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REPORT 60619

NUMERICAL ANALYSIS OF EXPECTED PILLAR STRESSES

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Consulting Engineers

REPORT 60619

NUMERICAL ANALYSIS OF EXPECTED PILLAR STRESSES

Prepared for:

CURRAGH RESOURCES - FARO UNDERGROUND
Box 1000
Faro, Yukon
Y0B 1K0

Prepared by:

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November 15, 1990
Project Number 60619

Curragh Resources
Box 1000
Faro, Yukon
Y0B 1K0

Attention: Leo Hwozdyk

Dear Leo.

RE: FARO UNDERGROUND - NUMERICAL ANALYSIS

Attached is a short report on the numerical analysis work we have carried out for the Faro Underground.

The results confirm our conclusions that stresses in the pillars may be lower than were assumed for the initial design. Once we know a little more about the behaviour of the existing pillars we may be able to translate the results into increased percentage extraction. But we need some visual evidence of pillar stability before this can be done. One should not forget that the modelling process is a gross approximation of reality and is simply one element of the overall design process.

I think it would be appropriate for me to make another visit sometime in late November early December. The opportunity for increased extraction could be discussed at that time.

The results of numerical analysis are not easy to communicate and if there are areas of difficulty please do not hesitate to call me.

Yours truly,

STEFFEN ROBERTSON AND KIRSTEN (B.C.) INC.

Chris Page

Chris H. Page, P.Eng.

CHP/004bm

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CONTENTS

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NUMERICAL ANALYSIS OF EXPECTED PILLAR STRESSES

1.0 SUMMARY

Initial pillar designs for the Faro underground mine have been based on the tributary area method for calculating pillar loads (letter report of June 27, 1990). This method tends to predict conservative pillar stresses as it assumes the mining area extends to infinity and that the entire overburden load is carried by the pillars. In practice, when the abutments are relatively closely spaced, they tend to carry a significant portion of the overburden load reducing the load carried by the pillars. It was agreed that a numerical analysis of the underground mine should be conducted to determine the magnitude of the conservatism in the tributary area calculations of loads.

A numerical model of the operation was constructed, to determine the stresses in an elastic pillar, including the stress variations caused by the open pit and assumed in-situ stresses. The numerical model was constructed using data provided by Curragh Resources in conjunction with the BEAP-M (combined boundary element, displacement-discontinuity element) three dimensional stress analysis package. Only the South Extension was modelled.

Results indicate that, for an in-situ stress field of 1.5:1 horizontal to vertical stress ratio, the pillar stresses in the area underneath the original topography (i.e. removed from the pit vicinity) should be about 15% less than predicted by tributary area method. The pillar safety factor of 1.5 calculated using tributary area loads would become a safety factor of approximately 1.7 using the numerical analysis stresses.

2.0 BASE DATA

The ultimate pit contours and underground plan layout were provided as PC-MINE plot files by Ian Bilquist of Fox Geological (Curragh Resources). These files were then converted to AUTOCAD drawing files, the pit translated and rotated into the underground coordinate system, and overlain. The resulting composite drawing is shown as Drawing 1. This map formed the basis for the geometric modelling of the operation.

The orebody was modelled by fitting a plane to the hanging wall contours as provided in the geologic model. The true thickness of this plane was taken to be 30 feet.

Material properties assumed for the model were as follows:

- Modulus of elasticity

Ore	15 GPa
Host rock	5 GPa

- Unit weight

Host rock	170 pounds/cubic foot

- Poisson's ratio

Ore	.22
Host rock	.22

An in-situ stress field with the stress ratio of 1.5 horizontal to 1 vertical was assumed. The vertical stress was calculated from normal gravity loading on the rock mass.

Although the above values are approximate, they are consistent with what may be expected given this geology. The model may be analyzed as to sensitivity to the above given parameters, but this was not deemed necessary at this stage.

3.0 NUMERICAL ANALYSIS

The analysis was carried out using the program BEAP-M, developed by J.A.C. Diering of Steffen, Robertson, and Kirsten Inc. for CANMET. This program combines two types of numerical analysis techniques. The displacement/discontinuity method is used for modelling underground seams, in this case the massive sulphide. The boundary element method is used for modelling surfaces, in this case the open pit and surrounding ground surface.

The surface boundary element mesh is shown as Drawing 2. The base elevation modelled in the pit is 3400 feet. Original surface topography (the crest of the pit) is taken to be a plane at 4000 feet elevation. This planar assumption will have little impact on the results given other generalizations in the mesh generation.

The mesh and assumed mining layout for the displacement/discontinuity grid is shown as Drawing 3. A 75% extraction ratio was used. Pillar dimensions of 30 feet wide by 30 foot long by 30 foot tall were assumed. Although this deviates slightly from the exact pillar design, it is sufficiently representative to calculate the expected stresses for a large excavation such as this.

4.0 RESULTS

A plan view of the underground layout and the stresses expected in each pillar (in MPa) is shown in Drawing 4. Isometric views of the underground mine in relation to the open pit are shown as Drawings 5 and 6.

A comparison of tributary area stresses with those predicted by the numerical model is shown as Figure 1. The stresses depicted in this graph for the numerical case were taken along an approximate centerline of the underground mesh parallel to the long axis of the mesh.

The vertical pillar stress is about 30% higher than that predicted by tributary area loading immediately under the pit wall. This is due to the "flow" of stresses around and under the pit excavation. However, as the distance from the pit increases, the vertical pillar stress decreases to approximately 85% of that calculated by the tributary area method. This decrease may be explained by the arching action of the rock over the excavation.

The latest pillar design (letter report 27/06/90) was based on a design depth of 590 feet. This translates into a vertical in-situ stress of 5.40 MPa (780 psi). The numerical analysis indicates that, at this depth, the in-situ stress for pillar loading analysis would be 4.65 MPa (675 psi). The pillars, which were designed to have a safety factor of 1.5 using tributary area loading, would have a safety factor approximately 1.7 using the numerical analysis results.

Some caution must be used in analyzing these results. The pillar and associated span were modelled as one displacement-discontinuity element apiece. This modelling technique may give slightly higher (conservative) pillar stresses than actually exist. More, and smaller, elements give a better approximation of the true stress field.

The rock mass has also been assumed to be elastic. Although this is not entirely correct, it should be within the bounds of accuracy for this analysis given the uncertainty in the input data. The area which would be most affected by this assumption would be the area between the pit wall and the underground excavation where plastic deformation may occur. This would contribute to a decrease in vertical stresses in this localized area.

Another possible concern is the large shear stresses which may be developed on the interface between the massive sulphide and the hanging wall material at the point of pillar contact. This may result in a rotational/shear failure mode and should be considered during underground visual monitoring.

Although the pillars designed using the tributary area method may be slightly conservative when compared to numerical analysis the variability of the rock mass is such that we recommend no change in the pillar design approach outlined in our previous communications.

This report, 60619 - Numerical Analysis of Expected Pillar Stresses - is respectfully submitted by:

STEFFEN, ROBERTSON AND KIRSTEN (B.C.) INC.

C.H. Page, P. Eng.

J.I. Mathis

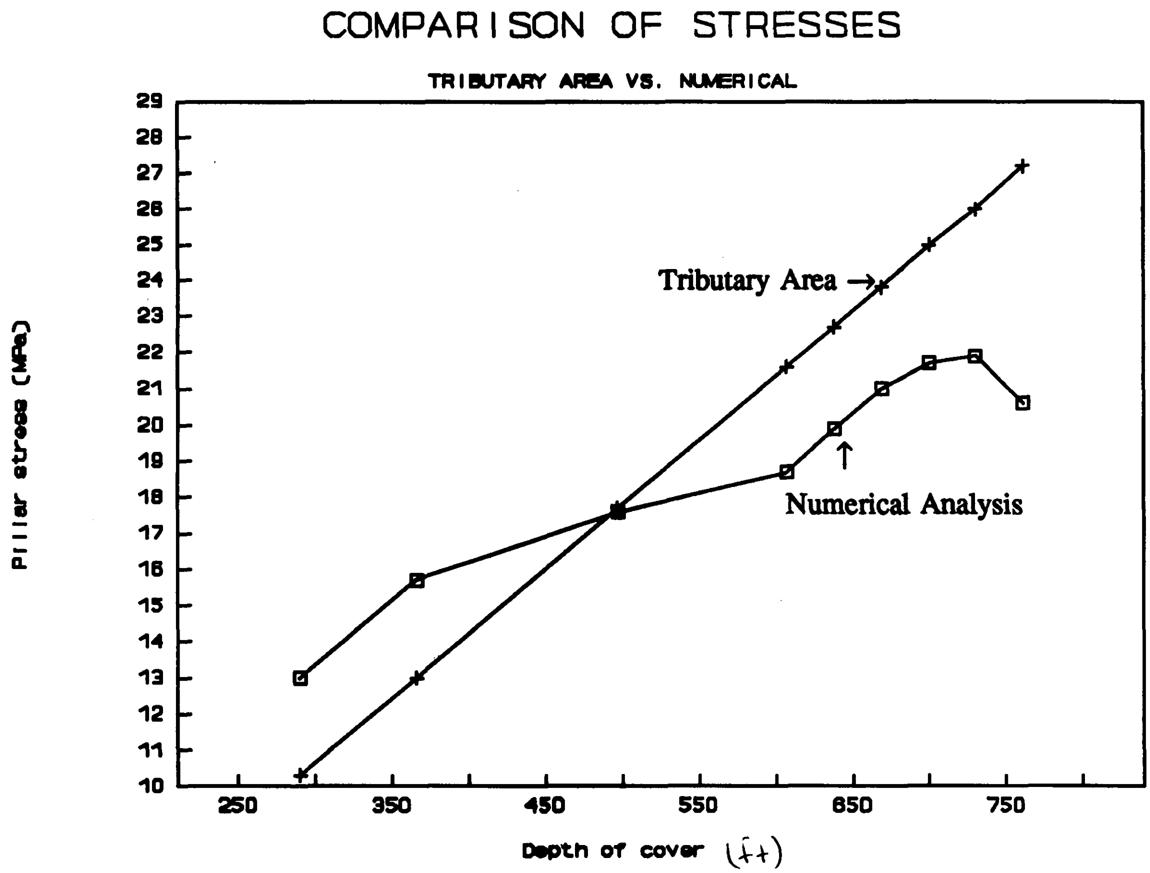
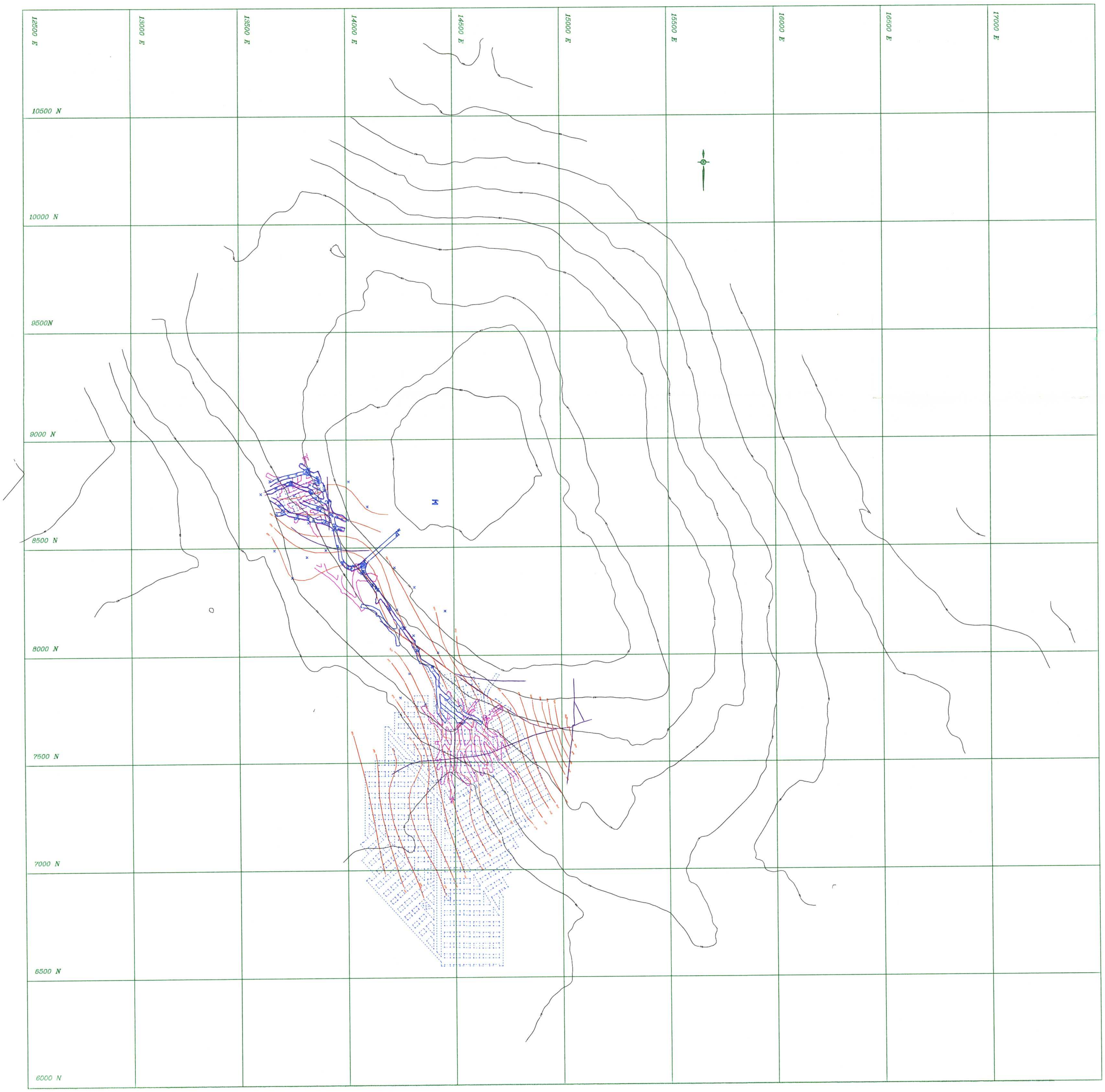

COMPARISON OF STRESSES
TRIBUTARY AREA VS. NUMERICAL
Pillar stress (MPa)
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
250
350
450
550
650
750
Depth of cover (ft)
Tributary Area
Numerical Analysis

FIGURE 1



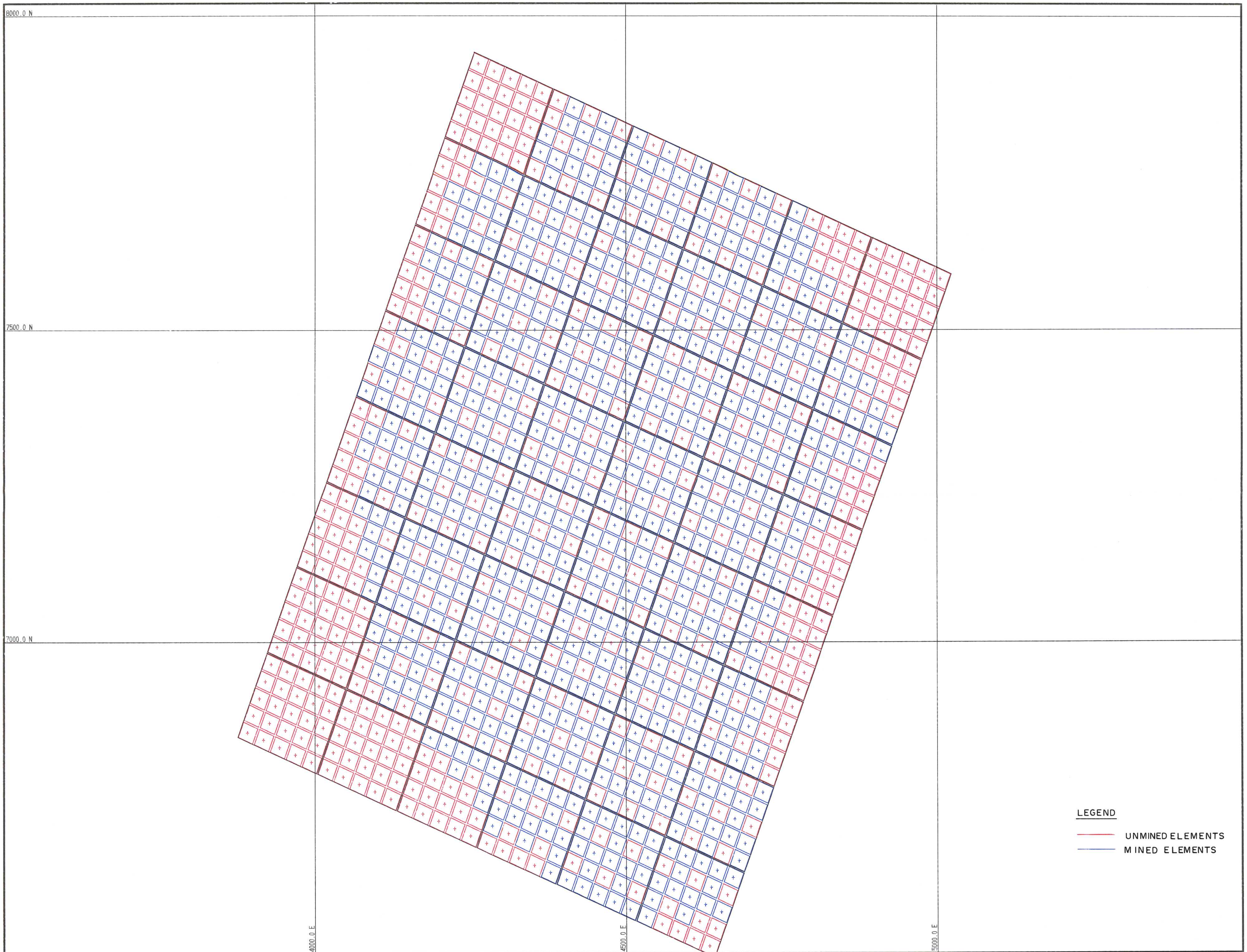
12500 E
13000 E
13500 E
14000 E
14500 E
15000 E
15500 E
16000 E
16500 E
17000 E
10500 N
10000 N
9500N
9000 N
8500 N
8000 N
7500 N
7000 N
6500 N
6000 N

DRAWING NO. 1

QUICK-PLOT GEMCOM Services Inc.	DATE = 09-11-90 TIME = 08:50:06	S.R.K. (BC) INC. VANCOUVER OFFICE	Faro open pit Boundary element mesh Mine layout as modelled
HORIZONTAL SCALE =	1 : 4800	VERTICAL SCALE = 1 : 4800	

DRAWING NO. 2

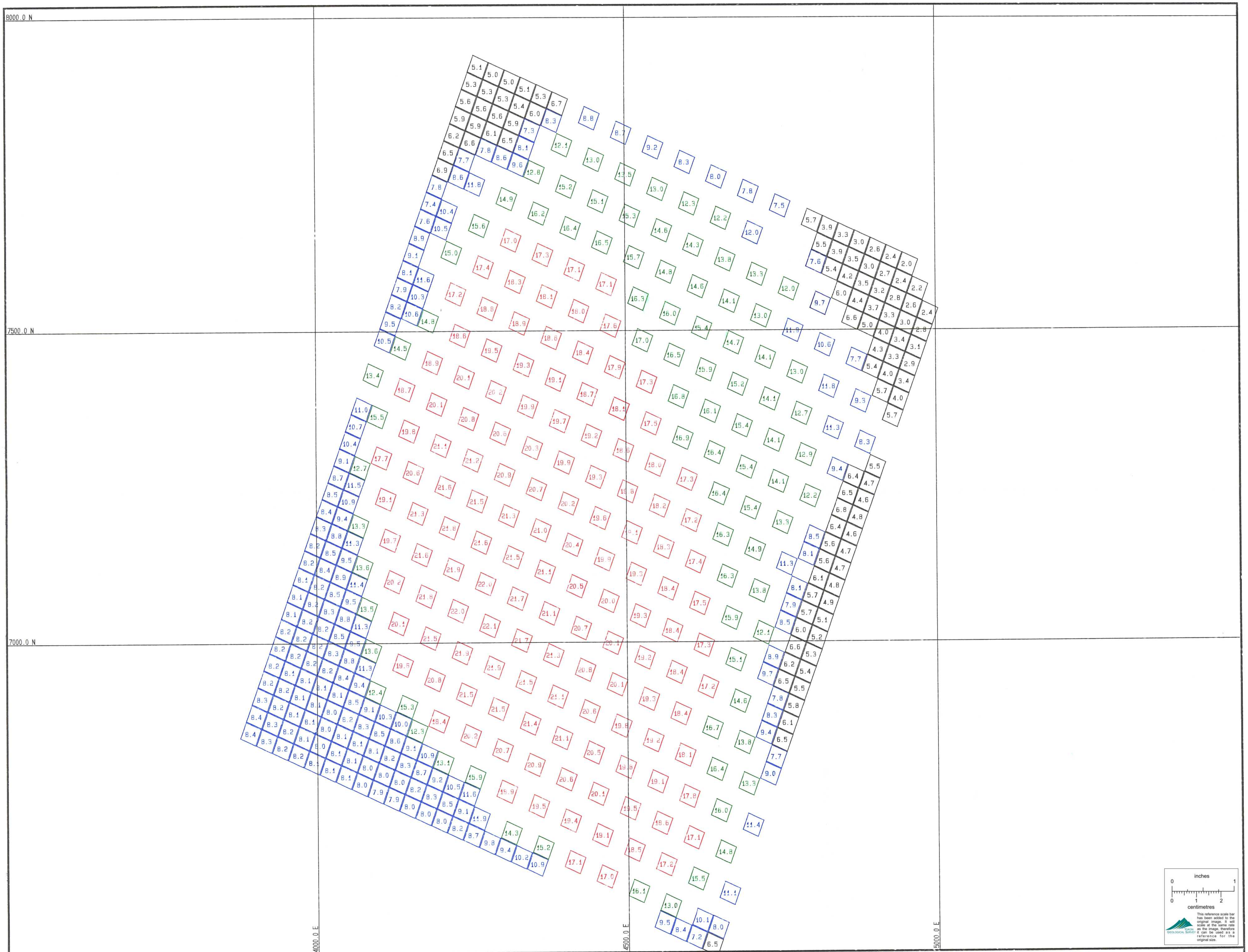
inches 0 1 2
0 1 2 3 4 5 centimetres



QUICK-PLOT GEMCOM Services Inc.	DATE = 09-11-90 TIME = 08:46:06	S.R.K. (BC) INC. VANCOUVER OFFICE
HORIZONTAL SCALE = 1 : 1200		VERTICAL SCALE = 1 : 1200

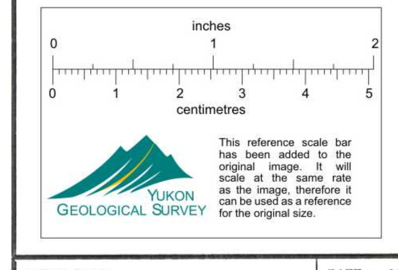
Faro underground
Underground displacement-discontinuity mesh
Mine layout as modelled

DRAWING NO. 3



QUICK-PLOT GEMCOM Services Inc.	DATE = 08-11-90 TIME = 09:06:23	S.R.K. (BC) INC. VANCOUVER OFFICE	Faro underground Induced pillar stresses at H:V = 1.5:1
HORIZONTAL SCALE =	1 : 1200	VERTICAL SCALE = 1 : 1200	

DRAWING NO. 4



QUICK-PLOT GEMCOM Services Inc.	DATE = 08-11-90 TIME = 09:15:25	S.R.K. (BC) INC. VANCOUVER OFFICE	Faro underground Induced pillar stresses at H:V = 1.5:1 Open pit and underground workings as modelled
HORIZONTAL SCALE = 1 : 1200		VERTICAL SCALE = 1 : 1200	

DRAWING NO. 5

This reference scale bar has been added to the original image. It will scale at the same rate as the image, therefore it can be used as a reference for the original size.

YUKON GEOLOGICAL SURVEY

DRAWING NO. 6

QUICK-PLOT GEMCOM Services Inc.	DATE = 08-11-90 TIME = 09:12:12	S.R.K. (BC) INC. VANCOUVER OFFICE	Faro underground Induced pillar stresses at H:V = 1.5:1 Open pit and underground workings as modelled
HORIZONTAL SCALE =	1 : 2400	VERTICAL SCALE = 1 : 2400	