DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

REPT.BK.NO. 80/59
SOUTH EASTERN FREEWAY, GLEN
OSMOND TO CRAFERS REALIGNMENT:
FEASIBILITY STUDY OF WYLIE
RIDGE TUNNEL
REPORT NO. 2

GEOLOGICAL SURVEY

by

C. CONOR

GROUNDWATER AND ENGINEERING SECTION

DME. NO. 335/79
ENG. NO. 78/66

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DEPARTMENT OF MINES AND ENERGY
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# SOUTHEASTERN FREEWAY, GLEN OSMOND TO CRAFERS REALIGNMENT:

## FEASIBILITY STUDY OF WYLIE RIDGE TUNNEL
- Report No. 2 -


ABSTRACT

A method developed by Hoek and Brown (1980) has been used to predict the volume and shape of wedge failures which could theoretically occur from the proposed tunnel roof in the vicinity of the northern portal. Six configuration have been determined, the largest having a volume of 1250 $m^3$.

The method should be applied more extensively before and during tunnel construction in order to recognise other potential failure masses along the tunnel alignment.


## INTRODUCTION

The planning Division, Highways Department, requested advice on the geological feasibility of by-passing the Devil's Elbow and the tortuous road above it with two parallel tunnels, 500 m long and 10 m high, passing through Wylie Ridge (Fig. 1).

A preliminary report, identifying the main geological features has been issued by Conor and Selby (1980). One of its recommendations was that further work should be directed towards a study of the effect that the rock mass discontinuties will have on the tunelling operation. Additional work in the vicinity of the northern portal has since been done on this aspect and is contained in this report.

## ROOF WEDGE FAILURES

A study of rock discontinuties on the face of the Union Quarry, which forms the northern portal area for the tunnel, was carried out during the earlier investigation and is shown in Figure 2. This identified four main joint directions which, together with bedding, form the main rock mass discontinuties in this area. Data from this analysis has been used to predict the possible shape and maximum volume of wedge failures that might be expected from the tunnel roof using a method developed by Hoek and Brown (1980). The method uses the stereographic projection technique to evaluate the shape and volume of the potentially unstable wedges in the tunnel roof. Fig 3 shows in diagrammatic form types of failure that might be expected within a rock mass. Figs 4 to 10 present specific examples recognised in Union Quarry, which are assessed using Hoek and Brown's method which is described in Appendix I. A summary of the results is given in the following table.

TABLE 1

MAXIMUM SIZE AND VOLUME OF POTENTIAL FAILURE WEDGES

| Wedge Identity | Base area sq. m | Height m | Volume Cu. m | Failure Type | Figure No. |
|---|---|---|---|---|---|
| J1/J2/J4 | 59 | 15 | 285 | Gravity | 4 |
| J1/J3/J4 | 73 | 28 | 678 | Gravity | 5 |
| J1/J2/J3 | 27 | 8 | 72 | Slide | 6 |
| J1/J4/B90 | 110 | 34 | 1248 | Gravity | 7 |
| J1/J4/B60 | 110 | 11 | 391 | Gravity | 8 |
| J1/J4/B30 | 110 | 4 | 161 | Gravity | 9 |

It should be noted that there are two modes of wedge failure:

1. gravity falls, where the apex of the wedge is directly above the base of the wedge and where there is no frictional resistance to failure, apart from roughness of the boundary discontinuities.
2. sliding failure, where the apex of the wedge is not directly above the base of the wedge; in this case failure can only occur by sliding on one of the joint surfaces or lines of intersection.

## DISCUSSION

The wedge volume calculations are related to a tunnel model which has a 13 m wide flat roof. Plans supplied by the Highways Department indicate that the tunnel may be curved in cross section and that maximum width would be halfway between obvert and invert. This means that the maximum volume for any block will be less than that indicated in Table 3 (see sketch on Figs. 7 to 9).

Actual failure will depend upon frictional parameters such as roughness of boundary discontinuities, joint infil, saturation and the steepness of the discontinuities. Smaller size wedges, whose shapes are directly related to the wedge families, are just as likely to fail as are wedges that are a composite of the families recognised. Since the calculations are designed to determine the maximum size of failure wedges they do indicate the maximum support required at those particular parts of the tunnel which traverse the joint pattern described, i.e. the northern portal.

It should be noted that conditions elsewhere along the tunnel will differ from the northern portal and will necessitate different styles of support as indicated in the earlier report. Therefore this type of study should be extended to all other parts of the tunnel if construction proceeds.

for

C. CONOR
Geologist

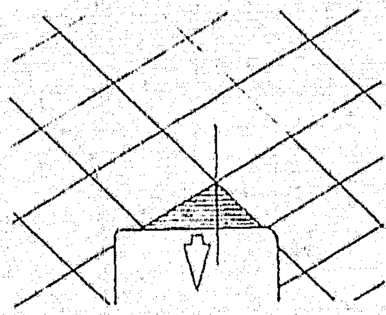
REFERENCES

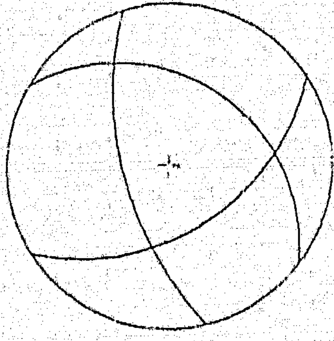
Hoek, E. and Brown, E.T. 1980. Underground Excavations in Rock. Inst. Mining and Metallurgy, 44 Portland Place, London WIN 4BR.

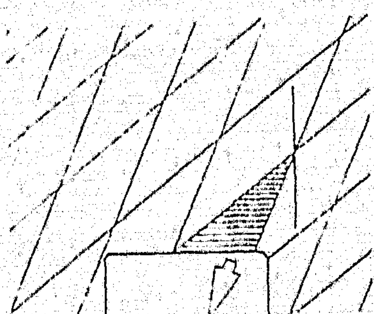
Conor, C. and Selby, J. 1980. South Eastern Freeway, Glen Osmond to Crafers Realignment. Feasibility Study of Wylie Ridge Tunnel. S. Aust. Dept. Mines report 80/76 (unpublished).

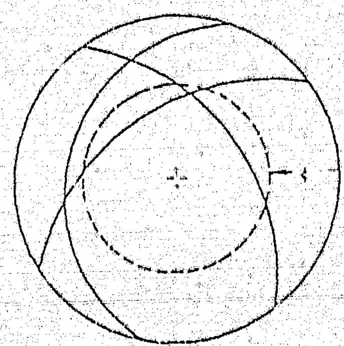
# APPENDIX A

## TECHNIQUE FOR ANALYSING POTENTIAL ROCK WEDGE FAILURES FROM HOEK AND BROWN (1980).









Structurally controlled failure can be analysed by means of the stereographic projection technique described in chapter 4 of this book. A simple example of the application of this method is illustrated in the margin sketch which shows a wedge of rock falling from the roof of an excavation in jointed rock. A vertical line drawn through the apex of the wedge must fall within the base of the wedge for failure to occur without sliding on at least one of the joint planes.

In the stereographic plot, the vertical line through the apex of the wedge is represented by the centre point of the net and the conditions stated above are satisfied if the great circles representing the joint planes form a closed figure which [illegible] the centre of the net.

This very simple kinematic check is useful for evaluating the potential for roof falls during preliminary studies of structural geology data which has been collected for the design of an underground excavation. The stereographic method can also be used for a much more detailed evaluation of the shape and volume of potentially unstable wedges as illustrated in figure 88.

Three planes are represented by their great circles, marked *A*, *B* and *C* in figure 88. The strike lines of these planes are marked *a*, *b* and *c* and the traces of the vertical planes through the centre of the net and the great circle intersections are marked *ab*, *ac* and *bc*. Suppose that a square tunnel with a span of S runs in a direction from 290° to 110° as shown in the lower part of figure 88. The directions of the strike lines correspond to the traces of the planes *A*, *B* and *C* on the horizontal roof of the tunnel. These strike lines can be combined to give the maximum size of the triangular figure which can be accommodated within the tunnel roof span, as shown in figure 88.

In the plan view, the apex of the wedge is defined by finding the intersection point of the lines *ab*, *ac* and *bc*, projected from the corners of the triangular wedge base as shown. The height $h$ of the apex of the wedge above the horizontal tunnel roof is found by taking a section through the wedge apex and normal to the tunnel axis. This section, marked XX in figure 88, intersects the traces *a* and *c* at the points shown and these points define the base of the triangle as seen in view XX. The apparent dips of the planes *C* and *A* are given by the angles $\alpha$ and $\beta$ which are measured on the stereographic projection along the line XX through the centre of the net.

The volume of the wedge is given by $^1/_3 . h$ x the base area of the wedge as determined from the plan view in figure 88.

If three joints intersect to form a wedge in the roof of an underground excavation but the vertical line through the apex of the wedge does not fall within the base of the wedge, failure can only occur by sliding on one of the joint surfaces or along one of the lines of intersection. This condition is represented stereographically if the intersection figure formed by the three great circles falls to one side of the centre of the net as illustrated in the lower margin drawing.

An additional condition which must be satisfied for sliding

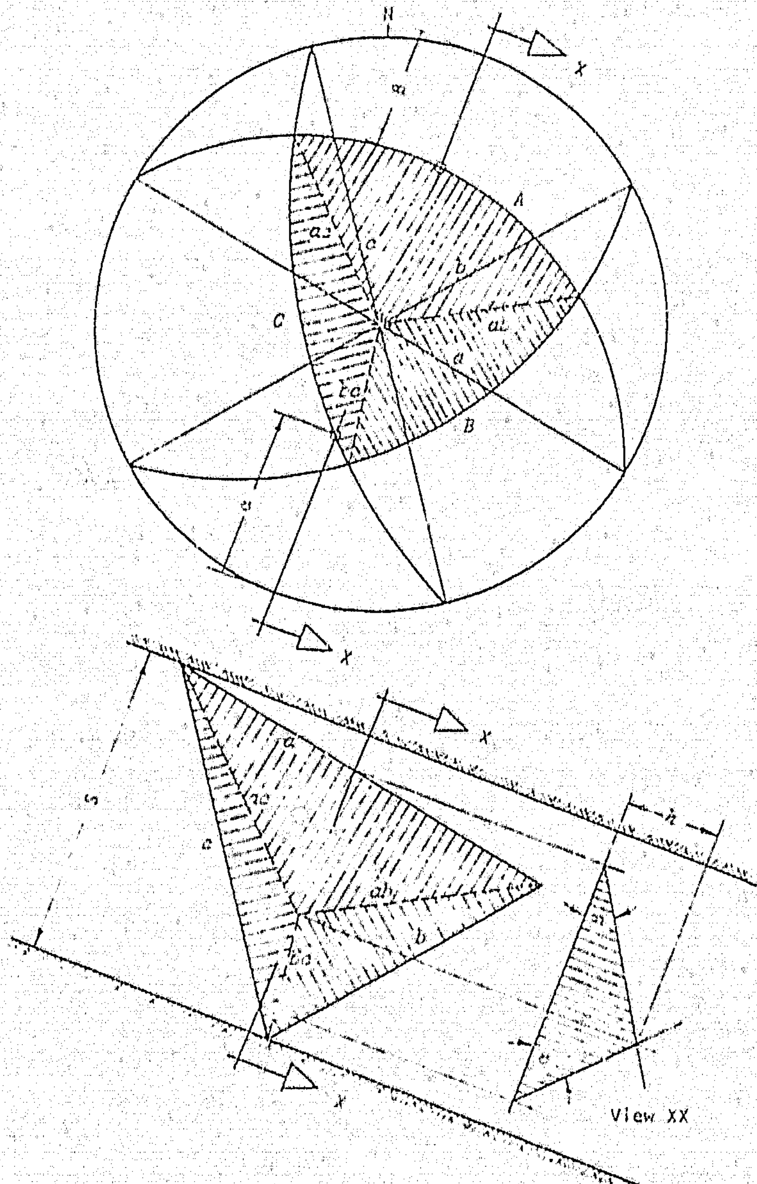
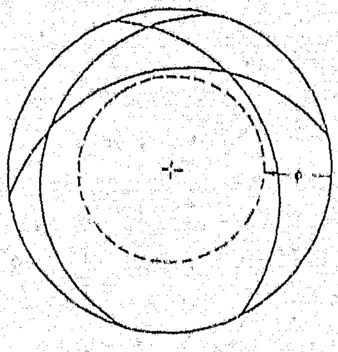
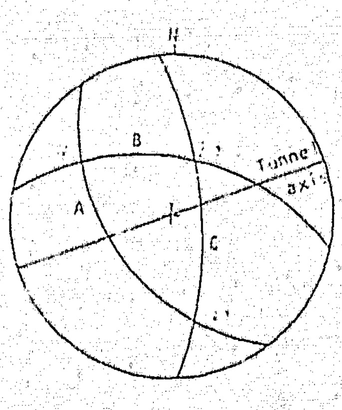



Figure 88: Supplementary construction in conjunction with a stereographic projection for the determination of the shape and volume of a structurally defined wedge in the roof of a tunnel.



Stable wedge conditions

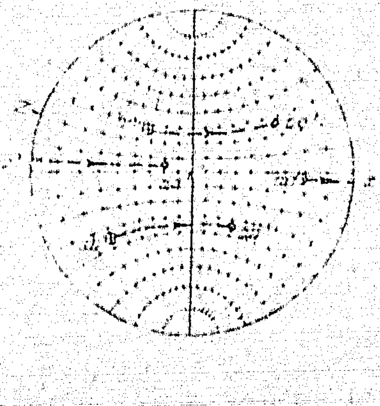
of the wedge to occur is that the plane or the line of intersection along which sliding is to occur should be steeper than the angle of friction $\phi$. This condition is satisfied if at least part of the intersection figure falls within a circle defined by counting off the number of degree divisions corresponding to the angle of friction from the outer circumference of the net.




The construction of the true plan view of the wedge follows the same principles as used in figure 88 and the construction for the case under consideration is illustrated in figure 89. In this example, the strike length of the trace $c$ of plane $C$ is defined by the dimension L.

In determining the height $h$ of the wedge, the view $XX$ has to be taken at right angles to the line $ab$ which passes through the centre of the net and the intersection of the great circles representing planes $A$ and $B$. The angle $\alpha$ is the true dip of the line of intersection of these two planes.

When the entire intersection figure falls outside the friction circle, as shown by the drawing in the margin, the gravitational weight of the wedge is not high enough to overcome the frictional resistance of the plane or planes on which sliding would take place. Under these conditions, the wedge is stable against sliding.



In the sidewall of an excavation in jointed rock, failure of wedges can occur in much the same way as in the roof except that falls are not possible and all sidewall failures involve sliding on a plane or along the line of intersection of two planes. Two methods for analysing sidewall failure are presented below.

# APPENDIX B

# FAILURE WEDGE SIZE AND VOLUME CALCULATIONS

# FAILURE WEDGE SIZE AND VOLUME CALCULATIONS

NORTHERN PORTAL, WHYLIE RIDGE TUNNEL

Volume of wedge = 1/3 height (h) of wedge x area of base of wedge see Fig. 10.

1. J1/J2/J4, see Fig. 4.

   Height (h) = 14.6 m

   Area of base = 58.5 sq. m

   Maximum Volume of Wedge = $\dfrac{14.6 \times 58.5}{3}$

   = 284.9 Cu m

2. J1/J3/J4, see Fig. 5.

   Height (h) = 27.89 m

   Area of base = 72.93 sq. m

   Maximum Volume of Wedge = $\dfrac{27.89 \times 27.93}{3}$

   = 678.01 Cu m

3. J1/J2/J3, see Fig. 6

Height (h) - 8.14 m

Area of Base = 26.51 sq. m

Maximum Volume of wedge = $\frac{8.14 \times 26.51}{3}$

71.93 Cu m

4. J1/J4/B90 (Bedding vertical), see "ig. 7

Height (h) = 34.2 m

Area of Base = 109.5 sq. m

Maximum Volume of Wedge = $\frac{34.2 \times 109.5}{3}$

= 1248.3 Cu m

5. J1/J4/B60 (Bedding dip $60^{\circ}$ westerly), see Fig. 8

Height (h) = 10.7 m

Area of Base = 109.5 sq. m

Maximum Volume of Wedge = $\frac{10.7 \times 109.5}{3}$

= 390.55 Cu m

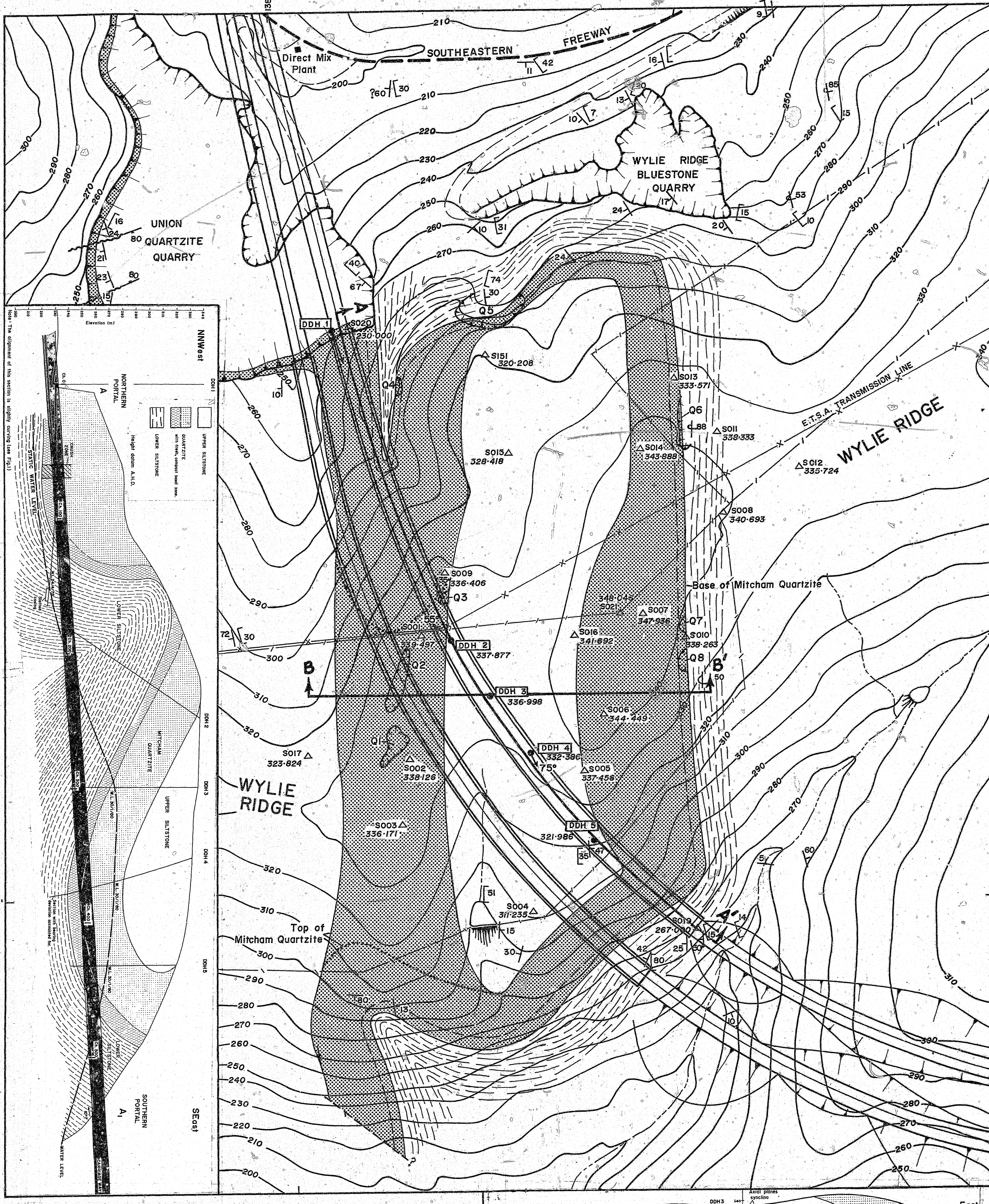
6. J1/J4/B30 (Beddibng dips 30$^{\circ}$ westerly, see Fig. 9

Height (h) = 4.4 m

Area of Base = 109.5 sq. m

$$\text{Maximum volume of wedge} = \frac{4.4 \times 109.5}{3}$$

$$= 160.6 \text{ Cu m}$$




0 50 100 150 200 Metres

UPPER SILTSTONE

MITCHAM QUARTZITE (compact basal zone)

LOWER SILTSTONE

35 — Strike and dip of bedding

50 — Strike and dip of overturned bedding

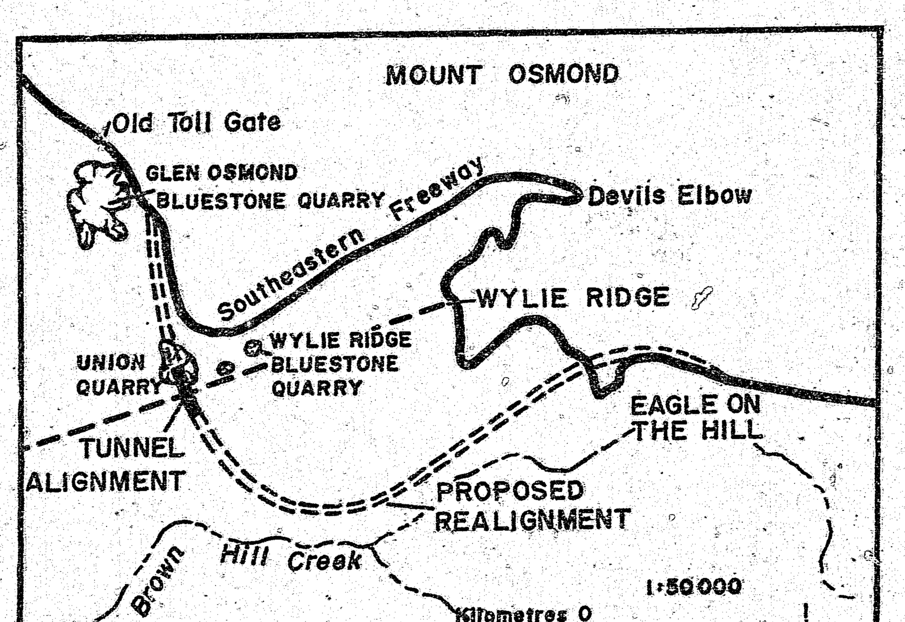
10 — Strike and dip of cleavage

—260— Elevation in metres

DDH — Highways Department Diamond Drill Holes 1–5

Q 1–8 — Wylie Ridge Quartzite Quarries

S004 311·235 — Highways Dept. bench mark with number and elevation (metres A.H.D.)



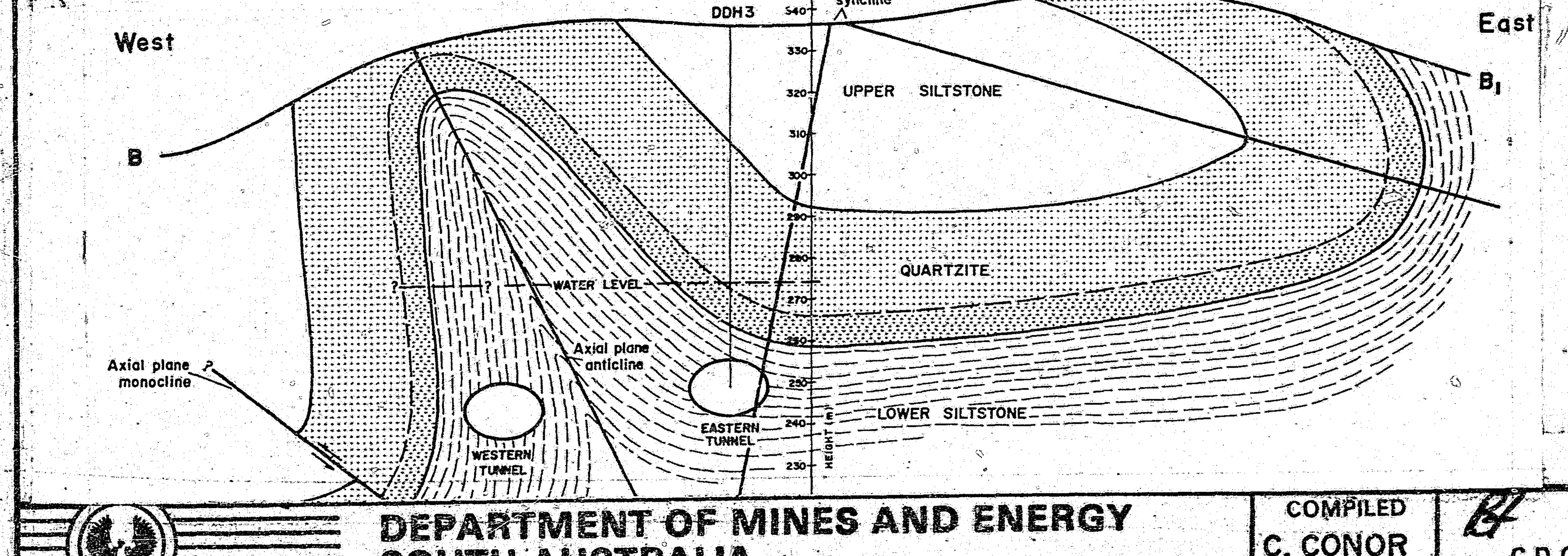




Fig. 1

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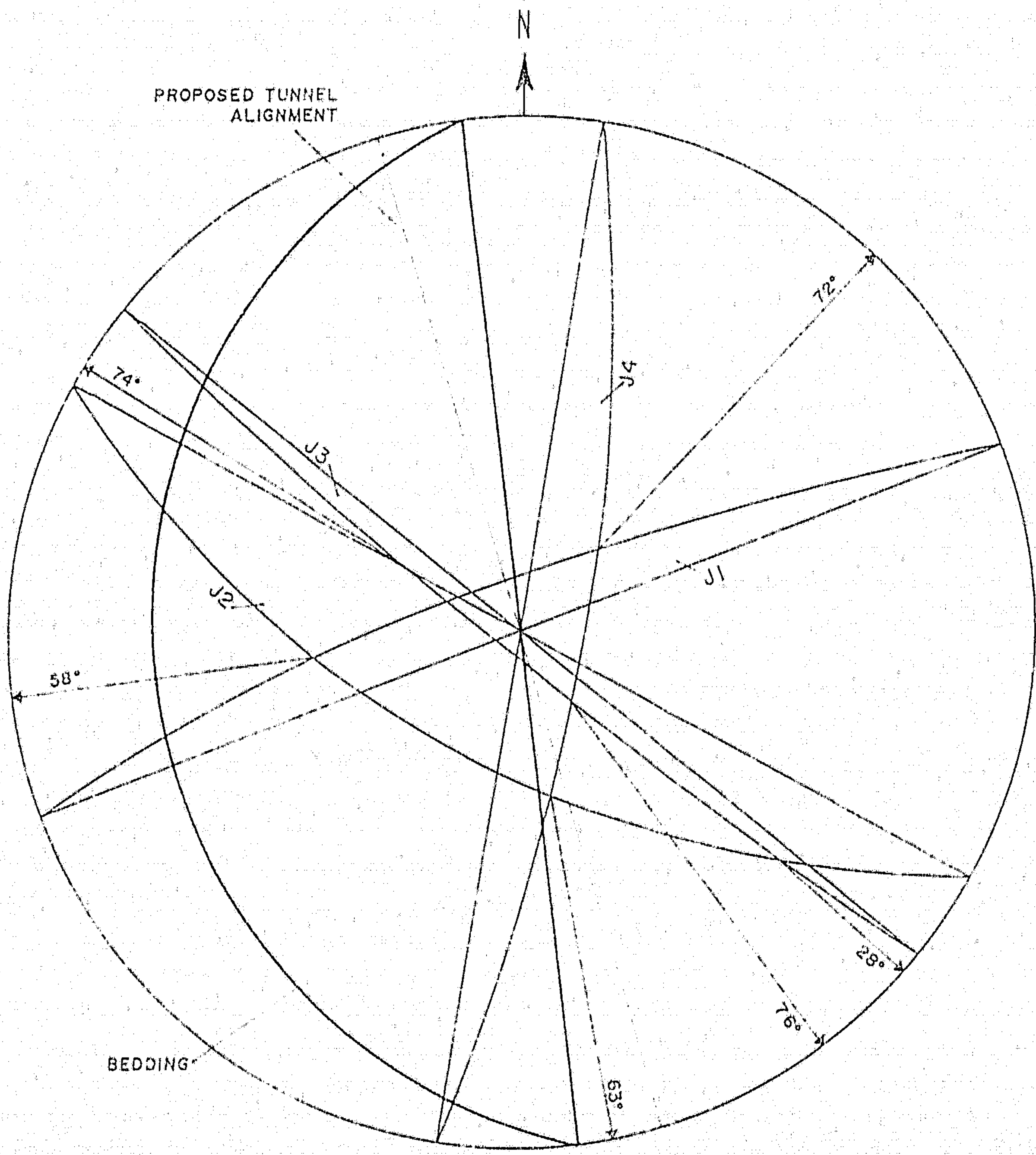
# S.E. FREEWAY – PROPOSED TUNNEL
## GEOLOGICAL PLAN AND SECTIONS AT WYLIE RIDGE, GLEN OSMOND

| | | |
|---|---|---|
| COMPILED C. CONOR | 5.8.80 C.D.O. | DATE |
| DRAWN M. B. | SCALE 1:2500 | |
| DATE 7-3-80 | PLAN NUMBER | |
| CHECKED | 80-629 | |

1820




DISCONTINUITIES

| Type | Average Dip (no. of readings) | Dip Direction (Magnetic) |
|---|---|---|
| Bedding | 30° | 264° |
| Joints J1 | 82°(10) | 340° |
| J2 | 70°(5) | 210° |
| J3 | 88°(6) | 220° |
| J4 | 80°(5) | 100° |

72° Trend and Plunge of wedge failure direction

Fig 3

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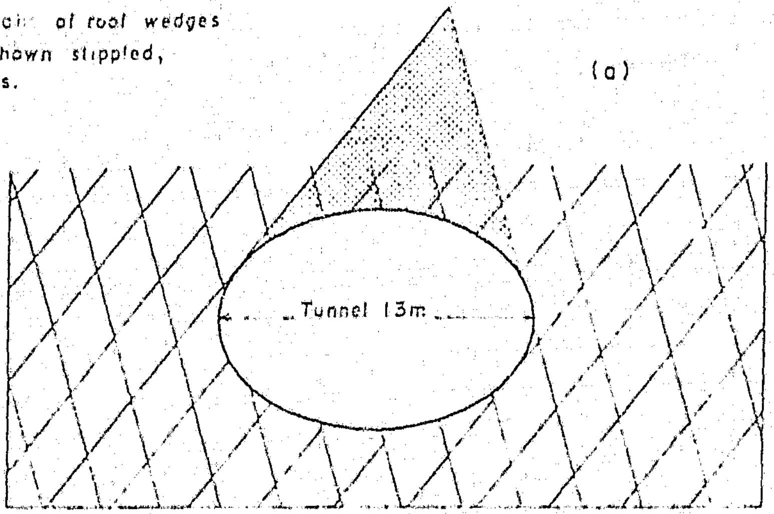
# WYLIE RIDGE TUNNEL - GLEN OSMOND

## ROCK DISCONTINUITY STEREOGRAM

C CONOR
M B
13-6-80
S·8·80
S 14891

Condition for gravity fail of roof wedges
Maximum wedge size shown stippled,
containing small wedges.

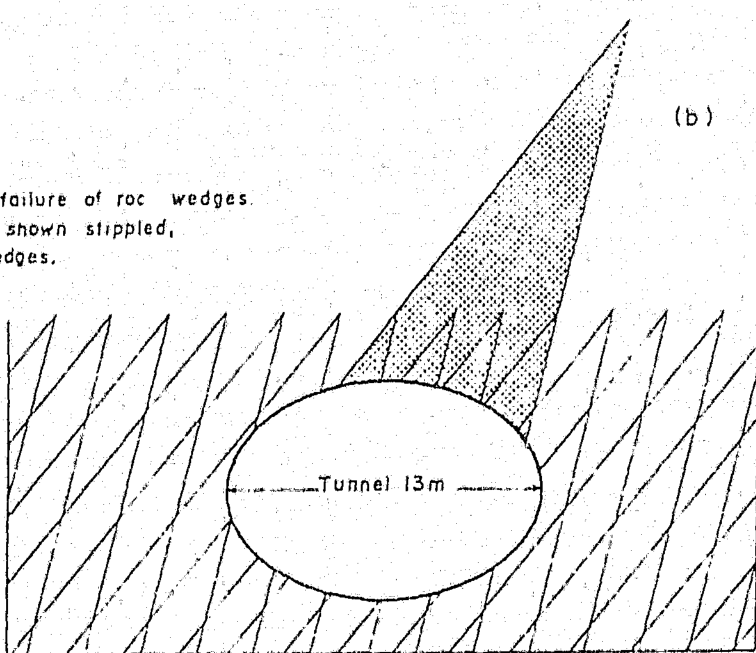
(a)




cf Fig 10,a

(b)

Condition for sliding failure of roc wedges.
Maximum wedge size shown stippled,
containing smaller wedges.




cf Fig 10,b

(c)

Condition for sidewall failure. Example showing bedding and joint controlled block.

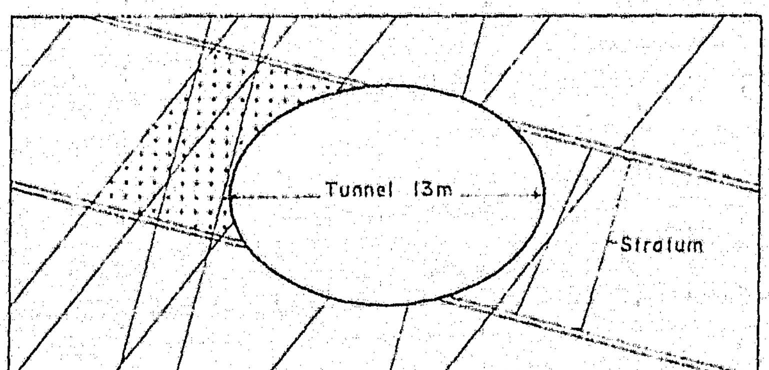
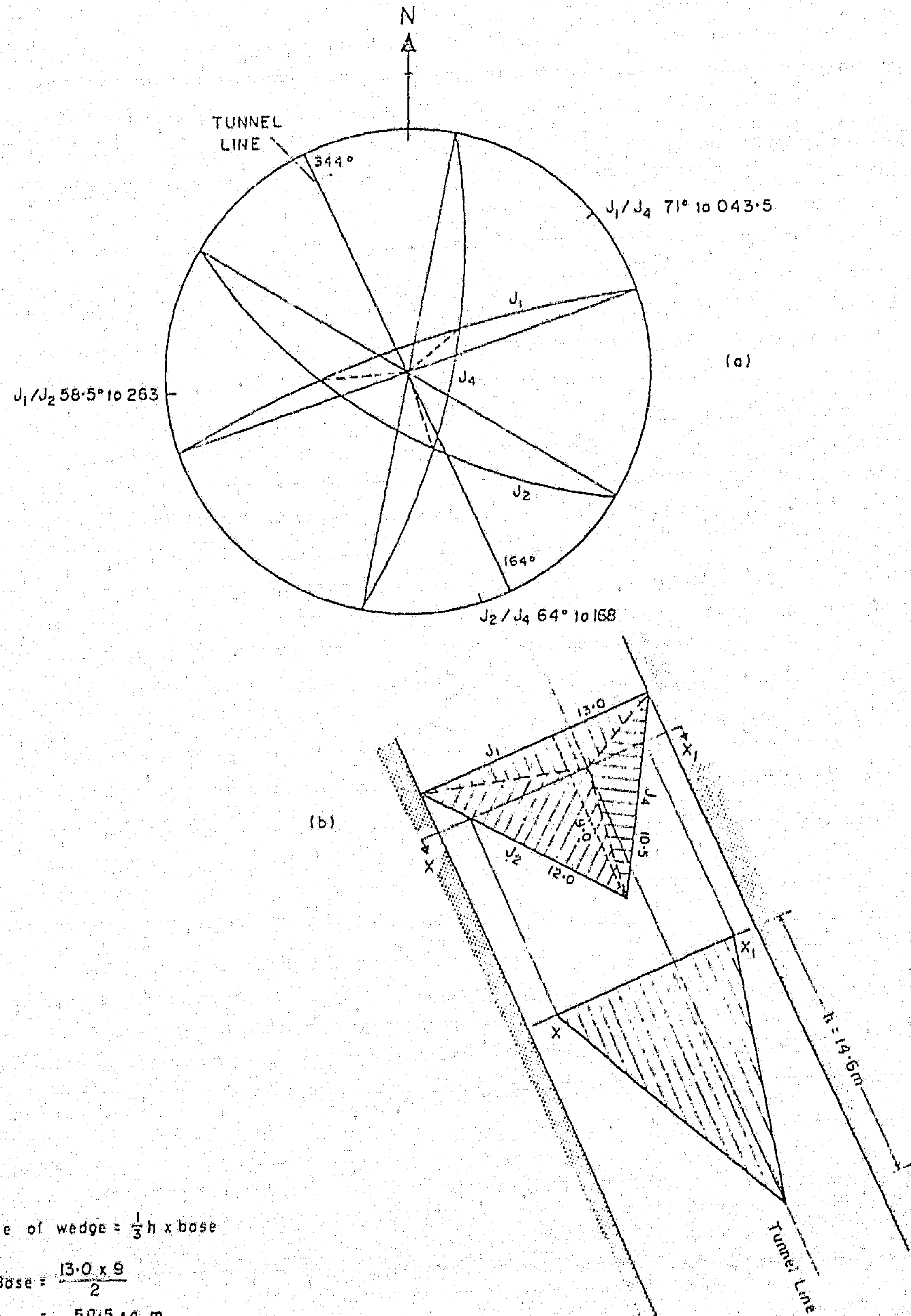



Fig. 3

| | | |
|---|---|---|
| DEPARTMENT OF MINES AND ENERGY<br>SOUTH AUSTRALIA | COMPILED<br>C. CONOR | 27-4-81<br>C.D.G. DATE |
| WYLIE RIDGE TUNNEL — GLEN OSMOND<br>EXAMPLES OF CONDITIONS<br>FOR POTENTIAL WEDGE FAILURES | DRAWN<br>M. B. | SCALE |
| | DATE<br>10-10-80 | PLAN NUMBER<br>S15181 |




(c)

Volume of wedge = $\frac{1}{3}$h x base

$$\text{Base} = \frac{13{\cdot}0 \times 9}{2}$$

= 58·5 sq. m.

$$\text{Volume of wedge} = \frac{14{\cdot}6}{3} \times 58{\cdot}5$$

= 284·9 cu. m

Fig. 4

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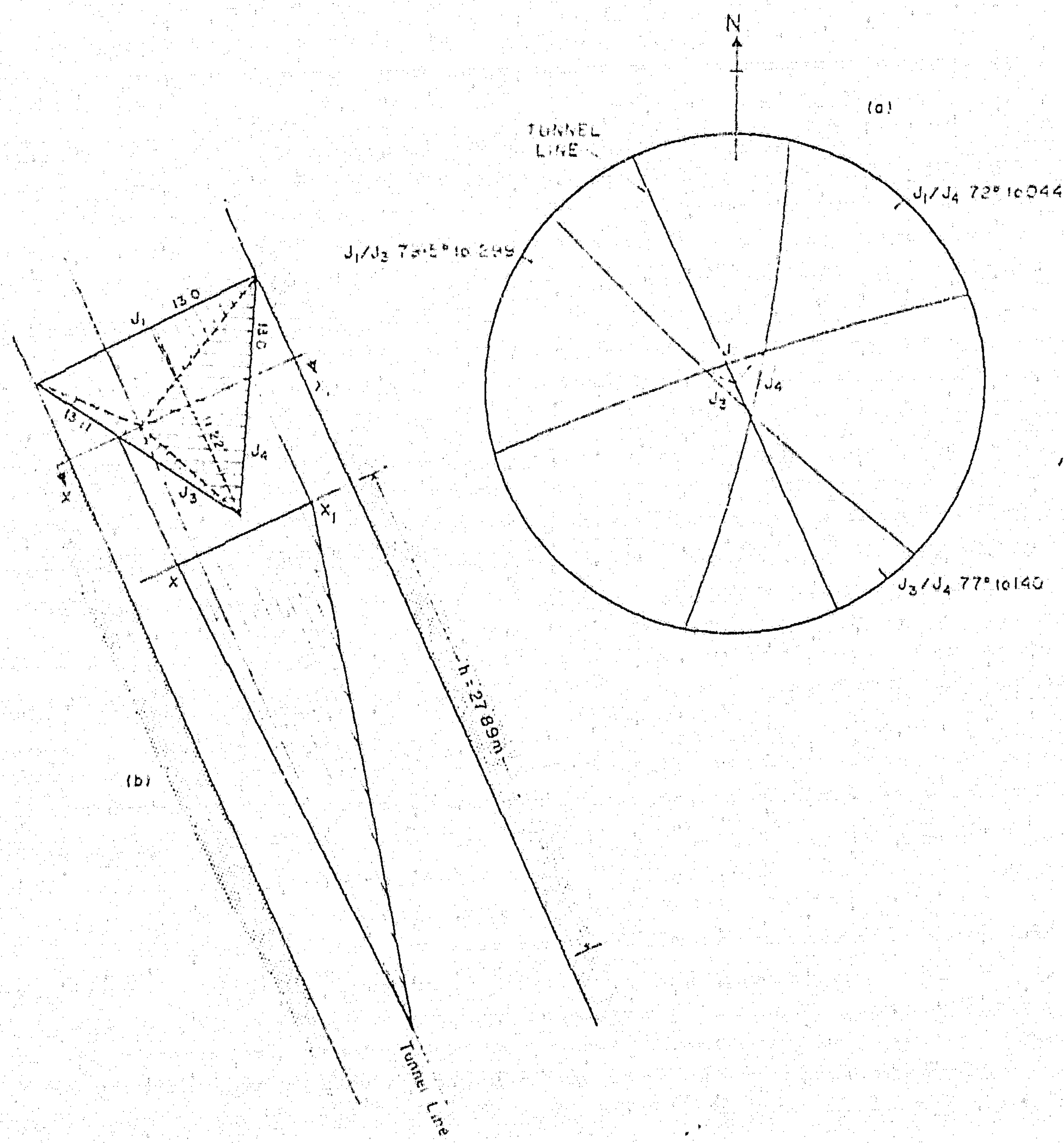
# WYLIE RIDGE TUNNEL – GLEN OSMOND
# GRAVITY FAILURE WEDGE CONTROLLED BY JOINT SETS J1, J2, J4

| | | |
|---|---|---|
| COMPILED C. CONOR | C.D.G. | DATE 27·4·81 |
| DRAWN M. B | SCALE | |
| DATE 16-10-80 | PLAN NUMBER S·15182 | |
| CHECKED | | |




(c)

$$\text{Volume of wedge} = \frac{1}{3} h \times \text{base}$$

$$\text{Base} = \frac{13{\cdot}0 \times 11{\cdot}22}{2}$$

$$= 72{\cdot}93 \text{ sq. m.}$$

$$\text{Volume of wedge} = \frac{27{\cdot}89}{3} \times 72{\cdot}93$$

$$= 678{\cdot}01 \text{ cu. m}$$

Fig. 5

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WYLIE RIDGE TUNNEL – GLEN OSMOND
GRAVITY FAILURE WEDGE
CONTROLLED BY JOINT SETS J1, J3, J4

| | |
|---|---|
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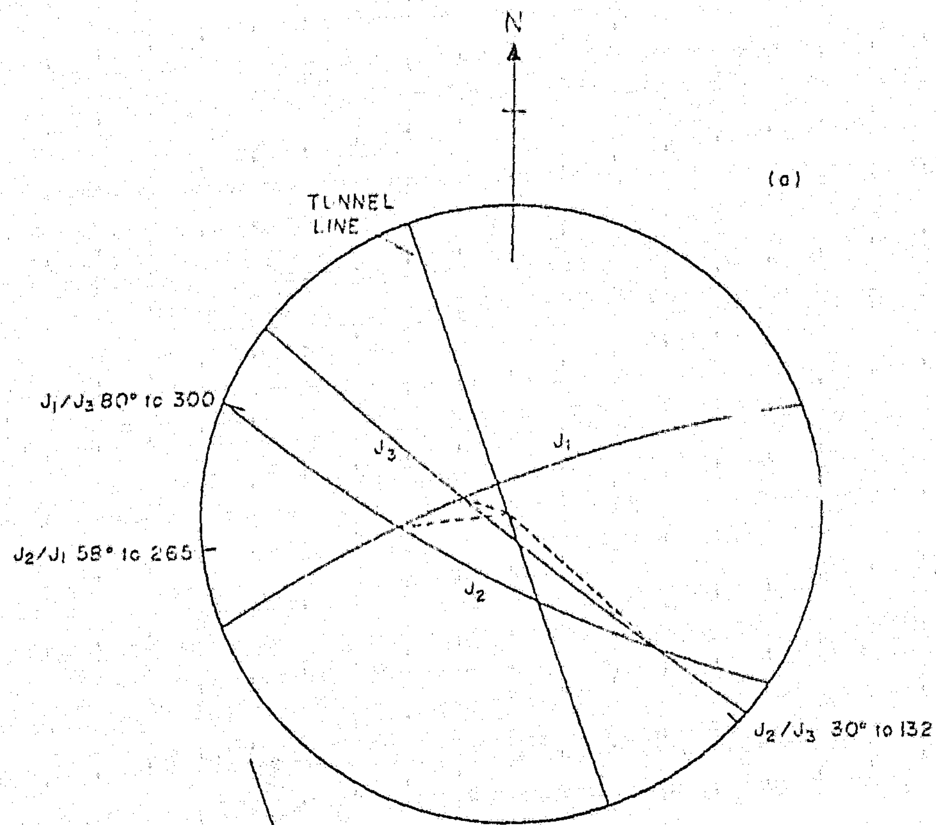
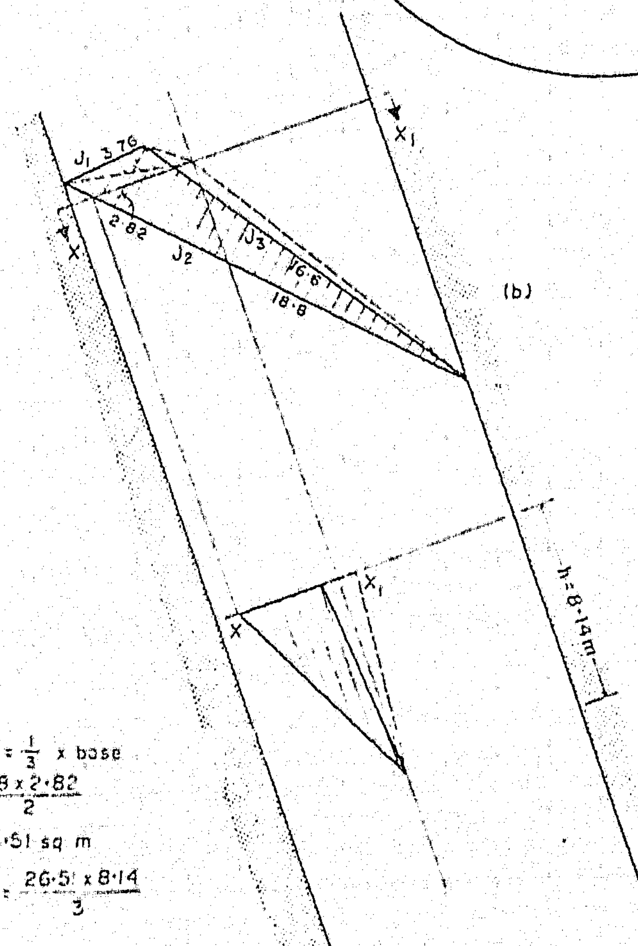
| DRAWN M.B. | SCALE |
| DATE 20-10-80 | PLAN NUMBER S15183 |




(c)

Volume of wedge $= \frac{1}{3} \times$ base

Base $= \frac{18{\cdot}8 \times 2{\cdot}82}{2}$

$= 26{\cdot}51$ sq m

Volume of wedge $= \frac{26{\cdot}51 \times 8{\cdot}14}{3}$

$= 71{\cdot}93$ cu. m

Fig. 6

| | | |
|---|---|---|
| DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA | COMPILED C. CONOR | 27-4-81 DATE |
| WYLIE RIDGE TUNNEL – GLEN OSMOND | DRAWN M.B. | SCALE |
| SLIDE FAILURE WEDGE CONTROLLED BY JOINT SETS J1, J2, J3 | DATE 20-10-80 CHECKED | PLAN NUMBER S15184 |

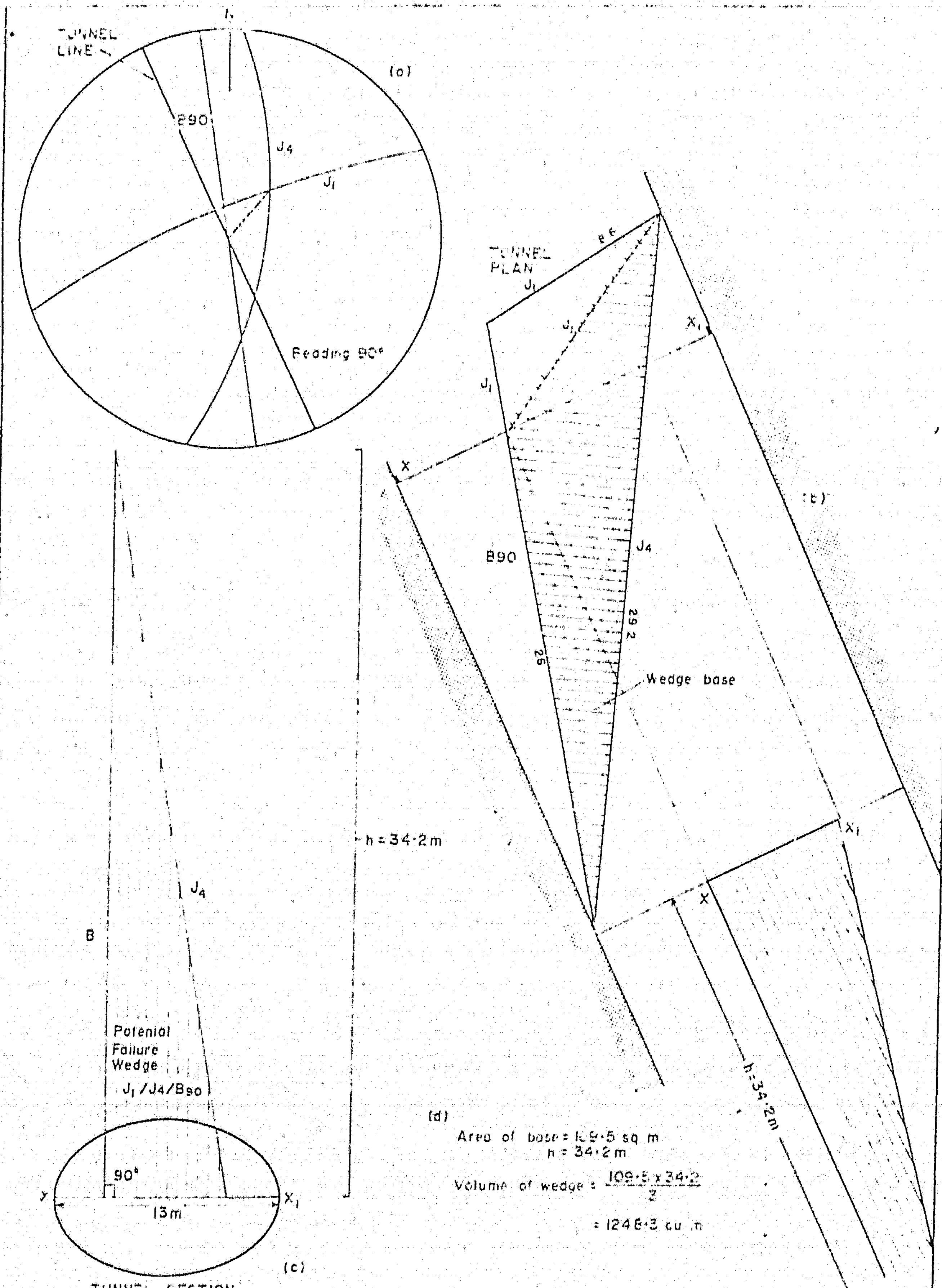



Fig. 7

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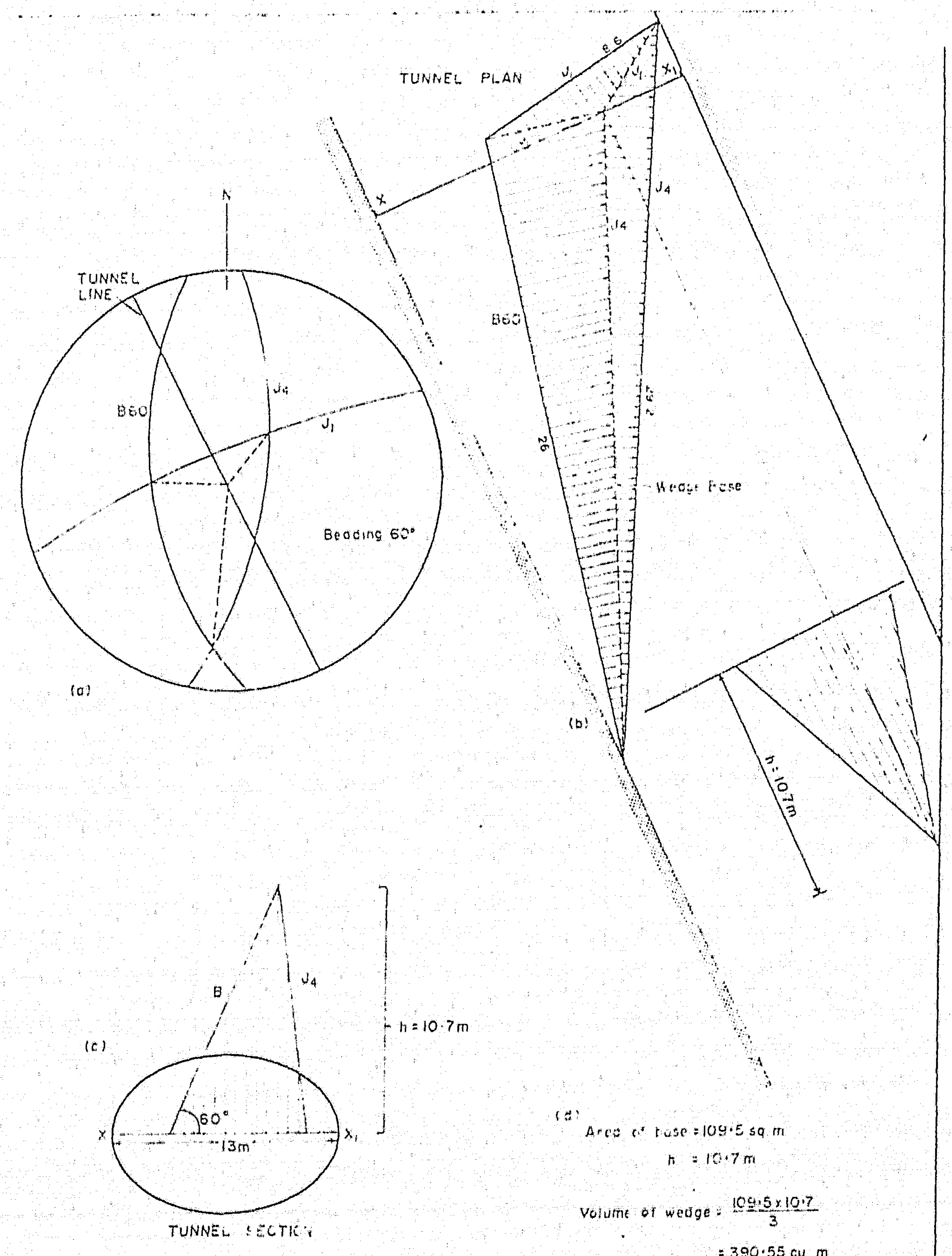
WYLIE RIDGE TUNNEL – GLEN OSMOND
GRAVITY FAILURE WEDGE CONTROLLED BY
JOINT SETS $J_1$ $J_4$ AND VERTICAL BEDDING

| | |
|---|---|
| COMPILED C. CONOR | CDC 27·4·81 DATE |
| DRAWN M. B | SCALE |
| DATE 14-10-80 | PLAN NUMBER |




Area of base = 109·5 sq m

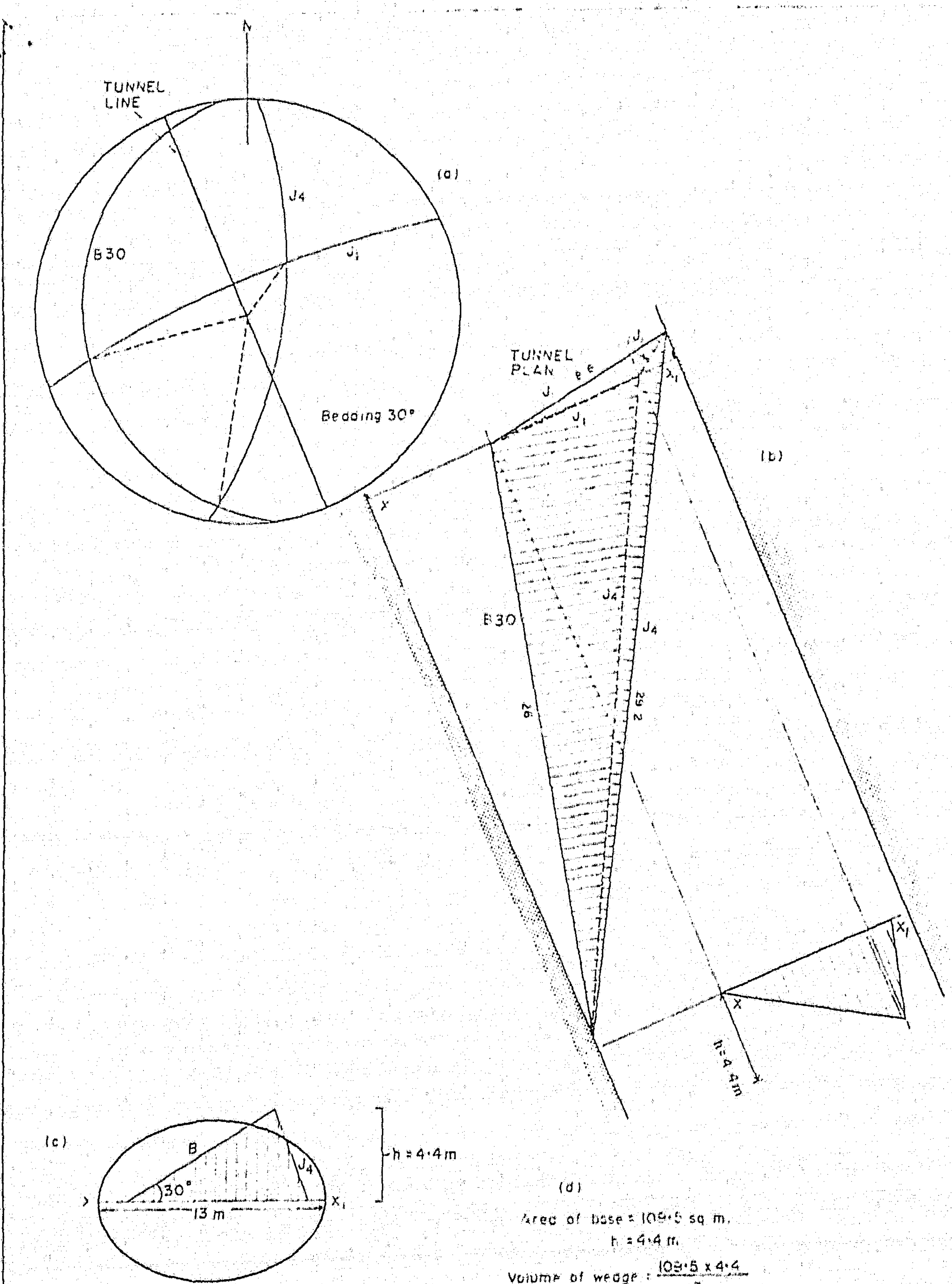
h = 10·7 m

Volume of wedge = $\frac{109{\cdot}5 \times 10{\cdot}7}{3}$

= 390·55 cu m

Fig. 8

| | | |
|---|---|---|
| DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA | COMPILED C. CONOR | C.D.O. 27-11-81 DATE |
| WYLIE RIDGE TUNNEL - GLEN OSMOND GRAVITY FAILURE WEDGE CONTROLLED BY JOINT SETS J1, J4 AND BEDDING 60° WEST | DRAWN M. B. | SCALE |
| | DATE 14-10-80 | PLAN NUMBER S15186 |
| | CHECKED | |




(d)

Area of base = 109·5 sq m.

h = 4·4 m.

Volume of wedge $= \frac{109 \cdot 5 \times 4 \cdot 4}{3}$

= 160·6 cu. m.

Fig. 9

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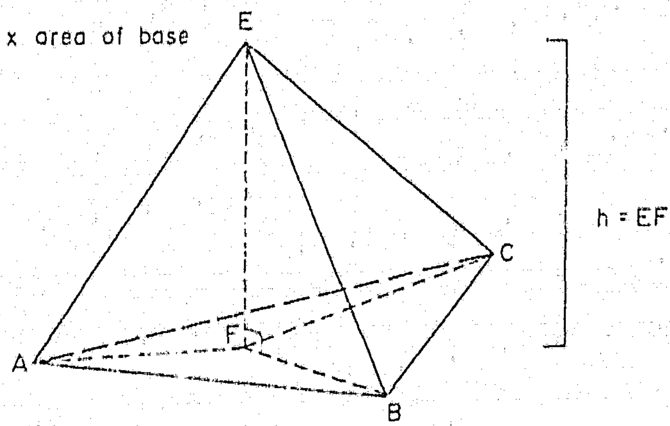
WYLIE RIDGE TUNNEL – GLEN OSMOND
GRAVITY FAILURE WEDGE CONTROLLED BY
JOINT SETS J1, J4 AND BEDDING 30° WEST

| | | |
|---|---|---|
| COMPILED C. CONOR | 27.4.81 DATE | |
| DRAWN M.B. | SCALE | |
| DATE 14-10-80 | PLAN NUMBER | |
| CHECKED | S15187 | |

Volume of wedge = $\frac{1}{3}$ height (h) x area of base

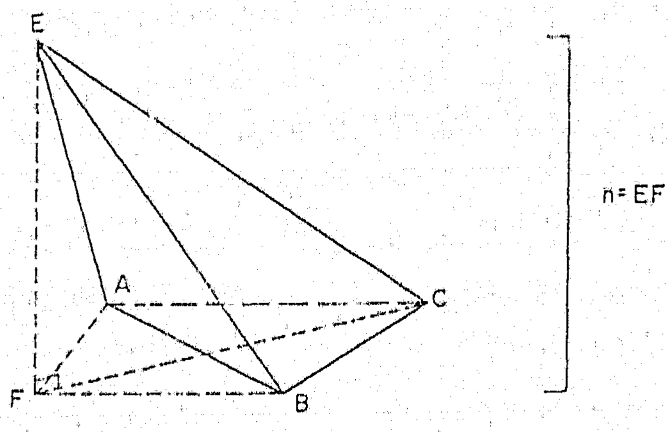
Gravity fall condition




(a)

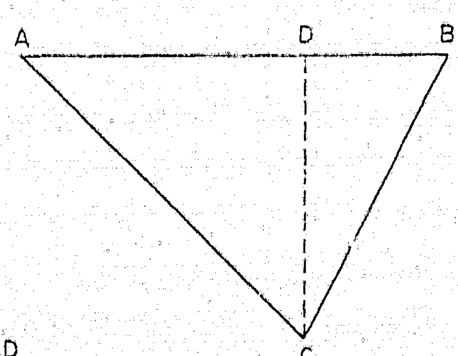
Height (h) of wedge = EF

Sliding failure condition




(b)

Area of base




(c)

Area of base = $\frac{AB \times CD}{2}$

Fig. 10

| | |
|---|---|
| DEPARTMENT OF MINES AND ENERGY<br>SOUTH AUSTRALIA | COMPILED C. CONOR — 27.4.81 |
| WYLIE RIDGE TUNNEL – GLEN OSMOND | DRAWN M.B. — SCALE |
| FAILURE WEDGE, SIZE AND VOLUME CALCULATIONS | DATE 22-10-80 — PLAN NUMBER S 15188 |
| | CHECKED |