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Assessment of the impact of subsidence from proposed underground mining at Airly, N.S.W.

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ASSESSMENT OF THE IMPACT OF SUBSIDENCE FROM PROPOSED UNDERGROUND MINING AT AIRLY, N.S.W.

REPORT PREPARED FOR

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ON BEHALF OF

NOVACOAL AUSTRALIA PTY LTD

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EXECUTIVE SUMMARY

This report determines subsidence predictions for coal extraction under the Airly Mesa, assesses the impact of subsidence, and proposes subsidence monitoring procedures.

Maximum subsidence will be 1.7 m to 1.8 m. Strain and tilt levels are predicted to range up to 43 mm/m and 85 mm/m respectively for full extraction panels. These levels will cause surface cracking and damage to rock structures within the mesa.

The degree of surface disturbance is considered acceptable, because the main features of the mesa will be protected from high levels of subsidence. These include the cliffs and headwaters of Genowlan Creek. The overall appearance of the mesa will not be altered, surface run off not materially changed, flora and fauna not substantially affected by subsidence.

The cliff lines, which are the outstanding feature of the mesa, will be protected by partial panel extraction in protection zones under the cliffs. The zones, based on a draw angle of 25 degrees, can be partially extracted when cover depth between the Lithgow Seam and cliff top exceeds 50 m.

Subsidence monitoring by way of surface cross lines over initial panels, coupled with laser ranging of cliffs is proposed. The results can be used to develop site specific subsidence guidelines.

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ASSESSMENT OF THE IMPACT OF SUBSIDENCE FROM PROPOSED UNDERGROUND MINING AT AIRLY, N.S.W.

1.0 INTRODUCTION

Novacoal Australia Pty Limited (Novacoal) is examining the feasibility of underground mining at the Airly Authorisation No. A232, located 5 km north east of Capertee in the Western Coalfield, New South Wales (see Figure 1 - Airly Authorisation Location Plan). The area is one with outstanding scenic beauty, and Novacoal has acknowledged this by proposing a mine plan which aims to avoid damage to major cliff lines. As part of the mine planning and environmental impact investigations, a detailed assessment of likely subsidence and its impact was undertaken. The results of the study are presented in this report.

The Airly coal deposit is contained entirely within a "mesa" known as the Airly Mesa. It is on the western most edge of the coal bearing strata of the Sydney Basin where the high sandstone terrain, characteristic of the Blue Mountains is eroded into separate mesas and sandstone capped ranges. The deposit, in the Lithgow Seam, is a gently dipping seam of coal contained entirely within the lower section of an irregular starfish outlier.

The mesa, which covers approximately 24,000 ha, is actually a more complex outlier of the Blue Mountains. It includes Mount Airly, Point Hatteras, Airly Turret and Genowlan Mountain. A central narrow pass splits the outlier into eastern and western parts. The eastern part has developed an internal drainage system.

It has scenically, spectacular cliff faces around much of the perimeter; the western, southern and eastern cliffs being visible along the the Capertee - Glen Davis road. It is acknowledged as a major feature of the regional landscape.

The Airly coal deposit contains approximately 200 million tonnes of coal.

A significant amount of the resource will be sterilised in order to protect the sandstone cliffs from the effects of subsidence.

Subsidence resulting from extraction of coal has the potential to cause significant impact to the landforms contained within the mesa. Consequently the geomorphology of the mesa has a large influence on the proposed mine plan, which needs to maximise resource extraction, while at the same time providing permanent protection for high cliffs.

In this report subsidence levels throughout the mesa are predicted, using the Western Coalfield Subsidence Guideline, published by the Department of Minerals & Energy. The impacts of predicted subsidence levels are considered, and recommendations for mitigation, and monitoring follow.

Definitions of terms used in subsidence prediction are given in Appendix I.

2.0 SITE DESCRIPTION

As stated above, the Airly coal deposit is contained entirely within the irregular starfish-shaped Mount Airly - Genowlan Mountain mesa (see Figure 1 for location). The mesa is a Permo-Triassic outlier of coal bearing strata capped by up to 200 m of Narrabeen Group cliff-forming sandstones. The sandstones are equivalent to those forming the Blue Mountains. Locally basalt overlies the cliff forming sandstones.

The Lithgow Seam, which is the only seam with economic potential in the mesa, crops out below, and in front of the cliffs around the lower perimeter of the mesa. Thickness range is 4.9 m to 5.9 m. It is continuous throughout the mesa with depth of cover ranging up to 300 m.

Above the seam and within the mesa there are a number of individual peaks. The most prominent western feature is Mount Airly, while there is another very prominent, unnamed peak on the

north western spur of the mesa. Mount Airly is separated from the rest of the mesa by the high level pass, "Airly Gap".
In the eastern part, Genowlan Mountain is the highest peak at the north eastern extremity. Other prominent points are Point Hatteras, Airly Turret and the Genowlan Trig Station.

The mesa stands out prominently above the rolling country formed in older Permian and Devonian strata, approximately 10 km west of the west-facing escarpments of the Blue Mountains. Elevation ranges from around 300 m on the western side of Mount Airly, to more than 500 m on the eastern side of Genowlan Mountain.

Basalt flows cap the high points of the mesa and are up to 40 m thick. Where basalt has eroded away the softer, underlying sandstones are heavily dissected. Natural joints and cracks are common. While the majority follow regional joint trends, of which there are several, there are also cracks and joints which do not. These appear to be the result of internal rock mass adjustments following movement of the sandstone cliffs during the natural erosion process.

The western part of the mesa (Mount Airly) is characterised by a relatively flat top of considerable extent, with only small areas of basalt capping. The basalt has limited erosion and dissection of the softer underlying sandstone to the small watercourses which drain from the flat top.

Arms of the Mount Airly mesa extend northwest and southwest. The north western arm ends with a high basalt capped isolated peak, with sandstone cliffs around the outer perimeter. The south western arm is lower in relief but rises directly above the Glen Davis road, which bends around its base.

To the east across Airly Gap there is a large area of basalt covering Point Hatteras. Several alluvial mining leases occur over this area. The capping ends abruptly on the western side of the mesa, at the cliffs overlooking Airly Gap.

On the eastern side, the headwaters of Genowlan Creek have eroded the basalt away, revealing a complex landscape of narrow gorges, cliffs, and beehive structures extending across to the main ridge of Genowlan Mountain further to the east. Near its headwater the creek cuts through the sandstone, forming a tunnel like passage known locally as "The Grotto". The creek drains north to join the Gap Creek beyond the mesa.

Sandstone stacks in the headwaters of Genowlan Creek are pointed dome structures, having a large base, and commonly a pointed top ("beehives"). The valley area between Point Hatteras and Genowlan Trig Station contains a large concentration of the beehive structures. Tall, narrow "pagodas" are uncommon.

Cliff faces occur, both around the perimeter of the mesa, and each side of Airly Gap. They are formed in Triassic medium to coarse grained sandstones with occasional, thin shale and claystone bands. The cliff forming sandstones occur in the upper 100 m to 150 m of the mesa between 850 m and 1,000 m AHD. Cliffs vary in height from 20 m to 50 m around the mesa, except for the two northern peaks on the eastern side, Point Hatteras and Genowlan Mountain, which have maximum cliff heights between 60 m and 100 m.

Slopes are heavily vegetated below the cliffs. They are formed from the Permian Illawarra Coal Measures, and are covered with a thin veneer of talus. Beyond the lower slopes of the mesa, land is generally cleared for grazing.

Capertee State Forest adjoins the mesa on the southern side, while grazing properties surround the remainder of the mesa.

Old oil shale (torbanite) workings are located around the north western part of Mount Airly. The oil shale horizons occur above the Lithgow Seam. The most extensive workings are located around the northern side of Mount Airly. The old workings developed from outcrop then advanced inside the mesa. Old plans indicate two areas , one close to outcrop, and one inside the mesa. The inner workings are separated from the outer workings by very large pillars.

3.0 PROPOSED MINE LAYOUT

The proposed mine layout has been developed to maximise resource recovery, and provide protection for all outer cliff lines, as well as those of Airly Gap. The plan concentrates panel extraction areas inside the mesas away from high cliffs, and where possible orients access roads near, or under cliff lines.

The mining operation for Airly is described in detail in the Environmental Impact Statement, and only enough details are repeated here in order to explain the impact of subsidence.

The mine will be developed by driving a set of five access roadways at 30 m centres (the main headings) through Mount Airly as shown in Figure 2. All roadways will be 4.8 m wide, enabling single pass operations by an appropriate continuous miner unit. Height of workings will be 3.0 m to 3.3 m.

Extraction panel sections, with three roadways will be developed off the main headings for up to 2 km. The extraction panel sections will be approximately 168 m wide. Subpanels will then be driven from the panel roadways across the solid block of coal. Then the subpanel and panel pillars will be extracted on the retreat. These panels will be successively extracted for the 20 year mine life.

In theory the proposed mine layout would enable 100% extraction of coal, but in practice the maximum amount of coal normally extracted is about 85%. Safety considerations are responsible for less than 100% extraction.

In areas where it is considered that damage to cliff lines might ensue with full extraction, partial extraction methods will be employed. Pillars remaining will be sized large enough to provide permanent support to overlying strata.

Coal under the central portions of the two mesa will be extracted first, from west to east. Subsidiary five heading developments will then be driven from the main headings to access coal in the arms of the mesas. Extraction in the arms will be a combination of partial and full extraction. The choice of method in the various arms will depend on limits set by subsidence predictions, which will preclude damage to cliffs.

Figure 2 shows the partial extraction areas both within the main two mining regions, and in the peripheral arms of the mesa.

Other ventilation adits, or men and materials entry will be developed according to mining needs, but these have no subsidence impact.

4.0 SUBSIDENCE PREDICTIONS

4.1 METHOD OF SUBSIDENCE PREDICTION

The Department of Minerals and Energy published "Surface Subsidence Prediction in the Western Coalfield" in April, 1991 (Holla, 1991). The guideline predictions are based directly on the survey results over four longwall mines in the Western Coalfield; Angus Place, Baal Bone, Fernbrook and Invincible Collieries. Extraction in all four collieries was in the Lithgow Seam, with mining depth between 75 m and 285 m, for seam thickness varying from 2.3 m to 3.1 m. The longwall panel widths were between 140 m and 200 m, with chain pillars separating the extracted areas.

The static subsidence profiles resulting from conventional coal extraction methods are similar to those developed over longwall blocks, such as measured for the Subsidence Guideline. The dynamics of the two methods of extraction differ, but the end result is similar. These observations justify adoption of the Western Coalfield Subsidence Guideline prediction methods.

Subsidence is calculated as a percentage of the actual seam thickness mined. The maximum possible subsidence measured in the Western Coalfield is 65% of the seam thickness mined (mining Height). This occurs when width of workings exceeds 1.6 x cover depth.

Once maximum subsidence is determined, other measures of subsidence; strain, tilt and curvature can be determined.

The predicted values are considered to be the maximum values expected.

The Western Coalfield Guideline also enables estimates of subsidence over commencing, finishing and longitudinal ribs, as well as determination of the dynamic subsidence profile. This profile is useful in assessing likely damage to surface structures when a longwall passes below. If the rate of extraction is slow then the dynamic profile is similar to the static profile.

The Guideline also introduces angle of fracture, which is defined as the angle between the vertical line joining the edge of an extraction panel and the point of maximum tensile strain on the surface (where surface cracking is most likely to occur). THe angle is less than the draw angle.

Airly deposit is planned to be mined by continuous mining equipment. No inter panel pillars will remain, as is the case with the longwall method.

There are three types of workings to consider, and each will impact the surface through the effects of subsidence in different ways.

They are:

- o Roadway Development
- o Full Extraction Panels
- o Partial Extraction Panels

The subsidence predictions for each are detailed in the following sections.

4.2 SUBSIDENCE EFFECTS FROM ROADWAY DEVELOPMENT

The locations of main access roadways are shown in Figure 2. Roadways will be 4.8 m wide and from 3.0 m to 3.3 m high. Openings with these dimensions cause negligible movements at the surface at the depths to be experienced at Airly.

The basis for this statement is the results of surface monitoring at Grose Valley Colliery near Bell. After three years of detailed surveying the surface movements were 2 mm or less, and the survey period covered the breaking of a drought in late 1983 (Holt, 1984).

The National Energy Research, Development & Demonstration Council sponsored the study of the effects of mining under the Great Western Railway near Bell, in the Western Coalfield in 1981 - 1984. It specifically monitored roadway openings from underground, undertook mathematical and physical models of roadway stability, and monitored the surface above workings for movement.

In the long term, well after mining has been abandoned, and the mine site rendered safe and/or rehabilitated according to requirements at the time, limited areas near portal entries over some roadways might cave in.

4.3 SUBSIDENCE EFFECTS FROM FULL EXTRACTION PANELS

The method for determining the likely subsidence levels is detailed in Section 4.1 above. The important factors in determining subsidence and strain levels are:

- o Seam thickness (more correctly, effective working height)
- o Seam depth
- o Width of extracted area (panel width)

Since the proposed extraction method aims to leave no barrier pillars between mined out panels, the width of the extracted area becomes the total width of all adjoining panels. This leaves only seam depth and thickness as critical parameters in calculating subsidence.

The method of mining aims to extract all coal, but in practice the percentage of coal taken will typically be 85%, for the reasons stated above.

The unmined coal has will reduce the amount of subsidence that will occur over mined out areas. The prediction method takes this into account by reducing the maximum possible subsidence, according to the percentage of coal extracted.

The thickness of the coal seam varies across the area, and must be accomodated in the prediction method. The prediction method only considers an average seam thickness for the area under examination, so thickness variations are averaged.

The two areas, Mount Airly and Point Hatteras/Genowlan Mountain have different average seam thickness, and this will result in slightly different subsidence
predictions. Consequently the two areas are treated separately.

4.3.1 Subsidence Predictions for the Mount Airly Region

The average working thickness under Mount Airly is 3.0 m. With 85% extraction the effective seam thickness for calculation purposes is 2.55 m. The cover depth ranges between 100 m and 250 m for the extraction panels. Maximum possible subsidence is 65% of the effective seam thickness, which is 1.66 m (say 1.7 m).

Maximum subsidence occurs when the width of the extracted panel exceeds 1.6 x Cover Depth (this is the critical width). Critical width clearly varies according to depth of workings, as follows.

Depth of Workings (m)	50	100	150	200	250
Critical Width (m)	80	160	240	320	400

The width of a single extraction panel will be approximately 168 m, and this increases to 230 m when the adjoining pillars are extracted. However the goafs from successive extraction panels will join, meaning that the entire Mount Airly set of panels will cause maximum subsidence over the entire area.

Maximum subsidence predicted is approximately 1.7 m.

4.3.2 Strain Predictions for the Mount Airly Region

Application of the formulae listed in the Guideline yields the maximum values listed in Table 1 overleaf. The Guideline gives a range of coefficients for the calculation of strain and tilt because of the variations in terrain, strata strengths, slope and survey variables. In order to determine maximum figures, the maximum coefficient values are utilised here. Such an approach will overstate strain and tilt levels.

The ranges of values for each parameter are similar to the static subsidence values published in the guideline, although the minimum values are slightly higher. The maximum tilt values are in accord with the highest guideline values (for longitudinal rib profiles) of 80 mm/m.

Cover Depth (H) (m)	100	150	200	250
Smax/H	0.017	0.011	0.0085	0.0068
Tensile Strain (mm/m)	25.5	16.5	12.8	10.2
Compressive Strain (mm/m)	42.5	27.5	21.3	17
Tilt (mm/m)	85	55	42.5	34

TABLE 1. Strain & Tilt Predictions for Airly Mountain Region

4.3.3 Subsidence Predictions for Point Hatteras/Genowlan Mtn

The averaged working thickness under the eastern area is 3.3 m. With 85% extraction the effective seam thickness is 2.8 m. The cover depth ranges between 100 m and 300 m for the extraction panels. Maximum subsidence is 65% of the effective seam thickness, which is 1.82 m (say 1.8 m).

As with the Mount Airly extraction panels the critical width will be exceeded for all cover depths and maximum subsidence of around 1.8 m will occur over all panels. This includes the first panel, where areas that did not initially undergo maximum subsidence will settle to the maximum 1.8 m.

4.3.4 Strain Predictions for Point Hatteras/Genowlan Mountain

Application of the formulae listed in the Guideline yields the maximum values listed in Table 2. The Guideline gives a range of coefficients for the calculation of strain and tilt because of the variations in terrain, strata strengths, slope and survey variables. In order to determine maximum figures, the maximum coefficient values are utilised here. Such an approach will overstate strain and tilt levels, but at least the values represent upper bounds, not minimal limits.

Cover Depth (H)	100	150	200	250	300
Smax/H	0.017	0.011	0.0085	0.0068	0.006
Tensile Strain (mm/m)	25.5	16.5	12.8	10.2	9.0
Compressive Strain (mm/m)	42.5	27.5	21.3	17	15
Tilt (mm/m)	85	55	42.5	34	30

TABLE 2. Strain predictions for Point Hatteras/ Genowlan Mountain area

4.4 SUBSIDENCE PREDICTIONS FOR PARTIAL EXTRACTION AREAS

Partial extraction areas are proposed at the northern end of extraction panels in the Mount Airly mesa, at the north eastern end of panels under Point Hatteras/Genowlan Mountain, and in arms of the mesa (see Figure 2). The purpose of the partial extraction areas is to maximise coal extraction, but at a level which protects substantial cliff lines above.

There are no published guidelines on what defines a "substantial" cliff, but any cliff 20 m or higher is considered substantial in this report.

There are also no published allowable levels of subsidence for protection of cliffs, except for the policy of the Department of Mineral Resources that it will not support mining "within a protection zone" until it is proved that major rock falls would not occur. It is the level of extraction under cliffs which dictates the amount of subsidence, and adoption of the conservative partial extraction system proposed by Novacoal allows for some coal mining at a level which will not damage cliffs. It is known from mining experience in the Western Coalfield that some extraction can take place under cliffs without causing damage due to subsidence.

A protection zone is normally defined as a zone between the limit of full extraction and the top of cliffs. The width of the zone is defined by the angle of draw pertaining to that area. The two lines defining the width of a protection zone are drawn from the top of cliffs, 20 m high or higher, down 65 degrees to the Lithgow Seam both in front, and behind the cliff face. The declination is based on an angle of draw of 25 degrees, determined by the Western Coalfield Subsidence Guideline.

The width of the protection zone will vary with cover depth as shown in Table 3 overleaf. The areas of cliff protected are shown in Figure 2.

Cover Depth (Seam to cliff top) (m)	50	100	150	200	250	300
Width of Protection Zone	47	94	140	187	234	280

TABLE 3: Variation in Width of Cliff Protection Zone with Depth

First workings, ie roadway development, and partial pillar extraction will take place within the protection zone. Partial extraction will be based on extraction of a row of pillars, and retention of the next row of pillars. Pillars will be sized for economic coal extraction, whilst conforming to the requirements of the Coal Mine Regulation Act. As a guide the minimum pillar dimension will be in the range 20 m to 30 m.

At 50 m cover depth to cliff top or less, the cliff protection zone will merge with the outcrop barrier, and no secondary workings are proposed. There are three areas with cover depth less than 50 m, and all are located on the western side of the mesa, as shown in Figure 2.

Elsewhere cover depth exceeds 150 m, and there is sufficient cover depth to reduce the impact at the cliff to very low subsidence levels. Indeed the Western Coalfield guideline indicates that below a panel width/cover depth ratio of 0.3, subsidence is effectively zero. This ratio is achieved with a panel width of 30 m (pillar width 20 m) at a depth of 100 m from the cliff top to seam roof.

It follows that with neglible subsidence, strains and tilt are also neglible. If monitoring demonstrates that higher levels of subsidence do not cause major cliff face slides then the extraction ratio could be increased.

5.0 IMPACT OF SUBSIDENCE

5.1 INTRODUCTION

The Airly Mesa lies to the west of the Wollemi and Blue Mountains National Park system, and there is pressure to extend national parks over the areas presently set aside for coal mining, including the mesa. However the area is not natural wilderness, having already suffered a major episode of mining as well as logging. Several mining leases are in force over part of the area, and mining has taken place.

The old shale workings resulted in a sizeable mining operation in the north west part of the area. Roads, tunnels, houses, a railway line, and oil extraction plant were developed. Since abandonment of the oil shale business the visible signs of mine operations have become largely overgrown and derelict.

Logging activities removed the large trees from gullies and adjacent slopes in and around the mesa, although since the abandonment of logging there has been considerable regrowth of natural timbers.

Grazing properties have developed around the base of the mesa, and short distances up the lower slopes, beyond outcrop of the Lithgow Seam.

Mining for diamonds has continued intermittently below the basalt capping the mesa. Workings consist of tunnels dug into old river channels, buried by basalt flows. They are still in use, and Mining leases are still current.

Apart from the mine workings there are no "improvements" in the area that will be impacted by subsidence so considerations of impact centre on the effect of subsidence on the natural features.

5.2 IMPACT ON INTEGRITY OF THE MESA

The proposed mine plan for the Airly underground coal mine was developed to maximise extraction of coal while preserving the main features of the area, the sandstone cliffs. The mine plan allows for all major cliff faces to be protected from significant subsidence events, while allowing some extraction from under the cliffs.

Full panel extraction is proposed away from cliffs. Such extraction will cause maximum subsidence of the surface of between 1.7 m and 1.8 m.

The strains at these levels of subsidence range between 9 mm/m and 43 mm/m, while the tilt range is between 30 mm/m and 85 mm/m.

At the levels of subsidence predicted, experience from elsewhere in the Western Coalfield indicates that some damage to surface rock will result. The type of damage that can be expected is surface cracking of sandstone rock. Such cracking has no structural impact on general rock strata. Observations over mined areas in the Western Coalfield appear to suggest that rock cracking *in situ* has no impact on the natural environment.

It can cause instability in isolated rock masses. The common isolated rock masses in the Airly mesa are "beehives". A beehive typically has a large base, and even when cracked, does not become unstable unless the supporting strata are tilted sufficiently to cause failure by sliding or toppling.

Where strain and tilt levels, such as predicted here, impact cliffs, then damage is greater. At Baal Bone Colliery damage occurred to 5% of some 30 kms of cliffs affected by longwall operations. The damage manifested as rock falls from specific parts of cliff faces, spalling, collapse of the roofs of caves formed at the base of cliffs, extensive cracking across major faces, and movement of very large masses of cliff. Large rock falls have also occurred.

At Airly the plan for full extraction is designed to avoid the effects of large strains and tilts on major cliff faces. The area affected by the levels of subsidence indicated above coincides with the locations of the proposed full extraction panels, shown in Figure 2.

Partial extraction will be carried out, in zones designated by a 25 degree draw angle, under major cliff lines. The system will involve extracting a row of pillars, and leaving a row. This will be undertaken where cover depth from seam to cliff top is more than 50 m. Subsidence, strain and tilt will be neglible.

There will be a protection barrier under The Grotto and Genowlan Creek in the same way protection barriers will be placed under the high cliffs.

Research associated with production of the Western Coalfield Guideline demonstrated that a fracture angle can be measured. The angle defines the point of maximum tensile strain over workings, and it is inside the goaf edge. This means that the zone most likely to fail in tension is over the extracted panels on each side of a protection zone.

This characteristic provides an additional safety barrier to cliffs. When panels approaching cliffs stop at the draw angle limit, the area of maximum tension at the surface will be further away from the cliff base than the goaf edge.

Significant areas of the mesa will not be unduly affected by subsidence because the blanketing effect of basalt flows over buried sand channels will minimise the impact at the surface. Once panels have been extracted much of the rock will be under compression, rather than tension, and this reduces the impact of cracking.

Overall, extraction of coal will not destroy the outward appearance of the mesa, nor really alter the way it appears.

Lowering of the internal sections may result in land surfaces behind cliff faces tilting in towards the mined area but it is doubtful that such tilting will be noticeable because of the nature of the terrain.

The tilting of land behind cliff faces may cause some material that is eroding on the cliffs, but presently just stable, to fall. It is difficult to predict such events because the amount of tilting will be small due to protection given by partial extraction zones. Also all strata exhibit elastic behaviour, and a certain portion of strain induced by strata subsiding is taken up within the rock.

In parts of the mesa where major cliffs are not present Novacoal intend to employ full seam extraction methods, and subsidence will affect smaller cliffs in the parts of the mesa above workings.

There are always geological discontinuities in rock masses that give rise to unexpected events, and it can be assumed that such discontinuities exist at Airly, so that disturbance to cliff faces will occasionally happen. It is already happening in the Genowlan Trig area of the mesa. Natural erosion processes have resulted in extensive cracking of the rock strata.

The proposed mine has been designed not to affect the cliffs of Airly. It can be concluded that the design is such that none is expected, while accepting that unpredictable events can occur albeit at a very low level of probability.

5.3 OTHER IMPACTS

5.3.1 Oil Shale Workings

There is growing community interest in preserving some remains of the workings, and the mining proposal avoids the main area of old buildings, located near Carinya. It will cause subsidence of abandoned workings, where mining of coal takes place underneath. Since the workings are unsafe, the loss of some old workings is not considered a significant loss of European heritage.

5.3.2 Impact on Ecosystems

Subsidence of the order of 1.7 m to 1.8 m will have some impact on ecosystems and watercourses. The watercourses within the mesa are generally cut down to bedrock so any additional erosion of channels is going to have minimal impact. Strata cracking may have limited local impact on run off but cracks normally fill and seal very quickly, and normal run off patterns would be expected to quickly re-establish.

5.3.3 Impact on Ground Water

Much ground water moves through pre-existing cracks and joints before entering the water courses at Airly. The addition of many more cracks will increase the water carrying capacity of the strata.

Run off from the mesa is rapid since soil cover is thin and rock predominates.

The impact of subsidence might be to slightly reduce peak flows and extend the run off period following rain, but the difference will probably be not measurable. It is unlikely that large volume flows resulting from thunderstorm activity would be affected.

There are two properties using run off from the mesa, Portion 11 "Airly Mountain", owned by Mr C. Ribaux, and Portion 35, owned by Mr & Mrs Papoulias.

Portion 11 - Ribaux Property

The property is situated between the Glen Davis Road and Airly

Turret. It occupies the lower slopes of this section of the Airly Mesa. Its freshest water supply is a small spring emanating from the talus/outcrop area below Airly Turret. The spring is at about the level of the Lithgow Seam subcrop, and is outside Portion 11. There is also a dam on the lower part of the property close to the Glen Davis road.

Water flow was found in the creek below Airly Turret just below the spring. The undergrowth was too dense to locate the actual spring, but it is on the up-dip side of the coal measure sequence. The sweet, fresh quality of the water discounts the coal seam as a water source. The water source is more likely surface run off soaking down through joints and colluvium from the overlying sandstone rather than along rock strata, against gravity. The fresh nature of the water implies a sandstone related source rather than the coal measures. The flow is small but consistent.

The section of cliff line containing the spring water supply, behind the Ribeux property, is not planned to be undermined. If the mine plan changed, only first workings or partial extraction would be possible in this area and the spring would not be affected.

Portion 35 - Papoulias Property

The Papoulias property covers approximately 400 ha immediately to the north of Airly Gap, the pass that separates the two main mesas forming Airly Mesa. The property is in a rain shadow formed by the main Airly mesa. There are two intermittent streams crossing the property; Genowlan and Gap Creeks.

Genowlan Creek is classified intermittent, but appears to have a year round flow in the upper reaches, which disappears into alluvials formed in the creek bed, before reappearing some distance downstream. Gap Creek has no permanent flow. The two named creeks join near the northern boundary of the property, and also supply other properties further downstream.

A dam, located on Genowlan Creek near the south eastern corner of the property, collects the water shed from Airly Mountain into Genowlan Creek. The dam apparently leaks but the collected water is piped to a larger dam near the junction of Gap and Genowlan Creeks for stock and human use. The water is regarded as of very good quality.

A second source of supply from two springs is located near the old shale workings just south west of Portion 35. The springs are located on the down dip side of strata forming Mount Airly, and are above a dam constructed by the previous owner on a separate portion (owned or held by Mr and Mrs Papoulias). They are separated by several hundred metres, and each appears to collect water from seepage areas spread over a wide area of hillside. The springs are apparently permanent. Water quality is not as good as the Genowlan Creek sourced water but it is potable.

Collection pits direct the flow into polyethylene piping, which takes it directly to the main property.

The location of the springs with respect to the Lithgow Seam could not be determined accurately because of lack of outcrop, and scrub density on the talus slopes below the main sandstone cliffs. However they are above the shale workings, which are also above the Lithgow Seam.

The springs are below the outer faces of sandstone cliffs, just beyond a partial extraction protection zone. The actual springs area will be subsided, and this may interrupt the water flow. It is expected that flow would re-establish, but some interruption is possible.

5.3.4 Impact on Other Mine Workings

Subsidence will affect the adits driven into and under basalt cover on Point Hatteras. Appropriate precautions will need to be taken if there are intentions to work the adits during coal extraction below. The same applies to the water supply dam on Point Hatteras.

6.0 SUBSIDENCE MONITORING

The subsidence levels predicted in this report are based on the Guideline, recently published for the Western Coalfield. That guideline utilised subsidence monitoring data over longwall panels at four Western Coalfield collieries.

There are some differences in the nature of subsidence over conventional extraction panels and longwall panels, brought about by the different layout of longwall operations, and the speed of coal extraction.

Longwall panels necessarily retain chain pillars between panels. The pillars reduce the maximum subsidence, but complicate the overall strain picture. Conventional extraction, such as planned for Airly, will increase overall subsidence levels, maintain similar maximum strain and tilt levels, but result in a simplified strain and tilt distribution. This results in a more stable final landscape since strain variations are much reduced.

In addition the rate of coal extraction by conventional mining machines is much slower, and strata have much more time to redistribute and accommodate stresses. This fact is implicit in the Western Coalfield Guideline. It examines the difference between dynamic and static subsidence, and compares subsidence at different rates of extraction.

Compared with rapid extraction, slow extraction rates result in more subsidence sooner, with very little residual subsidence, while allowing strata to accommodate the changes.

The differences in mining methods means that there may be variations from predictions based on the Guideline. The differences would be small for subsidence, but could be larger for strains and tilt. It may be that strain and tilt values will be less than predicted by the Guideline. The practical answer to overcome any possible shortfall in the prediction method is site monitoring.

Surface cross lines can be positioned over panels which will be mined early in the mine life to monitor actual subsidence. The results of such monitoring can then be used to guide future extraction.

The early extraction panels will not impact major cliff lines, and this provides an added protection of gaining site specific data, without the risk of major cliff damage.

The terrain is rough, and this renders conventional surface survey methods subject to large errors (by survey standards). Apart from careful siting of cross lines, laser ranging equipment can be used to measure cliff movement, and movement in normally inaccessible places. Local strain triangles can be established to gather detailed strain movements at selected localities.

This latter point is important because in rough terrain it is the strain measurements which show the greatest discrepancies.

At a conceptual stage it is impractical to detail subsidence monitoring layouts. These need to be positioned so that data is not compromised, and so that surveyors can access them.

Such monitoring is a normal requirement of the Chief Inspector of Coal Mines for the secondary extraction approval process, and it consequently comes under close scrutiny.

7.0 CONCLUSIONS

Maximum subsidence levels likely to be experienced from mining the Lithgow Seam at the Airly Mesa will be in the range 1.7 m to 1.8 m above full extraction panels. Strain levels will vary with depth, and some surface impact can be expected.

Cracking of sandstone strata will occur, and there will be occasions when rock face, and other damage to strata will occur. The key features of the mesa, the high cliff faces, and "The Grotto", will be protected by subsidence protection zones.

Subsidence and strain levels over partial extraction areas are predicted to be negligible. Even so, it is considered that even high cliffs can tolerate small strains and subsidence movements without damage.

Definition of protection barriers by adoption of an angle of draw from workings to the top of cliffs of 25 degrees is based on the draw angle reported in the Western Coalfields Subsidence Guideline.

It is recommended that protection zones be initially defined on the basis of recommendations described in this report. These should be capable of revision according to results of subsidence monitoring.

Mining will have negligible impact on run off and ground water within and around the mesa. The water supplies to two properties drawing water from the mesa are unlikely to be affected. The owners would have recourse to replacement of water supplies under the Coal Mining Act.

It must be emphasised that while the area can be described as scenic it is similar to other areas of eroded sandstone within the nearby extensive National Parks system. The proposed layout maximises resource recovery and provides a balance between resource utilisation and a reasonable level of environmental protection. The subsidence levels predicted are considered tolerable for the site.

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Graham Holt

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Principal

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APPENDIX I

SUBSIDENCE TERMINOLOGY

SUBSIDENCE TERMINOLOGY

The following symbols, terms and definitions are taken from " Mining Subsidence in New South Wales 1. Surface Subsidence Prediction in the Southern Coalfield" by L. Holla, published by the Dept of Mineral Resources, December, 1985. Units of measurement are given in brackets.

H	=	cover depth (m)
L	=	panel length (m)
T	=	effective extracted seam thickness (m)
W	=	panel width (m)
D	=	distance from goaf edge to any point on subsidence profiles (m)
D1	=	distance of the point of maximum tension from goaf edge (m)
D2	=	distance of inflection point from goaf edge (m)
S	=	subsidence at any point (m)
Sc	=	subsidence at panel centre line
S_m (or S_{max})	=	maximum subsidence along a profile (m)
Gmax	=	maximum change in tilt along a subsidence profile (mm/m)
Rmin	=	minimum radius of curvature along a profile (km)
+Emax	=	maximum tensile strain along a profile (mm/m)
-Emax	=	maximum compressive strain along a profile (mm/m)
K1	=	tensile strain factor (non-dimensional)
K2	=	compressive strain factor (non-dimensional)
K3	=	tilt factor (non-dimensional)

TERMS AND DEFINITIONS

Cover depth(H): The depth of a seam below the surface averaged over the extraction panel.

Critical area: The area of panel which causes the maximum possible subsidence of one point on the surface. The area which causes S_{max} to reach its maximum value.

Extracted seam thickness: The thickness of seam extracted, averaged over the panel.

Effective extracted seam thickness (T): The extracted seam thickness, modified if required, to account for unmined pillars (modification based on the percentage of extraction within the panel).

Goaf: Mined out area into which the immediate roof layers break off in large fragments.

Inflection Point: The point on the subsidence profile at which strain changes sign and subsidence is half S_{max}.

Panel: The plan area of coal extraction.

Panel length (L): The longitudinal distance along a panel measured in the direction of mining.

Panel width (W): The transverse distance across a panel, usually equal to the face length plus the widths of roadways on two sides.

Sub-critical area: An area of panel smaller than the critical area.

Super-critical area: An area of panel greater than the critical area.

CRITERIA FOR DETERMINATION OF MAXIMUM SUBSIDENCE

Maximum subsidence can be predicted using the empirical guidelines if the following criteria are met:

- Only one seam is extracted, or in the case of multi-seam extraction, the workings in the other seams are too far away to have any influence.
- The extraction panel is nearly rectangular. Otherwise average width used.
- The extracted seam thickness is adjusted, if required to account for unmined pillars or pillar remnants. The adjusted thickness is referred to as the effective extracted seam thickness (T).
- The residual subsidence has occurred.
- The roof contained within the extracted panel is caved.
- The overburden is free from dykes, faults or other geological discontinuities which can alter the normal subsidence behaviour.

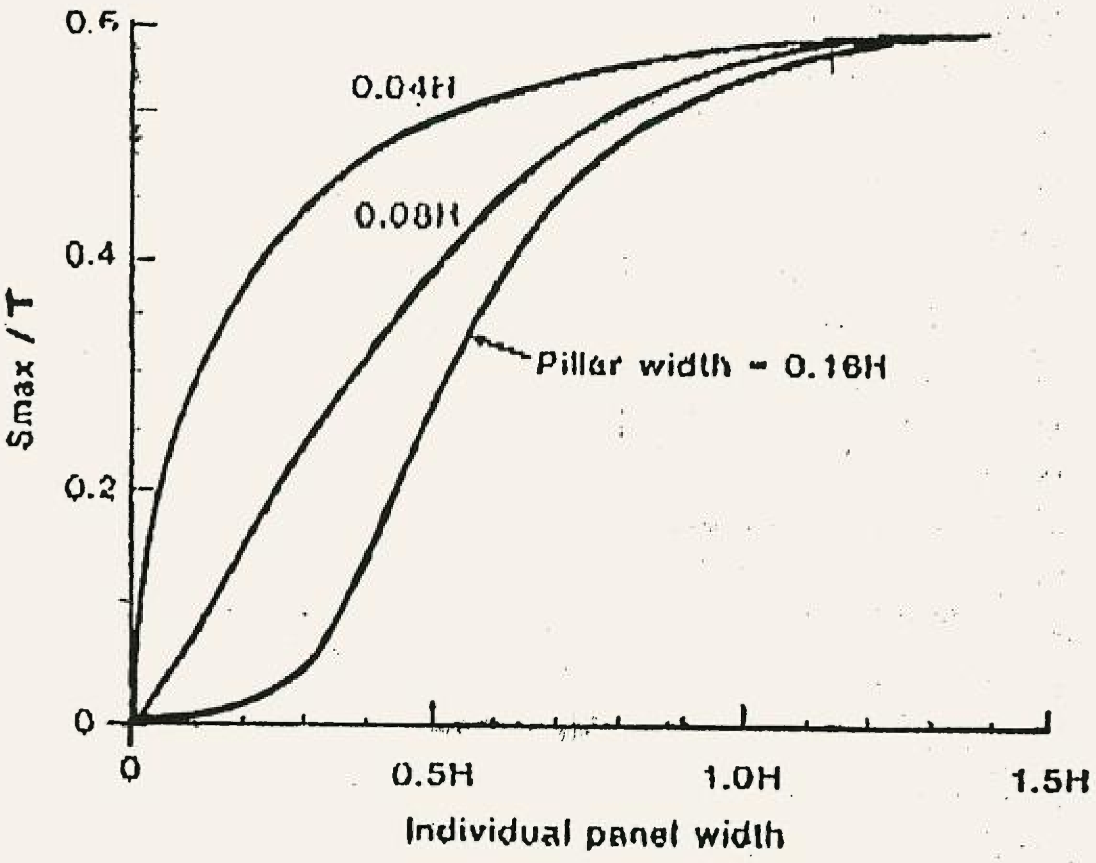
For the Western Coalfield, maximum subsidence S_{max} occurs when panel width is equal to or greater than 1.6 x cover depth (H). The probable value of the maximum possible subsidence for critical and super-critical extraction widths can be taken as 0.65T.

Subsidence Prediction for a Series of Panels

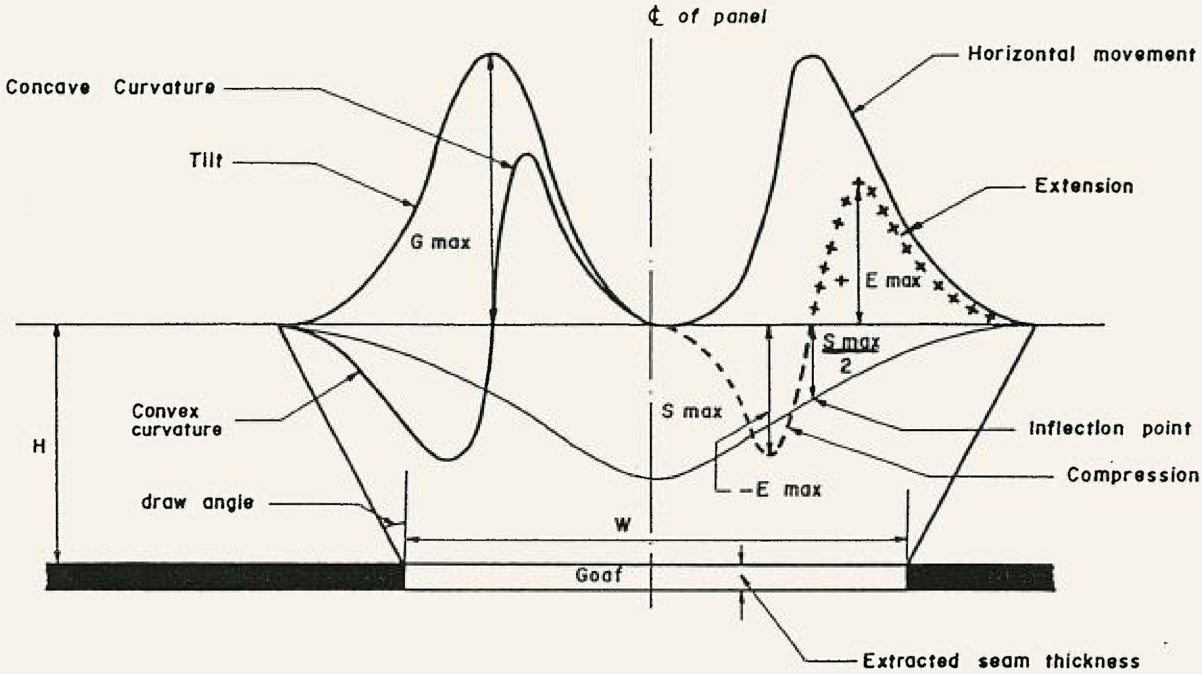
Holla (1988) improved on the method for prediction of subsidence for a series of panels. Previously only panels within limited width and cover depth ranges could utilise the method outlined in the Southern Coalfield Guideline.

Prediction curves were re-drawn to enable prediction of maximum subsidence for critical extraction conditions for other pillar widths and depths by interpolation. The curves are strictly applicable to the Southern Coalfield but can be extended to the Newcastle Coalfield.

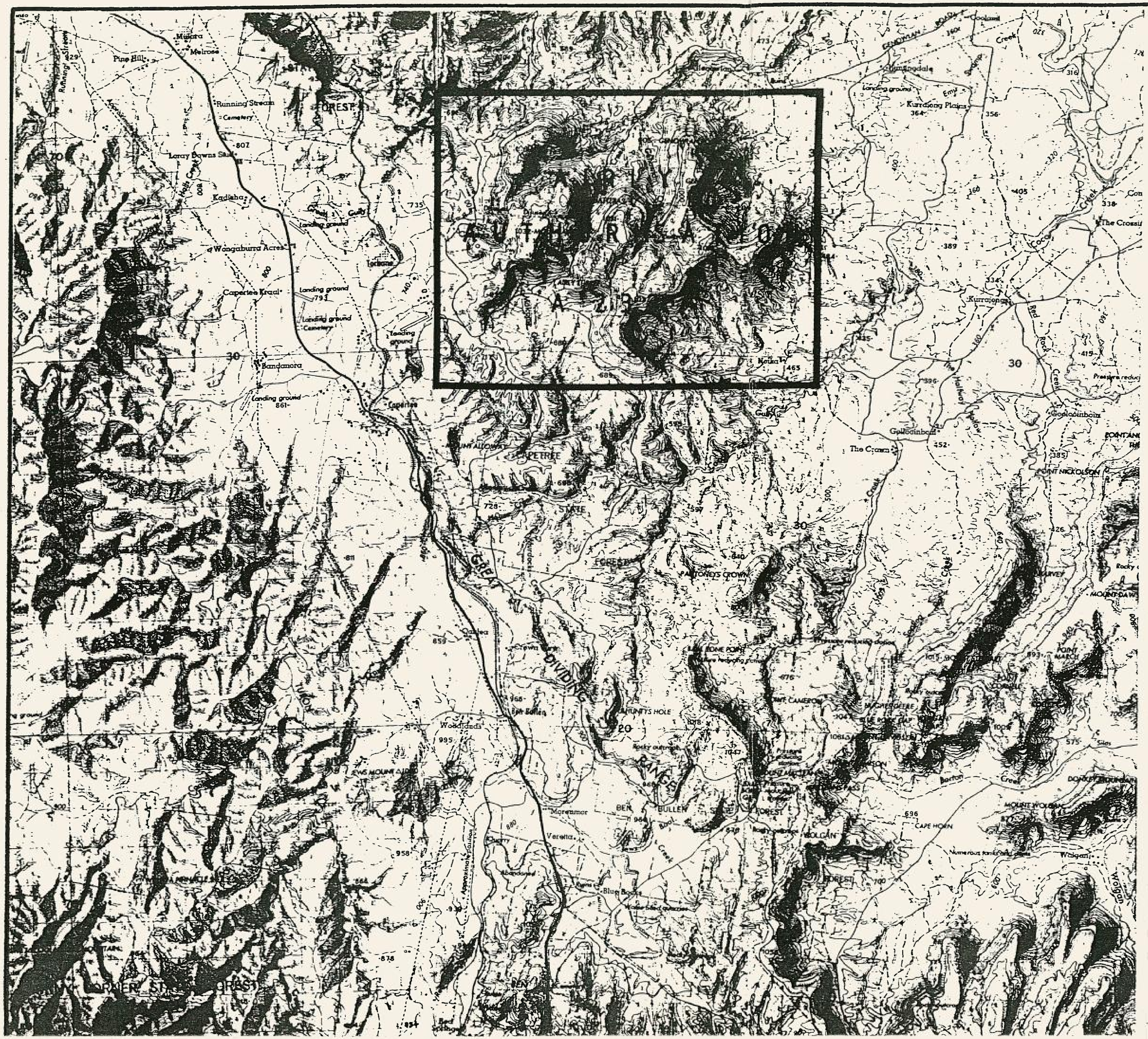
A copy of the panel subsidence prediction curves is reproduced below .



Maximum Subsidence Over a Series of Panels for Critical Extraction Conditions



Characteristics of trough subsidence
Left half of profile: Vertical Components
Right half of profile: Horizontal Components



SCALE 1 : 100 000

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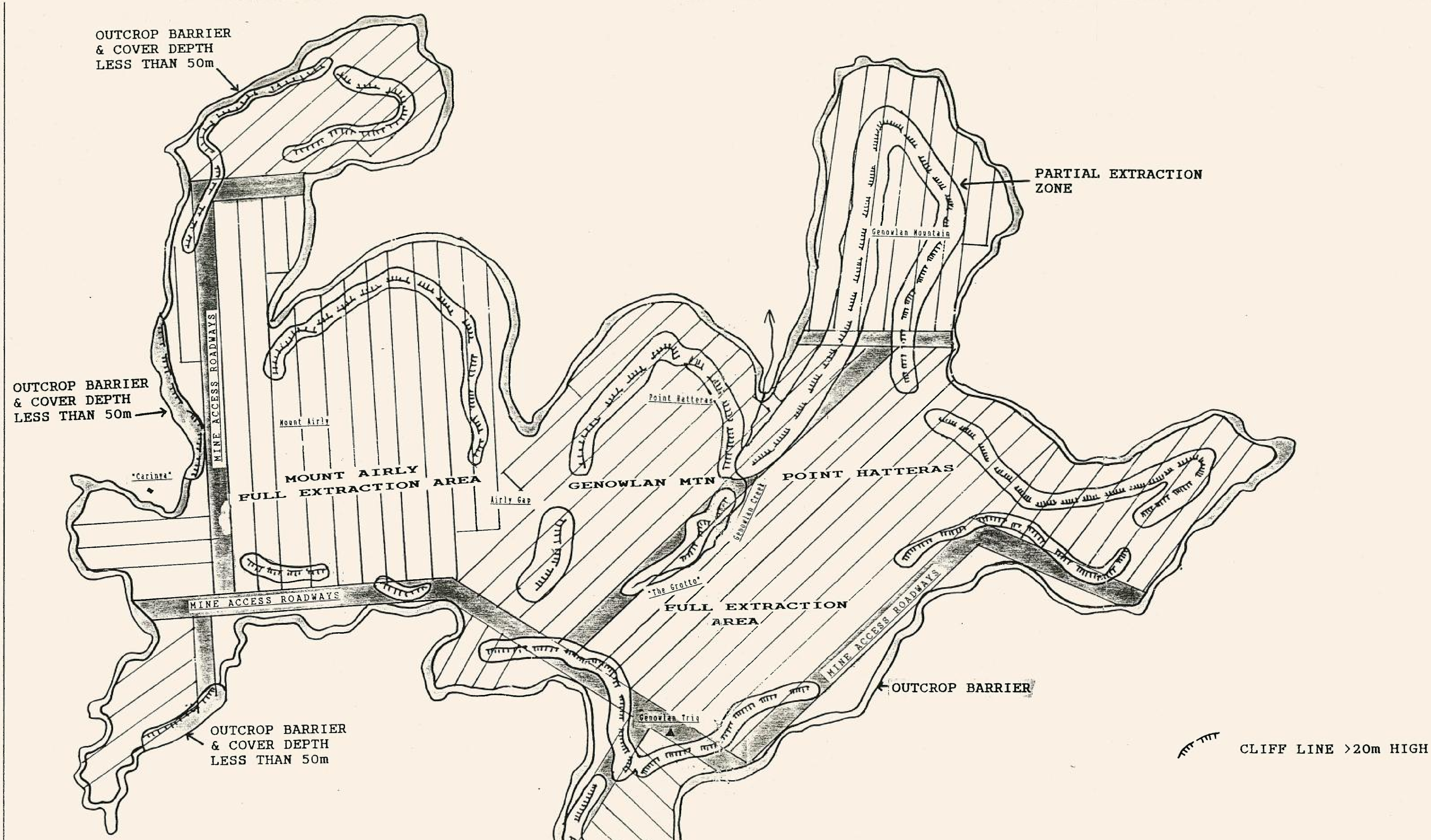
PROPOSED AIRLY COAL MINE

AIRLY AUTHORISATION
LOCATION PLAN

FIGURE 1	JUNE 1991



SCALE 1:25,000 APPROX.

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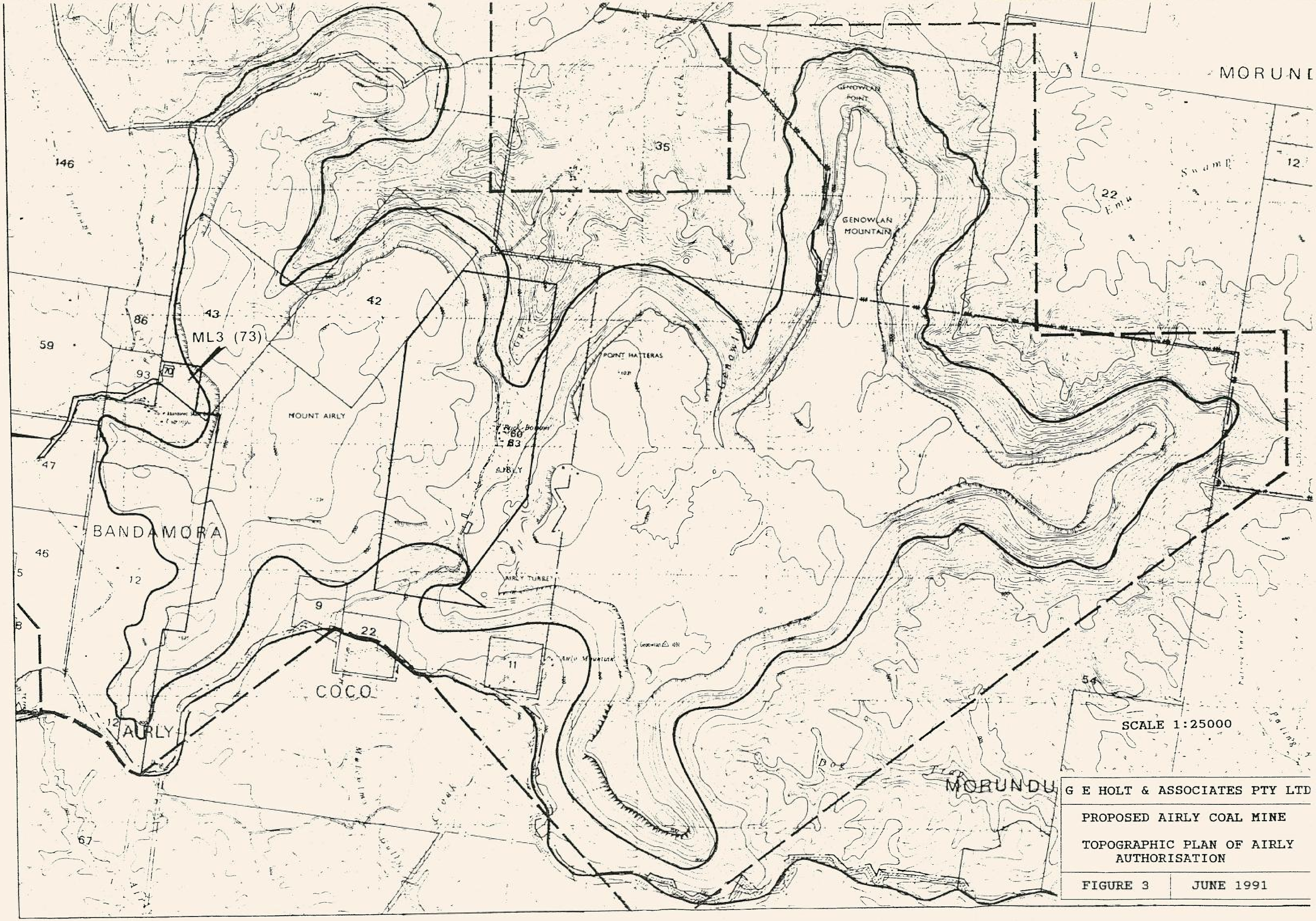
PROPOSED AIRLY COAL MINE

PLAN OF MINE SHOWING
PARTIAL AND FULL EXTRACTION
ZONES

FIGURE 2 | JUNE 1991



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PROPOSED AIRLY COAL MINE

TOPOGRAPHIC PLAN OF AIRLY AUTHORISATION

FIGURE 3 | JUNE 1991