form a road platform with a suitable grade. On the section of road across the ridge and the more gentle slopes above the gorge it would be possible to construct passing bays and areas for stockpiling materials. Dunedin District Office estimated the cost of construction of a road along this route at $500,000.

Table 2 gives a summary of the geology and design of this route.

A5.2 Geotechnical Aspects of Road Design

The route will be traced from Chinky Gully flume to the present platform upstream of tunnel 2. It will be divided up into convenient sections for discussion purposes. These sections are shown on figure A5 and plates A2 and A3.

TABLE 2 : SUMMARY OF OPTION 2

Section	Geology/Topography	Problems	Recommended design
A Chinky Gully to top of ridge (existing track)	Schist rock overlain by colluvium. Variable average to gentle slopes		Ease one sharp corner. Regrade road
B Top of ridge to change in slope	Undulating 18°-20° slopes of colluvium, and landslide debris with loess pockets		Cut/fill. Fill 1.5:1 Cut in coluvium 2:1 Cut in landslide debris 1:1 Controlled drainage
C Change in slope to loess filled valley	Ridges of relaxed schist rock. Slopes of land-slide debris and colluvium with pockets of loess		Cut/fill. Fill 1.5:1 Cut in colluvium 2:1 Cut in landslide debris 1:1 Cut in rock 0.75:1 Controlled drainage
D Loess filled valley	35° loess slope above race, 26° debris slope below race with shear rock face dipping towards river below	Active failure and tunnel gully erosion of loess. Instability of fill on shear rock face	Minimise size of fill 1.5:1 drainage under fill and upslope. Costly maintenance will be required
E Loess valley to old race level	Schist rock spurs slopes of landslide debris		Cut in rock 0.5:1 Cut/fill in landslide debris fill 1.5:1 cut 1:1 Controlled drainage

See Option 1
Sections J and K
for remainder of
route

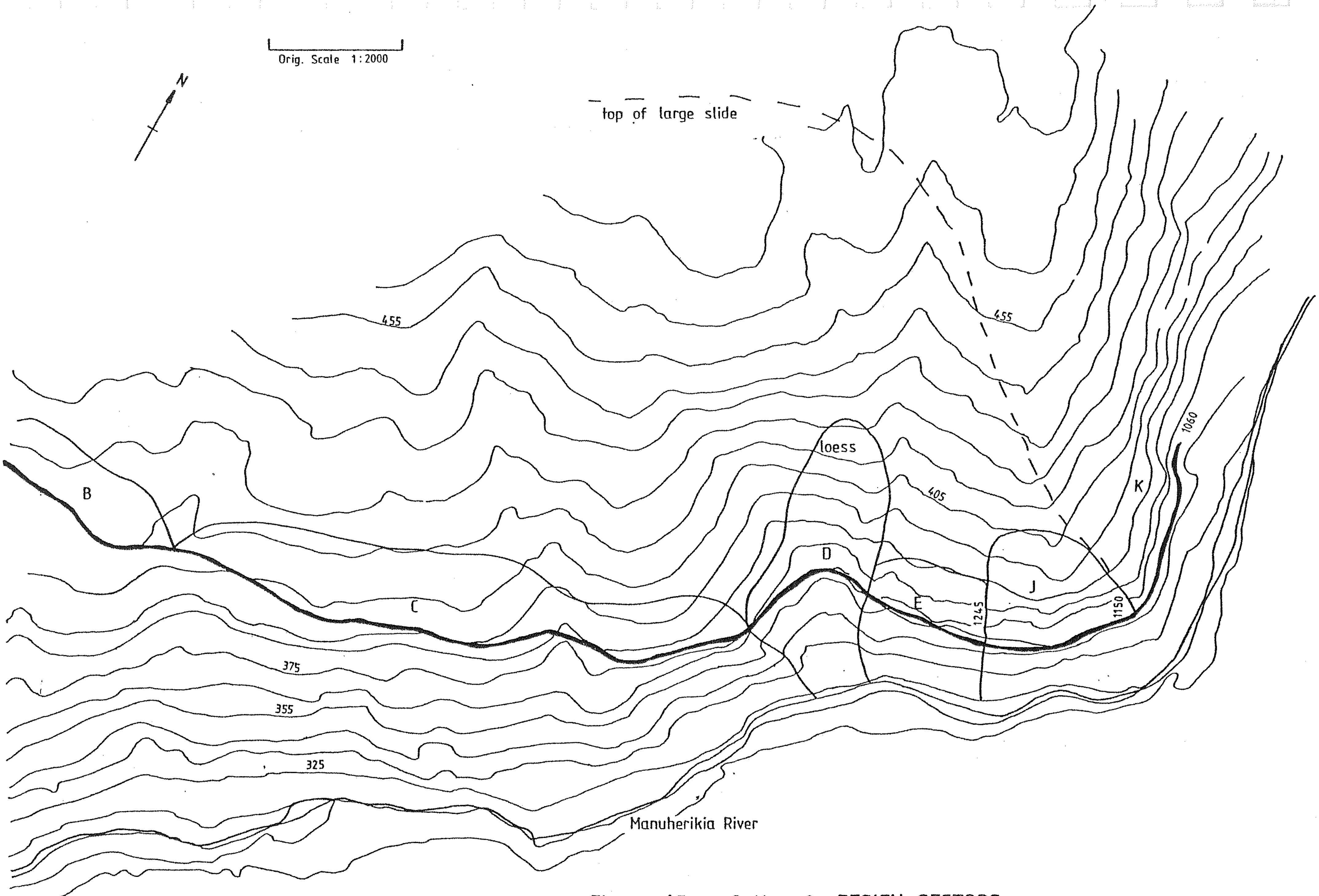


Figure A5 : Option 2 DESIGN SECTORS

<u>Section A</u> (Chinky Gully to top of ridge)

This section of the route is along the existing access road. The access road is at present badly rutted and in need of regrading. The corner marked on figure A1 is also too sharp and steep for easy manoeuvering by most vehicles. In winter it can become permanently icy, making access very difficult. This corner therefore needs to be eased.

<u>Section B</u> (top of ridge to change in slope)

Dunedin District Office have assumed a 1 in 10 grade over this section of the route, resulting in cuts up to 8 m high and fills up to 5 m high. Increasing the grade of the road and reducing it's width will reduce the amount and size of the required earth-works.

Fill batters are recommended to be 1.5:1, cuts in colluvium 2:1 and cuts in landslide debris 1:1. Good control of run-off water is required to prevent the initiation of failures in this section or further downslope.

<u>Section C</u> (change in slope to loess valley)

A 1 in 8 grade has been assumed by Dunedin District Office over this section. The resulting 20 m high cuts in these materials are undesirable. Increasing the grade to 1 in 6 and using a sidling cut/fill construction method is suggested for this section.

Surficial rock exposures indicate that the rock in this section is in a relaxed condition. The recommended cut batters are 2:1 in colluvium, 1:1 in landslide debris and 0.75:1 in rock out-crops. Controlled drainage would be required in this section also.

<u>Section D</u> (loess valley)

A description of this loess filled valley is given in section H of Option 1. The problems described for section H of Option 1 are common to section D of Option 2. As there are active failures of the loess slope it is proposed to cross the loess on a fill. Reducing the height and volume of fill may be achieved by reducing the gradient of the road from the old race level to the loess valley.

<u>Section E</u> (loess valley to old race level)

This section is described in section I of Option 1. The road should be constructed by cutting through the rock spurs at 0.5:1 and by crossing landslide debris on a sidling cut/fill section. Fill batters should be 1.5:1 and cuts in landslide debris 1:1. Controlled drainage should be undertaken.

Remainder of Route

The remainder of this route corresponds to sections J and K of Option 1 (section A4.2).

A5.4 Summary of Option 2

Option 2 avoids most of the areas of slope instability encountered by Option 1 but large cuts in the rock bluff in the vicinity of the entrance to tunnel 2 cannot be avoided. The problems of design and construction of the road around these bluffs are the dominant feature of this option.

The second major problem of this option is the fill over the loess filled valley. Careful design and investigation of this section of road is needed, with attention to drainage.

The design of the remainder of the new length of road is dependent on accurate identification of the materials present and the final grade and route alignment chosen. Significant savings in construction costs may be obtained if the grade of the road is increased and the formation width decreased.

Controlled drainage of this route is essential. Uncontrolled drainage and channelling of run-off water may initiate slope failures and accelerate erosion in loess deposits.

A6. OPTIONS 3 AND 3A

A6.1 Introduction

Access Option 3 utilises the existing road to climb up the ridge north of the river to the scarp above the gorge proper (figure A1). This scarp is the upper bound of a large basal slide. The route then traverses the slide to the borrow pit and cuts back across the oversteepened toe of the slide to meet the existing road about 50 m upstream of the turning area. Dunedin District Office have prepared a road alignment and cross-sections based on a 1 in 8 grade across the face of the slide (figure A6). After an initial cut to drop down to the slide surface a sidling cut/fill section is assumed across to the borrow pit. Large cuts up to 40 m high in the unstable toe of the slide are then required to bring the road down to race level. These cuts are unacceptable due to the marginal stability of this part of the slide.

Option 3A is a variation on Option 3, proposed to avoid cutting into the unstable face at the toe of the basal slide. This route is the same as Option 3 down to the borrow pit. It then utilises the existing access road, in an upgraded form, to reach race level about 300 m upstream of the entrance to tunnel 2.

Dunedin District Office estimated that the construction of the new section of option 3 would cost $400,000. Option 3A will be significantly cheaper.

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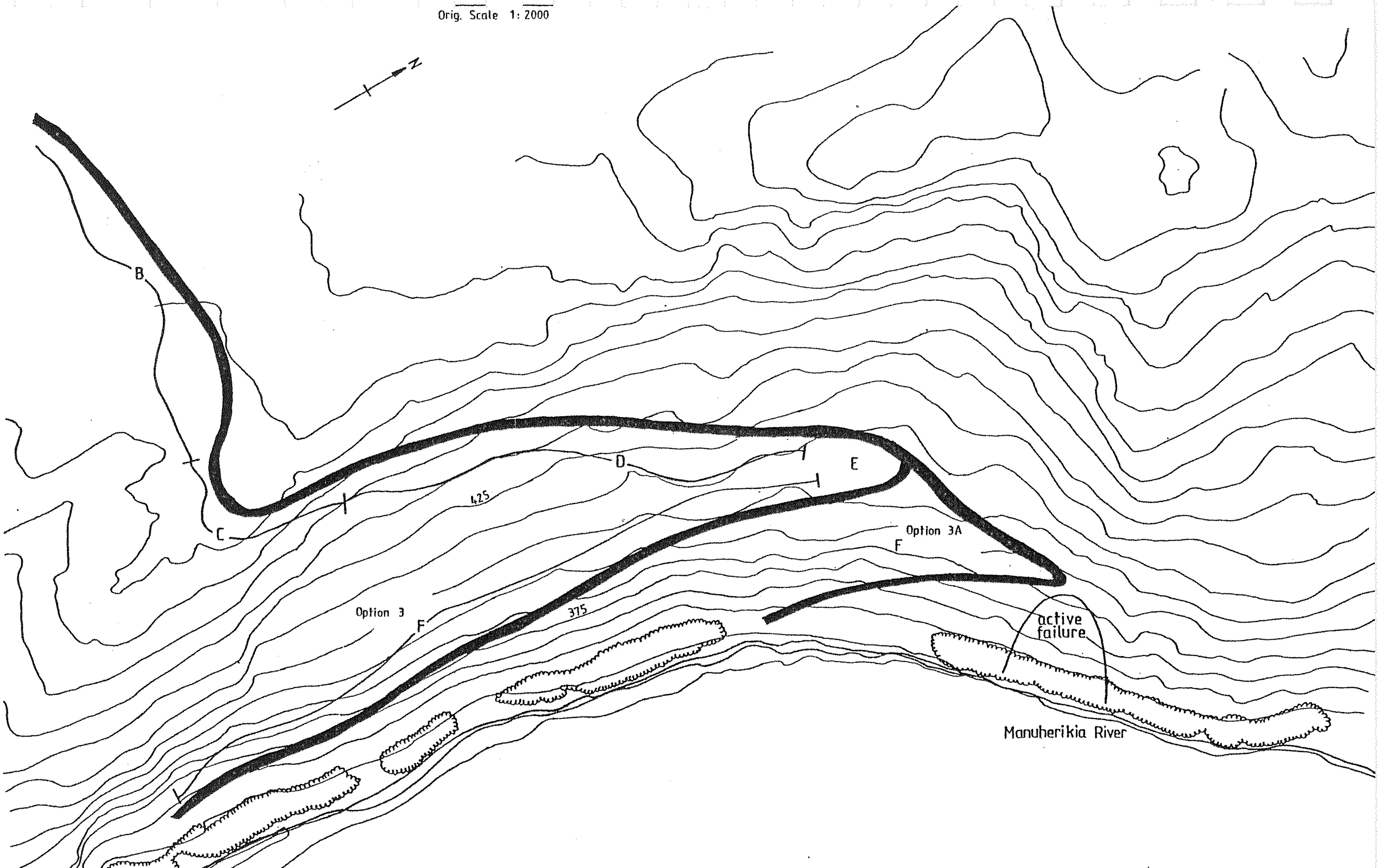


Figure A6 : Options 3 & 3A DESIGN SECTORS

A6.2 Geotechnical Aspects of Road Design

The route from the Chinky Gully Flume up the ridge to the scarp above the gorge and then down to the borrow area, will be divided into five sections for discussion purposes. Below the borrow pit Options 3 and 3A will be discussed separately. The discussion sections are shown in figure A6 and plate A4 and table 3 summarises the geology and design of this route.

Section A (Existing road)

The discussion of section A, Option 2 applies to this section.

Section B (from existing road to slide scarp)

This section of road requires the construction of a road formation for about 200 m across gently sloping schist rock terrain. No problems are envisaged.

Section C (through slide scarp)

Cuts up to 10 m high are required to bring the road through the scarp onto the top of this slide. The schist rock in the scarp is in a very relaxed condition. Cut batters of 1:1 are recommended where the dominant defect direction is away from the batter and 1.75:1 where the defect direction is unfavourable.

Controlled drainage is required to prevent run-off water from the top of the ridge being channelled into the top of the basal slide via this section of road.

Section D (slide scarp to borrow pit)

Sidling cut/fill construction across the slide will reduce the effect of road construction on the basal slide and the slopes above road level. Fills at 1.5:1 and cuts at 1.5:1 are recommended (figure A2). Control of run-off water is important.

Section E (borrow pit)

The borrow pit is in fine sand at the base of a depression filled with a higher proportion of fine grained material than is generally prevalent on the basal slide. There is evidence of large and small scale instability and tunnel gully erosion. Construction of the road on a fill across the borrow pit should have a beneficial effect on the stability of the slopes above the borrow pit. Good drainage under the fill and upslope will be needed to prevent erosion of the fine grained material.

Section F, Option 3 (borrow pit to race level)

Dunedin District Office have proposed constructing a road down to race level by cutting a road bench across the toe of the landslide. The face across which this route cuts is actively

TABLE 3 : SUMMARY OF OPTION 3A

Section	Geology/Topography	Problems	Recommended Design
A Existing access track	Schist rock overlain by colluvium. Variable average to gentle slopes		Ease one sharp corner regrade road
B Existing track to slide scarp	Gentle slopes of schist rock overlain by colluvium		Construct road formation
C Through slide scarp	Relaxed insitu schist rock and loose schist blocks	Unravelling of schist blocks. Channelling water onto basal slide	Cuts at 1:1 and 1.75:1 depending on rock defect orientation. Controlled drainage
D Slide scarp to borrow pit	Landslide debris and colluvium. Undulating slope at average 28°	Cutting of support from slopes above	Sidling cut/fill; fills 1.5:1 Cuts 1.5:1, controlled drainage. Some superficial failures above road possible
E Borrow pit	Valley filed with fine grained material	Active instability on large and small scale. Tunnel gully erosion	Fill 1.5:1 Drainage under fill and upslope
F Existing track to race level	40° slopes of landslide debris	Active unravelling of landslide debris above road, active failure below corner of road	Ease grade of road to 6:1 by placing fill at 1.4:1 Control drainage, especially at corner. Possible failure of road at corner. Regular costly maintenance will be necessary
G Existing track parallel to race	Loose, end tipped fill	Active slumping of road	Regrading of road, riprap bank protection. Costly maintenance will be necessary

fretting and failing at a batter of 1.3:1. Regrading the face to a stable batter would result in the removal of large volumes of material from the toe of the basal slide. This may initiate large scale movements on the interface between the landslide debris and the insitu schist. Smaller scale progressive failures in the slope debris are also likely to be initiated.

This section of Option 3 should therefore be abandoned.

Option 3A, Section F

Option 3A section F is proposed as a more feasible road alignment than Option 3. This option utilises the existing access road, in an upgraded form, from the borrow pit to race level.

There are four main problems assicated with this section of road:

(i) There is an active failure below the corner of the road, probably initiated by the channelling of run-off water down the road (plate A4).

(ii) There is active fretting of schist blocks onto the road from the oversteepened toe of the slide.

(iii) The grade of the road down to the race is as steep as 3:1.

(iv) Most vehicles need to do a three point turn to get around the corner below the borrow pit.

It is considered that a lower standard of road should be accepted for this section. Therefore it is recommended that the corner in the road be left as it is, but that very good drainage measures be undertaken to prevent any run-off waters entering the area of instability. The possibility of failure of the road at this corner remains. In this event it should be possible to lift the corner higher up the slope away from the failed area.

The grade of the lower part of the road can be improved to 6:1 by placing a fill at 1.4:1 batter over the existing road. The unravelling of schist blocks onto the road would remain.

This section of road would not be expensive to construct but regular costly maintenance will be necessary.

Section G (existing track parallel to race)

This section of the existing road is on loose, end tipped fill, which is slumping towards the river in places. It is recommended that this section of road be regraded and rip rap protection be placed on the fill below flood level. This section of road will require continued maintenance to reinstate the formation after further slumping. There will also be frequent rock falls and some larger slips from the face of the slide.

A6.3 Summary of Options 3 and 3A

The construction of Option 3 has been estimated by Dunedin District Office to be the most economic of the three Options. However the potential problems of slope instability caused by Option 3 construction are unacceptable and this option should therefore be abandoned.

Option 3A provides an alternative to the unacceptable lower section of Option 3. This Option involves using the existing road from the borrow pit to race level and the acceptance of the possibility of new road failure. Higher levels of maintenance than for Options 1 and 2 would probably be required also. As the only improvements to the existing road, are good drainage and some fill, Option 3A should be the most economic of the three geotechnically acceptable Options.

A sidling cut/fill construction across the top of the basal slide is recommended to reduce the effects of construction on the surrounding slopes. The stability of the road is reliant on good control of run-off water, especially in the area of the borrow pit and the active slope failure below the corner of the existing road.

A7. SUMMARY AND RECOMMENDATIONS

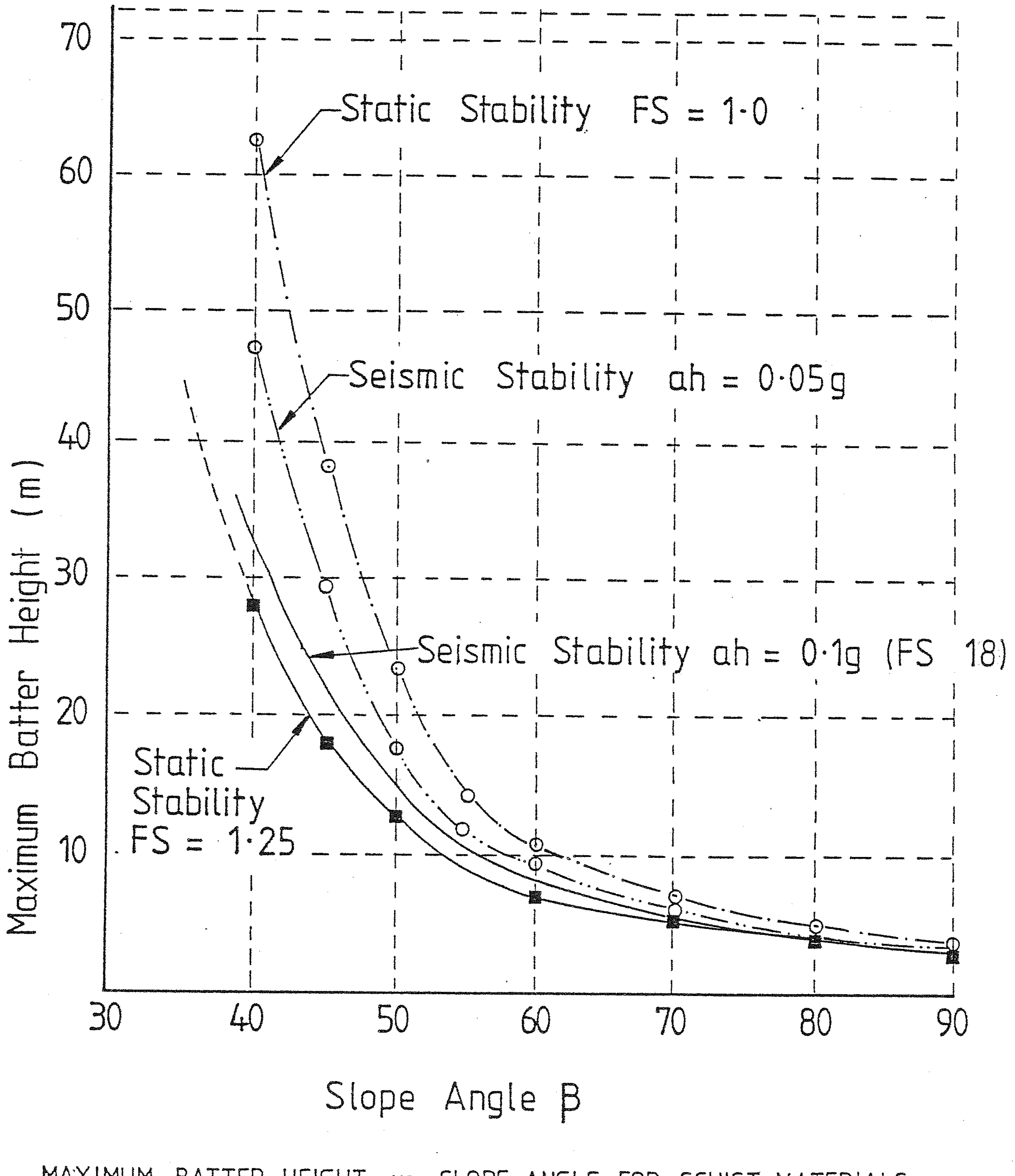
(1) Option 1 requires construction of a greater length of new road than the other options, with considerable earthworks needed. The route crosses many unstable area and construction in some areas will be difficult, especially around the rock bluffs at the entrance to tunnel 2. The estimated construction cost is $850,000.

(2) Option 2 avoids most of the unstable areas encountered by Option 1, and construction will generally be easier except around the rock bluffs common to both options. Construction of a large fill across a loess filled valley will also be difficult. The ROC estimated cost of construction is $500,000.

(3) Option 3 should be abandoned due to the instability it would cause in cutting across the oversteepened toe of a major slide.

(4) Option 3A has been proposed as an alternative to Option 3. Option 3A avoids cutting into the toe of the major slide. Construction of this option should be straight forward without the large cuts in massive rock which are common to Options 1 and 2. The estimated cost of construction is less than $400,000. But this option has poor geometrics.

(5) The final choice of road alignment and cross-sections details of the preferred option will be dependent on more detailed geological investigations and stability assessments.



MAXIMUM BATTER HEIGHT vs SLOPE ANGLE FOR SCHIST MATERIALS

Based on $C = 12kPa$ $\phi = 36°$ depth < 5·0m
$C = 34kPa$ $\phi = 29°$ depth > 5·0m
(after salt 1983, ref)

Figure A7: STABILITY CHART FOR LANDSLIDE DEBRIS

(6) The choice of any borrow areas necessary for all of the Options should be made considering the marginal stability of most of the slopes above the gorge.

(7) Option 3A is recommended as the most economic of the three options because of its low capital cost. However, Option 3A would have substandard geometrics and would probably result in high maintenance costs. Proper drainage and control of run-off water is essential to the success of Option 3A. The reliability of access Options 1 and 2 would not be much greater than that of Option 3A.

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