

EIS 1420

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Elura Mine subsidence, 16 & 17 March 1996 : report



**ELURA MINE SUBSIDENCE
16 & 17 MARCH 1996**

REPORT

by

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Chief Inspector of Mines
Department of Mineral Resources, NSW**

at the direction of

**The Hon. Bob MARTIN, MP
Minister for Mineral Resources
Minister for Fisheries**

NSW DEPARTMENT OF
MINERAL RESOURCES

7 JUL 2003

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EXECUTIVE SUMMARY

A major collapse of ground occurred at the Elura Mine over the weekend of 16, 17 March 1996. At the direction of the Minister I investigated the incident. It was fortunate that no-one was injured in the collapse. Even so, it was such a significant occurrence as to warrant close attention.

At its simplest the collapse was caused ultimately (some nine months later) by the removal of a rib pillar of ore between two underground stopes one of which had almost been depleted of ore while the other had been mined and then filled with wet soft rock. Pillar recovery is a common imperative for mines. The circumstances of this pillar recovery were unique: it was the first pillar fired adjacent to a wet filled stope.

Part of the pillar was fired while part was left. However, the unfired part collapsed and the wet fill flowed from the one stope into the other. A large span was created across the two stopes and the intervening pillar area. This span appeared to stabilise quickly - within days of the pillar collapse.

Some nine months later, without warning and without an apparent trigger the ground above the large opening collapsed. The airblast from the falling ground and the ejection of fill material from overlying stopes at level openings between the area of collapse and the surface would have killed people had they been in the area at the time. Some people were underground at the time but were not in danger areas. Escape from the mine was conducted in an exemplary manner.

The decision to fire part of the pillar was deliberate and involved key operators. The decision did not have everyone's commitment. Nevertheless, it appears to have been accepted because avenues to review the decision were not followed: that is, any objection was not registered with either the employees representative Check Inspector nor with the local Inspector of Mines.

(ii)

A collapse through to the surface was not identified as a risk by anyone at any time. Some precautions were taken relating to the possibility of a limited collapse immediately after the pillar firing and for regular visual monitoring after that (and up until the time of collapse). Geomechanic expertise was engaged to assist in stability evaluation.

In two events crown pillars above stopes and unmined ground above the top stope collapsed through to the surface. In the first event, stope fill from overhead stopes on Nos. 2, 3 Levels ran into the largely open stope on No. 4 Level. Approximately a day and a half later the ground from the top of the No. 2 Level stopes collapsed through to the surface.

The weekend of the collapse separated the end of a 5-day 8 hour shift roster system and the beginning of a 7-day 12 hour shift roster system: ie the mine would produce ore continuously with mining crews working 4, 12 hour shifts then having 4 days off and so on. This change was not universally liked: it added a complexity to the investigation but it did not have an obvious impact on my inquiries.

Having reviewed all the circumstances, and concluding that the mine's risk management and communication processes need significant improvements, I am, however, of the opinion that there are evidentiary difficulties which would be hard to overcome in proving an offence. The relative effectiveness of a prosecution is also questionable.

Pasminco Mining, owners of the Elura Mine, have since adopted a formalised risk management approach and have been determined to improve their communication processes.

Following the collapse, mining was suspended until urgent precautions were taken and measures adopted in other parts of the mine where there was any possibility of a similar collapse. Directions from the Inspectorate confirmed these actions. Regular re-examination of the event and progress against these directions will soon culminate in a review on site including management, miners and the Inspectorate.

(iii)

A Significant Incident Report was circulated widely after the event to warn others that airblast and stope fill ejection can have profound impacts.

The Inspectorate is moving to a new style of operation which will help its oversighting of situations like this one.

ACKNOWLEDGMENT

I acknowledge Pasminco's permission to incorporate their Geomechanic's report into this report.

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BACKGROUND

The Elura mine owned by Pasminco Mining, is situated about 50 km North North West of Cobar. It is an underground mine, producing mainly zinc and lead concentrates from massive sulphides in siltstone-slate host rocks. Operations at the time were concentrated on Nos. 4, 5 and 6 Levels from Long Hole Open Stopes.

Stopes are progressed in an East-West direction across the orebody and are separated by rib pillars. Stopes are about 30 m wide while rib pillars are about 12 m wide. Rib pillars between primary and secondary stopes have previously been extracted by firing the pillar into the secondary stope with the primary stope having been filled with cemented fill. No. 4/8 rib pillar was the first attempt at recovering a rib pillar against a stope which had been filled with uncemented fill. Crown pillars separating stopes in the vertical direction were planned to be extracted later in the mine life.

On 16 March 1996, some nine months after 4/8 rib pillar was fired, the crown pillar which effectively spanned 4/7 to 4/9 stopes failed. Fill material in stopes on Nos. 2, 3 Levels fell through to the void in 4/7 to 4/9 stopes.

On 17 March 1996 the ground between the 2 Level stopes and the surface collapsed into the void created the day before.

The collapse had no apparent trigger, although there was a suggestion that rock joints may have been lubricated by localised water movement. While a partial collapse was likely, no-one foresaw the extent of the subsidence which occurred. Time is a common factor in ground instability.

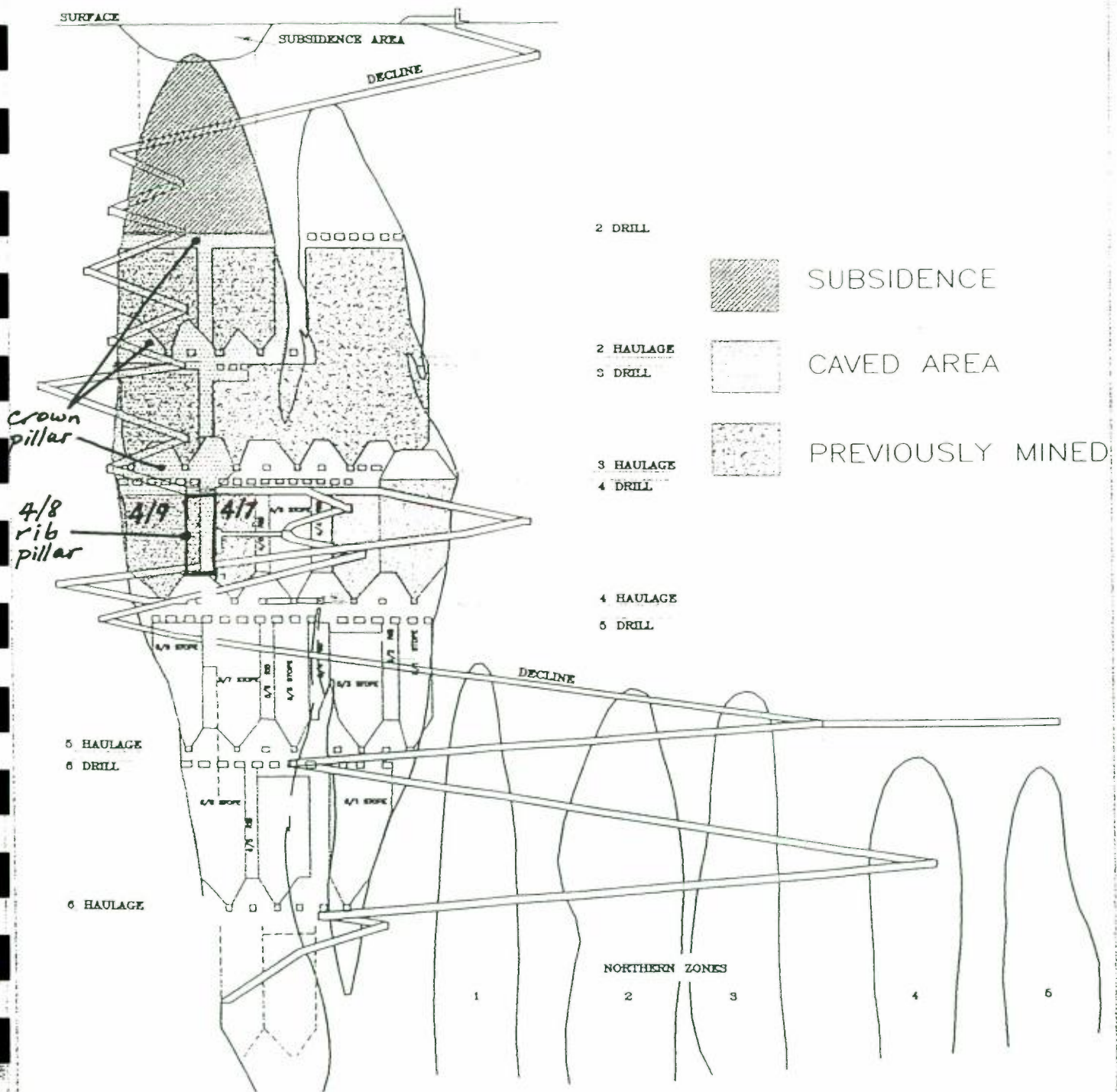
Further background is well set out in the Geomechanic's report appended to this report.

During my inquiries I spoke to all people reasonably connected with the collapse, including miners and management. I have had the benefit of geotechnical assessments and accept the advice of Messrs O'Bryan and Rosengren (I have a Masters degree in mining geomechanics).



ELURA MINE

COBAR, N.S.W.
PASMINGCO MINING



SECTION THROUGH ELURA OREBODY LOOKING WEST

ISSUES

Key issues arising from the collapse include:

1. lessons from the collapse itself - in particular the nature of the airblast, its power and the extraordinary behaviour of ejected material in an air-mobilised flow travelling considerable distances from stope openings;
2. the mine's risk management and people management practices - given the possibility of a partial collapse;
3. lessons for the inspectorate - supporting recent developments away from prescriptive regulations and for training in risk management. A critical problem with prescriptive legislation is a focus on legal requirements rather than on risk control. However, it is clear, given our lack of recognition of the potential for such an incident that we have further progress to make.

COLLAPSE ISSUES

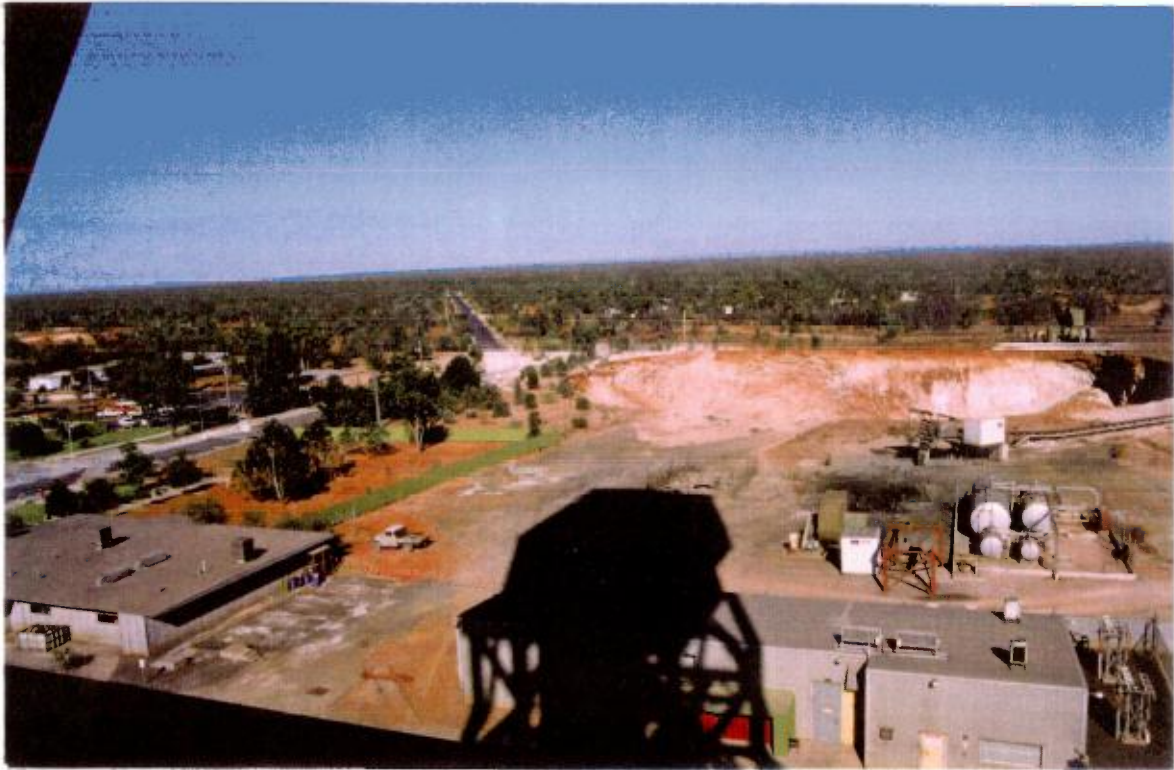
A report of the incident has been circulated via inspectorates in other States/Territories as a warning of:

1. airblast damage potential;
2. air-mobilisation of fill material being ejected at considerable velocity and volume from stope openings;
3. the need for risk **management** of significant hazards; and
4. ground stability deterioration with time.



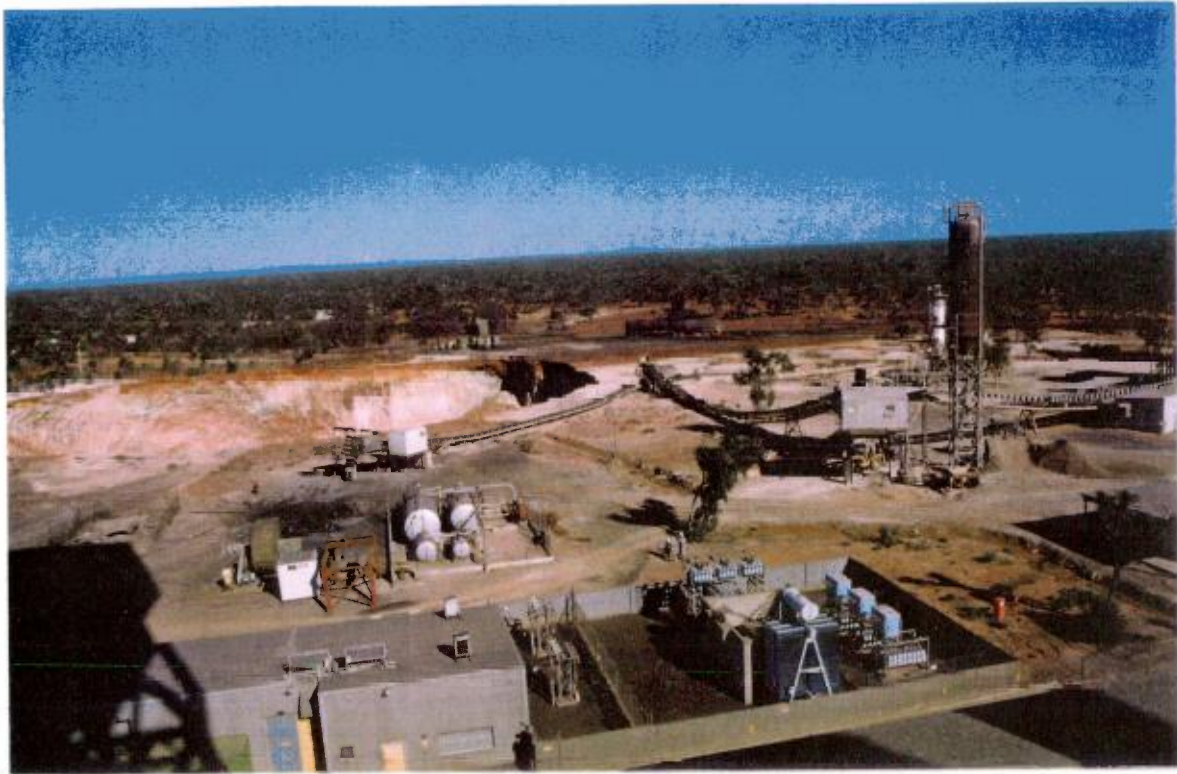
18 March 1996

Road near Elura gate
Showing flyrock from rock fall

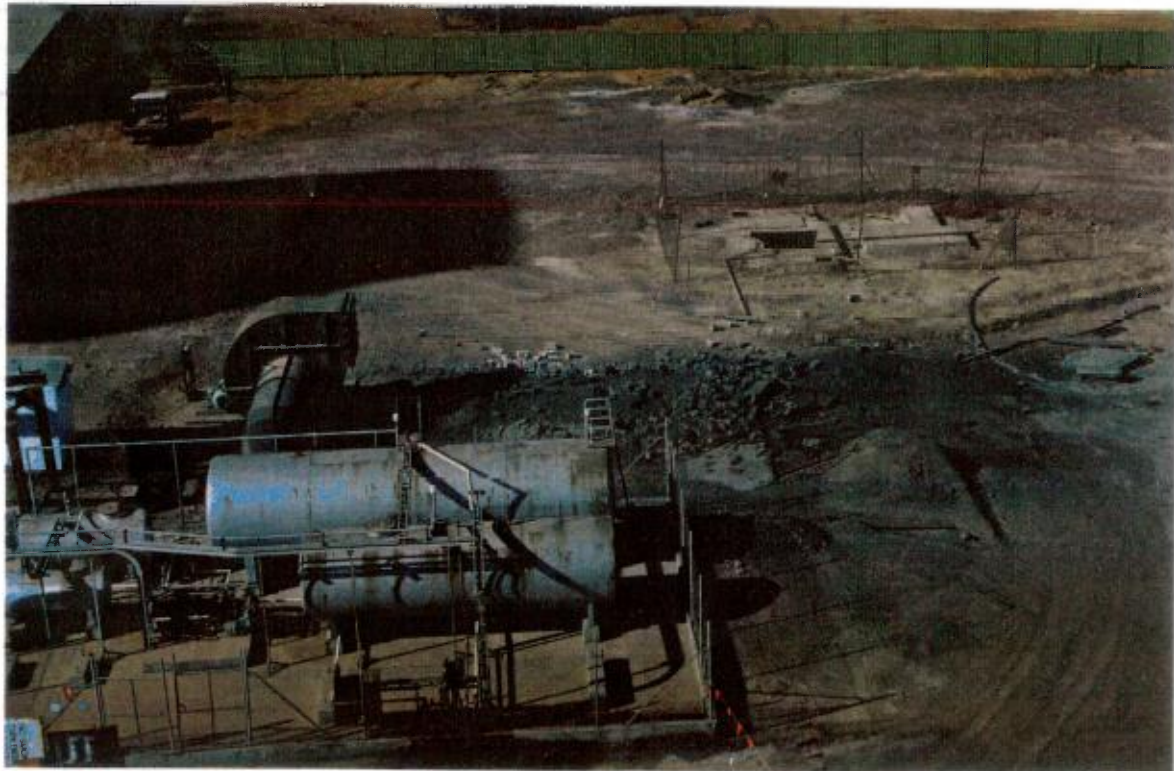


18 March 1996

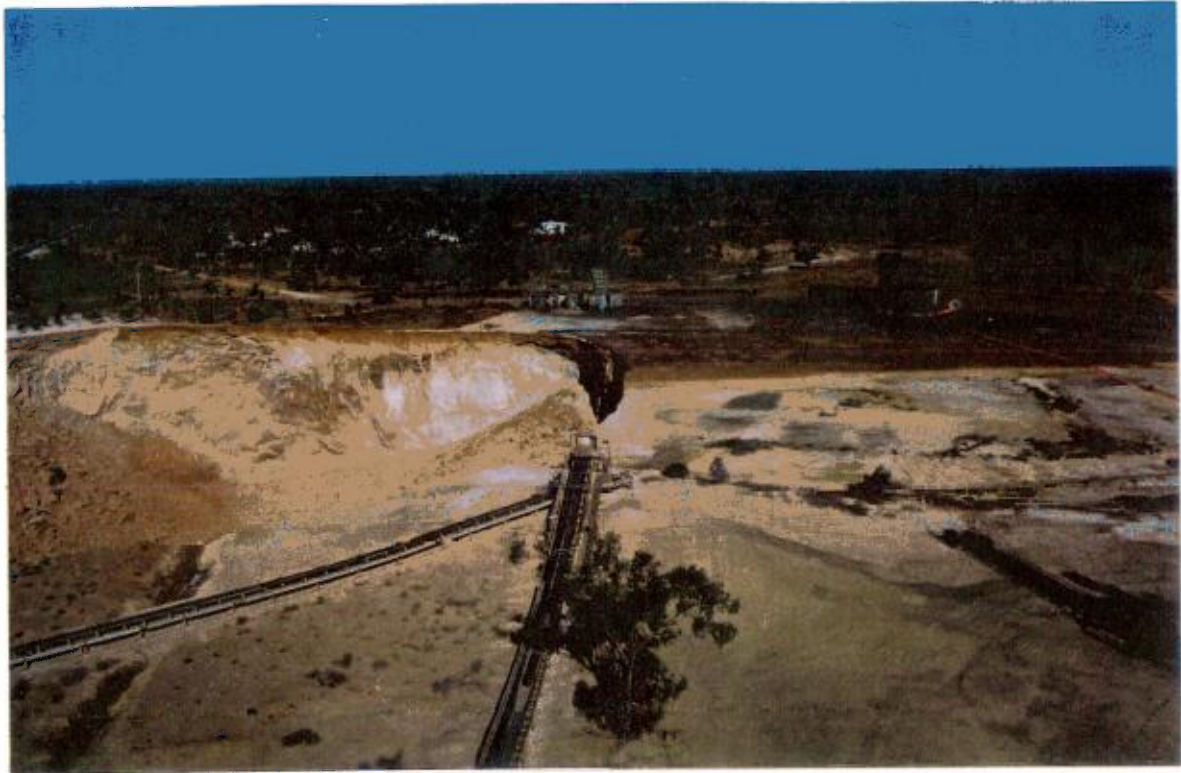
Subsidence looking West from Headframe



18 March 1996 Subsidence looking West from Headframe



18 March 1996 Damage to Wall Infront of Allied Vent Fan



18 March 1996 Subsidence from Cement Silo looking West

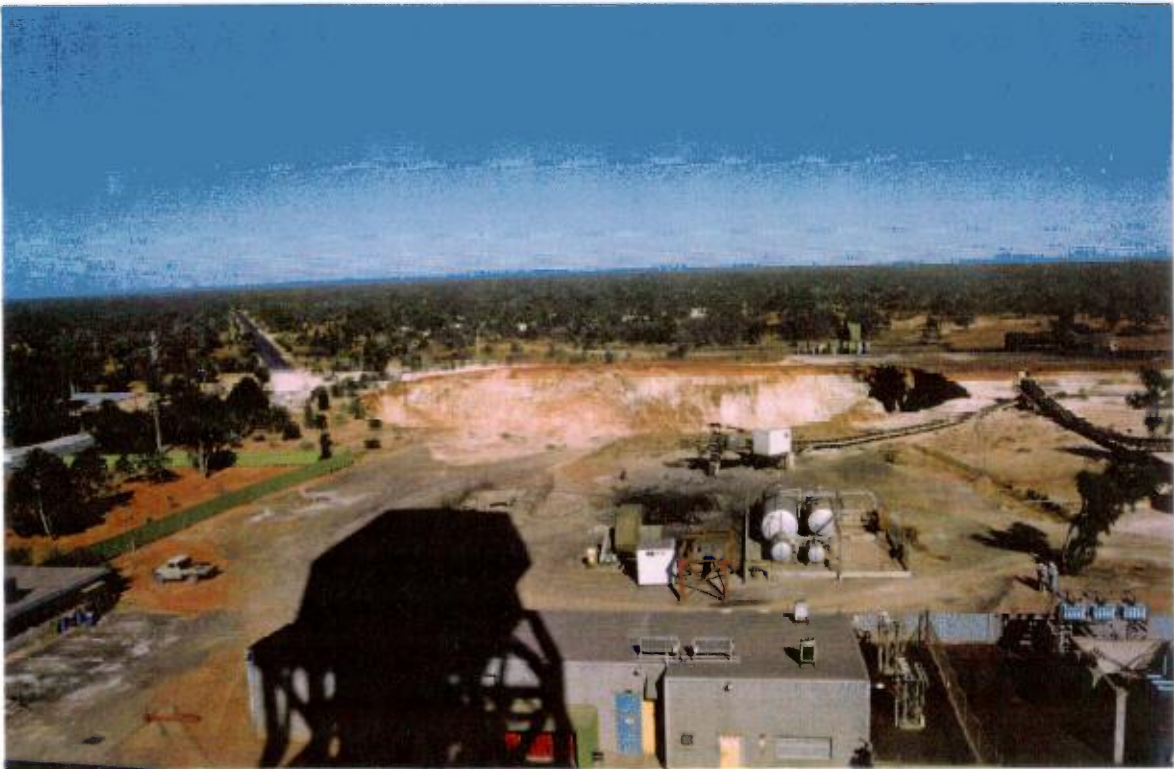


18 March 1996 Subsidence looking West from Cement Silo



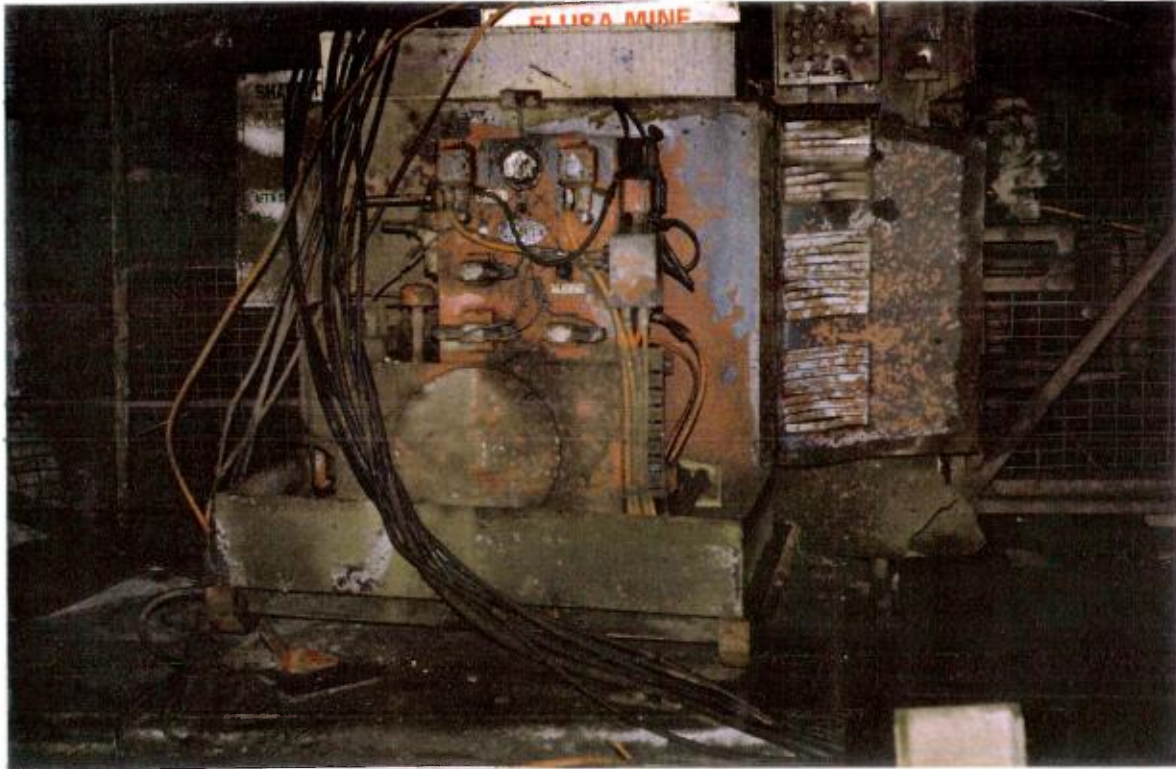
18 March 1996

Subsidence looking West from Headframe

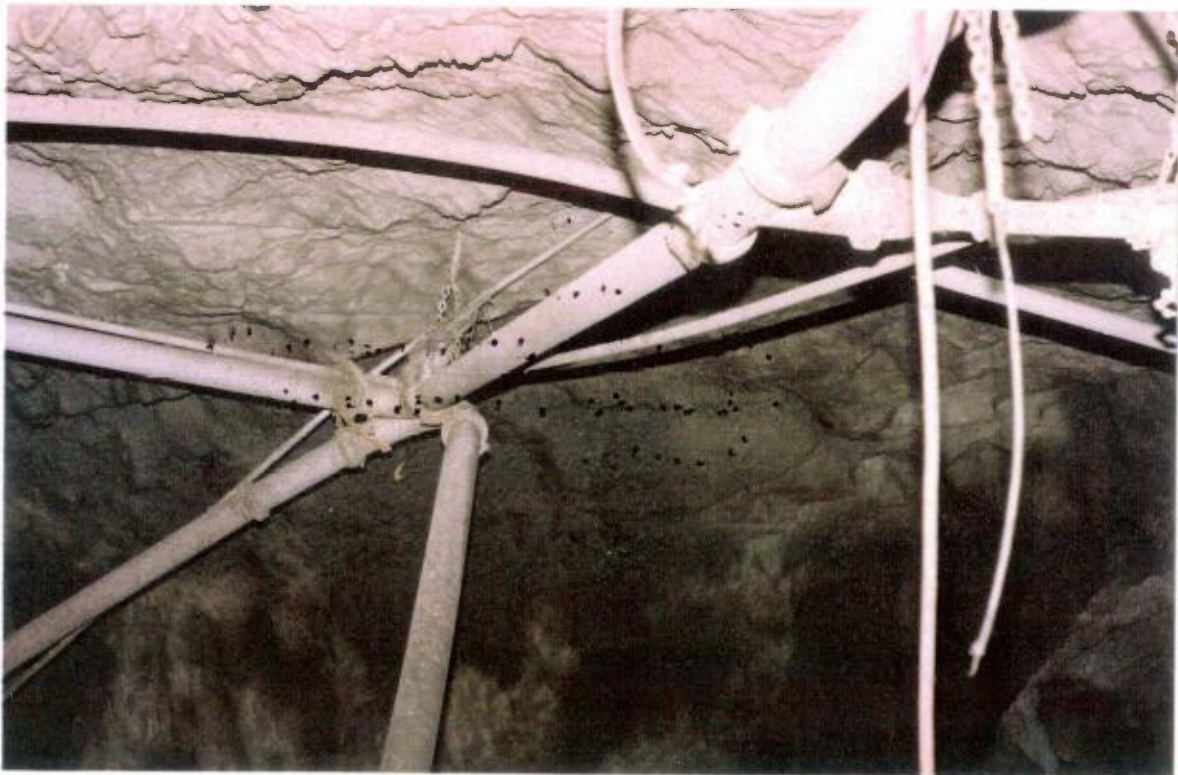


18 March 1996

Subsidence looking West from Headframe



18 March 1996 **Power Pack for Plat**
1 Haulage level, showing displacement due to air blast



18 March 1996 **2 Drill Access**
Decline Intersection
Large diameter pipes (150mNB)
Largely undamaged



18 March 1996

2 Drill

Debris from supergene workings in fallen ground



18 March 1996

2 Drill Access

Damage to cables



18 March 1996

2 Drill

Fallen ground showing debris from supergene workings



18 March 1996

2 Haulage Plat

Debris from air blast

MINE ISSUES

Recovery of pillars is a common imperative for all mines.

The mining of 4/8 rib pillar is the focus of this report since it began the chain of events which led to the collapse over 16, 17 March 1996 and because it raises questions critical to the prevention of a recurrence of a similarly significant event and critical to people management.

4/8 RIB PILLAR MINING - RISK MANAGEMENT

Hazard Identification

The extraction of 4/8 rib pillar was questioned: there were expectations of possible total pillar collapse, of a run of liquefied wet weathered rock from the adjacent 4/7 stope into 4/9 stope across a collapsed rib pillar, and of a crown pillar failure resulting in a run of fill from the stopes above. The possibility of a run of fill from above No. 3 Level stopes was not countenanced. Some information came to light following the collapse which might have helped identify the hazard from falling ground above the No. 3 Level stopes. A partial collapse of ground between Nos. 2 and 3 Level stopes was found (January 96) by a miner but not known by the mine manager.

The stability of 4/8 rib pillar was suspect. If it failed at an unplanned time there could have been dire consequences. Firing of the pillar should control the time of collapse.

If the crown pillar collapsed above the No. 4 Level stopes, and brought down fill from the No. 3 Level stopes above, some airblast and fill exudation at the openings in between the Nos. 3 and 4 Level stopes could have been (and was) anticipated.

The **severity** of the airblast with the run of fill from above was not identified. The possibility of collapse through to the surface was not countenanced (by anyone at any time, not even those who were underground on 17 March when the collapse ran through to the surface.)

Improved communications may have drawn out the "what if" discussions.

Hazard Evaluation

Weighted against leaving the rib pillar were production needs, ore blending needs, common practice of pillar recovery and the risk that the pillar might fail at an unpredictable and unmanaged time. These mitigating factors appear to have been known by those miners who may have counselled against mining the rib pillar. Even so, the decision-making process had evidently not been well communicated and had limited confidence in some miners.

Precautions

Evacuation of all people from the mine is standard practice for stope and rib pillar firings. All people were kept clear of the stope, ie on the Level at the top of the stope, for some days after the firing.

Drawpoints at the bottom of 4/9 stope were choked off preventing airblast impacts at the draw horizon.

An improved communication process may well have drawn out the need for additional precautions.

Monitoring

After a period of about 10 days following the rib pillar firing there **appeared** to be no further danger.

Although the crown pillar was known to have partially collapsed following the rib pillar firing it was thought that the crown pillar had stabilised. The mine's geomechanics consultant returned some time after the pillar removal to monitor developments. A daily visual check on the ground above 4/7 - 4/9 was made during the period July 1995 - March 1996.

INSPECTORATE ISSUES

I am not being critical of individual inspectors: no-one would have been more concerned over ground stability issues than those inspectors who were involved. However, I am critical of an inspectorate approach which does not have as a core function a structured review of critical risks.

While the inspectorate is clearly moving to a style of operation which overlooks management systems, examines critical risk control and which questions risk management, it needs further development in situation appraisal, structured decision-making (including allocation of priorities) and project management (for leading major safety health and environment campaigns). Having been critical, however, I am not aware of any better approach by any other inspectorate.

It is significant that the risk of collapse was not raised with the inspectorate before the events of 16, 17 March 1996. Further, it is significant that our regional inspector, who had detailed knowledge of the mine, was, on 17 March 1996 underground at the time of the second collapse (with the mine manager and a check inspector) and supports my conclusion that a collapse to the surface had never been identified as a risk.

LEGAL CONSIDERATIONS

1. Legal action

Legal action against the manager of the mine may be taken under section 19 of the Mines Inspection Act 1901.

Section 19 states that:

"19. If at any time representation is made to the Minister by an inspector that any manager or engine-driver is by reason of incompetency or negligence, unfit to discharge his duties, or has been convicted of an offence against this Act (not being an offence under section 18A), the Minister may cause inquiry to be made into the conduct of the manager, ..."

Production pressures, and problems stemming from the mine's earlier rationalisation go beyond the accountability of the mine's management, of the day. The difficulties of establishing clear accountability would be significant.

Legal action could also be taken against the owner of the mine under section 15 of the Occupational Health and Safety Act 1983.

Section 15 states that:

"15. (1) Every employer shall ensure the health, safety and welfare at work of all his employees.

(2) Without prejudice to the generality of subsection (1), an employer contravenes that subsection if he fails: ...

(d) as regards any place of work under the employer's control:

(i) to maintain it in a condition that is safe and without risks to health; or ..."

Clauses 7 and 23 of the Mines Inspection General Rule 1994 impose a duty on the manager of the mine, Mr Colin Farr, to "ensure that the mine is worked safely" and to "ensure that operations are carried on in such a manner as to avoid danger to persons from falls of ore rock or other substances". Evidence which I have seen regarding the decision to mine the rib pillar, discussions which I have had with some miners about their concerns over the pillar removal, and a failure to take risk control measures for the events of 16, 17 March 1996 would all be debated at length.

Prosecution action is not taken as a matter of course even for such serious occurrences as fatal accidents. Tests of equity, efficiency and effectiveness are applied in each case. The philosophy and practice which underpins these tests I set out in the NSW Guidelines for Safe Mining. In this case there would be considerable debate about who should be prosecuted, a question about the prospects for a successful and timely prosecution and the effect that such a prosecution may have in the long term. Other action may represent a more efficient use of resources and have a greater, lasting impact.

ALTERNATIVE ACTION

Design and implement an improved process for risk management at the mine. Pasmaico has adopted a well recognised risk management system but it needs to become a way of life at the mine - this will take time.

This course would need the commitment of management and the **involvement** of miners. The process would mean a shared responsibility for risk management and would need to address information processes, hazard identification, hazard controls and monitoring processes. The crucial element is the proper involvement of miners.

This is the preferred course of action.

The mine's management has changed since 16, 17 March 1996 with a new General Manager (now John Dini instead of Ian Smith) and a new Mine Manager (now Jaimie Dennis instead of Colin Farr). It will be easier to follow this option because "personalities" are removed from consideration.

CONCLUSION

The incident was significant in that there could easily have been multiple fatal injuries. Urgent action and on-going improvement measures were taken immediately and progressively in full consultation with the Inspectorate.

The apparent gulf between some miners and mine management would not have aided risk analysis or monitoring.

The adequacy of risk evaluation or precautions in terms of statutory requirements is difficult to ascertain given the complexities and timeframes involved.

An improved risk management culture and improved communications at the mine has been given particular attention.

The inspectorate's approaches to safety surveillance is also being critically reviewed.

PASMINCO MINING LTD

**PRELIMINARY GEOTECHNICAL ASSESSMENT
MINE SUBSIDENCE MARCH 1996**

**ELURA MINE
NEW SOUTH WALES**



Peter O'Bryan & Associates



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**PRELIMINARY GEOTECHNICAL ASSESSMENT
MINE SUBSIDENCE MARCH 1996
ELURA MINE
NEW SOUTH WALES**

Report No.: 9603011
Prepared for: Pasminco Mining Ltd
Elura Mine
PO Box 433
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Prepared by: PR O'Bryan
May 1996

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1.0 INTRODUCTION

This report presents a preliminary assessment of geotechnical conditions at Elura Mine (Elura) following major falls of ground and mine backfill on 16 March and 17 March 1996. The second event involved failure to surface. Recommendations regarding recovery of the mine, amendment to existing stope designs, possible changes in stoping methods and future geotechnical monitoring are also presented.

Further geotechnical work is required to confirm and refine the recommendations of this report, and to more fully assess long term implications to mining and the use of alternative stoping methods.

The reported work was carried out at the request of Mr M Boon, Production Engineer, Elura.

Findings and recommendations are based on:

- discussions with Messrs I Smith, General Manager, C Farr, Manager Mining, M Boon and C Lutherburrow, Senior Mine Geologist of Elura during, and subsequent to, a site visit held from 19 to 23 March 1996
- discussion with various members of the underground workforce
- underground inspections of accessible areas around the collapse area and of general as-mined conditions
- inspections of the subsidence pipe walls and surrounding area on surface
- inspection of structural geological data provided by Elura
- consideration of the findings and recommendations of previous geotechnical reviews^{1,2,3}.

2.0 BACKGROUND INFORMATION

2.1 Geology

At depth, the Elura silver-lead-zinc orebody is an elliptically shaped sub-vertical pipe extending from near surface to an as yet unclosed depth. The major axis extends about 200m approximately north - south, with a minor east - west axis of around 120m. Above 300m depth the pipe is split, by a waste block, into two smaller elliptical pipes. The pipe is inferred to taper with depth (below 4 Drill Level). Figure 1 is a long section view of the orebody/mine (looking west).

The core of the orebody consists of strong, stiff, generally massive pyrrhotitic ore. This is enveloped by equally competent pyritic ore which becomes increasingly siliceous towards the ore margins. The country rock is siltstone.

The orebody occurs within a north north-westerly trending anticline, and is inferred to lie sub-parallel to the axial plane. A sub-vertical axial plane cleavage is clearly evident in the siltstones, and a similarly oriented fabric can be present as weak banding in the sulphides. The contact between the ore zone and the siltstone is typically sheared. The siltstones at and near the contact are frequently highly fissile.

A major north trending sub-vertical shear zone on the western side of the orebody exacerbates the stability conditions along this contact. This feature may also act as a conduit for groundwater flow. The pre-mining groundwater level is reported to have been at ~100m below surface (mbs).

2.2 Mining

Access to the mine is via either a decline or shaft.

Longhole open stoping is the predominant mining method. Stope are typically ~94m high, ~30m wide and up to 120m long. All stopes are backfilled.



18 March 1996 2H Plat Area
Undamaged vent curtain



18 March 1996 3 Haulage EPD North of Fuel Store (looking north)
Showing fill flow
Consistency of fill
* Foreground - Sloppy
* Rear - Firm and putty like



18 March 1996

3 Haulage Fuel Bay Drive (looking West)
Showing fill "flow"
Fill consistency - Dry and powdery

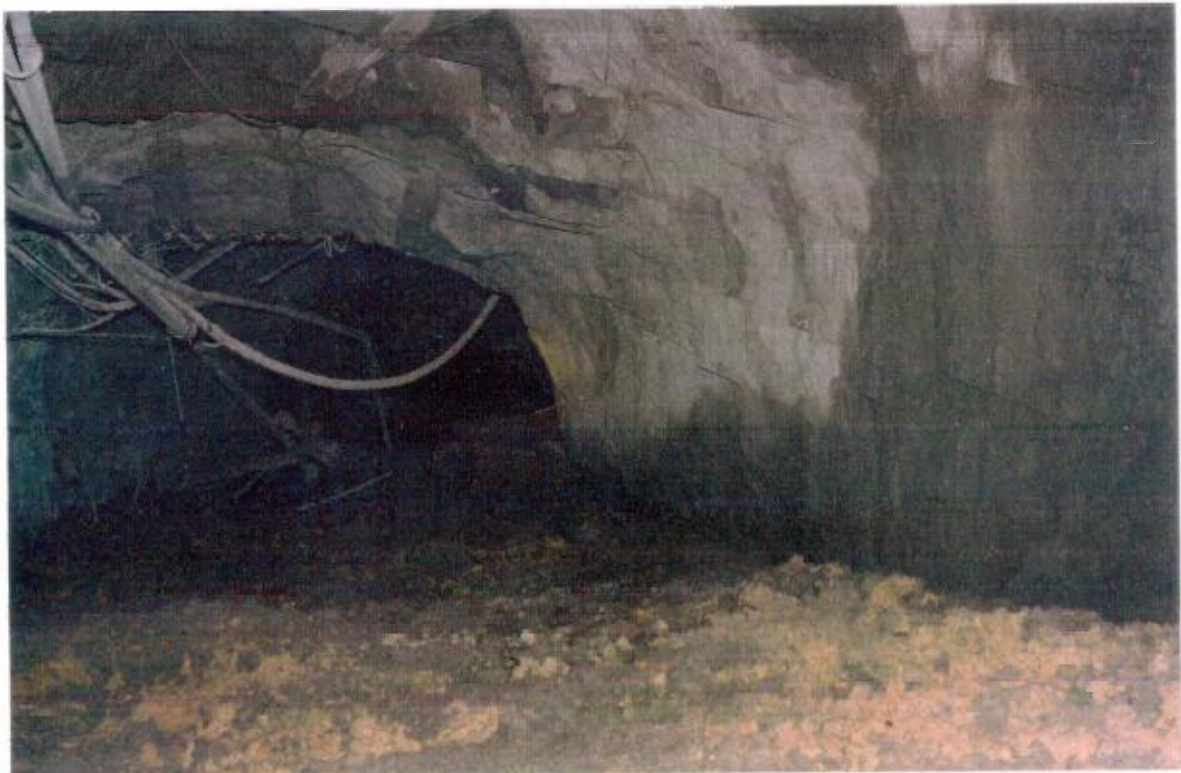


18 March 1996

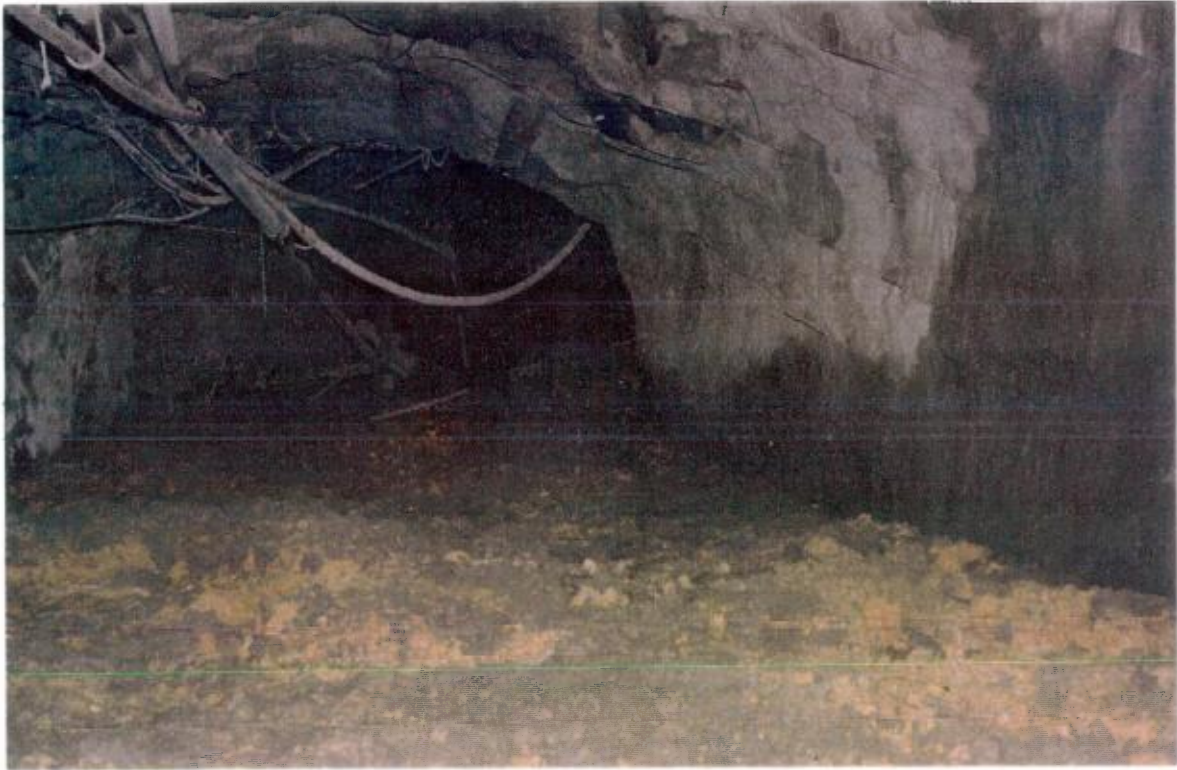
3 Haulage Fuel Bay Drive (looking West)
Showing fill flow
Fill consistency - Dry and powdery



18 March 1996 3 Haulage EPD North of Fuel Store
Showing fill flow
Consistency of fill
- Foreground - Sloppy
- Rear - Firm and putty like



18 March 1996 4 Drill Access just West of substation showing fill flow
Consistency of fill "sloppy"



18 March 1996

4 Drill Access just West of Substation

Showing fill flow

Consistency of fill - "sloppy"

3.0 PILLAR FAILURES AND SUBSIDENCE

3.1 Pillar Failure/Fill Run - Saturday 16 March 1996

Collapse, or at least partial collapse, of the (already holed) 4/7 Stope crown occurred at approximately 01:20 hours on Saturday 16 March 1996 (No. 1 Shift). The locations of the 4/7 and 4/9 stopes with respect to the overall mine structure are shown in Figure 1, while Figures 2A through 2G *schematically* show the chronological (local) mine development and sequence of events.

(Effectively) immediately following the crown collapse, a sudden run of fill occurred from the overlying southern 3 Level and 2 Level Stopes (3/6, 3/7, 3/9, 3/10, 3/11, 3/12, 2/6, 2/7, 2/8, 2/9 and 2/10 Stopes). The run/fall extended to just below the 2 Drill Level, at the base of the (unmined) southern 1 Level sulphides. It is likely that the fill run occurred immediately after the crown collapse, and it is possible that, once initiated, the moving fill material contributed to continued 4/7 - 4/9 crown pillar failure (if not already complete).

As the void of the 4/7 - 4/9 Stope choked, and provided resistance, the free-falling fill was forced laterally into openings on the 4 Drill and 3 Haul levels. A significant air-blast was generated by the collapse.

No material was ejected from the 4/9 or 4/7 drawpoints during or following this fall (or following later surface subsidence, refer Section 3.2). The 4/9 drawpoints contain broken ore/waste and fill from 4/7, and the 4/7 drawpoints are blocked by brick bulkheads (to contain stope backfill). Although it is possible that the 4/9 crown has not collapsed completely, given the energy involved, fluidised fill will have been forced into, and has probably filled, the 4/9 void.

3.2 Surface Subsidence - Sunday 17 March 1996

The arrest of the collapse just below 2 Drill Level was temporary. At approximately 15:00 hours on 17 March 1996, the 2 Drill Level and the southern 1 Level sulphide block, Figure 1, failed removing support from the overlying gossans and highly weathered country rock. Sudden failure of this material resulted in the formation of a pipe to the natural ground surface, Figure 3.

The surface cavity caused by this subsidence is roughly "elliptical" in plan, ~110m by ~140m, and up to ~40m deep. The walls of the pipe at surface are sub-vertical, and cracking, approximately "concentric" to the crest of the pipe, is currently evident up to ~40m outside the crest.

The air blast resulting from the second collapse was vented via underground openings which intersect the pipe, and from the surface breakthrough. Debris (moderately to highly weathered siltstone blocks to approximately football size) was thrown up to ~75m from the southern edge of the pipe. Ore, waste and debris from 1 Level oxide mining have been ejected onto the 2 Drill, 2 Haul and 3 Drill levels.

4.0 FAILURE MECHANISMS

The sequence of events which resulted in the surface subsidence of 17 March 1996 commenced at the 4 Drill horizon, and is inferred to have been initiated by failure and collapse of the 4/7 crown pillar.

4.1 Pre-failure Situation

The sequence of mining in this area of the mine was as follows, Figures 2A through 2F:

- 3 Level stopes mined and backfilled. All stopes **other than** 3/6, 3/7 and 3/9 were filled using cemented fill. The troughs/undercuts of 3/6, 3/7 and 3/9 stopes were filled with cemented mullock.
- 4/7 stope mined, leaving a 6m thick bridge pillar below the drill level - 1993
- 4/7 stope trough backfilled using cemented fill - 1994.
- Remainder of 4/7 stope filled with (gravity fed) uncemented wet rock fill (moderately to highly weathered siltstone at ~15% water content by weight) - 1994.
- 4/9 stope mined, including mining of the bridge pillar (as per design) - 1994-95
- 4/8 pillar/stope fired into 4/9 stope void - July 1995.
- 4/9 stope: ore/waste/fill level within the stope was at, or above, the top of the trough.

4/7 Stope

A portion of the 4/7 bridge pillar failed during the mining of this stope. This failure was interpreted to be structurally controlled. Wedges formed by joints and veins were exposed by mining, and eventually fell from, and holed the bridge pillar in the south-west of the stope, Figure 2B and Figure 4. The defects involved were moderately steep south dipping joints, sub-vertical north to north north-east trending veins, and pervasive and highly persistent sub-horizontal joints. Water pressures within defects may have exacerbated the potential for pillar failure. Seepage (inferred to be from a groundwater source) was evident in the area.

Further slabbing/thinning of the pillar, and extension of the hole occurred with time, but with **no** apparent major influence on the surrounding area. The hole at the 4 Drill floor was estimated to be ~15m north - south by ~25m east - west.

4/9 Stope

The 4/9 stope was mined with minimal overbreak, Figure 2C. As per standard Elura practice, the 4/9 bridge pillar was slightly arched in both the north - south and east - west directions. Local (sub-horizontal) joint controlled slabbing ($\leq 5\text{m}$ deep) occurred from the stope back when the bridge pillar was mined.

4/8 Pillar

Overbreak into the upper western portion of the 4/8 pillar also occurred with the mining of the 4/9 bridge pillar, Figure 2D and Figure 4. This overbreak extended $\sim 25\text{m}$ west from the edge of the slot. In this zone, vertical load transfer into the $\sim 15\text{m}$ thick 4/8 pillar was possible only via the $\sim 3\text{m}$ thick pillar separating the 4/8 and 4/7SB drill drives.

Significant dilation was observed within the 4/8 pillar following the removal of the 4/9 bridge pillar, Figure 2D. Sub-vertical tension cracking was observed in the 4/8, 4/7SB and 4/7SA drill drives, as was dilation across sub-horizontal joints in the pillars between these drives. Similar dilation across sub-horizontal joints, although of a significantly lesser magnitude, can be observed within the remaining portions of the 5/3 drill drives. In this case the dilation has occurred following the (partial) mining of the 5/3 bridge pillar.

The reduction in confinement caused by the removal of the 4/9 bridge pillar and the presence of the hole in the 4/7 bridge pillar, and (possibly) some active load from the partially saturated/saturated fill in the 4/7 stope are inferred to have been the major contributors to the deterioration and observed displacement of the 4/8 pillar.

Given the rates at which crack lengths, the number of cracks, and crack displacements were increasing, it was considered that pillar failure was inevitable, however, sufficient data were not available to predict the likely timing of its expected collapse. Although the likelihood of air blast and the possibility of a run of fill as results of a pillar collapse were recognised, the specific implications of such a collapse to stability in the 4/7 and 4/9 stopes were not known.

The situation can be summarised as follows:

- At least partial 4/8 pillar failure was expected.
- The likely timing of this failure was unknown and could not be accurately estimated.
- An uncontrolled pillar failure would be likely to cause some air blast (the magnitude of which would be dependent on the nature, rapidity and consequences of pillar collapse).
- Assuming a 4/8 pillar collapse, a run of fill from 4/7 stope into 4/9 stope and onto 4 Haulage level was possible.

Uncontrolled pillar collapse thus represented a potential major safety hazard, and had the observed rate of pillar deterioration continued, delay in action would have resulted in a situation where entry to the 4/8 pillar drill horizon (for charging) would not have been safe.

In this light, the accessible portions of the southern row of blastholes in the pillar were charged and fired while the area remained safely accessible, primarily to avoid the occurrence of a future uncontrolled pillar failure.

The initial 4/8 pillar mining design incorporated two rows of blastholes, however, it was considered that blasting both rows could potentially break into, and possibly liquefy, the uncemented fill in 4/7 stope (the specific characteristics and variation of the fill in the stope were unknown). Additionally, it was not practical to fire both rows. Rock movement within the pillar precluded full charging of the southern row, significantly reducing possible burden relief of the northern row.

The interpretation that the capacity of the failing 4/8 pillar was already compromised, but without obvious signs of distress in the crown, suggested that stope back stability could possibly be sustained, despite the ~70 to 80m north - south and (up to) 120m east - west spans. General stope wall stability conditions were interpreted to be good to very good, based on observation and the results of in-stope survey.

The blast was carried out with an acceptance that a variety of outcomes was possible:

- An ideal result in this situation would have been the formation of an ~6m thick diaphragm pillar between the 4/7 and 4/9 stopes, with retention of fill, and no overbreak into the 4/7 or 4/9 crown pillar. This was not considered impossible given the observed/inferred performance of very wide spans elsewhere in the mine (for example the 2 Level crown). However, the stability and lateral load bearing capacity of the thin vertical diaphragm pillar was considered marginal at best.
- The worst case envisaged for the blast was that complete 4/8 pillar failure would be followed by overbreak of the 4/7 - 4/9 crown with a subsequent run of fill from the 3 Level stopes.

The blast was fired on 06 July 1995:

- the 4/7 crown, in the vicinity of the pre-existing hole in the 4/7 bridge pillar, holed through to the 3 Haulage Level with or immediately following the blast, Figure 2E;
- the upper 30m (and possibly more) of the 4/8 diaphragm, and hence the 4/7 bridge pillar, failed with and/or shortly following the blast, Figure 2E;
- fill from 4/7 stope flowed into the 4/9 void, onto and through the broken ore, Figure 2E; and
- additional rockfalls occurred within the days following the blast. No air blast associated with these rockfalls was reported. It is inferred that these falls were localised, involving rock volumes $< 1\text{m}^3$ to $\leq 25\text{m}^3$, and were associated with progressive failure around the 4/7 crown overbreak.

Obvious signs of rock mass relaxation/settlement in the area are reported to have ceased within (~10?) days of the blast, and mucking from drawpoints was resumed. Fill migration and large rocks made this operation difficult. One run of fill was experienced from drawpoint 1 in late 1995. This run of fill differed from those which occurred on the 16 and 17 March in that it initiated under quasi-static conditions and flowed after movement within the muck pile in the stope. It was neither accelerated by free fall, nor by impact of free falling material.

Elura reports that no changes in the stability conditions or behaviour of the 4 Drill and 3 Haulage Levels were observed up to 16 March 1996.

4.2 Triggering Mechanisms

The mine scale failures of the 16 and 17 March 1996 developed from a situation which had appeared to be stable for a period of 9 months. Mining activity is not considered a contributing factor - the most recent blast in the mine was in 5/3 stope on 09 March 1996, and no other mining activity which may have caused disturbance to the 4/7 - 4/9 crown pillar had been, or was being carried out. Clearly, the ~80m span could not be sustained.

It is considered that a triggering event, possibly very localised, was necessary since it is unlikely that critical/metastable conditions would persist for 9 months without some observable sign(s) of impending collapse. However, no accurate identification or assessment of the triggering mechanism is possible.

The following comments are based on observations made during inspections of the area prior to the firing of the 4/8 pillar, structural mapping data from the area, and inspections of the mine following the events of 16 and 17 March 1996, and can only be considered as surmise.

A number of factors must be considered:

- o It is possible that (visually imperceptible) changes were occurring within the rock mass, and that stability conditions were actually deteriorating with time.

Further overbreak from the 4/7 crown could have been periodically monitored by further in-stope surveys (it is understood that a survey had been planned for a time in late March 1996).

Comprehensive monitoring of the situation would have required that numerous borehole instruments (extensometers) be installed over the whole crown pillar area. Such instruments may have detected local/relative displacements. Extensometers installed from the crown into the country rock may have detected movement of the crown (which any instruments entirely within the crown could not detect).

Microseismic monitoring may have detected noise associated with deterioration and movement within the crown. Data from a microseismic system may have indicated areas which should have been examined more closely. Such systems are expensive and require specific expertise in installation, maintenance and data interpretation.

- Country rocks in the immediate vicinity of the orebody contact are typically fissile (more intensively schistose/cleaved).
- Intensively fissile rock conditions are evident within the country rocks along the western boundary of the orebody in the southern stopes at the 3, 4 and 5 Levels. These rock conditions are interpreted to be associated with a regional, sub-vertical north - south trending shear zone which lies immediately adjacent to the western boundary of mineralisation, and as such is inferred to persist both to surface and to depth.
- The structural conditions/defects which caused the failure in the 4/7 bridge pillar, and probably played some role in the holing of the 4/7 crown may also be widespread on the western side of the orebody.
- The western shear zone is inferred to be a conduit for groundwater. Although limited volumes of water were evident prior to the failure, it is possible that hydrostatic pressures were sufficient to contribute to instability.

(Inferences to hydrogeological conditions should be checked/confirmed by experts. It is recommended that structural and hydrogeological assessments within the Main orebody at Elura be conducted by appropriately qualified personnel.)

- Low to moderate stress levels (in relation to the strength of the rock mass) exist within the mining areas at Elura. This is evidenced by the lack of distress following local failures within bridge and crown pillars, either in the immediate vicinity of these features or via obvious load adjustment(s) elsewhere in the mine. The sheared/fissile orebody contact zone is inferred to limit the transfer of mining induced stress concentrations to pillars within the orebody. Hence there is (an inferred) limited potential for pillars to be destabilised by concentration in horizontal loading, however, this also translates into limited horizontal "clamping" restraint on pillars.
- Stope backfill, even pumped pulp or cemented backfills, are (relatively) very weak materials, and would not be expected to be permanently stable when unsupported over spans of tens of metres. When undrained, the uncemented backfill used at Elura, even over spans as short as 1m (or less), would not be expected to be stable.

It is possible that the initial (Saturday) collapse was triggered by:

- Extension of the pre-existing hole in the 4/7 crown pillar, possibly via a key block failure, followed by general 4/7 - 4/9 crown (and A pillar) collapse and release of the uncemented fill from the overlying stopes.
- Sufficient extension of the pre-existing hole to breach beyond the cemented fill in the trough of the 3/9 stope, and initiate a run of fill which may have contributed to more widespread crown collapse.

- Movement on the western contact shear as a result of time related deterioration and/or possibly water pressure (due to the hydraulic gradient caused by the 4/9 stope void), resulting in loss of the western abutment, and subsequent pillar failure.

4.3 Collapse and Subsidence

Whatever the specific origin and manner of the 16 March 1996 crown failure, the resultant undercut was sufficiently large to initiate a run of fill from the overlying stopes.

The 3/6, 3/7 and 3/9 stopes immediately above the 4/7 crown were filled with uncemented material, Figure 2A, which would fail/run as soon as exposed. Given the size of the void (~220,000m³) within the 4/7 - 4/9 stope at the time, there was no chance of choking-off the initial run of fill. The fill would have fallen into 4/7, and fallen and/or flowed into 4/9.

The extent to which the 3/10, 3/11 and 3/12 fill has moved is unknown, however, it is assumed that at least some of its vertical support was lost, hence a fall/run would have been inevitable, and it is likely that the sudden loss of lateral support would have lead to mobilisation.

The 3 Level crown had previously overbroken (locally) into the 2 Haulage Level above the 3/8 stope, Figure 2C. Given this weakness, it is inferred that the crown collapsed immediately following its exposure and loss of support. The sudden loss of fill and removal of wall support in the southern 3 Level stopes will have disturbed whatever lateral support was provided from the surrounding country rock. Given the presence of the western shear zone, such an effect may have been worse on the western side. Additionally, the competence of southern 3 Level crown is inferred to have been reduced as a result of an earlier failure (1988?) of the northern portion of the crown.

Collapse of the 3 Level crown caused a run of fill from the southern 2 Level stopes. The 2/8, 2/9 and 2/10 stopes fill was uncemented, hence propagation of the fall would have occurred readily. Loss of vertical support would have ensured collapse of the 2/6 and 2/7 stopes fill.

The failure was temporarily arrested just below the 2 Drill Level, presumably strongly influenced by the presence of the unmined 1 Level sulphide block, Figure 1. The exposed span, plus the disturbance to abutment support and the presence of the western shear zone, were sufficient to cause failure of this block of transitional material (moderately weathered to slightly weathered to fresh rock). At least some of the "dull rock noise" heard following the initial collapse is attributed to have been from progressive failure along/within the western shear zone. Failure of this block occurred ~38 hours after the first event.

Once undercut by a span of 60 to 70m (?) by the failure of the 1 Level sulphides, the overlying supergene ore, backfill, gossans and highly weathered country rock were simply incapable of standing, and the failure progressed to surface. An undercut of this span in these weak highly weathered materials is simply not sustainable.

4.4 Surface Collapse

The area immediately influenced by surface subsidence is estimated to be ~110m by up to ~140m. Figure 3. The deepest point of subsidence is estimated to be ~40m (at the mid point of the area). The photogrammetrically surveyed volume of the surface expression of the pipe is 230,000m³. Cracking is currently evident up to 40m behind the pipe crest.

5.0 PROGNOSIS

5.1 Future Pipe Behaviour

Localised fretting and collapse is expected in the immediate vicinity of the pipe, both underground and on surface.

Such events underground may occur intermittently for some time, but at a scale that will not (further) influence the mine structure, and within areas which are, or must be made, inaccessible. Apart from the effects of air blast and fill flow, ground/stability conditions away (>10m) from the collapsed area appear to be generally good. No major deterioration (since June 1995) is discernible.

While the pipe remains open, surface cracking will continue, and collapses up to ~20m behind the current crest will occur. The pipe walls are ~415m high, however, the walls at surface are expected to behave as though the hole was ~60m deep (around this depth the restraint provided by the rock debris is probably sufficient to permit only minor movement), and in this case the cracked zone may extend to ~75m from the pipe crest. The buttressing effect of expected falls and introduced backfill will provide restraint to surface movement, and in this respect backfilling would ideally be carried out to completion.

The forces generated by the falling material is assumed to be have caused relatively tight packing in the 4/7 - 4/9 stope void. Accordingly, no sudden major runs of fill are expected. However, it is considered that local voids remain within the fill, and further settlement is expected.

While the volume of the surface void is larger than that of the 4/7 - 4/9 stope void, suggesting complete filling, voids were known to exist within the supergene/gossan around the level of the pre-mining water table (~100mbs), and some fill/debris has been forced onto upper levels. Although it is likely that the 4/7 - 4/9 void is full (due to the velocity and mass of the impacting material), this cannot be concluded as fact. The precise volumes of the pre-existing voids and the spills from the pipe are unknown.

It is recommended that the base of the pipe be probed by drilling, and where possible/feasible, that it be monitored so that increasing free water/slurry pressures may be detected.

5.2 Influence on Mine Structure

The existence of the pipe will potentially act as a focus for relaxation and loosening on existing structural defects through the orebody. While the debris which chokes the pipe would limit displacement of the pipe walls, it can do little to reduce the influence on stress re-distribution. This factor must be taken into account in assessment of future mining.

5.3 Potential for Future Subsidence

There is potential for a run of fill/caving and subsidence on the northern side of the orebody. This potential could be significantly reduced by backfilling the existing void over the 4/1 stope.

Further failure of the 4/1 crown pillar, and particularly where this extends above the top of the 3/1 trough, could initiate a run of fill from the 3/1 and 3/2 stopes. Fill from the 3/3 and 3/4 stopes could also possibly be drawn down since extended failure of the 4/1 crown would be likely to cause (at least partial) collapse of the 3/3 and 3/4 crown. Although the fill in these stopes is cemented, the span of the possible undercut would exceed that over which the material could arch.

The current void above the 4/1 stope is an elliptical dome shape, with ~40m and ~50m long axes in plan, and ~40m high. Progressive failure of both rock and backfill with time is expected. When/if this failure approaches or passes the top of the overlying stope trough, the support and arching capability of the fill will be substantially reduced, and the rate of failure of the exposed fill could increase rapidly.

Once initiated, a run of fill could proceed through the 3 Level and 2 Level stope. The 3 Level crown failed in 1989, and would thus be unable to arrest a fall. Additionally, and despite the limited size of the void (in comparison to the 4/7 - 4/9 void), minimal bulking would occur since most of the fall material would be fill. The 1 Level sulphides may or may not act as a restraint to the failure. The north - south span at the base of the sulphides in the northern orebody is less than that in the south, however, the relaxation which accompanied the southern subsidence will act to reduce the competence of the block as a structural member.

Collapse of the 4/5 crown during or following the mining of that stope would provide an alternative initiation point for collapse on the north side of the orebody. Also, it is possible that a collapse initiated above 4/1 stope could break into 4/5 stope if such an event occurred during or subsequent to mining and prior to backfilling. These possibilities are dependent on the presence of a stopping void, development mining, for example in 4/5 drill horizon is not considered sufficient to cause initiation of such a 4/1 - 4/3 crown collapse.

Given the potential outlined, it is recommended that the void over the filled 4/1 stope be backfilled using $\geq 10\%$ cement fill. It is conceded that this would be difficult and expensive.

6.0 IMPLICATIONS TO FUTURE MINING

6.1 Mine Recovery - Bulkheads

The immediate requirement for mine recovery is the isolation of the failed area. Concrete bulkheads are being constructed on the 3 Haulage (8 bulkheads) and 4 Haulage (5 bulkheads) Levels to permit safe long term access to lower levels for development and stoping to resume. Additional bulkheads will be constructed on other levels as required.

The bulkheads have been designed assuming:

- hydrostatic heads of 315m and 415m for the 3 and 4 Levels respectively
- density of the "fluid" material = 20 kN/m³
- concrete - rock interface shear strength = 3 MPa
- contact with a (nominal) 5m by 5m drive occurs only on the floor and walls
- concrete uniaxial compressive strength = 20 to 25 MPa

The bulkheads on the 3 Level and 4 Level are to be 4m and 5m long respectively. Using the same design assumptions, bulkheads at 3 Drill and 2 Haulage Levels should be 2.5m long, and 1.5m long at 2 Drill Level.

Resistance to the static head is provided predominantly by the shear restraint provided by the concrete - rock interface, with minor contributions from the weight of the concrete and the shear strength of reinforcement keyed into the drive walls, back and floor. The assumption of a full column of a heavy, fluidised medium is considered to be conservative for the static case.

It is considered that the bulkheads would be sufficiently strong to withstand a **transient** load approximately twice the static load, such as would be generated in the (unlikely) event of a further rush of fill, **provided** the rock surrounding the drive is sound.

It is crucially important that the areas in which the bulkheads are built are:

- away from stope brows
- thoroughly re-scaled and re-secured (very tightly bolted)
- floors are cleaned back to fresh, sound rock
- wherever possible the concrete must be vibrated
- successive pours of concrete are keyed together with reinforcement
- attempts should be made to pressure fill the drive as tightly as possible.

6.2 Resumption of Mine Development and Stopping

Resumption of mining needs also to take into account the need to keep the failed zone isolated, and to isolate current and near future stopes from each other.

Containment of saturated/partially saturated fill material is crucial.

Initial estimates for pillar dimensions are presented below, however, it is emphasised that these are subject to future review (to be commenced in April 1996).

It **may** be possible in the future and at depth (away from the current levels of mining) to re-adopt extraction methods similar to those used to date (this is subject to further assessment).

Alternative stopping methods should be examined. The geotechnical ramifications of potentially viable stopping methods will be examined as part of continuing work.

Regardless of the stopping method(s) employed in future, **dry backfill only** should be used.

6.2.1 4/5 Drill Drive Development

Development of the drill drives for 4/5 stopes is approximately at the mid point of the stope. Development is proceeding east to west.

The southern drill drive is within ~6m of the pipe (the northern edge of 4/7 stope).

It is recommended that before development in this southern drive resumes:

- angled probe drilling be carried out to locate the edge of the 4/7stope/pipe in relation to planned drill drive wall positions
- detailed structural mapping be carried out to assess the likelihood of intersecting structural defects which could lead to instability, either by permitting/causing movement towards the pipe (which may occur with pipe settlement?), or via sliding or wedge failure into 4/5 stope when this is mined. Southerly dipping shears are evident, albeit infrequently, within the as-developed drives, as are northerly dipping joints. Persistent sub-horizontal joints are ubiquitous. Local cable bolt reinforcement may be advisable.

6.2.2 5/9 Stope

The partially mined 5/9 stope lies directly below 4/9 stope. The adjacent 5/8 pillar remains intact, however, the 5/7 bridge pillar has failed, and local, structurally controlled overbreak has occurred in the 5/7 crown.

Maintenance of the integrity of the 5 Level crown pillar is critical. Crown pillar thickness and/or reinforcement must be such that holing is unlikely. Vertical support must be provided by a rib pillar.

In this situation it is recommended that:

- 5/7 stope be filled as tightly as possible, as soon as possible
- a 10 to 15m thick bridge pillar be left in place in 5/9 stope (final dimensions are yet to be assessed); *or*,

extensively reinforce the 5/9 crown pillar to permit safe extraction of the bridge, (however, the requirements of such reinforcement are also yet to be assessed)
- the 5/8 pillar be left in place
- structural geological mapping be carried out in all accessible 5/9 drill drives, and on 4/9 haul drive while this is accessible - the data obtained will be critical to stability assessment
- quantitative monitoring of the crown pillar be carried out using extensometers (and/or inclinometers), however, currently available access (which is essentially from 5 Drill Level only) limits instrument borehole locations and orientations. Some extensometers could be installed through the crown into country rock, while others would remain entirely within the pillar. In-stope surveys should be carried out periodically until 5/9 stope is filled.
- 5/9 stope be backfilled with dry waste rock (or some stronger medium)

This configuration leaves a crown up to ~25m thick (or a thinner reinforced crown) above 5/9, and a 12m thick rib pillar between the 5/7 and 5/9 stopes. Given the lesser spans in 5/9 (compared with 4/7 and 4/9), a crown pillar and rib pillar of the quoted dimensions are considered sufficient to carry/disperse the self and superincumbent (pipe) loads applied.

Given the sheared condition of the orebody contact, the competence of abutment support to the bridge pillar may be low (at least locally) due to the slenderness of the bridge and the presence of numerous overlying large drill drives (which tend to isolate the bridge from the inferred more competent crown - A pillar configuration). Structurally controlled slab failure from the bridge has been common in the past. These factors will be considered in more detail as part of future work.

On the basis of the observed behaviour of the 4/8 pillar (prior to blasting) a minimum 12m wide 5/8 rib pillar is recommended. Although holed at its western end, and locally undercut towards the centre and eastern end, the 12 to 15m thick 4/8 pillar was at least marginally stable. The proposed 5/8 rib pillar will be of a similar thickness, but is located beneath the apex of an A pillar (whereas 4/8 was nearer to the trough of the overlying stope), and will have additional lateral support from the 5/9 bridge pillar, and is thus considered of suitable dimensions to contain the wet fill in 5/7 stope.

Stringent control on drilling and blasting, in both design and implementation, will be critical to pillar stability. Overbreak, even locally, into the rib could result in major destabilisation. In-stope surveys showed that very good drill and blast control was achieved in 4/9 stope. Efforts to ensure this quality of work is maintained or improved are recommended.

6.2.3 5/3 Stope - 5/1 Stope

Mining in 5/3 stope is almost complete, with only part of the bridge pillar to be mined. Mining in 5/1 stope commenced relatively recently.

The remaining portion of the 5/3 bridge pillar is relaxing (dilating on sub-horizontal joints), and if unmined, it is likely that slab failures (potentially generating significant air blasts) would occur in the future.

In this light it is recommended that:

- mining of the 5/3 bridge pillar be completed - very close observation of conditions within the bridge will be essential during the remainder of this operation
- 5/1 stope be mined leaving a 10 to 15m thick bridge pillar (comments with respect to the competence of the recommended 5/9 bridge are also applicable here) - bridge pillar design will account for the limited span of 5/1 stope
- the 5/2 rib pillar be left in place
- both 5/3 and 5/1 stopes be backfilled with dry waste rock (or better)
- structural geological mapping should be carried out in the 5/3 and 5/1 drill drives.

It is understood that Elura will not complete mining of the 5/3 bridge until preparations which will enable rapid stope filling are completed. In this case it will be necessary to (at least visually) monitor the condition of the 5/3 bridge and drill drives in order that local stability conditions can be continually assessed. It is possible that slabbing from the bridge, and continued relaxation (as evidenced by dilation on sub-horizontal joints) will make the drill drives unsafe to enter for final blast(s) charging.

6.2.4 6/4 Stope

The 6/4 stope is approximately 60% mined. A bridge pillar (drill drive floor pillar) remains intact. 6/4 is the only stope to be mined on 6 Level to date. Development for the longitudinal 6/1 stope is effectively complete, however, southern drill drive development (for 6/6 stope) is yet to commence.

Given the need to ensure as best as possible the integrity of the 6 Level crown, previous recommendations to mine the 6/4 bridge pillar are (at least temporarily) revoked. The need for, and dimensions of, this pillar are subject to further assessment. Further work should also review the benefit/implications of the development of a (possibly) recoverable regional pillar at the 6 Level crown.

It is recommended that the 6/5 rib pillar be left intact.

Assessment of the likely interaction between adjacent stoping and the longitudinal 6/1 stope is yet to be carried out. It is understood that, given the low grades within the 6/1 - 6/4 pillar, this pillar will be a permanent structure.

6.3 Surface Recovery

Elura has commenced mining in the vicinity of the pipe on surface to stabilise the crest of the pipe, and to produce waste rock to (at least partially) backfill the pipe.

A shallow pit (to 10 or 15mbs) will be mined adjacent to the north side of the pipe. The pit will be mined in 5m flitches. Excavated material will be dumped and dozed to form a tip head in the north western sector of the pipe. The edges of the pipe will be battered to $\sim 45^\circ$ by an hydraulic excavator standing outside a 45° angle subtended from the crest of the rill abutting the face.

The floor of the pit is to have a gradient to a sump in the north. Surface drainage must be diverted so that the only rainwater entering the pipe will be directly meteoric. Water from average annual rainfall, and/or the highest recorded daily rainfall would saturate less than $20,000\text{m}^3$ of the pipe material ($\ll 1\%$ of the estimated pipe volume) to the moisture content of recently used backfill.

The potential influence from groundwater is yet to be assessed. However, should a hazard exist, it is likely that suitable preventive/precautionary action can be taken to remove or reduce this.

The buttress formed by the dumped/dozed backfill will restrain future cracking and surface movement. It is particularly critical that the north-western pipe face (nearest the vent shafts) be buttressed as soon as possible. *Ideally, the pipe should be completely backfilled.*

It is recommended that surface monitoring comprise electronic distance measuring (EDM) prisms fixed permanently at $\sim 40\text{m}$ intervals around the periphery of the pipe. The prisms should be mounted on stakes driven firmly into the ground $\sim 10\text{m}$ behind the battered crest. The prisms should be mounted $\leq 300\text{mm}$ above the ground. Daily readings should be taken over ~ 10 days following installation in order to obtain a base set of readings and to detect movement trends. Subsequent reading intervals would be based on the movement rates indicated by the initial data. However, it is recommended that intervals between readings be no greater than 1 week.

It is also recommended that consideration be given to fitting a tiltmeter to the evasee structure of the No. 1 West Vent rise.

6.4 Other Issues

6.4.1 Groundwater / Mine Water

Significant flows/volumes of water are evident at a number of locations within the mine. These flows variously come from groundwater, mine water (ruptured water lines et cetera) and fill water.

The volume of water liberated from backfill is expected to be limited, however, it is possible that large volumes had pooled on fill, and that this has been re-introduced into the mine following the collapses and subsidence.

Water losses from mine supplies should be minimal, and managed as a matter of course by good mining practices. Accumulations of water, from whatever source(s) should be similarly managed. For example, water accumulating on 5/7 stope fill should be pumped out as quickly as possible.

It is inferred that groundwater is the major source of the water currently infiltrating the mine. Based on reported wet exploration drilling conditions, and observations within the western sectors of underground workings, the western shear zone is inferred to be a conduit for groundwater.

The water at the western end of the 5 Haul Level, and from the western 4/9 stope drawpoints (at present) is inferred to be from groundwater sources, possibly from the western shear. It is possible that the occurrence of the fall/subsidence events caused disturbance to the shear zone, and thus possibly increased the rate and volume of flow into the mine.

Should the western shear prove to be a major source of infiltration to the mine, action to remove or reduce the capacity this water source may be necessary. Installation of depressurising and/or dewatering bores into the shear from underground and/or surface may be advised. If the shear has a low storage and low re-charge capacity, underground depressurisation drilling may be adequate, however, if the shear is a major aquifer, dewatering/interception bores may be needed along the strike of the shear both north and south of the mine.

Inferences with respect to groundwater must be checked, and it is considered that further investigations by appropriately qualified personnel are warranted. Accordingly, **it is strongly recommended that Elura engages the services of an experienced hydrogeologist to investigate, and advise on management of, the groundwater regime(s) within and around the mine.**

6.4.2 Western Shear Zone

The western shear zone is a regional, sub-vertical, north - south trending feature. It is characterised by an intensive schistose/cleavage fabric and is possibly (locally) up to 20m wide. It occurs on the western boundary of alteration to the ore zone. Discrete sub-vertical defects, which are inferred to be associated with the shear are clearly evident on the west wall of the pipe at surface. The shear is anticipated to be adjacent to the ore zone over the full height of mining.

Given the persistence and inferred weakness of the western shear, it is likely to have contributed to the occurrence of the crown failures associated with, and possibly the initiation of the collapse/subsidence events. It is therefore possible that this feature could act in a similar (but currently unknown) capacity in the future.

Further work is necessary in accurately defining the location and geological and hydrogeological characteristics of the shear, and their implications to mine stability. Significant input from Elura geologists will be crucial in these respects.

6.4.3 Time Related Deterioration

Some degree of deterioration (relaxation/loosening) will occur with time, however, it is difficult (impossible?) to quantify without information from site specific structural mapping and direct monitoring data obtained during development and mining and following mining.

Given that the likelihood that monitoring may be severely limited in identifying potential collapse zones, it is crucial that detailed structural data are obtained during development and that action is taken, prior to mining, to ensure, as best as practicable, that suitable reinforcement is installed and/or mining designs are appropriately adjusted to adequately allow for the lack of support prior to stope backfilling.

7.0 FUTURE STOPING

7.1 4/5 Stope

The unmined 4/4 - 4/5 - 4/6 panel stope lies at the (north - south) centre of 4 Level stoping, immediately below the base of the barren pillar separating the upper northern and southern ore zones. As such, this panel acts as a key block in the mine structure.

At this stage it is recommended that limited mining be planned for the 4/4 - 4/5 - 4/6 panel in that:

- a 15m bridge pillar be left in 4/5 stope
- 4/4 and 4/6 rib pillars be left intact
- 4/5 stope be backfilled with dry waste rock (or better).

The dimensions of the pillars surrounding 4/5 are subject to review. It may be necessary to increase the thickness of the 4/4 and/or 4/6 rib pillars.

7.2 5/1 Stope

Refer to Section 6.2.3.

7.3 Alternative Stopping Methods

The mining, economic and geotechnical viability of alternative stoping methods should be examined in light of the facts that:

- although the provisional adjustments to stope designs recommended above reduce the potential for further mine scale failure, they cannot obviate the potential for structurally controlled failure within individual stopes or pillars
- the recommended increases in pillar dimensions impinge significantly on ore reserves.

Methods which permit controlled collapse/failure of pillars with subsequent downward migration of backfill (for example as per Mt Charlotte and Mt Lyell operations) should be examined, as well as investigating potential means and/or sequences which would safely permit reductions in pillar dimensions.

These issues, and the limitations and restraints of possible changes, will be assessed in ongoing investigations.

8.0 ONGOING AND FUTURE GEOTECHNICAL WORK

Given the current status, additional geotechnical work is required to more fully assess:

- the potential for future similar subsidence events, and the likely influence these may have on the mine structure
- the means available to avoid or reduce the potential for such events
- possible means of identifying and monitoring potential collapse/subsidence areas (note that potential for definitive monitoring may be limited)

More detailed assessments of conditions, requirements for pillars in existing and future stopes, and the implications of alternative stoping methods are also necessary. This will entail:

- detailed structural analysis using existing and future mapping data
- three-dimensional modelling of proposed and alternative stoping methods and sequences
- examination of possible stoping methods and sequences as identified by Elura.

Potential benefits and limitations of rock reinforcement used in association with stoping will also be examined.

With respect to obtaining as much as possible from the above assessments, it is strongly recommended that Elura examines existing records to determine, as best as possible, the sequence of mining, stability conditions experienced during mining, and the nature of backfill of all stopes.

Means of more precisely assessing the location, size and nature (location of large blocks and voids) of the pipe should be pursued by Elura.

9.0 CLOSURE

This report is a preliminary summary of two major collapse/subsidence events at Elura. It describes the events, possible causes of the events, likely future behaviour of the mine, the approach to future mining, and ongoing geotechnical assessments. As such it is not exhaustive.

Additional geotechnical work commenced in April 1996.

We trust that the information presented in the report meets your current needs. Please do not hesitate to call should there be a need for clarification or further discussion of any issue.

PETER O'BRYAN & ASSOCIATES

per:



Peter O'Bryan
Principal

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unpub report to Pasminco Ltd, Elura Mine

FIGURES



ELURA MINE

COBAR, N.S.W.

1995 - 1996 PLAN

1.11 MILLION TONNES

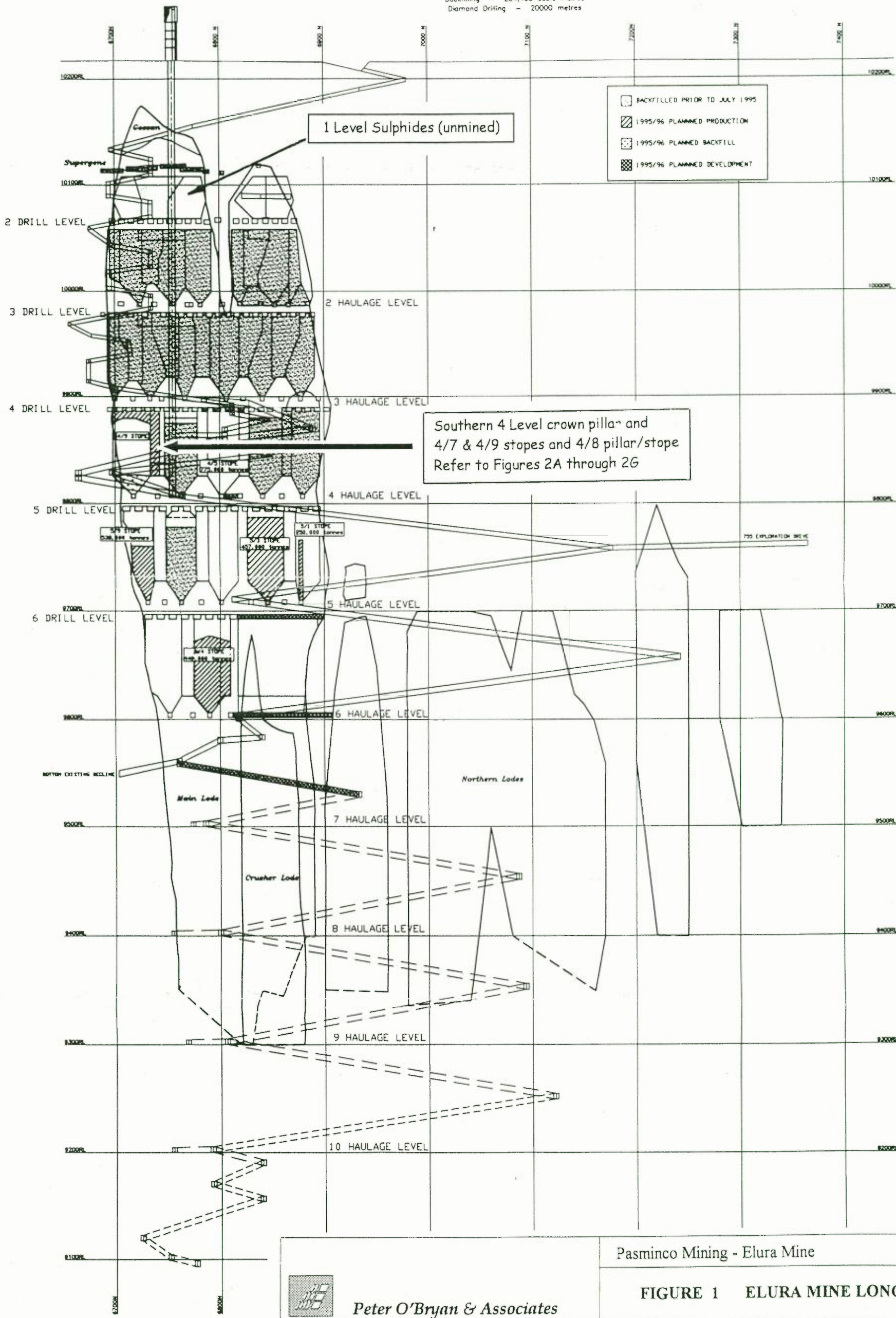
5.70% Pb, 8.80% Zn, 70g/t Ag.

Development Ore - 99,900 tonnes

- Development - 1,647 metres
- Rotary Drilling - 16,240 metres
- Solo Drilling - 10,700 metres
- Cable Dowelling - 12,380 metres
- Backfilling - 254,400 cubic metres
- Diamond Drilling - 20,000 metres



N

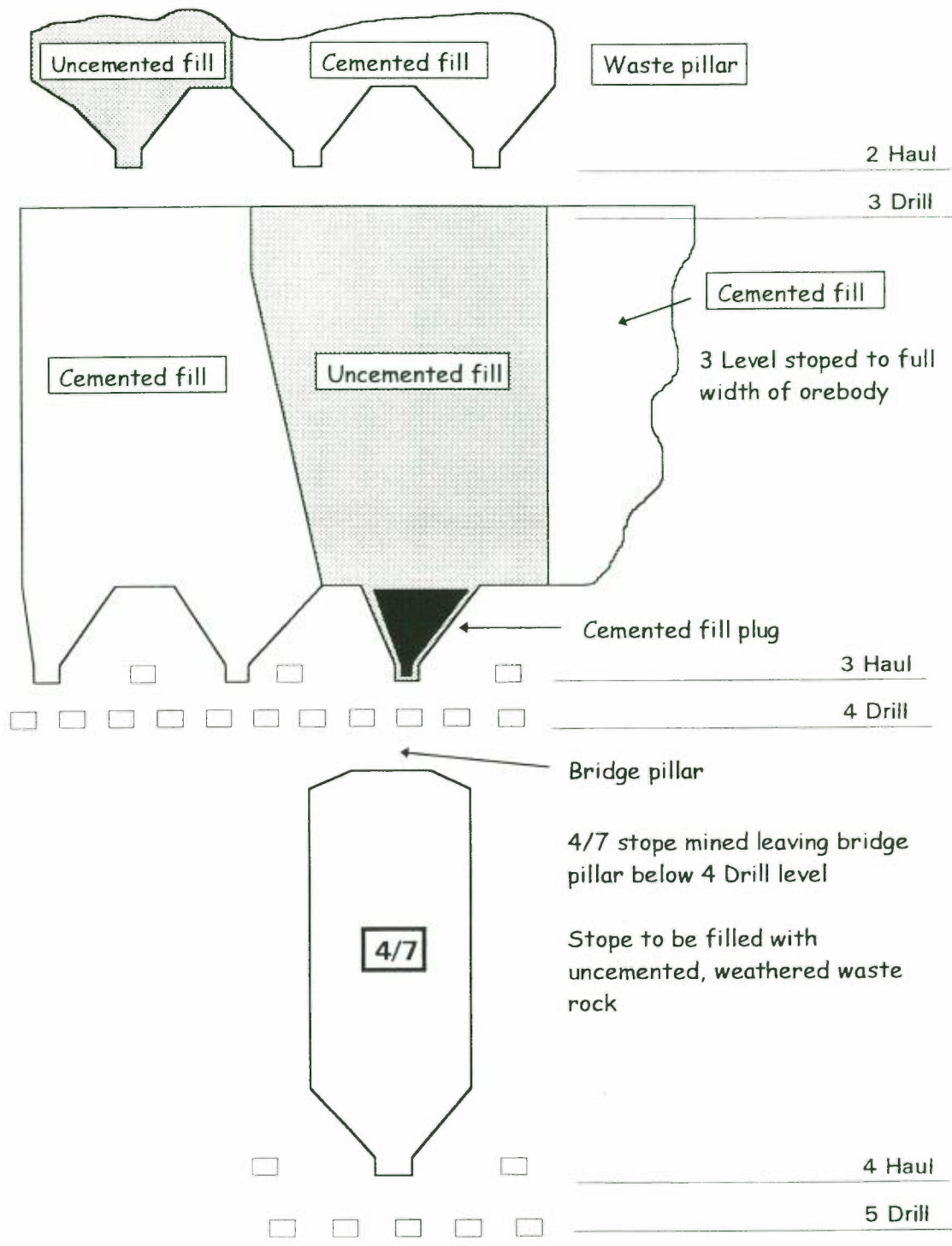


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Pasminco Mining - Elura Mine

9603011
May 1996

FIGURE 1 ELURA MINE LONG SECTION



NOT TO SCALE - SCHEMATIC ONLY

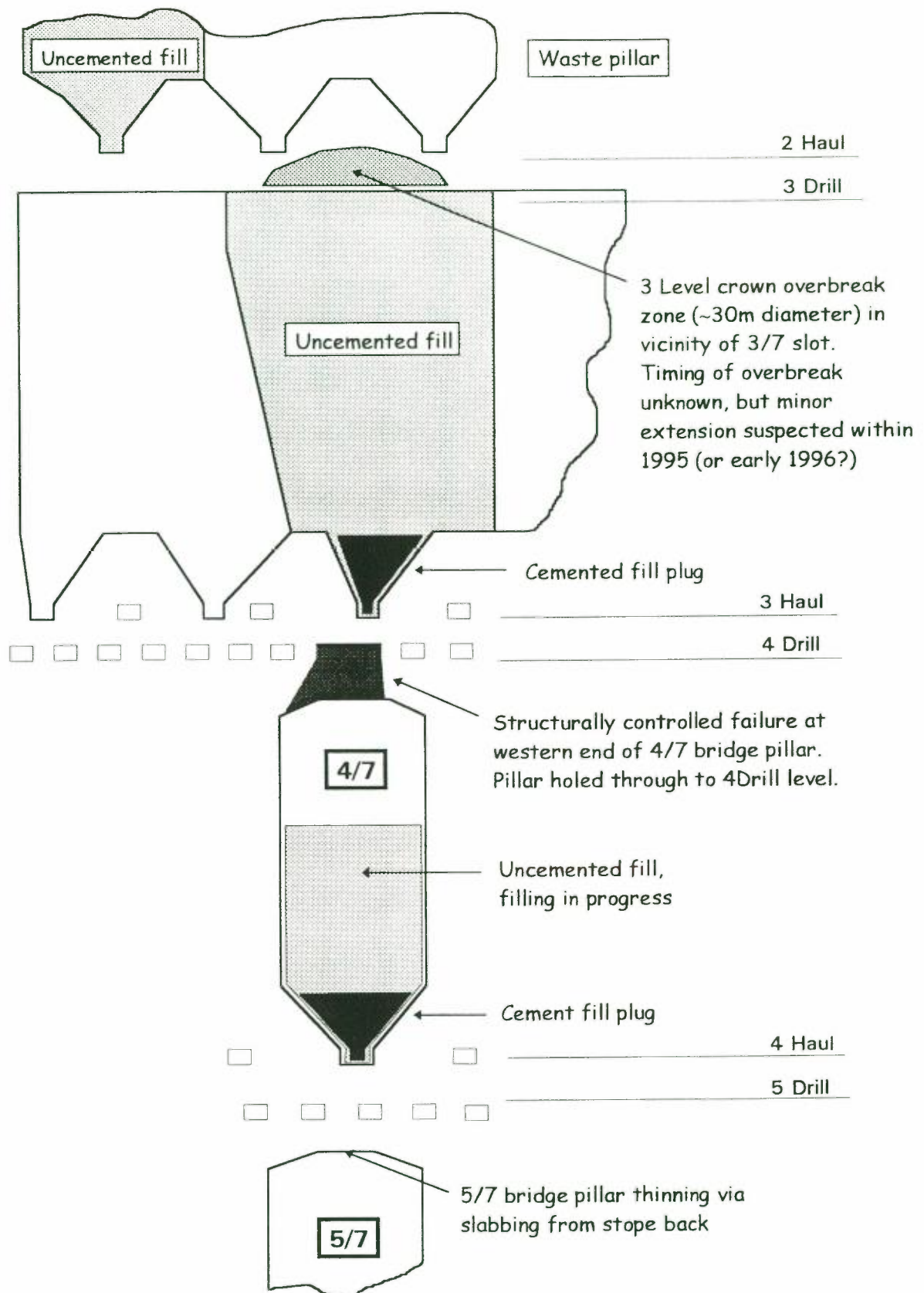
Pasminco Mining - Elura Mine

9603011
May 1996



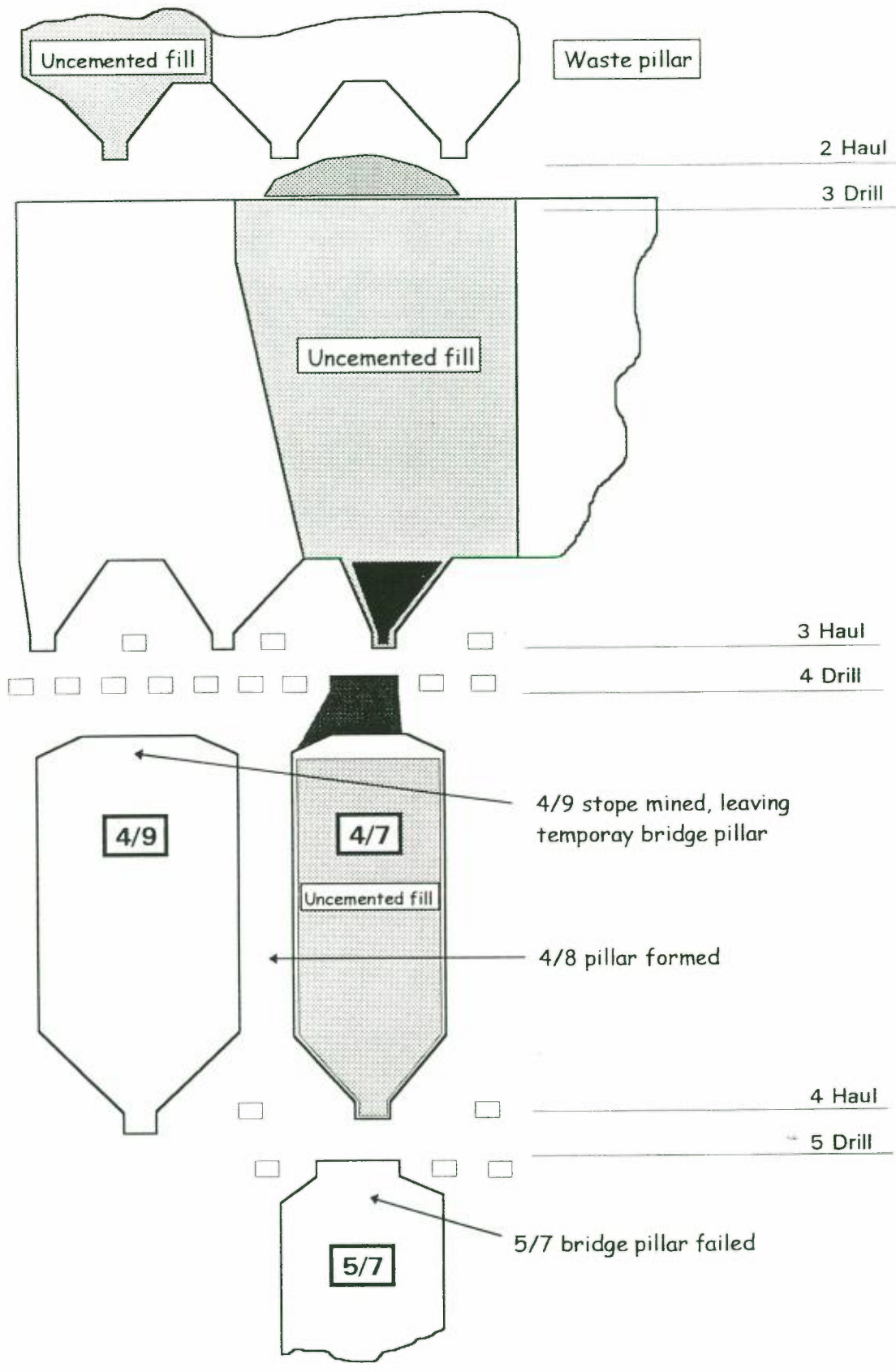
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FIGURE 2A ELURA STATUS - PRE 1994



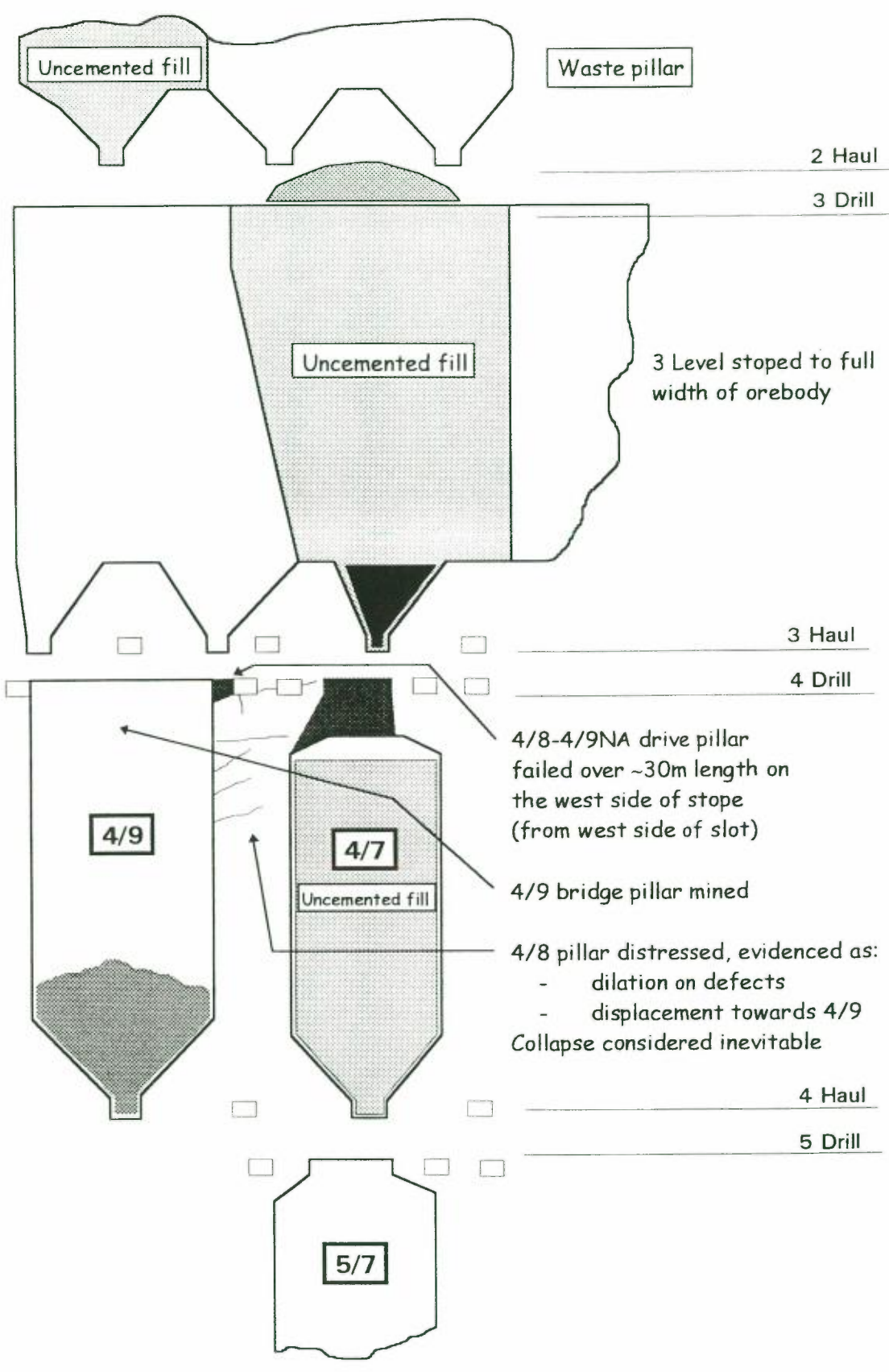
NOT TO SCALE - SCHEMATIC ONLY





NOT TO SCALE - SCHEMATIC ONLY





NOT TO SCALE - SCHEMATIC ONLY

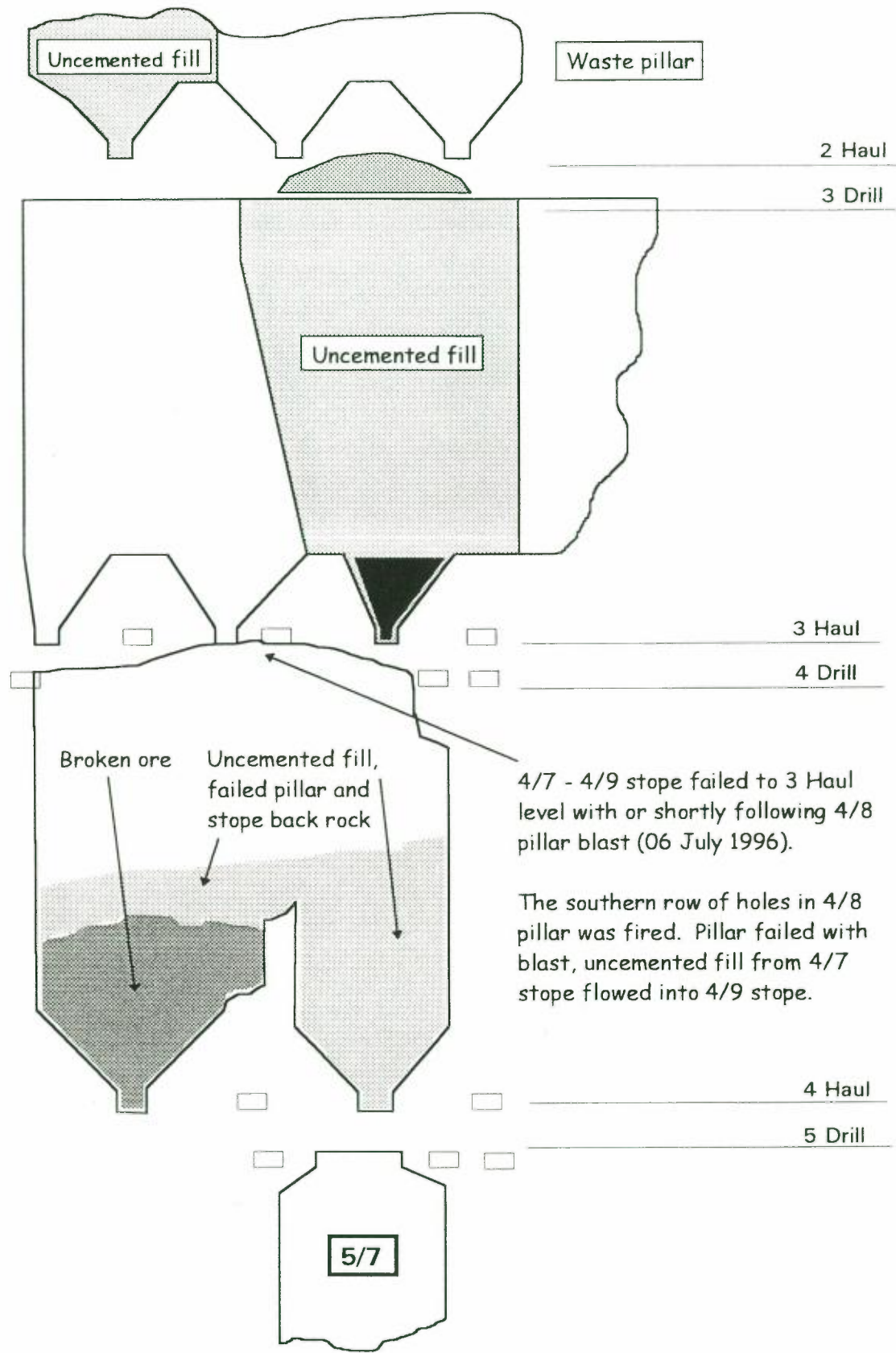
Pasminco Mining - Elura Mine

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May 1996



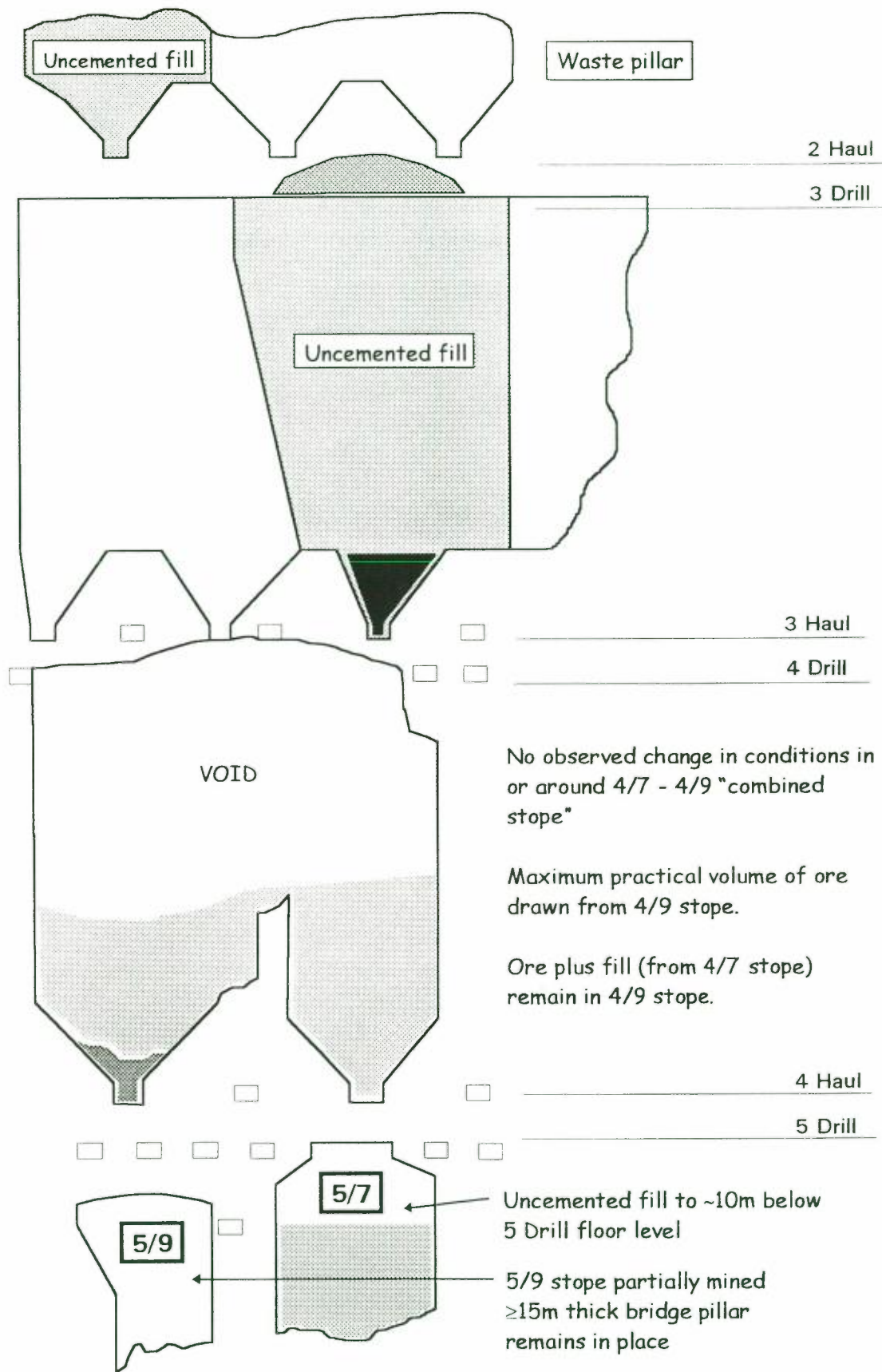
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FIGURE 2D ELURA STATUS - JUNE 1995



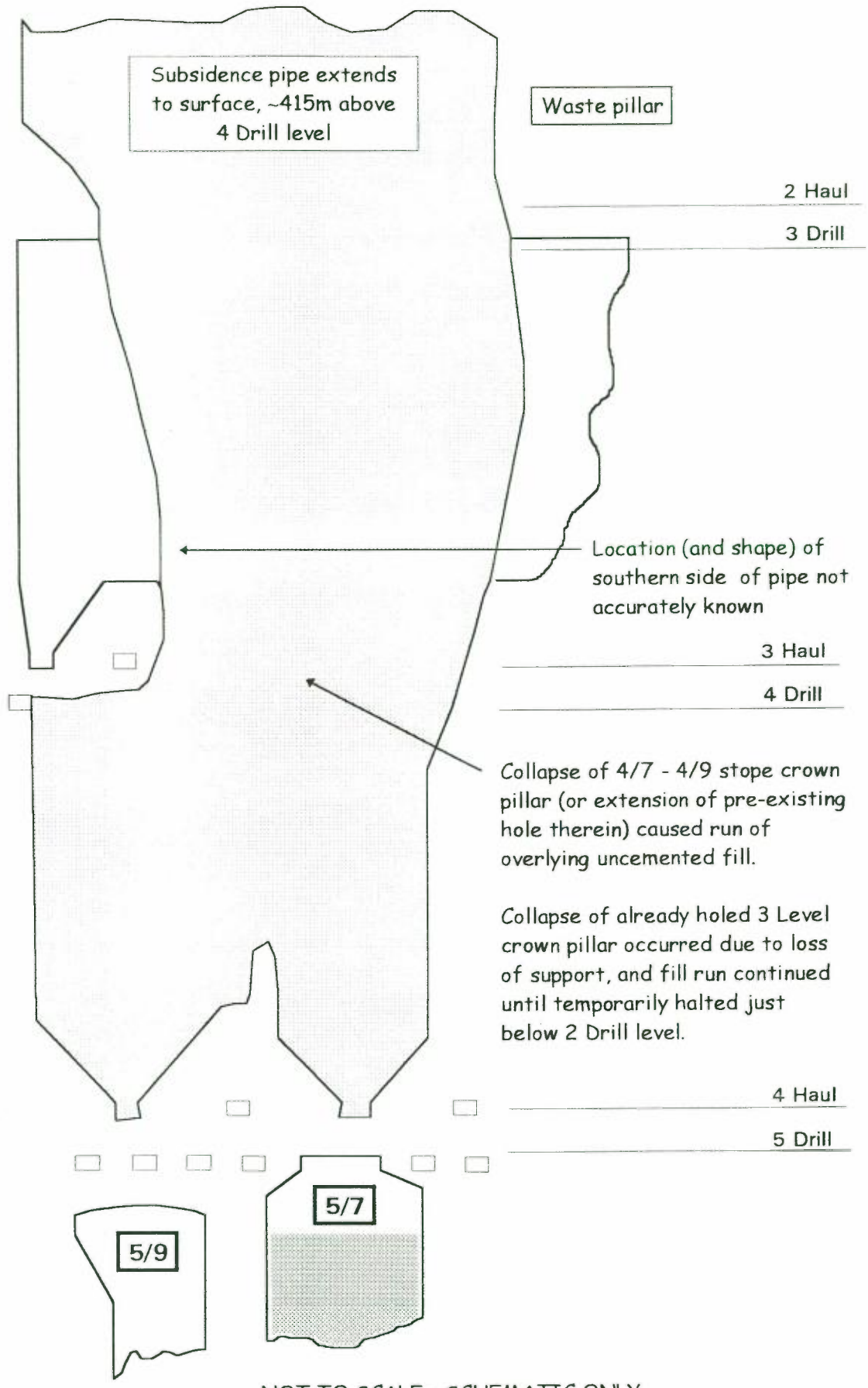
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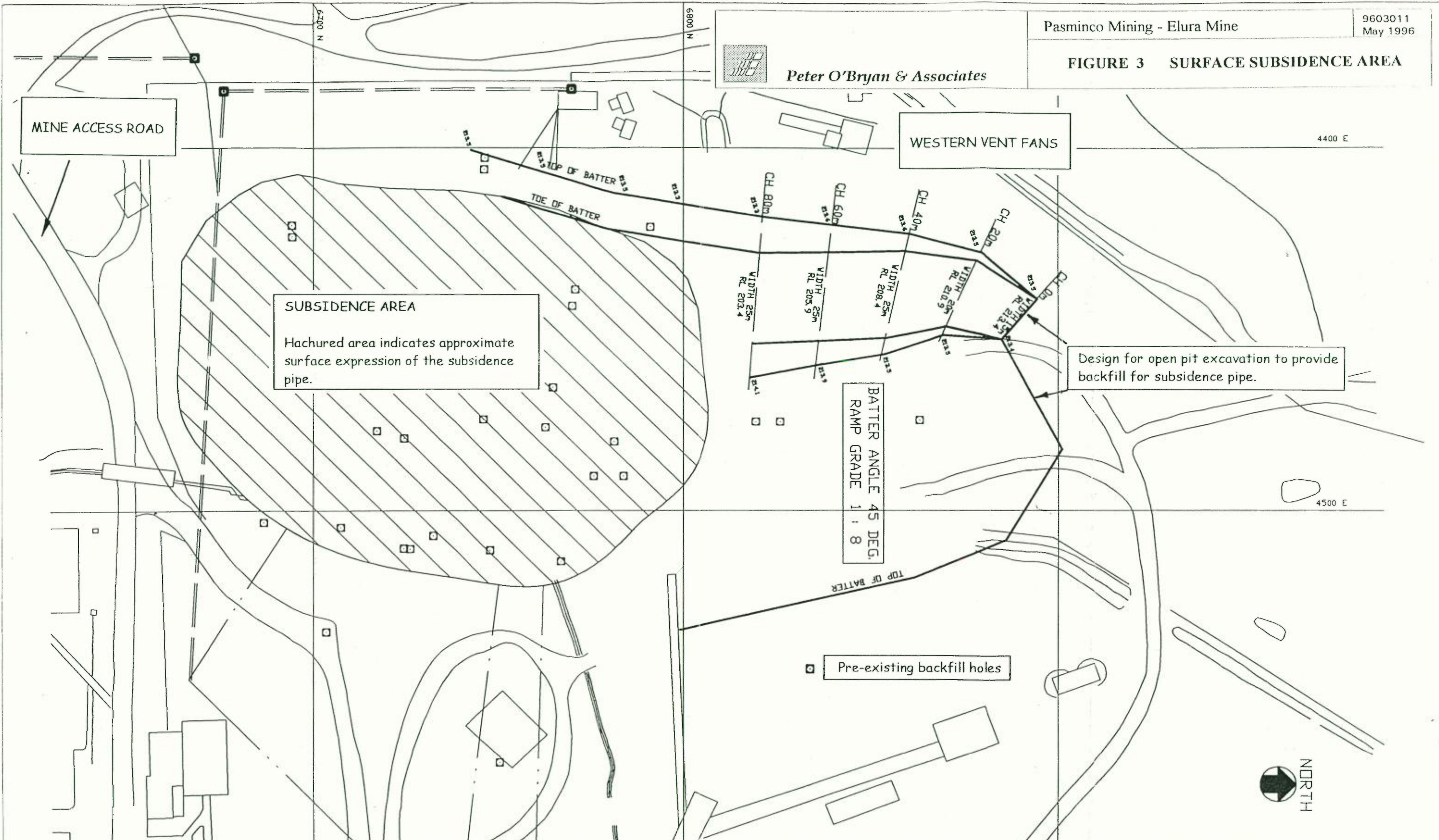


NOT TO SCALE - SCHEMATIC ONLY




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FIGURE 3 SURFACE SUBSIDENCE AREA



						DESIGNED	T MAC
						DRAWN	T MAC
						CHECKED	
						APPROVED	
No.	BY	DATE	REVISIONS	APP.	DRG.No	REFERENCE DRAWINGS	

TITLE
**ELURA ORE BODY
OPEN CUT
SUBSIDENCE AREA
SURVEY DETAILS**

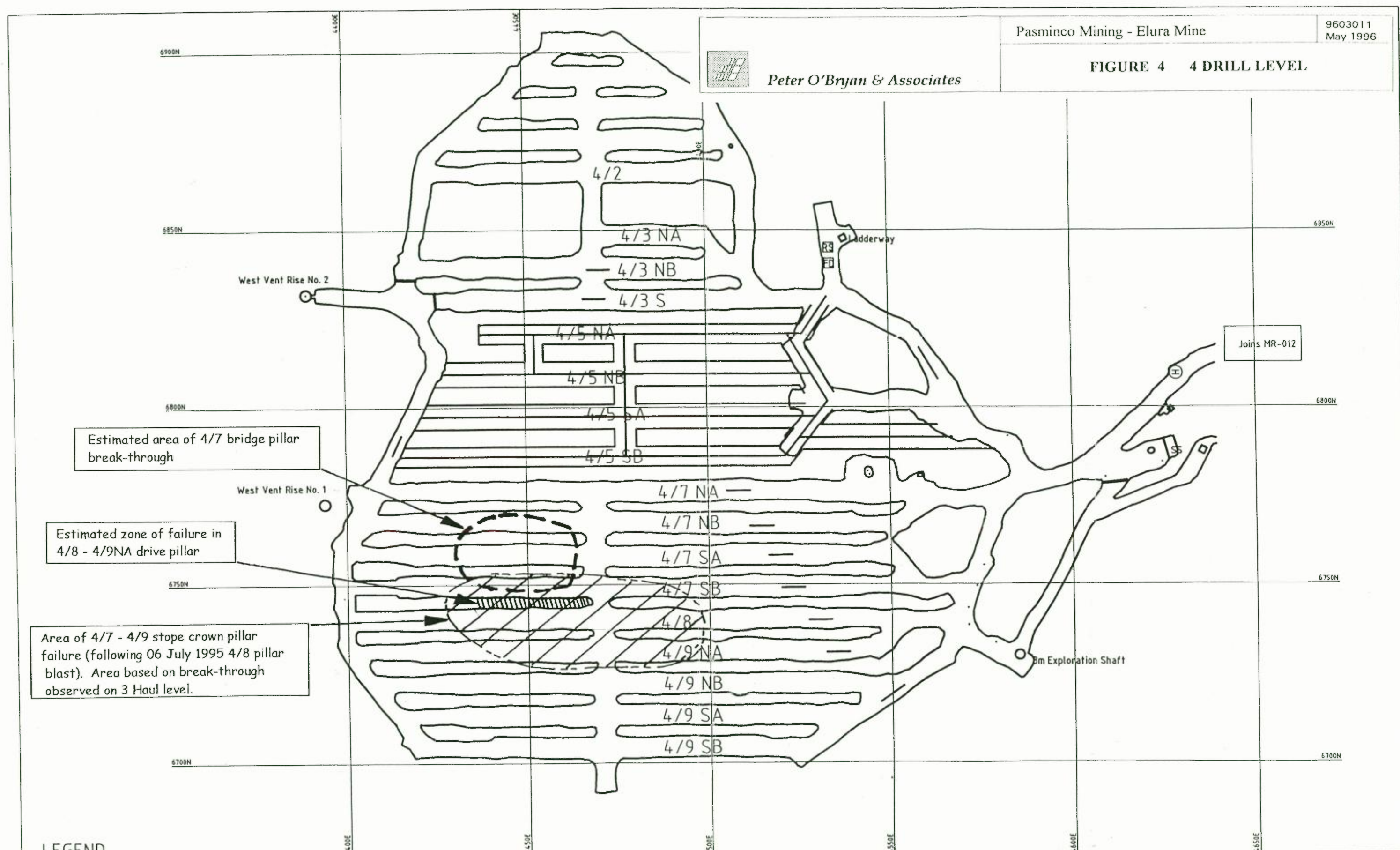
 **PASMINCO** ELURA MINE
COBAR, N.S.W.

DATE	DRAWING No.	SCALE	REV
22-03-96	S-093	1:1000	1

FIGURE 4 4 DRILL LEVEL



Peter O'Bryan & Associates



Estimated area of 4/7 bridge pillar break-through

Estimated zone of failure in 4/8 - 4/9NA drive pillar

Area of 4/7 - 4/9 stope crown pillar failure (following 06 July 1995 4/8 pillar blast). Area based on break-through observed on 3 Haul level.

LEGEND

(SS)	SUB STATION	(D)	DOOR	DESIGNED	
(T)	TELEPHONE	(=)	WALL	DRAWN	AMM
(E)	FIRE EXTINGUISHER	(F)	FLAPS	CHECKED	
(E)	TAG IN-OUT BOARD	(FD)	FIRE DEPOT	APPROVED	
(RS)	RESCUE STATION	(K)	FIRST AID KIT		
(R)	REGULATOR	(+)	LOUVERS		

TITLE
4 DRILL

PASMINCO ELURA MINE
COBAR, N.S.W.

DATE	DRAWING No.	SCALE	REV
19/3/96	MR-029	1:1000	○