VOLUME 2 APPENDICES FEBRUARY 2009

AGL Leafs Gully Power Project Environmental Assessment

MP 08_0077

Appendix H

Predicted Subsidence Parameters

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AGL Power Generation (NSW)

Leafs Gully Power Station

REPORT

on

PREDICTED SUBSIDENCE PARAMETERS AT THE PROPOSED LEAFS GULLY POWER STATION DUE TO MINING AT WEST CLIFF COLLIERY

Mine Subsidence Engineering Consultants
1/1767 Pittwater Road – Mona Vale – NSW 2103
PO Box 1421 – Mona Vale – NSW 1660
Tel. (02) 9979 1723 Fax. (02) 9979 1726
Email: enquiries@minesubsidence.com

www.minesubsidence.com

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Drawings

Drawings referred to in this report are included in Appendix A at the end of the report.

CHAPTER 1. INTRODUCTION

1.1. Background

AGL Power Generation NSW Pty Ltd (AGL) is proposing to construct a gas fired power station adjacent to Leafs Gully located approximately 4.5 kilometres north-west of the township of Appin. The locations of the proposed power station and the footprint of the currently proposed longwalls at West Cliff Colliery are shown in Drawing No. MSEC248-01. The proposed power station is located above the western ends of proposed Longwalls 34 and 35 in the Bulli Seam.

It is proposed to construct the power station prior to the extraction of Longwalls 34 and 35 and, therefore, the power station is likely to be subjected to systematic subsidence movements resulting from mining these longwalls. The power station may also be subjected to upsidence and closure movements associated with Leafs Gully.

It is also possible that the power station could experience subsidence movements if future longwalls were to be extracted in the underlying Balgownie Seam, or adjacent to the current series of longwalls within the Bulli Seam.

Mine Subsidence Engineering Consultants Pty Ltd (MSEC) has been commissioned by AGL to provide subsidence predictions for the proposed Leafs Gully Power Station due to the extraction of the currently proposed longwalls and possible future longwalls at West Cliff Colliery.

It is possible that the currently proposed longwalls will be shortened at their western ends prior to their extraction. The predicted subsidence parameters have been determined, therefore, on the basis that the ends of the proposed longwalls could be located anywhere within the maximum longwall footprint which is shown in Drawing No. MSEC248-01.

1.2. Currently Proposed Longwalls at West Cliff Colliery

The proposed Leafs Gully Power Station is located in Area 5 at West Cliff Colliery which includes Longwalls 29 to 38 within the Bulli Seam. At the time of this report, Longwalls 29 and 30 had been extracted, and Longwall 31 was currently being extracted. At the current rate of extraction, it is likely that the power station will be constructed prior to the commencement of Longwall 34.

The maximum footprint of the proposed longwalls is shown in Drawing No. MSEC248-01. The power station is likely to experience subsidence movements due to mining Longwalls 34 and 35. If the power station is constructed prior to the commencement of Longwall 33, it may also experience some subsidence movements due to the extraction of this longwall, and therefore, Longwall 33 has also been included as part of this assessment.

The proposed Longwalls 33 to 35 are 305 metres wide and the proposed chain pillars are 40 metres wide. The overall lengths of Longwalls 33 to 35 are 3910 metres, 4025 metres and 4195 metres, respectively. The average depth of cover to the Bulli Seam at the location of the power station is 520 metres. The average thickness of the Bulli Seam at the location of the power station is 2.7 metres. It is proposed that the full seam thickness will be extracted.

1.3. Possible Future Longwalls at West Cliff Colliery

It is possible that future longwalls will be extracted in the underlying Balgownie Seam, or adjacent to the current proposed longwalls within the Bulli Seam. The predicted subsidence parameters at the power station as the result of mining possible future longwalls has been determined using generic longwall layouts as part of this assessment.

CHAPTER 2. PREDICTED SUBSIDENCE PARAMETERS FOR PROPOSED LONGWALLS AT WEST CLIFF COLLIERY

2.1. Subsidence Predictions for Proposed Longwalls 33 to 35

The Incremental Profile Method was used to predict the systematic subsidence, tilt and strain profiles for the proposed Longwalls 33 to 35, assuming that the maximum lengths within the current footprint will be extracted. The predictions are based on surface level contours, seam floor contours and extraction height information, which were provided by BHP Billiton (BHPB).

Predictions were made at points on a regular grid orientated parallel and perpendicular to the proposed longwalls. A grid spacing of 25 metres in each direction was adopted, which provides sufficient resolution for the generation of subsidence, tilt and strain contours.

2.1.1. Definition of Systematic Subsidence Parameters

The normal ground movements resulting from the extraction of longwall panels are referred to as systematic subsidence movements. These movements are described by the following parameters:-

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.

- **Tilt** is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %.

- **Curvature** is the second derivative of subsidence, or the rate of change of tilt, and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (1/km)*, but the values of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.

- **Strain** is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distance between two points increases and **Compressive Strains** occur when the distance between two points decreases. Ground strains are typically measured over a bay length of 20 metres in the Southern Coalfield.

A cross-section through a typical single longwall panel showing typical profiles of subsidence, tilt, curvature and strain is provided in Fig. 2.1.

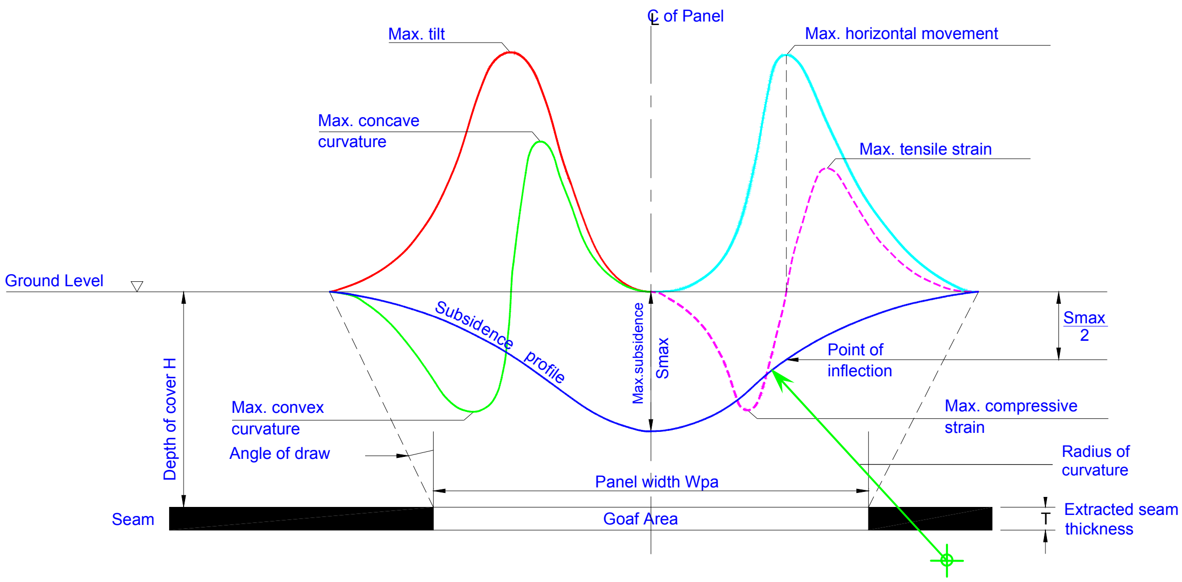


Fig. 2.1 Typical Profiles of Predicted Subsidence Parameter for a Single Longwall Panel

The predicted incremental subsidence, tilts, curvatures and strains are the maximum parameters which result from the extraction of a single longwall panel. The predicted cumulative subsidence, tilts, curvatures and strains are the total parameters which occur after the extraction of a series of longwalls.

2.1.2. Maximum Predicted Systematic Subsidence Parameters due to Mining Longwalls 33 to 35

The maximum predicted cumulative subsidence, tilt, tensile strain and compressive strain contours, due to the extraction of Longwalls 33 to 35, are shown in Drawings Nos. MSEC248-02 to MSEC248-05, respectively. A summary of the maximum predicted incremental subsidence, tilt and strain values, due to the extraction of each longwall, is provided in Table 2.1. A summary of the maximum predicted cumulative subsidence, tilt and strain values, after the extraction of each longwall, is provided in Table 2.2.

Table 2.1 Maximum Predicted Incremental Subsidence, Tilt and Strain for Longwalls 33 to 35

Longwall	Maximum Predicted Incremental Subsidence (mm)	Maximum Predicted Incremental Tilt (mm/m)	Maximum Predicted Incremental Hogging Radius of Curvature (km)	Maximum Predicted Incremental Sagging Radius of Curvature (km)	Maximum Predicted Incremental Tensile Strain (mm/m)	Maximum Predicted Incremental Compressive Strain (mm/m)
LW33	800	5.9	18.8	9.4	0.8	1.6
LW34	800	5.8	18.8	9.4	0.8	1.6
LW35	775	5.6	18.8	9.4	0.8	1.6

Table 2.2 Maximum Predicted Cumulative Subsidence, Tilt and Strain for Longwalls 33 to 35

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Hogging Radius of Curvature (km)	Maximum Predicted Cumulative Sagging Radius of Curvature (km)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
LW33	800	5.9	18.8	9.4	0.8	1.6
LW34	1070	6.0	15.0	9.4	1.0	1.6
LW35	1140	6.0	13.6	8.8	1.1	1.7

2.2. Systematic Subsidence Predictions for Possible Future Longwalls

It is unlikely that a future series of longwalls would be extracted in the Bulli Seam to the west of the current series, as these longwalls would directly mine beneath Devines Tunnel, the Upper Canal, or the Nepean River. Even if longwalls were mined to the west of the current series, the longwalls would need to be located a minimum distance of approximately 300 metres from the existing series. At this distance, the maximum predicted subsidence at the power station would be less than 20 mm, and the associated tilts and strains would be less than 0.1 mm/m, which are very small.

It is possible, in the future, that additional longwalls could be mined beneath the power station in the underlying Balgownie Seam. The Balgownie Seam is located beneath the Bulli Seam, at a depth of cover greater than 550 metres at the location of the proposed power station. The Balgownie Seam thickness contours are shown in Drawing No. MSEC248-08, and vary between 1.3 metres and 1.4 metres at the location of the proposed power station.

The Balgownie Seam is very thin at the location of the proposed power station, and it is unlikely that it would be economical to extract longwalls from this seam at this location. It may become economical to mine this seam, however, with future advancements in mining technology, and allowances should therefore be made for this situation.

If longwall panels were to be extracted with a width of up to 400 metres, the maximum predicted subsidence would be approximately 45 % of seam thickness. The average thickness of the Balgownie Seam at the power station is 1.35 m, and the maximum predicted subsidence is therefore approximately 600 mm.

The predicted tilts and strains resulting from possible future longwalls within the Balgownie Seam are less than those predicted for the current series of longwalls within the Bulli Seam, as the maximum predicted subsidence is less, and multi-seam profiles are typically flatter than single-seam profiles. The maximum tilt, tensile strain and compressive strain due to the extraction of possible future longwalls in the Balgownie Seam, based on a generic layout, are 4 mm/m, 0.7 mm/m and 1.2 mm/m, respectively.

2.3. Predicted Valley Related Movements at Leafs Gully

Where creeks and river valleys are located above or adjacent to extracted longwall panels, additional vertical movements in the bases of the valleys and horizontal movements in the valley sides are typically observed, which are referred to as valley related movements. These movements are described by the following parameters:-

- **Upsidence** is the reduced subsidence, or the net vertical movement within the base of a valley, and is typically expressed in units of *millimetres (mm)*. Upsidence results from the buckling of near surface strata in the base of the valley which results from the redistribution of, and increase in the horizontal stresses in the strata immediately below the base of the valley as mining occurs.

- **Closure** is the reduction in horizontal distance between the valley sides, and is expressed in units of *millimetres (mm)*. Closure also results from the redistribution of, and increase in the horizontal stresses in the strata as mining occurs.

- **Compressive Strains** occur within the valley as the result of valley closure and are calculated as the decrease in horizontal distance over a 20 metre bay length, divided by the bay length of 20 metres. **Tensile Strains** also occur adjacent to the valley as the result of valley closure, and are calculated as the increase in horizontal distance over a 20 metre bay, divided by the bay length of 20 metres. Compressive and tensile strains due to valley closure are typically expressed in units of *millimetres per metre (mm/m)*.

The proposed power station is located adjacent to Leafs Gully and, therefore, may be subjected to valley related movements. The maximum predicted upsidence, closure and compressive strain due to closure along Leafs Gully, due to the extraction of Longwalls 33 to 35, is provided in Table 2.3.

Table 2.3 Maximum Predicted Upsidence, Closure and Compressive Strain due to Closure at Leafs Gully due to the Extraction of Longwalls 33 to 35

Location	Equiv. Valley Depth (m)	Maximum Cumulative Upsidence (mm)	Maximum Cumulative Closure (mm)	Maximum Compressive Strain within the Valley due to Closure (mm/m)	Maximum Tensile Strain adjacent to the Valley due to Closure (mm/m)
Leafs Gully	4 ~ 32	140	105	8.2	< 0.5

The equivalent valley depth is calculated by multiplying the measured overall valley depth by a factor which reflects the shape of the valley and surrounding terrain within a radius of half the depth of cover. The factor varies from 1.0, for steeply sided gorges in flat terrain, to less than 0.5 for valleys of flatter profile in undulating terrain. A factor of 0.5 was adopted for Leafs Gully.

CHAPTER 3. SUBSIDENCE PREDICTIONS FOR THE POWER STATION AND ASSOCIATED INFRASTRUCTURE

The locations of the proposed power station and the maximum footprint of Longwalls 33 to 35 are shown in Drawing No. MSEC248-01. The locations of the gas and electrical services associated with the power station are also shown in this drawing.

3.1. Predictions at the Proposed Power Station

3.1.1. Predicted Systematic Subsidence Parameters due to Mining Longwalls 33 to 35

The maximum predicted cumulative subsidence, tilt, tensile strain and compressive strain contours, due to the extraction of Longwalls 33 to 35, are shown in Drawings No. MSEC248-02 to MSEC248-05, respectively. A summary of the maximum predicted incremental and cumulative subsidence parameters, due to the extraction of these longwalls, is provided in Section 2.1.

The power station is located above the western ends of the proposed longwalls. It is possible that these longwalls will be shortened at their western ends before they are extracted. The maximum predicted subsidence, tilt, curvatures and strains at the power station have been determined using the critical location of the longwall ends anywhere within the maximum footprint of the longwalls.

The maximum predicted subsidence at the power station, due to the extraction of the full extent of Longwalls 33 to 35, is 700 mm which occurs at the north-eastern corner of the power station. If any of the longwalls were shortened, the maximum predicted subsidence at the power station would be less than 700 mm.

The maximum predicted tilt at the power station, due to the extraction of the full extent of Longwalls 33 to 35, is 3.25 mm/m which occurs at the south-eastern corner of the power station after the extraction of Longwall 34. If Longwall 35 were to be shortened by 140 metres, the maximum predicted tilt after the extraction of this longwall is 3.5 mm/m.

The maximum predicted tensile strain at the power station, due to the extraction of the full extent of Longwalls 33 to 35, is 0.4 mm/m which occurs along the southern perimeter of the power station, after the extraction of Longwall 35. The maximum predicted compressive strain at the power station, due to the extraction of the full extent of Longwalls 33 to 35, is 0.6 mm/m which occurs along the southern perimeter of the power station after the extraction of Longwall 34. The maximum predicted tensile and compressive strains would not increase if the proposed longwalls were shortened. The minimum predicted radii of curvature associated with the maximum predicted tensile and compressive strains are 37.5 kilometres and 25 kilometres, respectively.

The predicted tilts and strains at the power station are less than what would normally be expected in the Southern Coalfield, as the power station is located above the end of Longwall 34, which can be considered to be the first panel in a series, due to the offsets of the previous longwalls.

3.1.2. Predicted Subsidence Parameters for Possible Future Longwalls

The maximum predicted subsidence parameters due to the extraction of possible future longwalls in the Bulli Seam adjacent to the current series of longwalls, or in the underlying Balgownie Seam below the current series of longwalls, is provided in Section 2.2.

It is expected that the predicted subsidence parameters at the power station, resulting from possible future longwalls adjacent to the current series within the Bulli Seam, would be very small or negligible as the future longwalls would likely be located a minimum distance of 300 metres from the current series.

The maximum predicted subsidence, tilt, tensile strain and compressive strain due to the extraction of possible future longwalls in the Balgownie Seam, based on a generic longwall layout, are provided in Section 2.2.

It is common practice that longwalls which are extracted in a lower seam are staggered or offset from the longwalls previously extracted in the overlying seam, and the result is that the locations of the maximum predicted subsidence parameters for each seam do not coincide. The maximum total subsidence parameters due to the extraction of the current series of longwalls within the Bulli Seam and possible future longwalls within the Balgownie Seam are not, therefore, the addition of the cumulative subsidence parameters from each seam.

The maximum predicted total subsidence at the power station due to the extraction of Longwalls 33 to 35 in the Bulli Seam and possible future longwalls within the Balgownie Seam, based on a generic longwall layout, is 1100 mm. The maximum predicted total tilt, tensile strain and compressive strain at the power station are 6 mm/m, 1.1 mm/m and 1.7 mm/m, respectively. The minimum radii of curvature associated with the maximum predicted tensile and compressive strains are 14 kilometres and 9 kilometres, respectively.

3.1.3. Predicted Valley Related Movements

The power station is located in the valley of Leafs Gully and may, therefore, be subjected to upsidence and horizontal movements due to closure, as the result of the extraction of the current series of longwalls, and possible future longwalls.

The maximum predicted upsidence at the power station, due to the extraction of the full extent of Longwalls 33 to 35, is less than 5 mm, which occurs at the south-western corner of the power station. If any of these longwalls were shortened, the maximum predicted upsidence at the power station would be reduced. The maximum predicted horizontal movement due to closure at the power station, due to the extraction of the full extent of Longwalls 33 to 35, is less than 5 mm, and the associated tensile strain is less than 0.1 mm/m.

The predicted upsidence and closure movements due to possible future longwalls within the Balgownie Seam are less than those which would occur due to the current proposed longwalls within the Bulli Seam, and are insignificant when compared to the systematic movements. The additional predicted upsidence and closure movements due to possible future longwalls has, therefore, been assessed as negligible.

3.1.4. Summary of Predicted Subsidence Parameters for the Power Station

A summary of the maximum predicted subsidence parameters for the power station, including the current proposed longwalls within the Bulli Seam and possible future longwalls within the underlying Balgownie Seam, is provided in Table 3.1.

Table 3.1 Maximum Predicted Total Subsidence, Tilt and Strain for the Power Station

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Radius of Curvature (km)	Maximum Predicted Total Sagging Radius of Curvature (km)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Power Station	1100	6.0	14	9	1.1	1.7

A summary of the maximum predicted upsidence, horizontal movements due to closure, and ground strains associated with the horizontal closure movements for the power station, is provided in Table 3.2.

Table 3.2 Maximum Predicted Total Upsidence, Horizontal Movement and Strains for the Power Station resulting from the Valley Related Movements at Leafs Gully

Location	Maximum Predicted Cumulative Upsidence (mm)	Maximum Predicted Horizontal Movement due to Closure (mm/m)	Maximum Predicted Cumulative Compressive Strain due to Closure (mm/m)	Maximum Predicted Cumulative Tensile Strain due to Closure (mm/m)
Power Station	< 5	< 5	< 0.1	< 0.1

The valley related movements at the power station are insignificant when compared to the systematic subsidence movements at the power station.

3.2. Predicted Subsidence Parameters for the Gas Pipelines

The locations of the gas pipelines between the proposed power station and the pipeline easement are shown in Drawing No. MSEC248-01. The pipelines will be directly mined beneath by proposed Longwalls 34 and 35. The predicted profiles of systematic subsidence, tilt and strain along the pipelines, due to the extraction of Longwalls 34 and 35, are shown in Fig. A.01 in Appendix A. A summary of the maximum predicted cumulative subsidence, tilt and strain along the pipelines, is provided in Table 3.3.

Table 3.3 Maximum Predicted Cumulative Subsidence, Tilt and Strain along the Proposed Gas Pipelines

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
After LW33	< 20	< 0.1	< 0.1	< 0.1
After LW34	380	2.3	0.3	0.6
After LW35	855	3.8	0.4	0.7

The predicted valley related movements along the gas pipelines are less than those for the power station, and are, therefore, negligible when compared to the systematic movements.

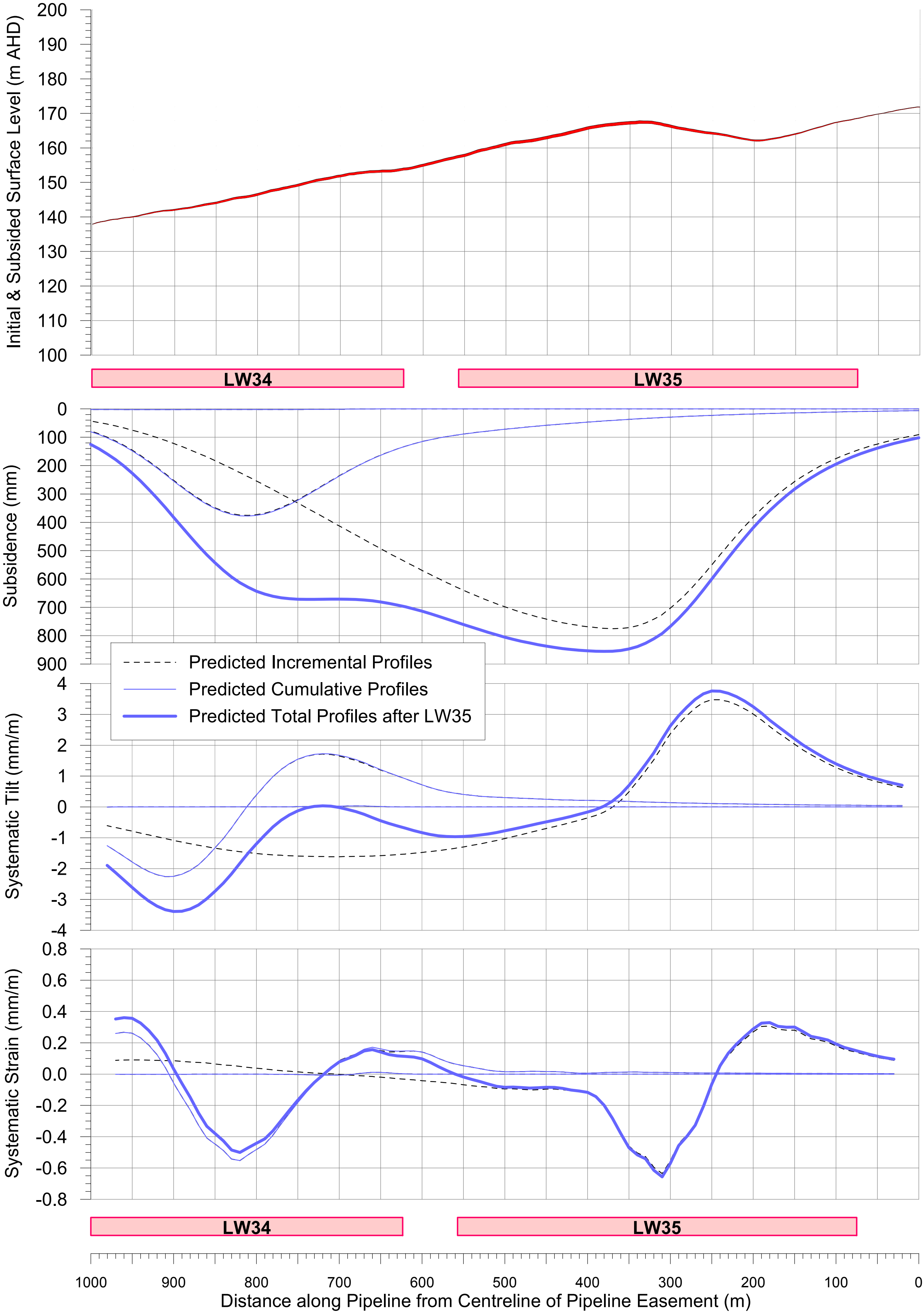
If the gas pipelines are designed for the maximum predicted subsidence parameters due to the extraction of Longwalls 33 to 35, it is likely that the pipelines will also be able to accommodate the subsidence movements due to possible future longwalls in the underlying Balgownie Seam.

3.3. Predicted Subsidence Parameters for the Electrical Services

The locations of the electrical services between the proposed power station and the transmission line are shown in Drawing No. MSEC248-01. The electrical services will be mined beneath by the proposed Longwalls 34 and 35. The maximum predicted systematic subsidence, tilt and strain along the electrical services are similar to, but slightly less than those for the gas pipelines, with similar overall profiles. The predicted subsidence parameters for the electrical services should, therefore, be taken as being the same as those provided for the gas pipelines in Section 3.2.

APPENDIX A.   DRAWINGS AND ILLUSTRATIONS

Predicted Subsidence, Systematic Tilt and Systematic Strain Profiles along the Proposed Gas Pipelines due to Mining Longwalls 33 to 35



Mine Subsidence Engineering Consultants

Fig. A.01

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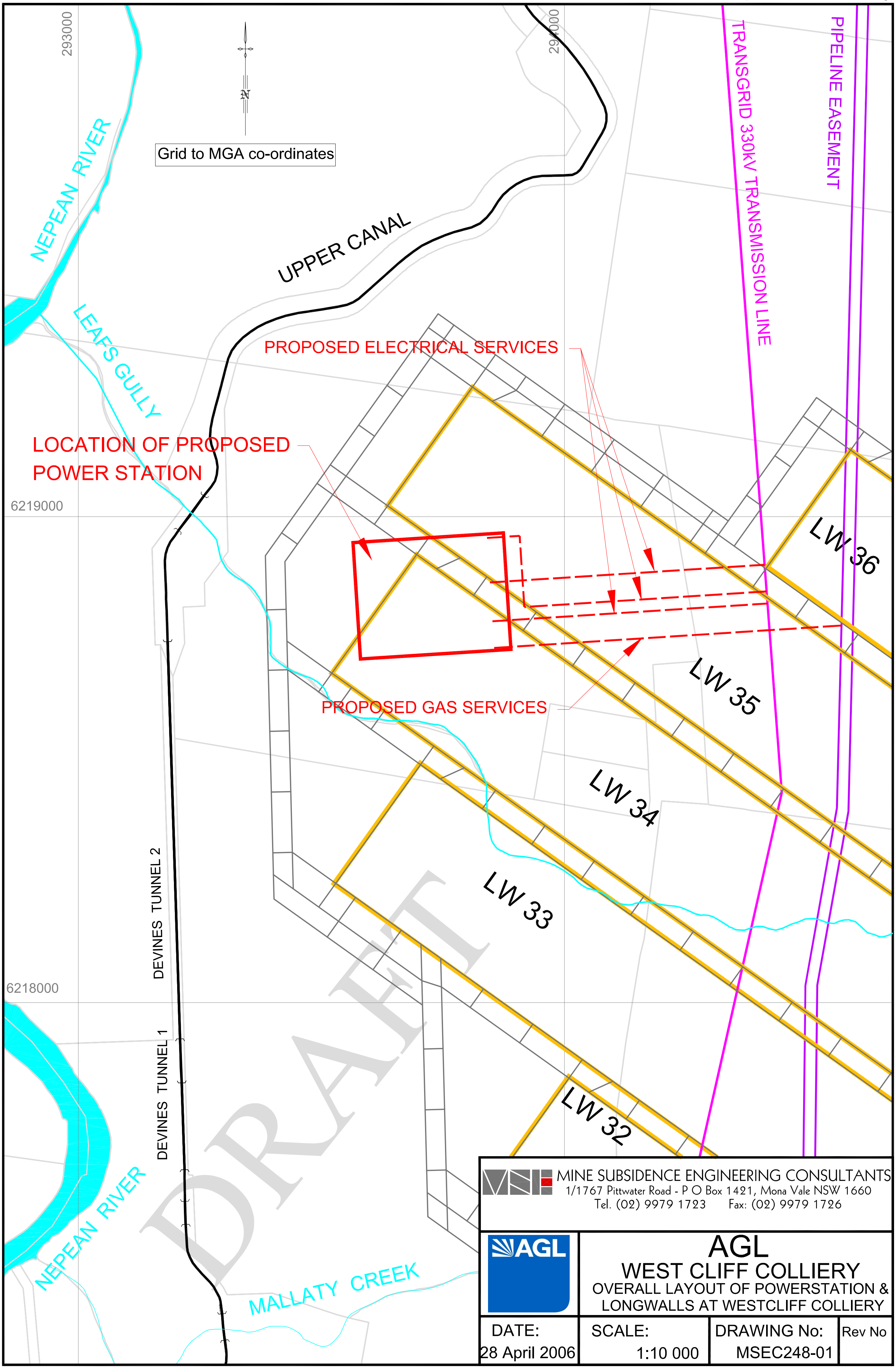

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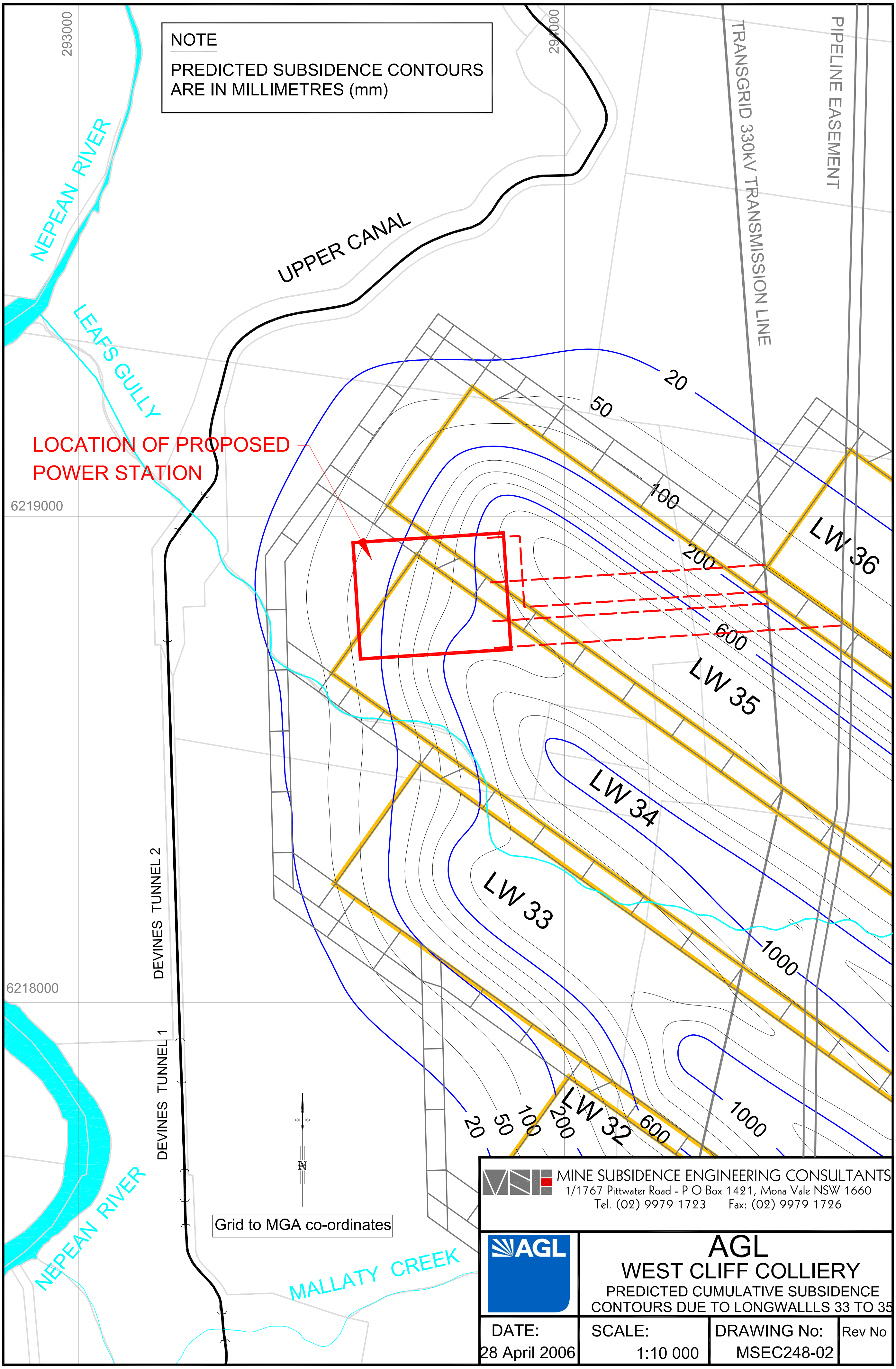

MINE SUBSIDENCE ENGINEERING CONSULTANTS
1/1767 Pittwater Road - P O Box 1421, Mona Vale NSW 1660
Tel. (02) 9979 1723 Fax: (02) 9979 1726

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WEST CLIFF COLLIERY
PREDICTED CUMULATIVE SUBSIDENCE CONTOURS DUE TO LONGWALLLS 33 TO 35

DATE:	SCALE:	DRAWING No:	Rev No
28 April 2006	1:10 000	MSEC248-02	

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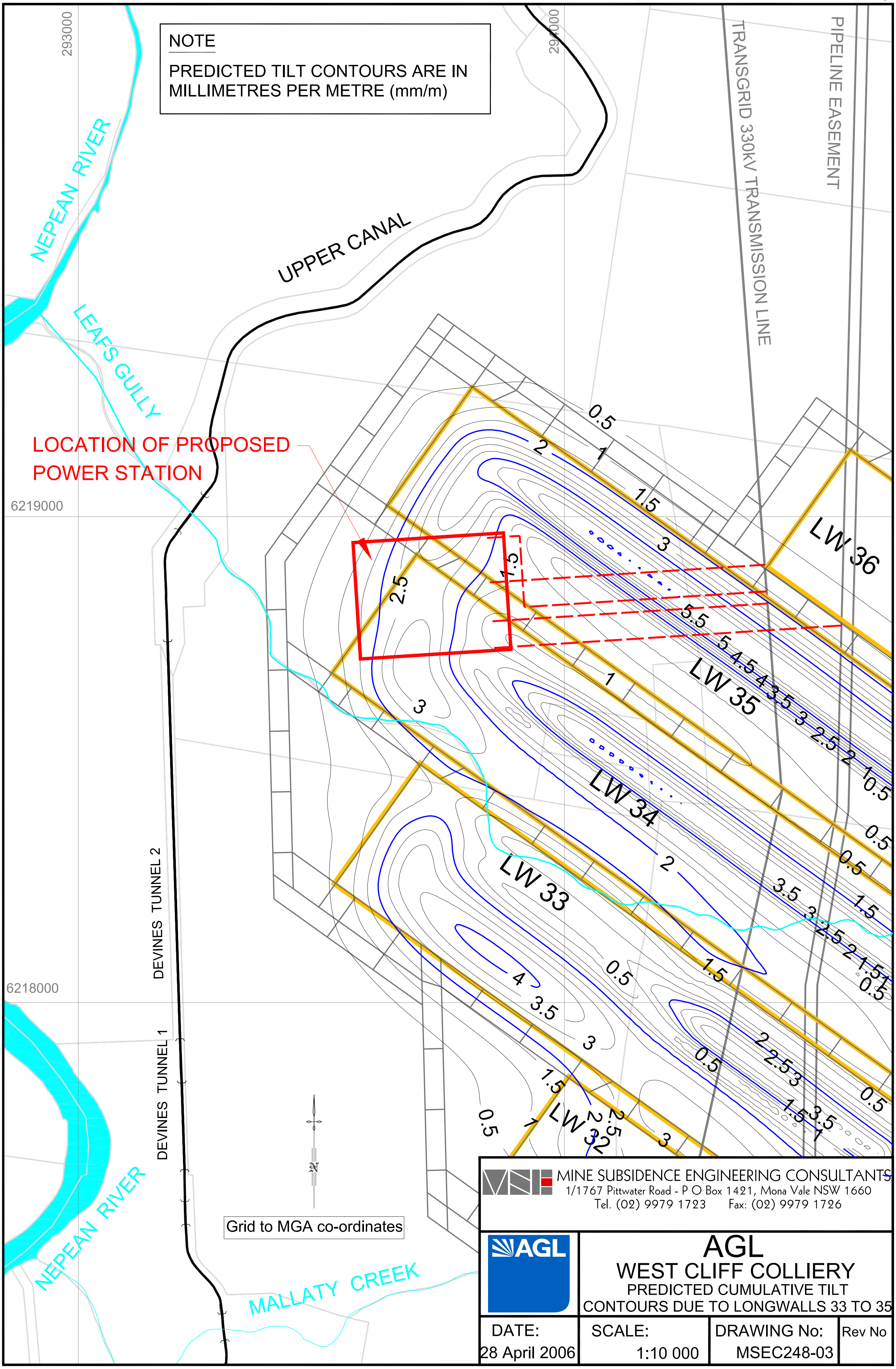

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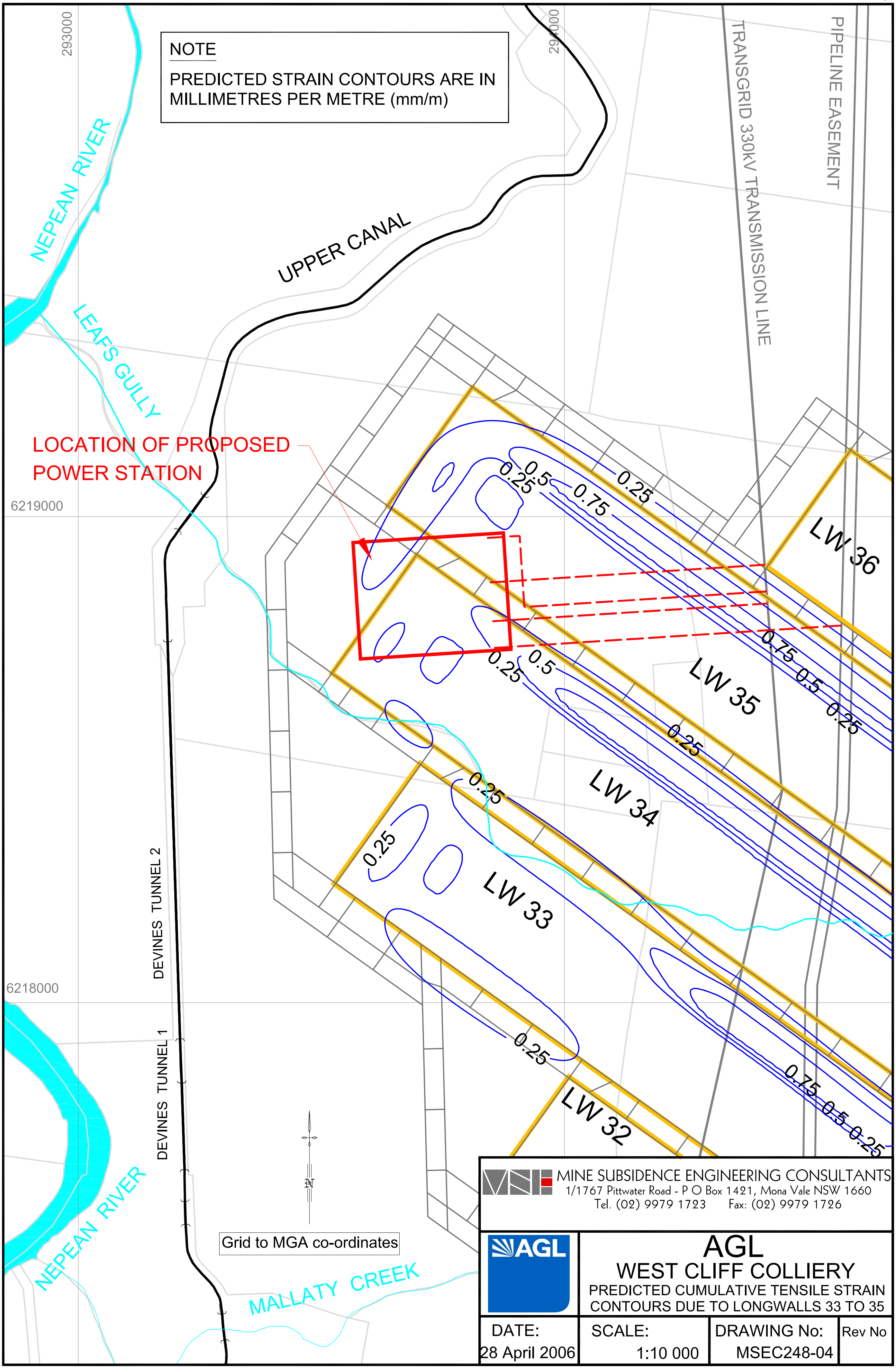

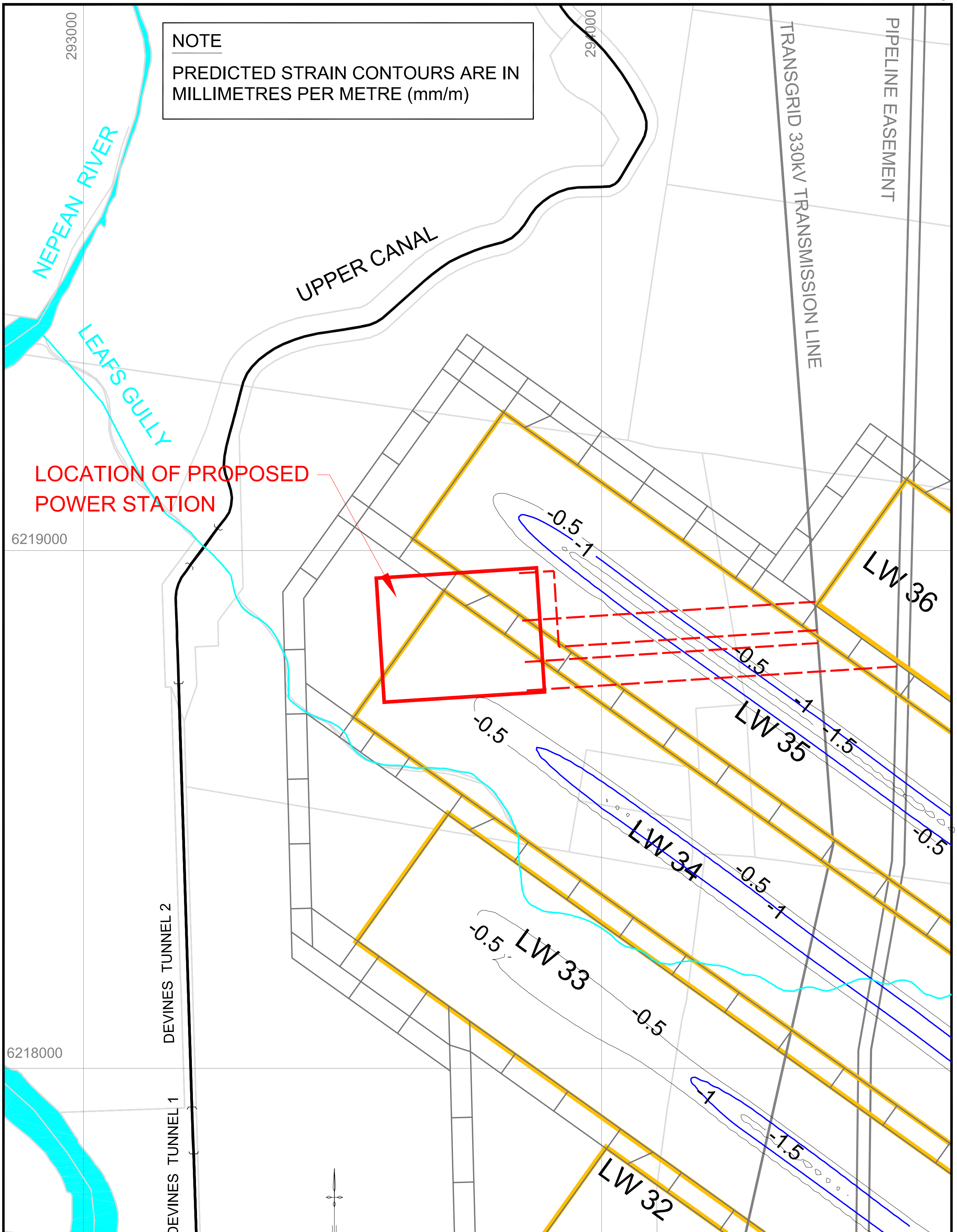

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1/1767 Pittwater Road - P O Box 1421, Mona Vale NSW 1660
Tel. (02) 9979 1723 Fax: (02) 9979 1726

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PREDICTED CUMULATIVE COMPRESSIVE STRAIN CONTOURS DUE TO LONGWALLS 33 TO 35

DATE:	SCALE:	DRAWING No:	Rev No
28 April 2006	1:10 000	MSEC248-05	

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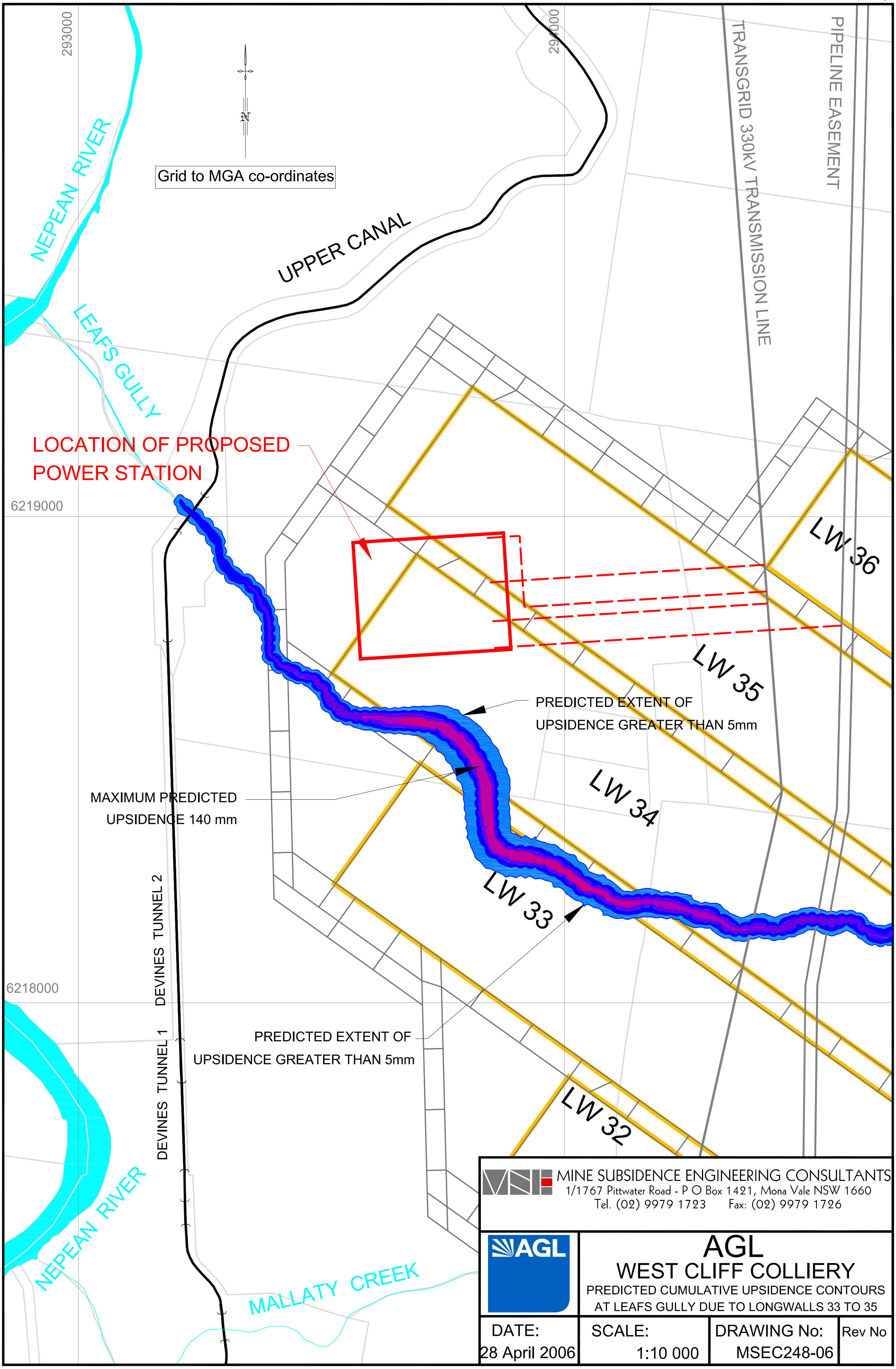

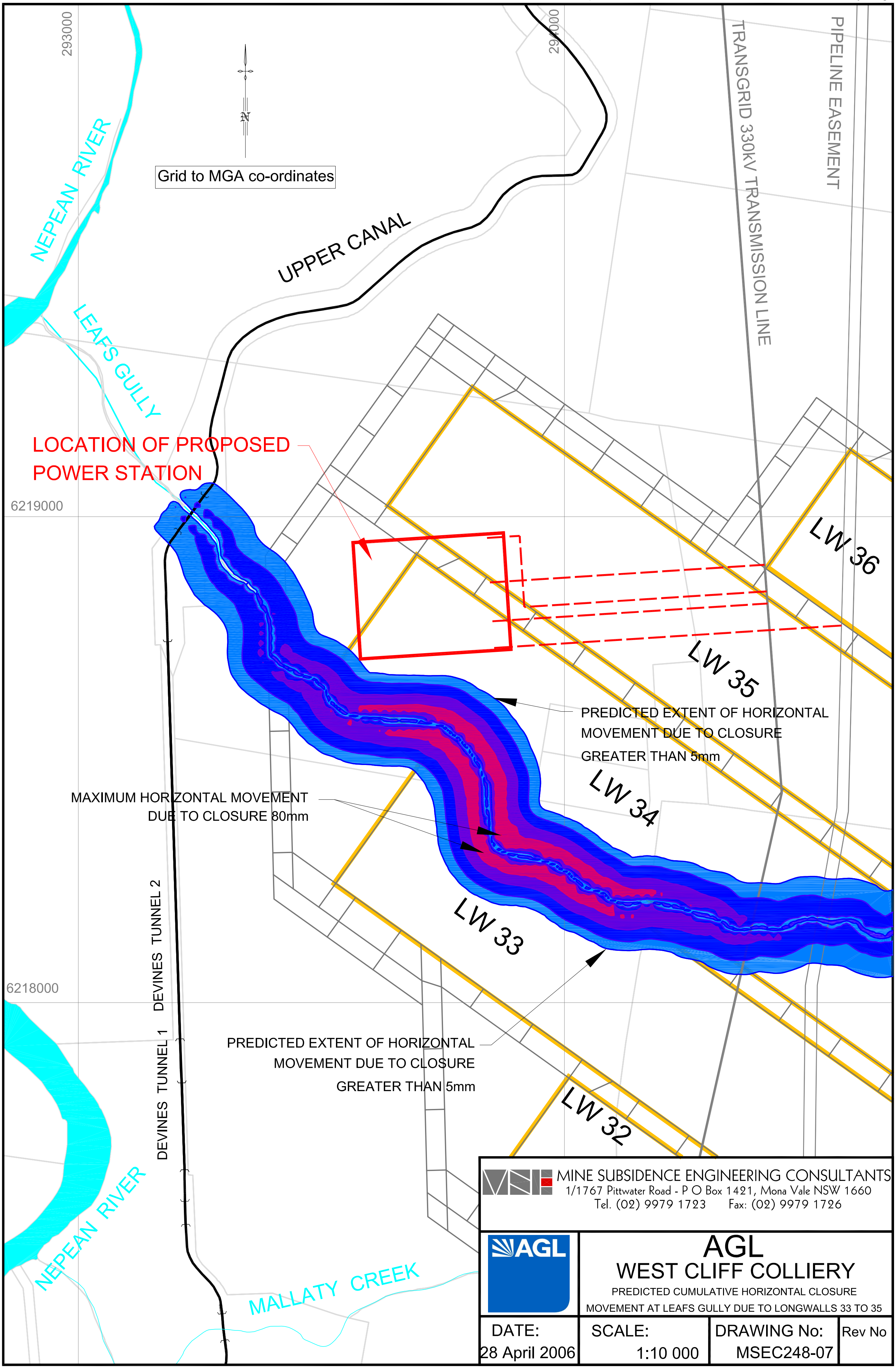

MINE SUBSIDENCE ENGINEERING CONSULTANTS
1/1767 Pittwater Road - P O Box 1421, Mona Vale NSW 1660
Tel. (02) 9979 1723 Fax: (02) 9979 1726

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PREDICTED CUMULATIVE HORIZONTAL CLOSURE MOVEMENT AT LEAFS GULLY DUE TO LONGWALLS 33 TO 35

DATE:	SCALE:	DRAWING No:	Rev No
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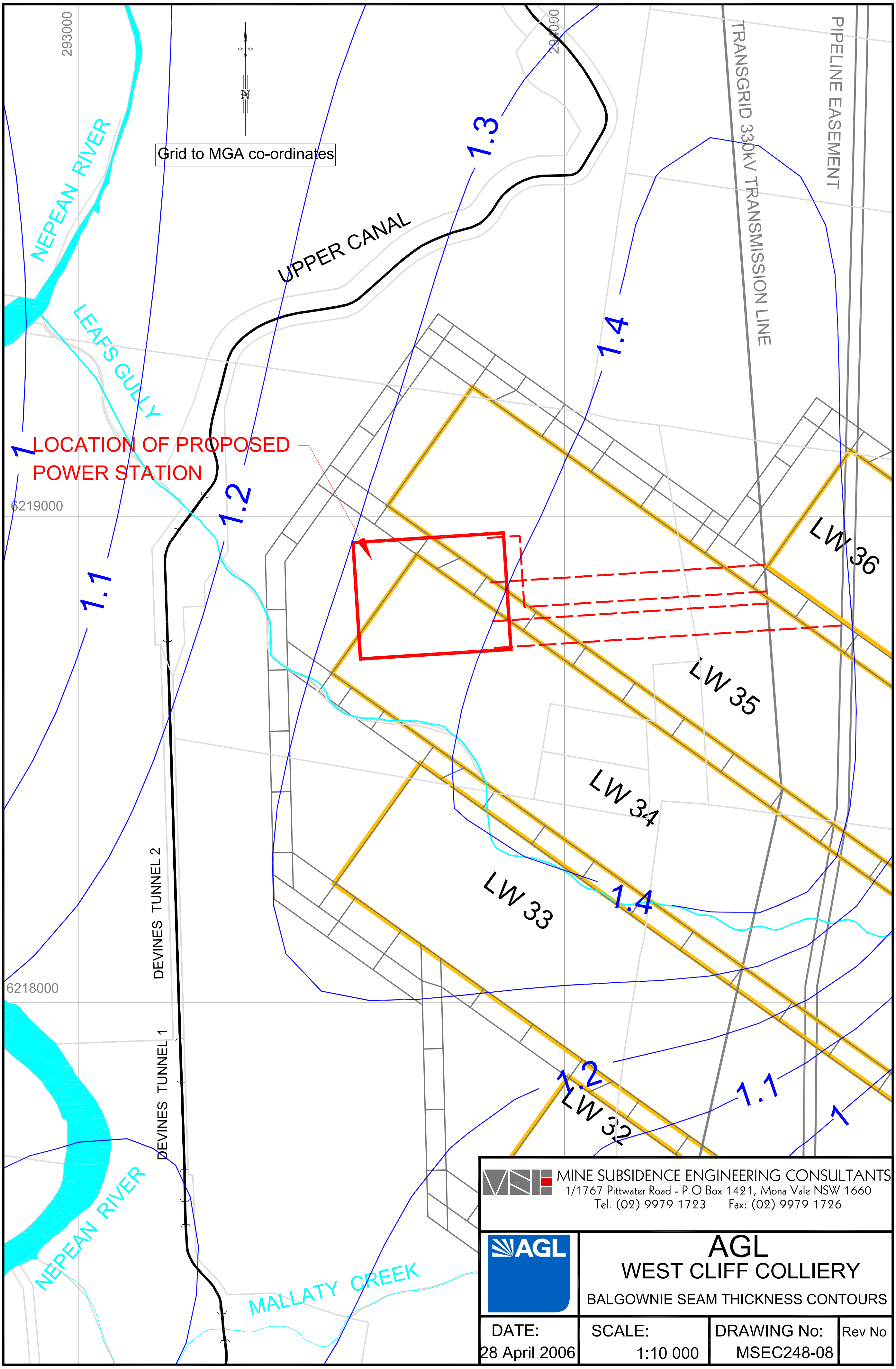

MINE SUBSIDENCE ENGINEERING CONSULTANTS
1/1767 Pittwater Road - P O Box 1421, Mona Vale NSW 1660
Tel. (02) 9979 1723 Fax: (02) 9979 1726

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WEST CLIFF COLLIERY
BALGOWNIE SEAM THICKNESS CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
28 April 2006	1:10 000	MSEC248-08	

In reply please send to: Picton

Our reference: FN97-00651P0 DB:LE

Your reference: Email 9/5/06

Contact: Darren Bullock (02) 4677 1967

Justin Flood
Project Manager Merchant Power AGL
72 Christie Street
ST LEONARDS NSW 2065

9 May 2006

Dear Justin

LOT 102 DP 716209 APPIN RD GILEAD
LEAFS GULLY POWER STATION – SUBSIDENCE PREDICTIONS

We refer to report supplied by AGL for Mine Subsidence Engineering Consultants, report number MSEC248 Revision A April 2006.

Parameters issued in report have been reviewed and found to be appropriate for design of Power Station and associated infrastructure.

Mine Subsidence Board approval is required for all building improvements on this property. During planning and design of proposed improvements, applicants should consult with our staff

Yours faithfully

Darren Bullock
District Manager

MINE SUBSIDENCE BOARD

HEAD OFFICE:
PO Box 488G
Newcastle 2300
Telephone: (02) 4908 4395
Facsimile: (02) 4929 1032

NEWCASTLE:
NSW Government Offices
117 Bull Street
Newcastle West 2302
PO Box 488G
Newcastle 2300
Telephone: (02) 4908 4300
Facsimile: (02) 4929 1032
DX 4322 Newcastle West

SPEERS POINT
143 Main Road
Speers Point 2284
PO Box 9 Boolaroo 2284
Telephone: (02) 4950 8088
Facsimile: (02) 4950 8101
DX 7820 Newcastle

WYONG:
Suite 3 Feldwin Court
30 Hely Street
Wyong 2259
PO Box 157 Wyong 2259
Telephone: (02) 4352 1646
Facsimile: (02) 4352 1757
DX 7317 Wyong

SINGLETON:
Coal Services Building
1 Civic Avenue
Singleton 2330
PO Box 524 Singleton 2330
Telephone: (02) 6572 4344
Facsimile: (02) 6572 4504

PICTON:
100 Argyle Street
Picton 2571
PO Box 40 Picton 2571
Telephone: (02) 4677 1967
Facsimile: (02) 4677 2040
DX 26053 Picton

EMAIL:
mail@minesub.nsw.gov.au

WEBSITE:
www.minesub.nsw.gov.au

Standard (Auto) Enquiries