**REPORT**: SUBSIDENCE PREDICTIONS AND IMPACT ASSESSMENTS

BHP BILLITON ILLAWARRA COAL:

# West Cliff Colliery – Longwalls 37 and 38

Subsidence Predictions and Impact Assessments for the Natural Features and Surface Infrastructure in Support of the Extraction Plan

## DOCUMENT REGISTER

| Revision | Description | Author | Checker | Date |
|---|---|---|---|---|
| 01 | Draft Issue | PA/PD | - | 27 Apr 2012 |
| 02 | Minor Edits | PA/PD | - | 8 May 2012 |
| 03 | Minor Edits | PD | PA/JB | 23 Jul 2012 |
| A | Final Issue | PD | JB | 6 Dec 2012 |
| B | Final Issue | PD | JB | 5 Jun 2013 |
| | | | | |
| | | | | |

Report produced to:- Support the Extraction Plan for submission to the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS).

Associated reports:- MSEC326 (Revision C – December 2007) - The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of Proposed Longwalls 34 to 36 in Area 5 at West Cliff Colliery (In Support of the SMP Application).

MSEC386 (Revision B – December 2008) - The Effects of Five Optional Modified Commencing Ends of Longwall 34 at West Cliff Colliery on the Previous Subsidence Predictions and Impact Assessments.

Letter to BHP Billiton Illawarra Coal dated 18th May 2009 – Confirmed Position For the Commencing End of Longwall 34.

MSEC440 (Report Nos. R01 to R20) – Report on the Observed Mine Subsidence Movements along the J-Line Monitoring Line due to the Extraction of West Cliff Longwall 34.

MSEC444 (Revision B – February 2010) – Effects of the Modified Finishing End of Longwall 34 on Subsidence Predictions and Impact Assessments.

MSEC491 (Report Nos. R01 to R26) – Review of the Observed Subsidence Movements along the B-Line Monitoring Line Resulting from the Extraction of West Cliff Longwall 34.

MSEC510 (Revision 02 – 28th November 2011) – End of Panel Subsidence Monitoring Report for West Cliff Longwall 34

MSEC524 (Report Nos. R01 to R18) – Review of the observed Subsidence Movements along the J-Line Monitoring Line Resulting from the Extraction of West Cliff Longwall 35.

Background reports available at *www.minesubsidence.com*:-

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

## EXECUTIVE SUMMARY


BHP Billiton Illawarra Coal (IC) proposes to continue its underground coal mining operations at West Cliff Colliery, which is located in the Southern Coalfield of New South Wales, by extracting coal from the Bulli Seam using longwall mining techniques. IC are seeking approval to extract Longwalls 37 and 38. Longwall 37 is located immediately north of Longwall 36. Longwall 38 is located to the east of Longwalls 33 to 37, on the opposite side of the Georges River. The overall layout of the longwalls at West Cliff Colliery is shown in Drawing No. MSEC533-01, which together with all other drawings is included in Appendix F.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by IC to study the mining proposal, to identify all the natural features and items of surface infrastructure and to prepare subsidence predictions and impact assessments for the proposed Longwalls 37 and 38.

The Study Area has been defined, as a minimum, as the surface area enclosed by a 35 degree angle of draw line from the limit of proposed mining and by the predicted 20 mm subsidence contour resulting from the extraction of the proposed Longwalls 37 and 38.

A number of natural features and items of surface infrastructure have been identified within the Study Area, including the Georges River, drainage lines, cliffs, steep slopes, roads, water pipelines, sections of the Upper Canal system, gas pipelines, electrical services, telecommunications services and building structures. A number of natural features and items of surface infrastructure which are located outside the Study Area and are considered sensitive to valley related or far- field horizontal movements have been included in the assessments in this report. The features located outside the Study Area, and for which assessments have been made, include sections of the Georges River and drainage lines, sections of the Upper Canal and Devines Tunnel, groundwater bores and survey control marks.

A number of mining options for Longwalls 37 and 38 were considered as part of the process to develop the final proposed mining geometry. These included variations in the locations of the ends of the longwalls relative to the Georges River. The proposed layout has been optimised to significantly reduce the levels of impact on the Georges River. The analysis also shows that very large tonnages of additional coal are required to be sterilised to achieve relatively small additional reductions in the maximum predicted movements along the river.

Chapter 1 of this report provides a general introduction to the study, which also includes a description of the mining geometry and geological details of the proposed mining area.

Chapter 2 defines the Study Area and provides a summary of the natural features and items of surface infrastructure included in this Extraction Plan report.

Chapter 3 includes overviews of mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls.

Chapters 5 through 11 provide the descriptions, predictions and impact assessments for each of the natural features and items of surface infrastructure within the Study Area and for those selected items identified outside the Study Area. Recommendations for each of these features are also provided, which have been based on the predictions and impact assessments.

The assessments in this report indicate that the levels of impact on the natural features and items of surface infrastructure are not significant and can be managed by the preparation and implementation of management strategies. It should be noted, however, that more detailed assessments of some natural features and items of surface infrastructure have been undertaken by other consultants, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

Monitoring of ground movements is recommended, as subsidence occurs, so that the observed ground movements can be compared with those predicted, to allow the prediction method to be continually improved and to allow regular reviews of the impact assessments in the light of new measured data.

This report provides revised predictions of the conventional and non-conventional subsidence effects and subsidence impacts for the West Cliff Area 5 Extraction Plan, incorporating relevant information obtained since approval of the Bulli Seam Operations by the Minister for Planning. The level of impact and proposed management strategies for West Cliff Area 5 is consistent with the Bulli Seam Operations Environmental Assessment and Conditions of Approval (Application No. 08_0150).

CONTENTS

**1.0 INTRODUCTION** **1**

1.1. Background 1

1.2. Mining Geometry 2

1.3. Surface Topography 2

1.4. Seam Information 2

1.5. Geological Details 2

**2.0 IDENTIFICATION OF SURFACE FEATURES** **5**

2.1. Definition of the Study Area 5

2.2. Natural Features and Items of Surface Infrastructure within the Study Area 6

**3.0 OVERVIEW OF MINE SUBSIDENCE PARAMETERS AND THE METHOD USED TO PREDICT THE MINE SUBSIDENCE MOVEMENTS FOR THE PROPOSED LONGWALLS** **8**

3.1. Introduction 8

3.2. Overview of Conventional Subsidence Parameters 8

3.3. Far-field Movements 9

3.4. Overview of Non-Conventional Subsidence Movements 9

3.4.1. Non-conventional Subsidence Movements due to Changes in Geological Conditions 9

3.4.2. Non-conventional Subsidence Movements due to Steep Topography 10

3.4.3. Valley Related Movements 10

3.5. The Incremental Profile Method 12

3.6. Reliability of the Predicted Conventional Subsidence Parameters 13

3.7. Reliability of the Predicted Upsidence and Closure Movements 15

**4.0 MAXIMUM PREDICTED SUBSIDENCE PARAMETERS FOR THE PROPOSED LONGWALLS** **17**

4.1. Introduction 17

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature 17

4.3. Comparison of Maximum Predicted Conventional Subsidence, Tilt and Curvature 18

4.4. Predicted Strains 19

4.4.1. Analysis of Strains Measured in Survey Bays 19

4.4.2. Analysis of Strains Measured Along Whole Monitoring Lines 23

4.4.3. Analysis of Strains Resulting from Valley Closure Movements 23

4.4.4. Analysis of Shear Strains 24

4.5. Predicted Conventional Horizontal Movements 25

4.6. Predicted Far-field Horizontal Movements 26

4.7. Non-Conventional Ground Movements 26

4.8. General Discussion on Mining Induced Ground Deformations 28

4.9. Estimated Height of the Fractured Zone 30

**5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES WITHIN THE STUDY AREA** **34**

5.1. Catchment Areas and Declared Special Areas 34

5.2. The Georges River 34

5.2.1. Description of the Georges River 34

5.2.2. Predictions for the Georges River 40

5.2.3. Comparison of Observed and Predicted Valley Closure Movements along Georges River 41

| | | |
|---|---|---|
| 5.2.4. | Comparison of Predictions for the Georges River with those provided in the Part 3A Application | 42 |
| 5.2.5. | Impact Assessments for the Georges River | 42 |
| 5.2.5.1. | The Potential for Changes in Surface Water Levels | 42 |
| 5.2.5.2. | The Potential for Increased Levels of Ponding, Flooding and Scouring | 43 |
| 5.2.5.3. | The Potential for Changes in Stream Alignment | 43 |
| 5.2.5.4. | The Potential for Fracturing of Bedrock and Surface Water Flow Diversions | 44 |
| 5.2.5.5. | The Potential for Ground Water Inflows | 51 |
| 5.2.5.6. | The Potential Impacts on Water Quality | 52 |
| 5.2.5.7. | The Potential Impacts on Flora and Fauna | 52 |
| 5.2.6. | Impact Assessments for the Georges River Based on Increased Predictions | 52 |
| 5.2.7. | Recommendations for the Georges River | 52 |
| 5.3. | Drainage Lines | 52 |
| 5.3.1. | Predictions for the Drainage Lines | 54 |
| 5.3.2. | Impact Assessments for the Drainage Lines | 55 |
| 5.3.3. | Impact Assessments for the Drainage Lines Based on Increased Predictions | 57 |
| 5.3.4. | Recommendations for the Drainage Lines | 58 |
| 5.4. | Aquifers and Known Groundwater Resources | 58 |
| 5.5. | Springs | 58 |
| 5.6. | Sea or Lake | 58 |
| 5.7. | Shorelines | 58 |
| 5.8. | Natural Dams | 58 |
| 5.9. | Cliffs | 58 |
| 5.9.1. | Descriptions of the Cliffs | 58 |
| 5.9.2. | Predictions for the Cliffs | 59 |
| 5.9.3. | Comparison of Predictions for the Cliffs with those provided in the Part 3A Application | 59 |
| 5.9.4. | Impact Assessments for the Cliffs | 59 |
| 5.9.5. | Impact Assessments for the Cliffs Based on Increased Predictions | 61 |
| 5.9.6. | Recommendations for the Cliffs | 61 |
| 5.10. | Rock Outcrops | 61 |
| 5.10.1. | Descriptions of the Rock Outcrops | 61 |
| 5.10.2. | Predictions for the Rock Outcrops | 62 |
| 5.10.3. | Impact Assessments for the Rock Outcrop | 62 |
| 5.10.4. | Impact Assessments for the Rock Outcrops Based on Increased Predictions | 62 |
| 5.10.5. | Recommendations for the Rock Outcrops | 62 |
| 5.11. | Steep Slopes | 62 |
| 5.11.1. | Descriptions of the Steep Slopes | 62 |
| 5.11.2. | Predictions for the Steep Slopes | 63 |
| 5.11.3. | Comparison of Predictions for the Steep Slopes with those provided in the Part 3A Application | 63 |
| 5.11.4. | Impact Assessments for the Steep Slopes | 63 |
| 5.11.5. | Impact Assessments for the Steep Slopes Based on Increased Predictions | 65 |
| 5.11.6. | Recommendations for the Steep Slopes | 65 |
| 5.12. | Escarpments | 65 |

5.13. Land Prone to Flooding and Inundation 65
5.14. Swamps, Wetlands and Water Related Ecosystems 65
5.15. Threatened, Protected Species or Critical Habitats 65
5.16. National Parks or Wilderness Areas 65
5.17. State Recreational or Conservation Areas 66
5.18. Natural Vegetation 66
5.18.1. Areas of Significant Geological Interest 66
5.18.2. Any Other Natural Feature Considered Significant 66
**6.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC UTILITIES 67**
6.1. Railways 67
6.2. Appin Road 67
6.2.1. Predictions for Appin Road 67
6.2.2. Comparison of Predictions for Appin Road with those provided in the Part 3A Application 68
6.2.3. Impact Assessments for Appin Road 68
6.2.4. Impact Assessments for Appin Road Based on Increased Predictions 70
6.2.5. Recommendations for Appin Road 71
6.3. The Local Roads 71
6.3.1. Descriptions of the Local Roads 71
6.3.2. Predictions for the Local Roads 71
6.3.3. Comparison of Predictions for the Roads with those provided in the Part 3A Application 72
6.3.4. Impact Assessments for the Local Roads 72
6.3.5. Impact Assessments for the Local Roads Based on Increased Predictions 73
6.3.6. Recommendations for the Roads 73
6.4. Bridges 73
6.5. Tunnels 73
6.6. Local Road Drainage Culverts 73
6.6.1. Descriptions of the Drainage Culverts 73
6.6.2. Predictions for the Drainage Culverts 73
6.6.3. Comparison of Predictions for the Local Road Drainage Culverts with those provided in the Part 3A Application 74
6.6.4. Impact Assessments for the Local Road Drainage Culverts 74
6.6.5. Impact Assessments for the Local Road Drainage Culverts Based on Increased Predictions 74
6.6.6. Recommendations for the Local Road Drainage Culverts 74
6.7. Macarthur Water Supply System 75
6.7.1. Predictions for the 1200mm Diameter Water Pipeline 75
6.7.2. Impact Assessments for the 1200 mm Diameter Water Pipeline 75
6.7.3. Impact Assessments for the 1200 mm Diameter Water Pipeline Based on Increased Predictions 75
6.7.4. Recommendations for the 1200 mm Diameter Water Pipeline 76
6.8. Sydney Water Infrastructure 76
6.8.1. Descriptions of the Sydney Water Infrastructure 76
6.8.2. Predictions for the Sydney Water Infrastructure 76
6.8.3. Comparison of Predictions for the Sydney Water Infrastructure with those provided in the Part 3A Application 77

6.8.4. Impact Assessments for the Sydney Water Infrastructure 77
6.8.5. Impact Assessments for the Sydney Water Infrastructure Based on Increased Predictions 77
6.8.6. Recommendations for the Sydney Water Infrastructure 78
6.9. Sydney Catchment Authority Infrastructure 78
6.10. Sewerage Pipelines and Sewage Treatment Works 78
6.11. Gas Pipelines 78
6.12. Liquid Fuel Pipelines 79
6.13. Electrical Infrastructure 79
6.13.1. Descriptions of the Electrical Infrastructure 79
6.13.2. Predictions for the Electrical Infrastructure 79
6.13.3. Comparison of Predictions for the Electrical Infrastructure with those provided in the Part 3A Application 79
6.13.4. Impact Assessments for the Electrical Infrastructure 80
6.13.5. Impact Assessments for the Electrical Infrastructure Based on Increased Predictions 81
6.13.6. Recommendations for the Electrical Infrastructure 81
6.14. Telecommunications Infrastructure 81
6.14.1. Description of the Telecommunications Infrastructure 81
6.14.2. Predictions for the Telecommunications Infrastructure 82
6.14.3. Comparison of Predictions for the Telecommunications Cables with those provided in the Part 3A Application 82
6.14.4. Impact Assessments for the Optical Fibre Cable 83
6.14.5. Impact Assessments for the Copper Telecommunications Cables 84
6.14.6. Impact Assessments for Telecommunications Infrastructure Based on Increased Predictions 85
6.14.7. Recommendations for Telecommunications Infrastructure 85
6.15. Water Tanks, Water and Sewage Treatment Works 86
6.16. Dams, Reservoirs or Associated Works 86
6.17. Air Strips 86
6.18. Survey Control Marks 86
6.19. Any Other Public Utilities 86
**7.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC AMENITIES 87**
7.1. Hospitals 87
7.2. Places of Worship 87
7.3. Schools 87
7.4. Shopping Centres 87
7.5. Community Centres 87
7.6. Office Buildings 87
7.7. Swimming Pools 87
7.8. Bowling Greens 87
7.9. Ovals or Cricket Grounds 87
7.10. Racecourses 87
7.11. Golf Courses 87
7.12. Tennis Courts 87
7.13. Any Other Public Amenities 87

**8.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE FARM LAND AND FARM FACILITIES 88**

8.1. Agricultural Utilisation 88

8.2. Rural Building Structures 88

8.2.1. Descriptions of the Rural Building Structures 88

8.2.2. Predictions for the Rural Building Structures 89

8.2.3. Comparison of Predictions for the Rural Building Structures with those provided in the Part 3A Application 90

8.2.4. Impact Assessments for the Rural Building Structures 90

8.2.5. Impact Assessments for the Rural Building Structures Based on Increased Predictions 91

8.2.6. Recommendations for the Rural Building Structures 92

8.3. Tanks 92

8.3.1. Descriptions of the Tanks 92

8.3.2. Predictions for the Tanks 92

8.3.3. Comparison of Predictions for the Tanks with those provided in the Part 3A Application 93

8.3.4. Impact Assessments for the Tanks 94

8.3.5. Impact Assessments for the Tanks Based on Increased Predictions 94

8.3.6. Recommendations for the Tanks 94

8.4. Gas and Fuel Storages 94

8.5. Poultry Sheds 95

8.6. Glass Houses 95

8.7. Hydroponic Systems 95

8.8. Irrigation Systems 95

8.9. Farm Fences 95

8.10. Farm Dams 96

8.10.1. Descriptions of the Farm Dams 96

8.10.2. Predictions for the Farm Dams 96

8.10.3. Comparison of Predictions for the Farm Dams with those provided in the Part 3A Application 98

8.10.4. Impact Assessments for the Farm Dams 98

8.10.5. Impact Assessments for the Farm Dams Based on Increased Predictions 99

8.10.6. Recommendations for the Farm Dams 100

8.11. Groundwater Bores 100

8.11.1. Descriptions of the Groundwater Bores 100

8.11.2. Predictions and Impact Assessments for the Groundwater Bores 100

8.11.3. Recommendations for the Groundwater Bores 101

**9.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE INDUSTRIAL, COMMERICAL AND BUSINESS ESTABLISHMENTS 102**

9.1. Factories 102

9.2. Workshops 102

9.3. Business or Commercial Establishments or Improvements 102

9.4. Gas or Fuel Storages and Associated Plant 102

9.5. Waste Storages and Associated Plant 102

9.6. Buildings, Equipment or Operations that are Sensitive to Surface Movements 102

9.7. Surface Mining (Open Cut) Voids and Rehabilitated Areas 102

9.8. Mine Infrastructure Including Tailings Dams or Emplacement Areas 102
9.9. Any Other Industrial, Commercial or Business Features 102
**10.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR AREAS OF ARCHEOLOGICAL AND HERITAGE SIGNIFICANCE 103**
10.1. Aboriginal Archaeological Sites 103
10.1.1. Predictions for the Aboriginal Archaeological Sites 103
10.1.2. Comparison of Predictions for the Aboriginal Archaeological Sites with those provided in the Part 3A Application 104
10.1.3. Impact Assessments for the Artefact Scatters 104
10.1.4. Impact Assessments for the Shelters 104
10.1.5. Impact Assessments for the Grinding Groove Sites 105
10.1.6. Impact Assessments for the Aboriginal Archaeological Sites Based on Increased Predictions 105
10.1.7. Recommendations for the Aborigial Archaeological Sites 105
10.2. Heritage Sites 106
10.3. Items on the Register of the National Estate 106
10.4. Items of Architectural Significance 106
**11.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE RESIDENTIAL BUILDING STRUCTURES 107**
11.1. Houses 107
11.1.1. Descriptions of the Houses 107
11.1.2. Predictions for the Houses 108
11.1.3. Comparison of Predictions for the Houses with those provided in the Part 3A Application 109
11.1.4. Impact Assessments for the Houses 109
11.1.5. Impact Assessments for the Houses Based on Increased Predictions 113
11.1.6. Recommendations for the Houses 114
11.2. Flats or Units 114
11.3. Caravan Parks 114
11.4. Retirement or Aged Care Villages 114
11.5. Swimming Pools 114
11.5.1. Descriptions of the Swimming Pools 114
11.5.2. Predictions for the Swimming Pools 115
11.5.3. Comparison of Predictions for the Pools with those provided in the Part 3A Application 116
11.5.4. Impact Assessments for the Swimming Pools 116
11.5.5. Impact Assessments for the Swimming Pools Based on Increased Predictions 117
11.5.6. Recommendations for the Swimming Pools 117
11.6. Tennis Courts 117
11.7. On-Site Waste Water Systems 117
11.8. Rigid External Pavements 118
11.9. Fences 118
11.10. Any Other Residential Feature 118
**APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS 119**
**APPENDIX B. REFERENCES 122**
**APPENDIX C. METHOD OF IMPACT ASSESSMENTS FOR HOUSES 125**

C.1. Introduction 126
C.2. Review of the Performance of the Previous Method 126
C.3. Method of Impact Classification 128
C.3.1. Previous Method 128
C.3.2. Need for Improvement to the Previous Method of Impact Classification 129
C.3.3. Broad Recommendations for Improvement of Previous Method of Impact Classification 131
C.3.4. Revised Method of Impact Classification 132
C.4. Method of Impact Assessment 134
C.4.1. Need for Improvement of the Previous Method 134
C.4.2. Factors that Could be Used to Develop a Probabilistic Method of Prediction 134
C.4.3. Revised Method of Impact Assessment 135
**APPENDIX D. TABLES 138**
**APPENDIX E. FIGURES 139**
**APPENDIX F. DRAWINGS 140**

## Tables

Tables are prefixed by the number of the chapter or the letter of the appendix in which they are presented.


| *Table No.* | *Description* | *Page* |
|---|---|---|
| Table 1.1 | Geometry of the Proposed Longwalls 37 and 38 | 2 |
| Table 2.1 | Natural Features and Surface Infrastructure | 7 |
| Table 4.1 | Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Each of the Proposed Longwalls | 17 |
| Table 4.2 | Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of Each of the Proposed Longwalls | 17 |
| Table 4.3 | Comparison of Maximum Predicted Conventional Subsidence Parameters over Longwalls 29 to 38 based on the Part 3A and Extraction Plan Layouts | 18 |
| Table 4.4 | Comparison of Maximum Predicted Conventional Subsidence Parameters | 18 |
| Table 4.5 | Probabilities of Exceedance for Strain for Survey Bays above Goaf | 20 |
| Table 4.6 | Probabilities of Exceedance for Strain for Survey Bays Located above Solid Coal | 22 |
| Table 4.7 | Probabilities of Exceedance for Mid-Ordinate Deviation for Survey Marks above Goaf for Monitoring Lines in the Southern Coalfield | 25 |
| Table 5.1 | Minimum Distances of the Proposed Longwalls from the Georges River | 34 |
| Table 5.2 | Rockbars along Georges River and within the Study Area | 35 |
| Table 5.3 | Boulderfields along Georges River and within the Study Area | 35 |
| Table 5.4 | Maximum Predicted Total Subsidence, Upsidence and Closure at the Georges River Resulting after the Extraction of Longwalls 36, 37 and 38 | 40 |
| Table 5.5 | Maximum Predicted Total Subsidence, Upsidence and Closure at the Mapped Features along the Nepean River after the Extraction of the Longwalls 37 and 38 | 41 |
| Table 5.6 | Summary of the Predicted and Observed Closure Movements at the Georges River Cross Lines | 42 |
| Table 5.7 | Comparison of the Maximum Predicted Conventional Subsidence Parameters along the Georges River after the Extraction of Longwall 38 | 42 |
| Table 5.8 | Summary of Gradients along selected Tributaries within the Study Area | 53 |
| Table 5.9 | Maximum Predicted Total Subsidence, Upsidence and Closure at the Drainage Lines after the Extraction of Longwalls 36 | 54 |
| Table 5.10 | Maximum Predicted Total Subsidence, Upsidence and Closure at the Drainage Lines after the Extraction of Longwalls 37 | 54 |
| Table 5.11 | Maximum Predicted Total Subsidence, Upsidence and Closure at the Drainage Lines after the Extraction of Longwalls 38 | 55 |
| Table 5.12 | Maximum Predicted Total Tilt at the Drainage Lines after the Extraction of Longwalls 38 | 55 |
| Table 5.13 | Examples of Previous Experience of Mining Beneath Drainage Lines in the Southern Coalfield | 57 |
| Table 5.14 | Details of Cliffs within Vicinity of the Study Area | 59 |
| Table 5.15 | Maximum Predicted Total Conventional Subsidence Parameters Cliffs Resulting from the Extraction of the Proposed Longwalls | 59 |
| Table 5.16 | Maximum Predicted Total Conventional Subsidence, Tilt and Curvature at the Steep Slopes Resulting from the Extraction of the Proposed Longwalls | 63 |
| Table 5.17 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Steep Slopes Based on the Part 3A and Extraction Plan Layouts | 63 |
| Table 6.1 | Maximum Predicted Incremental and Total Conventional Subsidence, Tilt and Curvature along the Alignment of Appin Road Resulting from the Extraction of Longwall 37 | 67 |
| Table 6.2 | Maximum Predicted Travelling Tilt and Curvature along the Alignment of Appin Road Resulting from the Extraction of Longwall 37 | 67 |
| Table 6.3 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for Appin Road Based on the Part 3A and Extraction Plan Layouts | 68 |
| Table 6.4 | Maximum Predicted Total Conventional Subsidence Parameters for Prediction Line 2 after the Extraction of Each of the Proposed Longwalls | 71 |
| Table 6.5 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for Menangle Road Based on the Part 3A and Extraction Plan Layouts | 72 |

| | | |
|---|---|---|
| Table 6.6 | Mine Subsidence Board Design Requirements for the 1200 mm Diameter Pipeline | 75 |
| Table 6.7 | Recommended Design Parameters the 225 mm Diameter Rising Sewer Main | 76 |
| Table 6.8 | Maximum Predicted Incremental and Total Conventional Subsidence Parameters for the Rising Sewer Main after the Extraction of Each of the Proposed Longwall 37 | 76 |
| Table 6.9 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Rising Sewer main Based on the Part 3A and Extraction Plan Layouts | 77 |
| Table 6.10 | Examples of Previous Experience of Mining Beneath Water Pipelines in the Southern Coalfield | 78 |
| Table 6.11 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the 11 kV Powerlines | 80 |
| Table 6.12 | Examples of Previous Experience of Mining Beneath Powerlines in the Southern Coalfield | 80 |
| Table 6.13 | Summary of Telecommunications Infrastructure within the Study Area | 81 |
| Table 6.14 | Maximum Predicted Incremental and Total Conventional Subsidence Parameters for the Optical Fibre Cable after the Extraction of Each of the Proposed Longwall 37 | 82 |
| Table 6.15 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Optical Fibre Cable on the Part 3A and Extraction Plan Layouts | 82 |
| Table 6.16 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for Copper Telecommunications Cables Based on the Part 3A and Extraction Plan Layouts | 83 |
| Table 6.17 | Examples of Mining Beneath Optical Fibre Cables | 84 |
| Table 6.18 | Examples of Mining Beneath Copper Telecommunications Cables | 85 |
| Table 8.1 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Rural Building Structures Based on the Part 3A and Extraction Plan Layouts | 90 |
| Table 8.2 | Examples of Previous Experience of Mining Beneath Rural Building Structures in the Southern Coalfield | 91 |
| Table 8.3 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Tanks Based on the Part 3A and Extraction Plan Layouts | 94 |
| Table 8.4 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Farm Dams Based on the Part 3A and Extraction Plan Layouts | 98 |
| Table 8.5 | Examples of Previous Experience of Mining Beneath Farm Dams in the Southern Coalfield | 99 |
| Table 8.6 | Details of the Groundwater Bore within the Study Area | 100 |
| Table 8.7 | Maximum Predicted Total Conventional Subsidence Parameters at the Groundwater Bores Resulting from the Extraction of the Proposed Longwalls | 100 |
| Table 10.1 | Archaeological Sites Identified within the Study Area | 103 |
| Table 10.2 | Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Archaeological Sites Resulting from the Extraction of the Proposed Longwalls | 103 |
| Table 10.3 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Archaeological Sites Based on the Part 3A and Extraction Plan Layouts | 104 |
| Table 11.1 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Houses Based on the Part 3A and Extraction Plan Layouts | 109 |
| Table 11.2 | Observed Frequency of Impacts for Building Structures Resulting from the Extraction of Tahmoor Longwalls 22 to 24A | 110 |
| Table 11.3 | Observed Frequency of Impacts for Houses Resulting from the Extraction of Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10 | 111 |
| Table 11.4 | Assessed Impacts for the Houses within the Study Area | 112 |
| Table 11.5 | Houses with Tilts Greater than 7 mm/m Based on a 2 Times Predicted Case | 113 |
| Table 11.6 | Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Pools Based on the Part 3A and Extraction Plan Layouts | 116 |
| Table C.1 | Summary of Comparison between Observed and Predicted Impacts for each Structure | 126 |
| Table C.2 | Classification of Damage with Reference to Strain | 128 |
| Table C.3 | Classification of Damage with Reference to Tilt | 128 |
| Table C.4 | Revised Classification based on the Extent of Repairs | 132 |
| Table C.5 | Probabilities of Impact based on Curvature and Construction Type based on the Revised Method of Impact Classification | 136 |
| Table C.6 | Observed Frequency of Impacts observed for all buildings at Tahmoor Colliery | 136 |

| | | |
|---|---|---|
| Table D.01 | Details of the Houses within the Study Area | Appendix D |
| Table D.02 | Maximum Predicted Conventional Subsidence Parameters and Impact Assessments for the Houses within the Study Area | Appendix D |
| Table D.03 | Maximum Predicted Conventional Subsidence Parameters for the Rural Building Structures within the Study Area | Appendix D |
| Table D.04 | Maximum Predicted Conventional Subsidence Parameters for the Farm Dams within the Study Area | Appendix D |
| Table D.05 | Maximum Predicted Conventional Subsidence Parameters for the Tanks within the Study Area | Appendix D |
| Table D.06 | Maximum Predicted Conventional Subsidence Parameters for the Pools within the Study Area | Appendix D |

**Figures**

Figures are prefixed by the number of the chapter or the letter of the appendix in which they are presented.

| *Figure No.* | *Description* | *Page* |
|---|---|---|
| Fig. 1.1 | Aerial Photograph Showing Longwalls 37 and 38 and the Study Area | 1 |
| Fig. 1.2 | Typical Stratigraphic Section for Southern Coalfield | 3 |
| Fig. 1.3 | Surface Lithology within the Study Area (I&I Geological Series Sheet 9029-9129) | 4 |
| Fig. 2.1 | The Proposed Longwalls and the Study Area Overlaid on CMA Map No. Picton 9029-1S | 6 |
| Fig. 3.1 | Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972) | 10 |
| Fig. 3.2 | Comparison of Raw Observed Incremental Closure versus Lateral Distances from Edges of the Incremental Panel for All Data, Valley Sites affected by Thin and Cross Bedded Bedrock Strata and Valley Sites not Undermined by Current or Previous Longwalls | 12 |
| Fig. 3.3 | Comparison of Raw Observed Incremental Closure versus Longitudinal Distances from Edges of the Incremental Panel for All Data, Valley Sites affected by Thin and Cross Bedded Bedrock Strata and Valley Sites not Undermined by Current or Previous Longwalls | 12 |
| Fig. 3.4 | Comparisons between Observed Incremental Subsidence and Predicted Incremental Subsidence for the Previously Extracted Longwalls | 14 |
| Fig. 3.5 | Comparisons between Maximum Observed Incremental Subsidence and Maximum Predicted Incremental Subsidence for the Previously Extracted Longwalls | 15 |
| Fig. 3.6 | Distribution of the Ratio of the Maximum Observed to Maximum Predicted Incremental Subsidence for Previously Extracted Longwalls | 15 |
| Fig. 4.1 | Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Goaf | 20 |
| Fig. 4.2 | Observed Incremental Strains versus Normalised Distance from the Longwall Maingate for Previously Extracted Longwalls in the Southern Coalfield | 21 |
| Fig. 4.3 | Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Solid Coal | 22 |
| Fig. 4.4 | Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines during the Extraction of Previous Longwalls in the Southern Coalfield | 23 |
| Fig. 4.5 | Total Closure Strain versus Total Closure Movement Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield | 24 |
| Fig. 4.6 | Distribution of Measured Maximum Mid-ordinate Deviation during the Extraction of Previous Longwalls in the Southern Coalfield for Marks Located Above Goaf | 25 |
| Fig. 4.7 | Observed Incremental Far-Field Horizontal Movements from the Southern Coalfield | 26 |
| Fig. 4.8 | Development of Strain at the Low Angle Thrust Fault Measured along the T-Line during the Extraction of Appin Longwall 408 | 27 |
| Fig. 4.9 | Surface Compression Humping due to Low Angle Thrust Fault | 27 |
| Fig. 4.10 | Surface Compression Humping due to Low Angle Thrust Fault | 28 |
| Fig. 4.11 | Development of Non-Conventional Anomalous Strains in the Southern Coalfield | 28 |
| Fig. 4.12 | Surface Compression Buckling Observed in a Pavement | 29 |
| Fig. 4.13 | Surface Tension Cracking along the Top of a Steep Slope | 29 |
| Fig. 4.14 | Surface Tension Cracking along the Top of a Steep Slope | 30 |
| Fig. 4.15 | Fracturing and Bedding Plane Slippage in Sandstone Bedrock in the Base of a Stream | 30 |
| Fig. 4.16 | Zones in the Overburden According to Peng and Chiang (1984) | 31 |

| | | |
|---|---|---|
| Fig. 4.17 | Zones in the Overburden according to Forster (1995) | 31 |
| Fig. 4.18 | Theoretical Model Illustrating the Development and Limit of the Fractured Zone | 33 |
| Fig. 4.19 | Observed Fracture Heights versus Panel Width | 33 |
| Fig. 5.1 | Photograph of Georges River Pool 52 looking Upstream (28th Feb 2011) | 36 |
| Fig. 5.2 | Photograph of Georges River Pool 57 looking Upstream (28th Feb 2011) | 36 |
| Fig. 5.3 | Photograph of Georges River Pool 63 looking Downstream (28th Feb 2011) | 37 |
| Fig. 5.4 | Photograph of Rockbar 64 looking Downstream (3rd Jan 2012) | 37 |
| Fig. 5.5 | Photograph of Rockbar 60 looking Cross Stream (26th Sep 2011) | 38 |
| Fig. 5.6 | Photograph of Boulder Field 62 looking Upstream (3rd Jan 2012) | 38 |
| Fig. 5.7 | Photograph of Boulder Field 50 looking Upstream (3rd Jan 2012) | 39 |
| Fig. 5.8 | Surface Cross-section over Longwall 37, across the Georges River and over Longwall 38 (Looking North) | 39 |
| Fig. 5.9 | Types of Surface Water Flow Diversions | 44 |
| Fig. 5.10 | Case Studies from the Southern Coalfield showing the Predicted Total Upsidence and Predicted Total Closure at the Times when Impacts were First Observed | 47 |
| Fig. 5.11 | Proportion of Type 3 Impacts versus Predicted Total Closure for Case Studies | 48 |
| Fig. 5.12 | Comparison of Predicted and Observed Upsidence Movements in Database | 49 |
| Fig. 5.13 | Comparison of Predicted and Observed Closure Movements in Database | 49 |
| Fig. 5.14 | Typical Stretch of Georges River Tributary GR110 within the Study Area | 53 |
| Fig. 5.15 | Typical Stretch of the Nepean Creek within the Study Area | 53 |
| Fig. 5.16 | Example of Surface Tension Cracking along the Top of a Steep Slope | 64 |
| Fig. 6.1 | Transverse Cracking (Photograph Courtesy of Colin Dove) | 69 |
| Fig. 6.2 | Small compression bump (Photograph Courtesy of Colin Dove) | 69 |
| Fig. 6.3 | Spalling of concrete kerb (Photograph Courtesy of Colin Dove) | 70 |
| Fig. 6.4 | Shear cracking (Photograph Courtesy of Colin Dove) | 70 |
| Fig. 8.1 | Agricultural Land Classification within the Study Area (Source NSW DII November 2008) | 88 |
| Fig. 8.2 | Maximum Predicted Conventional Subsidence and Tilt for the Rural Building Structures within the Study Area Resulting from the Extraction of the Proposed Longwalls | 89 |
| Fig. 8.3 | Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Rural Structures Resulting from the Extraction of the Proposed Longwalls | 89 |
| Fig. 8.4 | Maximum Predicted Conventional Subsidence and Tilt for the Tanks within the Study Area Resulting from the Extraction of the Proposed Longwalls | 93 |
| Fig. 8.5 | Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Tanks Resulting from the Extraction of the Proposed Longwalls | 93 |
| Fig. 8.6 | Distributions of Longest Lengths and Surface Areas of the Farm Dams | 96 |
| Fig. 8.7 | Maximum Predicted Conventional Subsidence for the Farm Dams within the Study Area Resulting from the Extraction of the Proposed Longwalls | 97 |
| Fig. 8.8 | Maximum Predicted Conventional Tilt after the Extraction of All Longwalls (Left) and after the Extraction of Any Longwall (Right) for the Farm Dams within the Study Area | 97 |
| Fig. 8.9 | Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Farm Dams Resulting from the Extraction of the Proposed Longwalls | 97 |
| Fig. 8.10 | Predicted Changes in Freeboards for the Farm Dams within the Study Area | 98 |
| Fig. 11.1 | Distribution of the Maximum Plan Dimension of Houses within the Study Area | 107 |
| Fig. 11.2 | Distributions of Wall and Footing Construction for Houses within the Study Area | 107 |
| Fig. 11.3 | Maximum Predicted Conventional Subsidence for the Houses within the Study Area Resulting from the Extraction of the Proposed Longwalls | 108 |
| Fig. 11.4 | Maximum Predicted Conventional Tilts After the Extraction of All Longwalls (Left) and Maximum Predicted Conventional Tilts After the Extraction of Any Longwall (Right) | 108 |
| Fig. 11.5 | Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses Resulting from the Extraction of the Proposed Longwalls | 109 |
| Fig. 11.6 | Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses Located Above Tahmoor Longwalls 22 to 24A | 111 |
| Fig. 11.7 | Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses at Teralba, West Cliff and West Wallsend | 111 |
| Fig. 11.8 | Distribution of Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses Based on a 2 Times Predicted Case | 113 |

Fig. 11.9 Maximum Predicted Conventional Subsidence and Tilt for the Pools within the Study Area Resulting from the Extraction of the Proposed Longwalls 115
Fig. 11.10 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Pools Resulting from the Extraction of the Proposed Longwalls 115

Fig. C.1 Example of slippage on damp proof course.......... 129
Fig. C.2 Example of crack in mortar only.......... 130
Fig. C.3 Comparison between Previous and Revised Methods of Impact Classification.......... 133
Fig. C.4 Probability Curves for Impacts to Buildings.......... 137

Fig. E.01 Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 Appendix E
Fig. E.02 Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 Appendix E
Fig. E.03 Predicted Profiles of Subsidence, Upsidence and Closure along the Georges River Appendix E
Fig. E.04 Predicted Profiles of Subsidence, Upsidence and Closure along Mallaty Creek Appendix E
Fig. E.05 Predicted Profiles of Subsidence, Upsidence and Closure along Nepean Creek Appendix E
Fig. E.06 Predicted Profiles of Subsidence, Upsidence and Closure along Woodhouse Creek Appendix E
Fig. E.07 Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR103 Appendix E
Fig. E.08 Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR104 Appendix E
Fig. E.09 Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR105 Appendix E
Fig. E.10 Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR107 Appendix E
Fig. E.11 Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR108 Appendix E
Fig. E.12 Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR110 Appendix E
Fig. E.13 Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR114 Appendix E
Fig. E.14 Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Appin Road Appendix E

Drawings

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


| *Drawing No.* | *Description* | *Revision* |
|---|---|---|
| MSEC533-01 | General Layout | A |
| MSEC533-02 | Surface Level Contours | A |
| MSEC533-03 | Seam Floor Contours | A |
| MSEC533-04 | Seam Thickness Contours | A |
| MSEC533-05 | Depth of Cover Contours | A |
| MSEC533-06 | Geological Structures at Seam Level | A |
| MSEC533-07 | Watercourses – Key Plan | A |
| MSEC533-08 | Georges River Features – Map 01 | A |
| MSEC533-09 | Georges River Features – Map 02 | A |
| MSEC533-10 | Cliffs and Steep Slopes | A |
| MSEC533-11 | Roads and Culverts | A |
| MSEC533-12 | Water & Gas Infrastructure | A |
| MSEC533-13 | Electrical Infrastructure | A |
| MSEC533-14 | Telecommunications Infrastructure | A |
| MSEC533-15 | Building Structures and Dams – Key Plan | A |
| MSEC533-16 | Building Structures and Dams – Map 01 | A |
| MSEC533-17 | Building Structures and Dams – Map 02 | A |
| MSEC533-18 | Building Structures and Dams – Map 03 | A |
| MSEC533-19 | Building Structures and Dams – Map 04 | A |
| MSEC533-20 | Building Structures and Dams – Map 05 | A |
| MSEC533-21 | Building Structures and Dams – Map 06 | A |
| MSEC533-22 | Archaeological Sites, Heritage Sites, Groundwater Bores and Survey Marks | A |
| MSEC533-34 | Predicted Incremental Subsidence Contours due to Longwalls 37 & 38 | A |
| MSEC533-35 | Predicted Total Subsidence Contours due to Longwalls 29 to 38 | A |

## 1.1. Background

BHP Billiton Illawarra Coal (IC) proposes to continue its underground coal mining operations at West Cliff Colliery, which is located in the Southern Coalfield of New South Wales, by extracting coal from the Bulli Seam using longwall mining techniques. IC are seeking approval to extract Longwalls 37 and 38, which are located immediately north and east respectively of the approved Longwalls 29 to 36. The overall layout of the longwalls at West Cliff Colliery is shown in Drawing No. MSEC533-01, which together with all other drawings is included in Appendix F.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by IC to:-

- Study the current mining proposals,
- Identify the natural features and items of surface infrastructure in the vicinity of the proposed Longwalls 37 and 38,
- Provide subsidence predictions for each of these natural features and items of surface infrastructure, and to
- Provide impact assessments, in conjunction with other specialist consultants, for each of these natural features and items of surface infrastructure.

The proposed longwalls and the Study Area, as defined in Section 2.1, have been overlaid on an orthophoto of the area, which is shown in Fig. 1.1. The major natural features and surface infrastructure in the vicinity of the proposed longwalls can be seen in this figure.

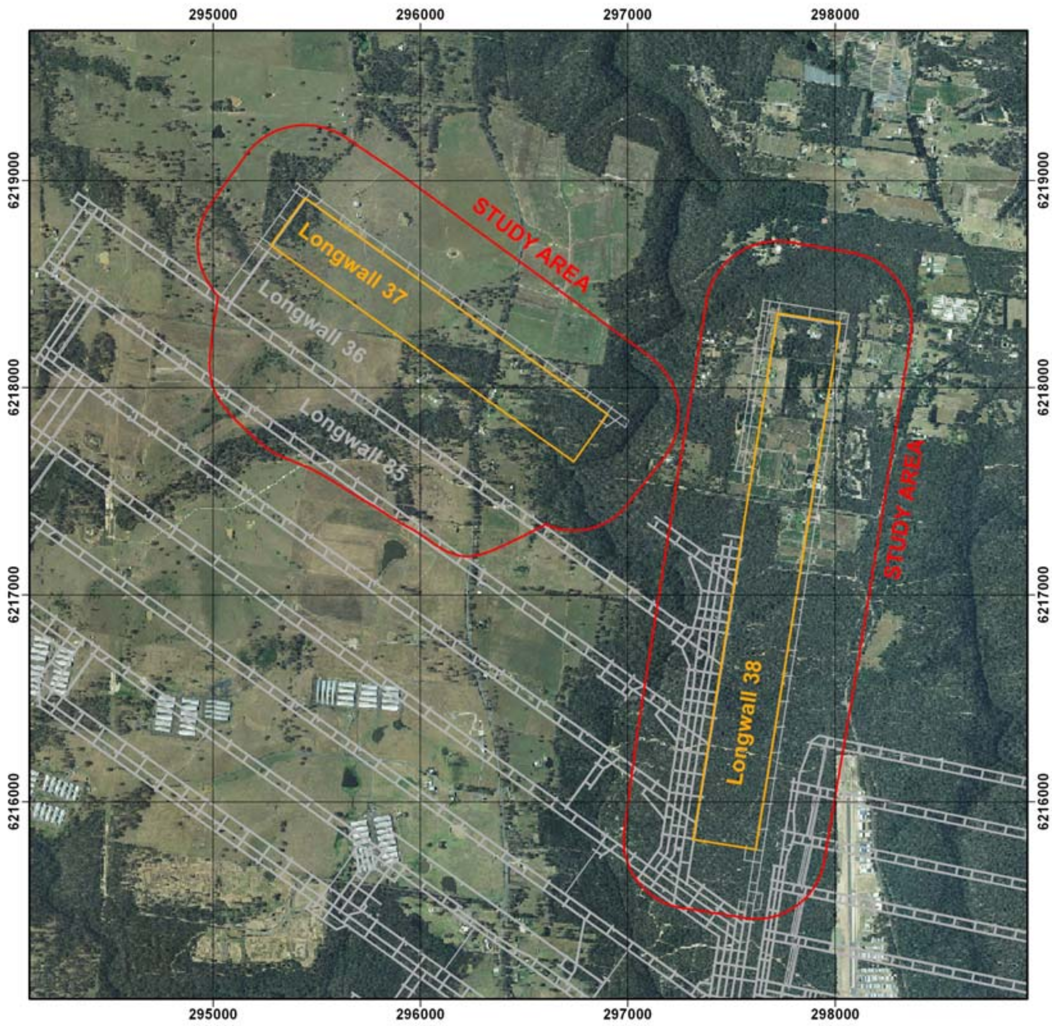



**Fig. 1.1 Aerial Photograph Showing Longwalls 37 and 38 and the Study Area**

Chapter 2 defines the Study Area and provides a summary of the natural features and items of surface infrastructure within the Study Area.

Chapter 3 includes overviews of mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls.

Chapters 5 through 11 provide the descriptions, predictions and impact assessments for each of the natural features and items of surface infrastructure within the Study Area. Recommendations for each of these features are also provided, which have been based on the predictions and impact assessments.

## 1.2. Mining Geometry

The proposed layout of Longwalls 37 and 38 is shown in Drawing No. MSEC533-01 in Appendix F. A summary of the proposed longwall dimensions is provided in Table 1.1. IC propose to shorten the commencing end of Longwall 36 by 1020 metres from the commencing end approved in the SMP Application, which is the subject of a separate modification application. The predictions and assessments provided in this report are based on the shortened commencing end of Longwall 36.

**Table 1.1 Geometry of the Proposed Longwalls 37 and 38**

| Longwall | Overall Void Length Including Installation Heading (m) | Overall Void Width Including First Workings (m) | Overall Tailgate Chain Pillar Width (m) |
|---|---|---|---|
| LW37 | 1795 | 282 | 32 |
| LW38 | 2575 | 305 | - |

## 1.3. Surface Topography

The surface level contours in the vicinity of the proposed longwalls are shown in Drawing No. MSEC533-02, which were generated from a 2009 airborne laser scan of the area.

The major topographical feature within the Study Area is the Georges River. Surface levels within the Study Area vary from a low point of approximately 155 metres AHD, in the base of the Nepean Creek at the north west corner of the Study Area, to a high point of approximately 255 metres AHD, at east side and south east corner of the Study Area.

## 1.4. Seam Information

The surface level contours, seam floor contours, seam thickness contours and depth of cover contours are shown in Drawings Nos. MSEC533-02, MSEC533-03, MSEC533-04 and MSEC533-05, respectively.

The depth of cover to the Bulli Seam within the Study Area varies between a minimum of 455 metres, in the base of the Georges River valley, and a maximum of 540 metres, in the south western part of the Study Area.

The seam floor within the Study Area generally dips from the east to the west. The seam thickness within the proposed longwall goaf areas varies between a minimum of 2.2 metres near the western end of Longwall 37 and 2.7 metres near the southern end of Longwall 38. The proposed longwalls will extract a minimum height of 2.4 metres where the seam thickness is less than 2.4 metres and will extract the full height where the seam thickness is greater than 2.4 metres.

## 1.5. Geological Details

West Cliff Colliery lies in the southern part of the Permo-Triassic Sydney Basin, within which the main coal bearing sequence is the Illawarra Coal Measures, of Late Permian age. The Illawarra Coal Measures contain numerous workable seams, the uppermost of which is the Bulli Seam.

All of the sediments that form the overburden to the Bulli Seam belong to the Hawkesbury Tectonic Stage, which comprises three stratigraphic divisions. The lowest division is the Narrabeen Group, which is subdivided into a series of interbedded sandstone and claystone units. It ranges in age from Lower to Middle Triassic and varies in thickness up to 310 metres. Overlying the Narrabeen Group is the Hawkesbury Sandstone Group, which is a series of bedded sandstone units which dates from the Middle Triassic and has a thickness of up to 185 metres. Above the Hawkesbury is the Wianamatta Group, which consists of shales and siltstones and is poorly represented in this region, having a thickness of only a few tens of metres. A typical stratigraphic section for the West Cliff Colliery area is shown in Fig. 1.2.

The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates. The major sandstone units are the Scarborough, the Bulgo and the Hawkesbury Sandstones and these units vary in thickness from a few metres to as much as 200 metres. The rocks exposed in the river gorges and creek alignments belong to the Hawkesbury Group. The other rocks generally exist in discreet but thinner beds of less than 15 metres thickness, or are interbedded as thin bands within the sandstone.

The major claystone unit is the Bald Hill Claystone, which lies above the Bulgo Sandstone at the base of the Hawkesbury Sandstone. This claystone varies in thickness and is, in some places, more than 25 metres thick. Due to the nature of the clay, which swells when it is wetted, it tends to act as an aquitard.

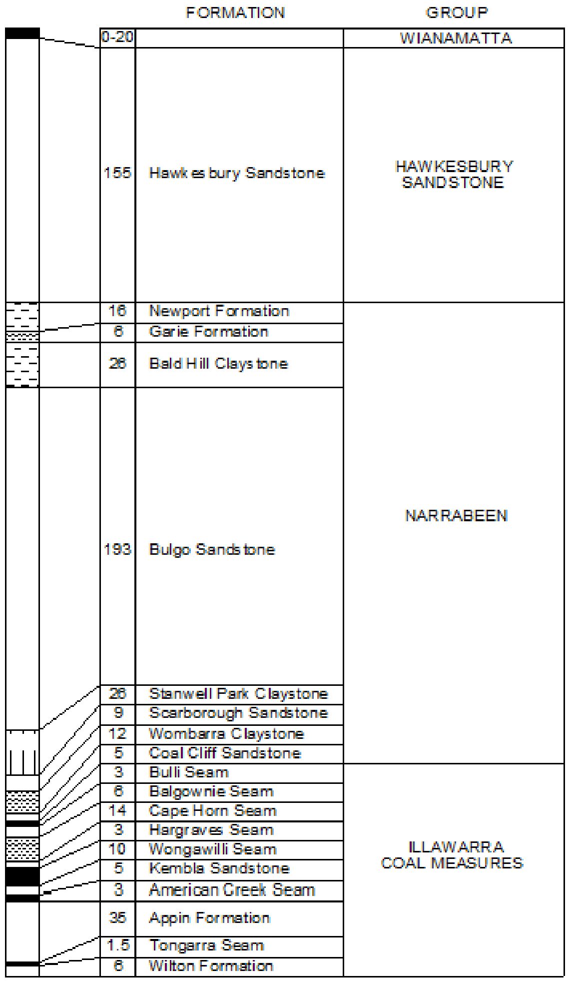



**Fig. 1.2 Typical Stratigraphic Section for Southern Coalfield**

The geological structures which have been identified at seam level are shown in Drawing No. MSEC533-06. The geological features identified at seam level within the Study Area include a minor faulting zone, which crosses near the mid-length of Longwall 37, and the series of faults located to the north of Longwall 37. Where these geological structures extend near to the surface, it is possible that irregular subsidence movements could result, which is discussed in Sections 3.4.1 and 4.7. Further details on irregular subsidence movements (i.e. anomalies) are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

The surface geology within the Study Area can be seen in Fig. 1.3, which shows the proposed longwalls overlaid on Geological Series Sheet 9029-9129, which is published by the DPI.

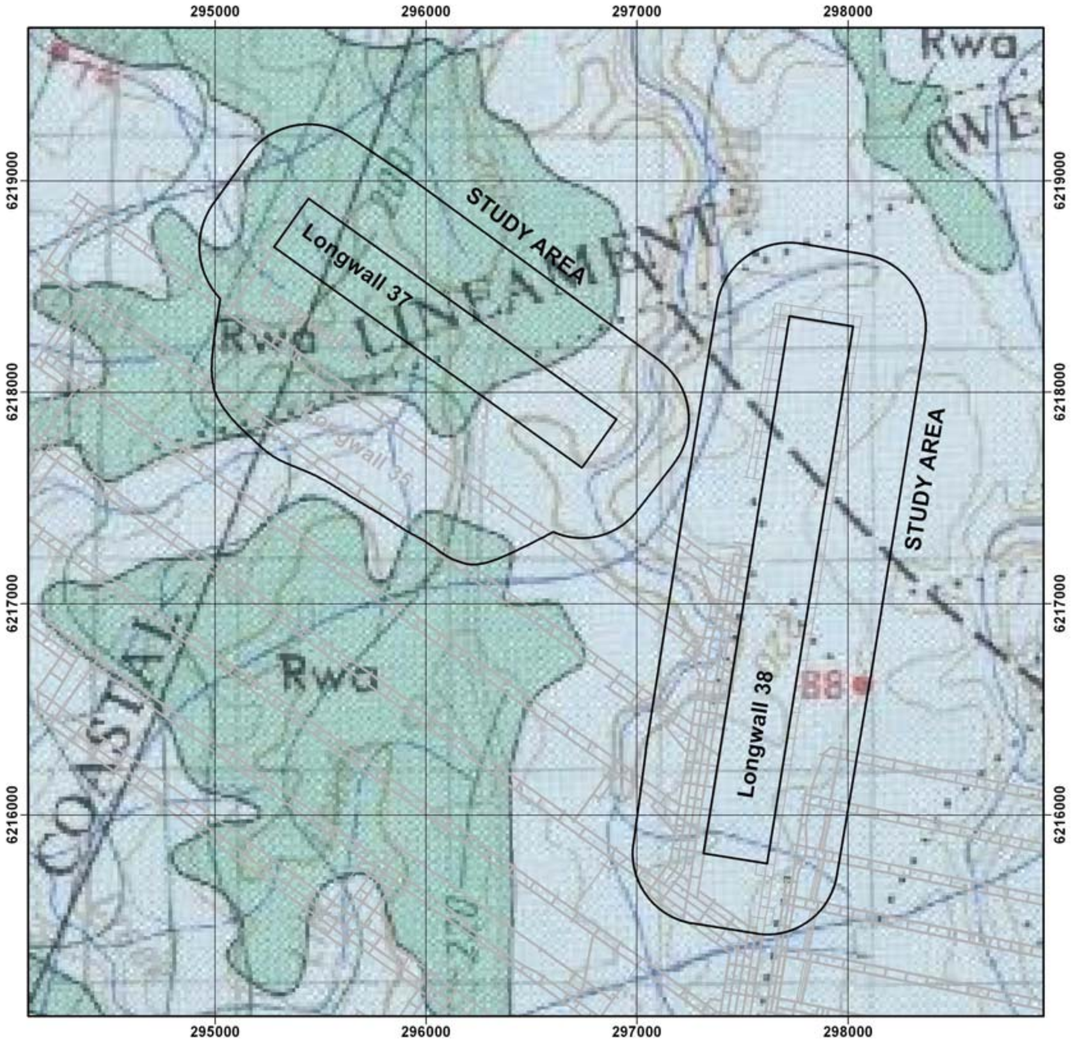



**Fig. 1.3 Surface Lithology within the Study Area (I&I Geological Series Sheet 9029-9129)**

It can be seen from the above Fig. 1.3 that the surface geology within the Study Area comprises areas of the Hawkesbury Sandstone Group (Rh) and areas of the Wianamatta Group (Rwa).

## 2.1. Definition of the Study Area

The *Study Area* is defined as the surface area that is likely to be affected by the proposed mining of Longwalls 37 and 38 at West Cliff. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:-

- A 35 degree angle of draw line from the proposed extents of Longwalls 37 and 38, and
- The predicted limit of vertical subsidence, taken as the predicted 20 mm subsidence contour resulting from the extraction of the proposed Longwalls 37 and 38.

The depth of cover contours are shown in Drawing No. MSEC533-05. It can be seen from this drawing, that the depth of cover directly above the proposed longwalls varies between a minimum of 455 metres, in the base of the Georges River valley, and a maximum of 540 metres, in the south western part of the mining area. The 35 degree angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 320 metres and 380 metres around the limits of the proposed extraction areas.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method, which is described in Chapter 3. The predicted total subsidence contours, resulting from the extraction of Longwalls 37 and 38, are shown in Drawing No. MSEC533-24.

A line has therefore been drawn defining the Study Area, based upon the 35 degree angle of draw line and the predicted total 20 mm subsidence contour, whichever is furthest from the longwalls, and is shown in Drawing No. MSEC533-01.

There are features that lie outside the Study Area that are expected to experience either far-field movements, or valley related movements. The surface features which are sensitive to such movements have been identified and have been included in the assessments provided in this report. These features are listed below and details of these are provided in later sections of the report:-

- Watercourses (including the Georges River), within the predicted limits of 20 mm total upsidence and 20 mm total closure;
- Wedderburn Airport;
- Groundwater bores; and
- Survey control marks.

## 2.2. Natural Features and Items of Surface Infrastructure within the Study Area

The major natural features and items of surface infrastructure within the Study Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered APPIN 9029-1S. The proposed longwalls and the Study Area have been overlaid on an extract of this CMA map in Fig. 2.1.

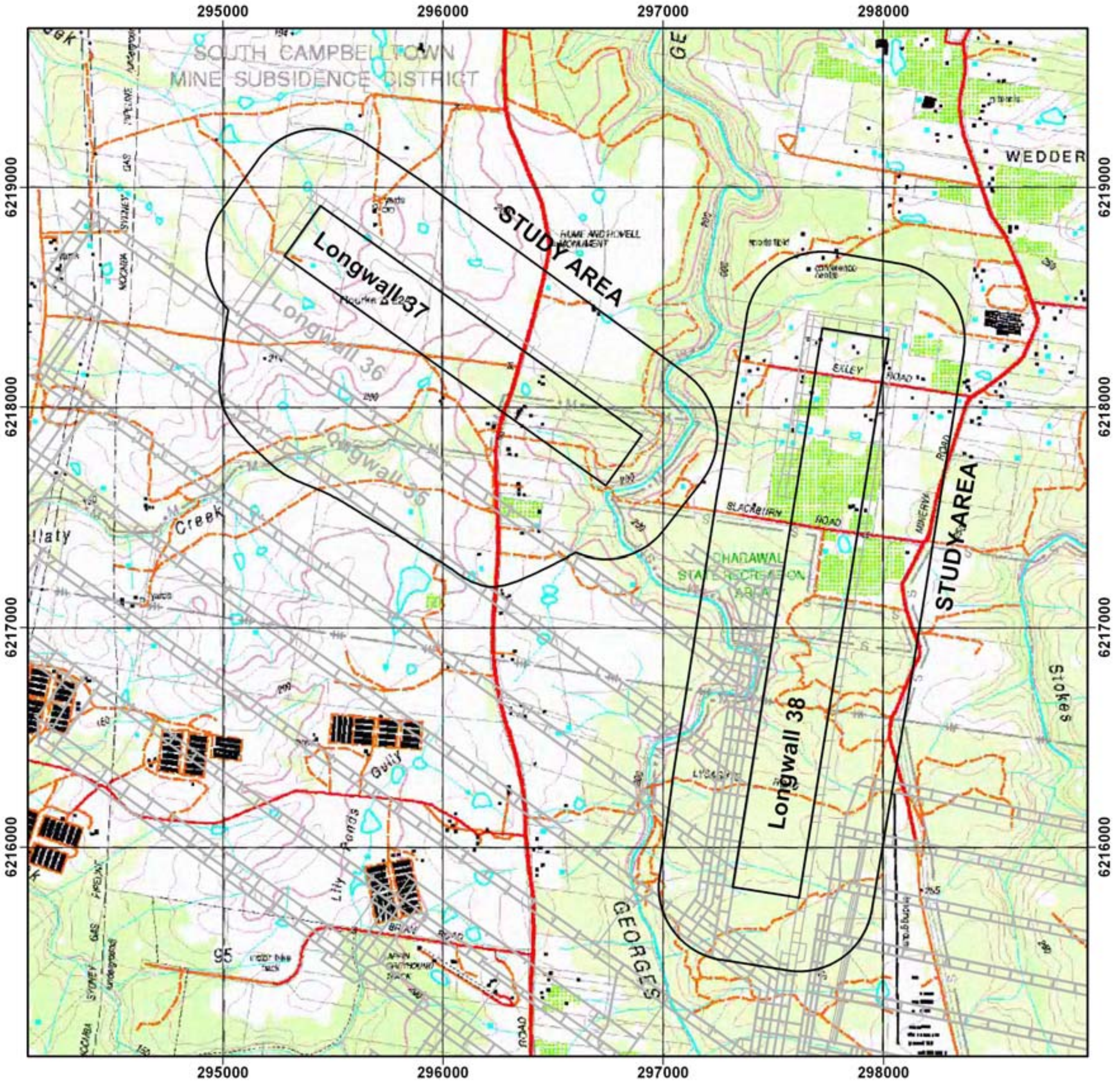



**Fig. 2.1 The Proposed Longwalls and the Study Area Overlaid on CMA Map No. Picton 9029-1S**

A summary of the natural features and items of surface infrastructure within the Study Area is provided in Table 2.1. The locations of these features are shown in Drawings Nos. MSEC533-07 to MSEC533-21, in Appendix F.

The descriptions, predictions and impact assessments for the natural features and items of surface infrastructure are provided in Chapters 5 through to 11. The section number references are provided in Table 2.1.

## Table 2.1 Natural Features and Surface Infrastructure

| Item | Within Study Area | Section Number Reference |
|---|---|---|
| **NATURAL FEATURES** | | |
| Catchment Areas or Declared Special Areas | × | |
| Rivers or Creeks | ✓ | 5.2 & 5.3 |
| Aquifers or Known Groundwater Resources | ✓ | 5.4 |
| Springs | ✓ | 5.5 |
| Sea or Lake | × | |
| Shorelines | × | |
| Natural Dams | × | |
| Cliffs or Pagodas | ✓ | 5.9 |
| Steep Slopes | ✓ | 5.11 |
| Escarpments | × | |
| Land Prone to Flooding or Inundation | × | |
| Swamps, Wetlands or Water Related Ecosystems | ✓ | 5.14 |
| Threatened or Protected Species | ✓ | 5.15 |
| National Parks | × | |
| State Forests | × | |
| State Conservation Areas | ✓ | 5.17 |
| Natural Vegetation | ✓ | 5.18 |
| Areas of Significant Geological Interest | × | |
| Any Other Natural Features Considered Significant | × | |
| | | |
| **PUBLIC UTILITIES** | | |
| Railways | × | |
| Roads (All Types) | ✓ | 6.2 & 6.3 |
| Bridges | × | |
| Tunnels | × | |
| Culverts | ✓ | 6.6 |
| Water, Gas or Sewerage Infrastructure | ✓ | 6.7 to 6.11 |
| Liquid Fuel Pipelines | × | |
| Electricity Transmission Lines or Associated Plants | ✓ | 6.13 |
| Telecommunication Lines or Associated Plants | ✓ | 6.14 |
| Water Tanks, Water or Sewage Treatment Works | × | |
| Dams, Reservoirs or Associated Works | × | |
| Air Strips | ✓ | 6.17 |
| Any Other Public Utilities | × | |
| | | |
| **PUBLIC AMENITIES** | | |
| Hospitals | × | |
| Places of Worship | × | |
| Schools | × | |
| Shopping Centres | × | |
| Community Centres | × | |
| Office Buildings | × | |
| Swimming Pools | × | |
| Bowling Greens | × | |
| Ovals or Cricket Grounds | × | |
| Race Courses | × | |
| Golf Courses | × | |
| Tennis Courts | × | |
| Any Other Public Amenities | × | |

| Item | Within Study Area | Section Number Reference |
|---|---|---|
| **FARM LAND AND FACILITIES** | | |
| Agricultural Utilisation or Agricultural Suitability of Farm Land | ✓ | 8.1 |
| Farm Buildings or Sheds | ✓ | 8.2 |
| Tanks | ✓ | 8.3 |
| Gas or Fuel Storages | ✓ | 8.4 |
| Poultry Sheds | × | |
| Glass Houses | × | |
| Hydroponic Systems | × | |
| Irrigation Systems | ✓ | 8.8 |
| Fences | ✓ | 8.9 & 11.9 |
| Farm Dams | ✓ | 8.10 |
| Wells or Bores | ✓ | 8.11 |
| Any Other Farm Features | × | |
| | | |
| **INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS** | | |
| Factories | × | |
| Workshops | × | |
| Business or Commercial Establishments or Improvements | ✓ | 9.3 |
| Gas or Fuel Storages or Associated Plants | × | |
| Waste Storages or Associated Plants | × | |
| Buildings, Equipment or Operations that are Sensitive to Surface Movements | × | |
| Surface Mining (Open Cut) Voids or Rehabilitated Areas | × | |
| Mine Infrastructure Including Tailings Dams or Emplacement Areas | × | |
| Any Other Industrial, Commercial or Business Features | × | |
| | | |
| **AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE** | ✓ | 10.1 & 10.2 |
| | | |
| **ITEMS OF ARCHITECTURAL SIGNIFICANCE** | × | |
| | | |
| **PERMANENT SURVEY CONTROL MARKS** | ✓ | 6.18 |
| | | |
| **RESIDENTIAL ESTABLISHMENTS** | | |
| Houses | ✓ | 11.1 |
| Flats or Units | × | |
| Caravan Parks | × | |
| Retirement or Aged Care Villages | × | |
| Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts | ✓ | 11.5 11.6 11.7 11.8 |
| Any Other Residential Features | × | |
| | | |
| **ANY OTHER ITEM OF SIGNIFICANCE** | × | |
| **ANY KNOWN FUTURE DEVELOPMENTS** | × | |

## 3.0 OVERVIEW OF MINE SUBSIDENCE PARAMETERS AND THE METHOD USED TO PREDICT THE MINE SUBSIDENCE MOVEMENTS FOR THE PROPOSED LONGWALLS

### 3.1. Introduction

This chapter provides overviews of mine subsidence parameters and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls. Further details on longwall mining, the development of subsidence and the methods used to predict mine subsidence movements are provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

### 3.2. Overview of Conventional Subsidence Parameters

The normal ground movements resulting from the extraction of pillars or longwalls are referred to as conventional or 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 beyond the longwall goaf edges, 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 %, or 1 in 1000.

- **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* ($km^{-1}$), 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 the relative differential horizontal movements of the ground. **Normal 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. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  Whilst mining induced normal strains are measured along monitoring lines, ground shearing can also occur both vertically and horizontally across the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured along subsidence monitoring lines, however, differential ground movements can also be measured across monitoring lines using 3D survey monitoring techniques.

- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using 2D or 3D monitoring techniques.

  High deformations along monitoring lines (i.e. normal strains) are generally measured where high deformations have been measured across the monitoring line (i.e. shear deformations). Conversely, high deformations across monitoring lines are also generally measured where high normal strains have been measured along the monitoring line.

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters which result from the extraction of each longwall. The **total** subsidence, tilts, curvatures and strains are the accumulative parameters after the completion of each longwall within a series of longwalls. The **travelling** tilts, curvatures and strains are the transient movements as the longwall extraction face mines directly beneath a given point

## 3.3. Far-field Movements

The measured horizontal movements at survey marks which are located beyond the longwall goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. These movements are often referred to as *far-field movements*.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. These movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased observed horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between longwalls or near other previously extracted series of longwalls. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt and strain.

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.6.

## 3.4. Overview of Non-Conventional Subsidence Movements

Conventional subsidence profiles are typically smooth in shape and can be explained by the expected caving mechanisms associated with overlying strata spanning the extracted void. Normal conventional subsidence movements due to longwall extraction are easy to identify where longwalls are regular in shape, the extracted coal seams are relatively uniform in thickness, the geological conditions are consistent and surface topography is relatively flat.

As a general rule, the smoothness of the profile is governed by the depth of cover and lithology of the overburden, particularly the near surface strata layers. Where the depth of cover is greater than 400 metres, such as the case within the Study Area, the observed subsidence profiles along monitoring survey lines are generally smooth. Where the depth of cover is less than 100 metres, the observed subsidence profiles along monitoring lines are generally irregular. Very irregular subsidence movements are observed with much higher tilts and strains at very shallow depths of cover where the collapsed zone above the extracted longwalls extends up to or near to the surface.

Irregular subsidence movements are occasionally observed at the deeper depths of cover along an otherwise smooth subsidence profile. The cause of these irregular subsidence movements can be associated with:-

- issues related to the timing and the method of the installation of monitoring lines,
- sudden or abrupt changes in geological conditions,
- steep topography, and
- valley related mechanisms.

Non-conventional movements due to geological conditions and valley related movements are discussed in the following sections.

### 3.4.1. Non-conventional Subsidence Movements due to Changes in Geological Conditions

It is believed that most non-conventional ground movements are the result of the reaction of near surface strata to increased horizontal compressive stresses due to mining operations. Some of the geological conditions that are believed to influence these irregular subsidence movements are the blocky nature of near surface sedimentary strata layers and the possible presence of unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts and strains.

Even though it may be possible to attribute a reason behind most observed non-conventional ground movements, there remain some observed irregular ground movements that still cannot be explained with the available geological information. The term “anomaly” is therefore reserved for those non-conventional ground movement cases that were not expected to occur and cannot be explained by any of the above possible causes.

It is not possible to predict the locations and magnitudes of non-conventional anomalous movements. In some cases, approximate predictions for the non-conventional ground movements can be made where the underlying geological or topographic conditions are known in advance. It is expected that these methods will improve as further knowledge is gained through ongoing research and investigation.

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.4 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural features and items of surface infrastructure, which are provided in Chapters 5 through to 11, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

### 3.4.2. Non-conventional Subsidence Movements due to Steep Topography

Non-conventional movements can also result from downslope movements where longwalls are extracted beneath steep slopes. In these cases, elevated tensile strains develop near the tops of the steep slopes and elevated compressive strains develop near the bases of the steep slopes. The potential impacts resulting from down slope movements include the development of tension cracks at the tops of the steep slopes and compression ridges at the bottoms of the steep slopes.

Further discussions on the potential for down slope movements for the steep slopes within the Study Area are provided in Section 5.11.

### 3.4.3. Valley Related Movements

The watercourses within the Study Area may be subjected to valley related movements, which are commonly observed along river and creek alignments in the Southern Coalfield. Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.1. The potential for these natural movements are influenced by the geomorphology of the valley.

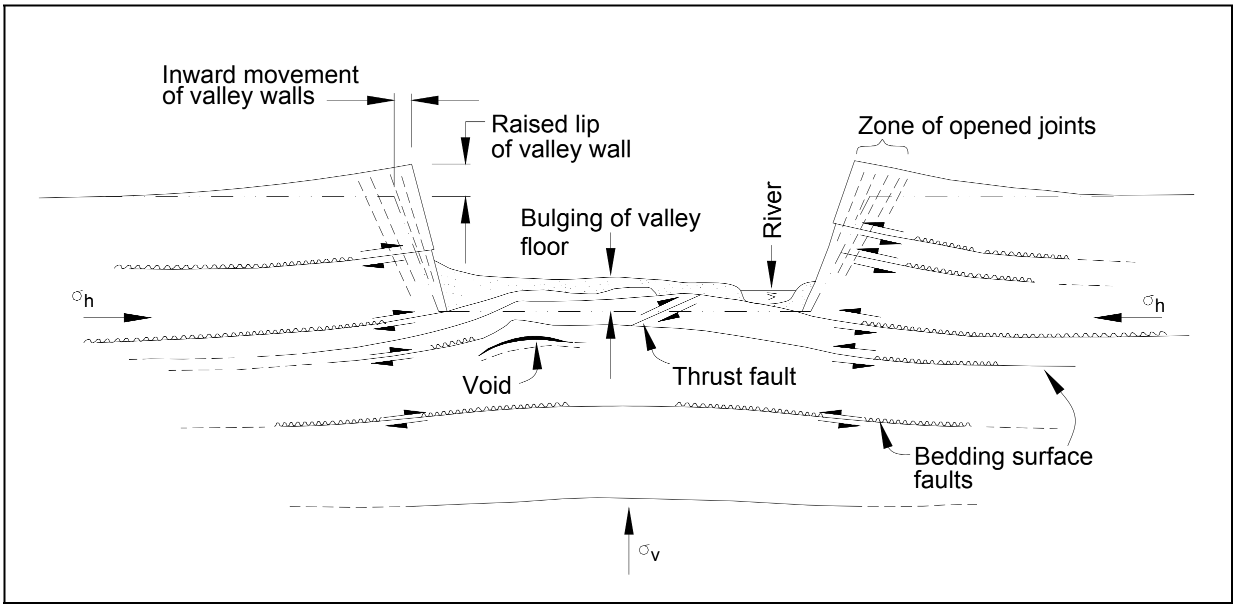



**Fig. 3.1 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)**

Valley related movements can be caused by or accelerated by mine subsidence as the result of a number of factors, including the redistribution of horizontal in-situ stresses and down slope movements. Valley related movements are normally described by the following parameters:-

- **Upsidence** is the reduced subsidence, or the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides.

- **Compressive Strains** occur within the bases of valleys as a result of valley closure and upsidence movements. **Tensile Strains** also occur in the sides and near the tops of the valleys as a result of valley closure movements. The magnitudes of these strains, which are typically expressed in the units of *millimetres per metre (mm/m)*, are calculated as the changes in horizontal distance over a standard bay length, divided by the original bay length.

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

Research has commenced with the objective of modifying the current ACARP upsidence and closure prediction method to allow for variations in surface geology, to provide probabilistic predictions and to provide specific predictions for specific “subset” cases. The industry has escalated its level of research to gain a better understanding of the impacts of these ground movements, in response to comments provided in the recent Southern Coalfield Inquiry. An improved method for predicting upsidence and closure movements at pools and rock bars and an improved method for assessing the possible impacts of upsidence and closure movements will evolve from these studies. Analyses for this report have been undertaken using the current ACARP method of predicting upsidence and closure together with some minor adjustments and with appropriate assessments of the local topography, geometry and geology of the pools and rock bars.

The reliability of the predicted valley related upsidence and closure movements is discussed in Section 3.7.

An improved method for predicting upsidence and closure movements at pools and rockbars and an improved method for assessing the possible impacts of upsidence and closure movements will evolve from these studies. Analyses for this report have been undertaken using the current ACARP method of predicting upsidence and closure together with some minor adjustments and with appropriate assessments of the local topography, geometry and geology of the pools and rockbars.

The ACARP Prediction Method provides one set of upsidence and closure prediction curves that were drawn over the available upsidence and closure monitoring data. Now that the available monitoring database has been extended with many more cases and, since the recently proposed mine plans involve extracting coal resources up to but not directly beneath the major creeks and rivers, consideration has been given to the preparation of a new set of upsidence and closure prediction curves using specific “subsets” of the database.

As indicated in the following two plots, Fig. 3.2 and Fig. 3.3, lower values of upsidence, closure and strain have been observed within those valley monitoring sites that have not been directly mined beneath by either the current or the previously extracted longwalls (shown in blue circles), than the upsidence, closure and strain observed in those valleys that have been directly mined beneath (shown as grey diamonds).

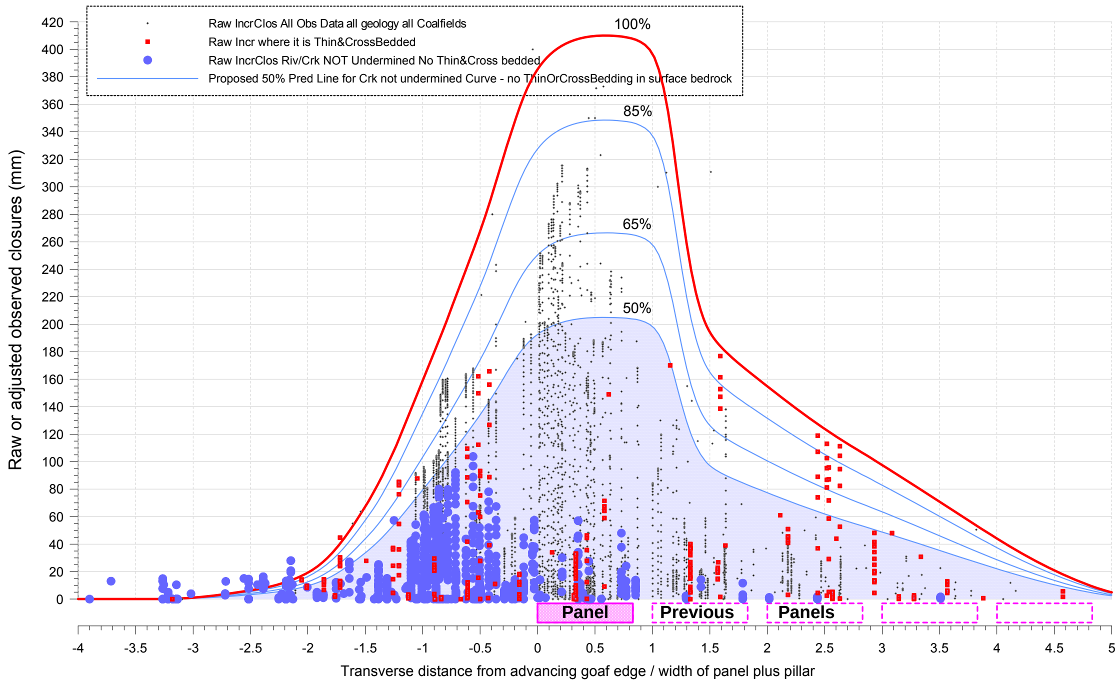


**Fig. 3.2 Comparison of Raw Observed Incremental Closure versus Lateral Distances from Edges of the Incremental Panel for All Data, Valley Sites affected by Thin and Cross Bedded Bedrock Strata and Valley Sites not Undermined by Current or Previous Longwalls**

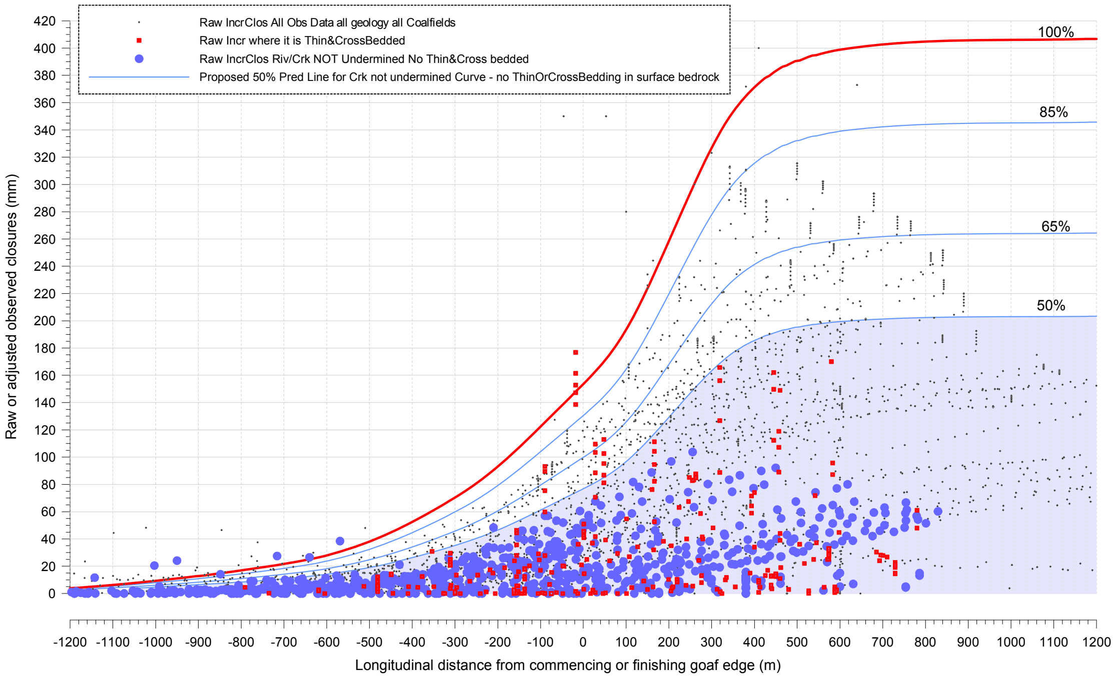



**Fig. 3.3 Comparison of Raw Observed Incremental Closure versus Longitudinal Distances from Edges of the Incremental Panel for All Data, Valley Sites affected by Thin and Cross Bedded Bedrock Strata and Valley Sites not Undermined by Current or Previous Longwalls**

Sometimes these reduction factors have been described as the “never undermined subset” factor. The red points shown on these figures are the monitoring points where there is “Known Weak Geology” in the valley base and it is clear that, wherever the geology of the bedrock in the base of the valley comprises thin highly jointed layers, the resulting upsidence and closure can be higher than where the bedrock comprises strong thick homogeneous strata layers.

Research is continuing in this regard, but, it is initially clear from these two figures that a reduction factor of about 0.5 could be applied when predicting upsidence and closure for those streams that have not been directly mined beneath by the current or previous longwalls. But to be conservative, for now, a reduction factor of 0.7 has been adopted until the ongoing research proves that lower reduction factors would be appropriate. After applying this 0.7 reduction factor, the majority of the observed closures were still less than half of those predicted and only 2 % of the observed closures exceeded those predicted.

The reliability of the predicted valley related upsidence and closure movements is discussed in Section 3.7.

## 3.5. The Incremental Profile Method

The predicted conventional subsidence parameters for the longwalls were determined using the Incremental Profile Method, which was developed by MSEC, formally known as Waddington Kay and Associates. The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales and from mining in the Bowen Basin in Queensland.

The database consists of detailed subsidence monitoring data from many mines and collieries in NSW including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Blakefield South, Bulli, Cardborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Grasstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, Moranbah, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each longwall within a series of longwalls. It can be seen from the normalised incremental subsidence profiles within the database, that the observed shapes and magnitudes are reasonably consistent where the mining geometry and local geology are similar.

Subsidence predictions made using the Incremental Profile Method use the database of observed incremental subsidence profiles, the longwall geometries, local surface and seam information and geology. The method has a tendency to over-predict the conventional subsidence parameters (i.e. is slightly conservative) where the mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the mining area.

Further details on the Incremental Profile Method can be obtained from *www.minesubsidence.com*.

## 3.6. Reliability of the Predicted Conventional Subsidence Parameters

The Incremental Profile Method is based upon a large database of observed subsidence movements in the Southern Coalfield and has been found, in most cases, to give reasonable, if not, conservative predictions of maximum subsidence, tilt and curvature. The predicted profiles obtained using this method also reflect the way in which each parameter varies over the mined area and indicate the movements that are likely to occur at any point on the surface.

The following findings have been previously documented in relation to the Incremental Profile Method:-

- The observed subsidence profiles reasonably match those predicted using the standard Bulli Seam prediction curves. While there is reasonable correlation, it is highlighted that in some locations away from the points of maxima and, in particular beyond the longwall goaf edges, that the observed subsidence exceeds that predicted. In these locations, however, the magnitude of subsidence is low and there were no associated significant tilts and strains.
- In some cases, however, the observed subsidence exceeds those predicted. It is highlighted, that in one rare case in the Southern Coalfield, the maximum observed subsidence substantially exceeded that predicted above Longwall 24A and part of Longwall 25 at Tahmoor Colliery. In the Tahmoor cases, the maximum observed subsidence of 1169 mm and 1168 mm, or 54 % and 53 % of the extracted seam thicknesses, were more than double the predicted amounts of 500 mm and 600 mm, or 23 % and 27 % of the extracted seam thickness. This was a very unusual and rare event for the Southern Coalfield and geotechnical advice indicates the cause was unusual geology ( Gale W, Investigation into Abnormal Increased Subsidence above Longwall Panels at Tahmoor Colliery NSW, MSTS Conference (2011). The abnormal subsidence was found to be associated with the localised weathering of joint and bedding planes above a depressed water table adjacent to the incised Bargo River Gorge. Similar increased subsidence has not been observed beside other incised gorges. To put this in perspective, the surface area that was affected by increased subsidence at Tahmoor represents less than 1 % of the total surface area affected by longwall mining in the Southern Coalfield.
- The observed tilt and curvature profiles also reasonably matched the predicted profiles using the standard Bulli Seam prediction curves. The observed curvatures were derived from the smoothed subsidence profiles, so as to obtain overall levels of curvature, rather than the localised curvatures at each survey mark.
- The maximum observed tilts and curvatures were, in most cases, similar to the maximums predicted using the standard Bulli Seam prediction curves. The observed tilts and curvatures exceeded those predicted at the tributary crossings, at the locations of the upsidence movements, as the predicted profiles did not include non-conventional valley related movements. There was also some scatter in the observed tilt and curvature profiles.

The prediction of the conventional subsidence parameters at a specific point is more difficult. Variations between predicted and observed parameters at a point can occur where there is a lateral shift between the predicted and observed subsidence profiles, which can result from seam dip or variations in topography. In these situations, the lateral shift can result in the observed parameters being greater than those predicted in some locations, whilst the observed parameters being less than those predicted in other locations.

The prediction of strain at a point is even more difficult as there tends to be a large scatter in observed strain profiles. It has been found that measured strains can vary considerably from those predicted at a point, not only in magnitude, but also in sign, that is, the tensile strains have been observed where compressive strains were predicted, and vice versa. For this reason, the prediction of strain in this report has been based on a statistical approach, which is discussed in Section 4.4.

The tilts, curvatures and strains observed at the streams are likely to be greater than the predicted conventional movements, as a result of valley related movements, which is discussed in Section 3.4.3. Specific predictions of upsidence, closure and compressive strain due to the valley related movements are provided for the streams in Sections 5.2 and 5.3. The impact assessments for the streams are based on both the conventional and valley related movements.

It is also likely that some localised irregularities will occur in the subsidence profiles due to near surface geological features. The irregular movements are accompanied by elevated tilts, curvatures and strains, which often exceed the conventional predictions. In most cases, it is not possible to predict the locations or magnitudes of these irregular movements. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains in the Southern Coalfield, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. Further discussions on irregular movements are provided in Section 4.7.

The Incremental Profile Method approach allows site specific predictions for each natural feature or item of surface infrastructure and hence provides a more realistic assessment of the subsidence impacts than by applying the maximum predicted parameters at every point, which would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts.

It is expected, therefore, that the standard Incremental Profile Method should generally provide reasonable, if not, slightly conservative predictions for conventional subsidence, tilt and curvature resulting from the extraction of the longwalls. Allowance should, however, be made for the possibility of observed movements exceeding those predicted as the result of anomalous or non-conventional movements, or for greater subsidence, to occur in some places.

The reliability of the predictions obtained using the Incremental Profile Method is illustrated by comparing the magnitudes of observed movements with those predicted for previously extracted longwalls in the Southern Coalfield. The comparisons have been made for monitoring lines at Appin Colliery (Areas 3, 4 and 7), Tower Colliery and West Cliff Colliery (Area 5).

The comparison between the observed incremental subsidence and the predicted incremental subsidence along the monitoring lines is illustrated in Fig. 3.4. The results shown in this figure are the observed and predicted subsidence at each survey mark at the completion of each longwall.

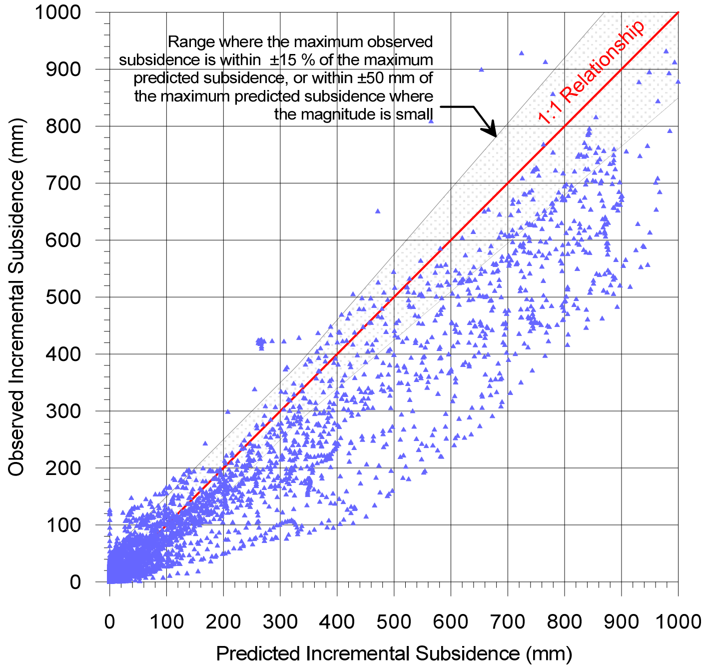



**Fig. 3.4 Comparisons between Observed Incremental Subsidence and Predicted Incremental Subsidence for the Previously Extracted Longwalls**

It can be seen from the above figure, that in the locations where the magnitude of subsidence was high (i.e. at or near the point of maximum subsidence), the observed subsidence was typically less than that predicted. In the locations where the magnitude of subsidence was in the mid range (i.e. away from the point of maximum subsidence), the observed subsidence exceeded that predicted in some cases, but was typically within +15 % or +50 mm of the prediction. In the locations where the magnitude of subsidence was small (i.e. beyond the limits of the active longwall), the observed subsidence was typically within ±100 mm of the prediction.

The comparison between the maximum observed incremental subsidence and the maximum predicted incremental subsidence for the monitoring lines is illustrated in Fig. 3.5. The results shown in this figure are the maximum observed and predicted subsidence for each monitoring line at the completion of each longwall.

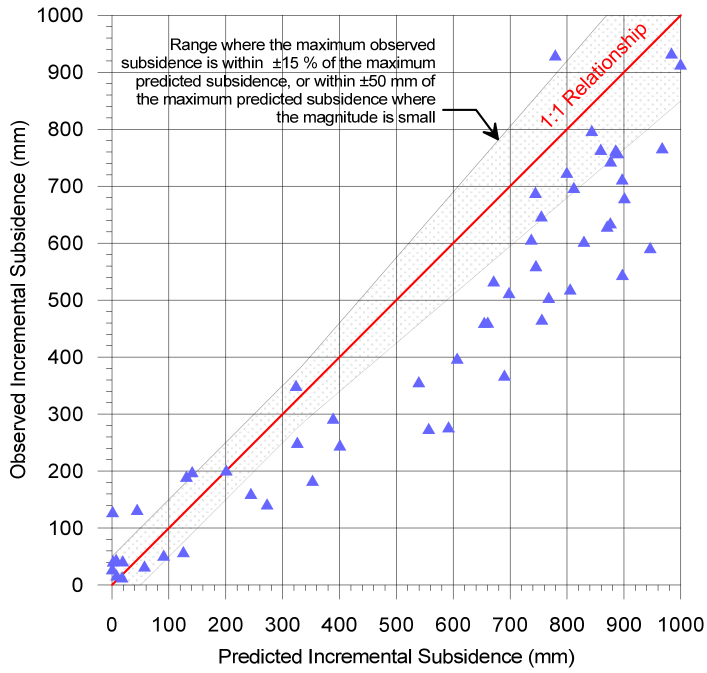



**Fig. 3.5 Comparisons between Maximum Observed Incremental Subsidence and Maximum Predicted Incremental Subsidence for the Previously Extracted Longwalls**

The distribution of the ratio of the maximum observed to maximum predicted incremental subsidence for the monitoring lines is illustrated in Fig. 3.6 (Left). A gamma distribution has been fitted to the results and is also shown in this figure.

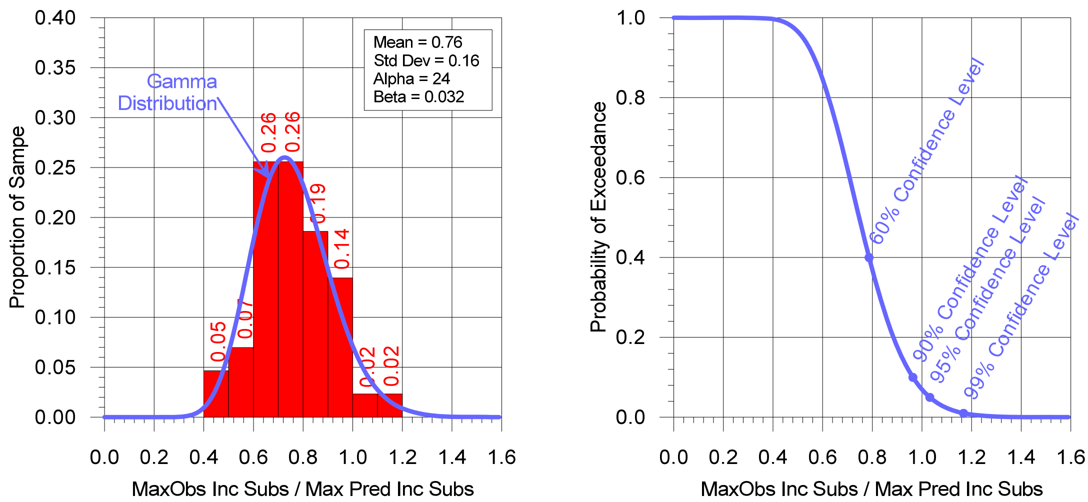



**Fig. 3.6 Distribution of the Ratio of the Maximum Observed to Maximum Predicted Incremental Subsidence for Previously Extracted Longwalls**

The probabilities of exceedance have been determined, based on the gamma distribution, which is shown in Fig. 3.6 (right). It can be seen from this figure that, based on the monitoring data, there is an approximate 93 % confidence level that the maximum observed incremental subsidence will be less than the maximum predicted incremental subsidence.

## 3.7. Reliability of the Predicted Upsidence and Closure Movements

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*. Discussions on the reliability of the method of prediction were provided in Report No. MSEC404.

The development of the predictive methods for upsidence and closure are the result of recent and ongoing research and the methods do not, at this stage, have the same confidence level as conventional subsidence prediction techniques. As further case histories are studied, the method will be improved, but it can be used in the meantime, so long as suitable factors of safety are applied. This is particularly important where the predicted levels of movement are small, and the potential errors, expressed as percentages, can be higher.

Whilst the major factors that determine the levels of movement have been identified, there are some factors that are difficult to isolate. One factor that is thought to influence the upsidence and closure movements is the level of in-situ horizontal stress that exists within the strata. In-situ stresses are difficult to obtain and not regularly measured and the limited availability of data makes it impossible to be definitive about the influence of the in-situ stress on the upsidence and closure values. The methods are, however, based predominantly upon the measured data from Tower Colliery in the Southern Coalfield, where the in-situ stresses are high. The methods should, therefore, tend to over-predict the movements in areas of lower stress.

Variations in local geology can affect the way in which the near surface rocks are displaced as subsidence occurs. In the compression zone, the surface strata can buckle upwards or can fail by shearing and sliding over their neighbours. If localised cross bedding exists, this shearing can occur at relatively low values of stress. This can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zone, existing joints can be opened up and new fractures can be formed at random, leading to localised concentrations of tensile strain.

Another factor that is thought to influence the movements is the characteristics of near surface geology, particularly in stream beds. Upsidence in particular is considered to be sensitive to the way in which the bedrock responds, since thin strata layers may respond differently to thicker ones. The location of the point of maximum upsidence is also considered to be strongly influenced by the characteristics of near surface geology.

Another factor that is thought to influence upsidence and closure movements is the presence of geomorphological features. Recent monitoring along a deeper and more incised valley has shown variable measurements around bends. There tended to be less movement at the apex of the bend than in the straight sections.

## 4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the proposed Longwalls 37 and 38. The predicted subsidence parameters and the impact assessments for the natural features and items of surface infrastructure are provided in Chapters 5 to 11.

It should be noted that the predicted conventional subsidence parameters were obtained using the standard Incremental Profile Model for the Southern Coalfield, which is based on monitoring data predominantly from the Bulli Seam.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and show the conventional movements and do not include the valley related upsidence and closure movements, nor the effects of faults and other geological structures. Such effects have been addressed separately in the impact assessments for each feature provided in Chapter 5 through to 11.

## 4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

The maximum predicted conventional subsidence parameters resulting from the extraction of the proposed longwalls were determined using the Incremental Profile Method, which was described in Chapter 3. A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of each of the proposed longwalls, is provided in Table 4.1.

**Table 4.1 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Each of the Proposed Longwalls**

| Longwall | Maximum Predicted Incremental Conventional Subsidence (mm) | Maximum Predicted Incremental Conventional Tilt (mm/m) | Maximum Predicted Incremental Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Incremental Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Due to LW37 | 775 | 6.0 | 0.06 | 0.12 |
| Due to LW38 | 625 | 4.0 | 0.04 | 0.08 |

The predicted total conventional subsidence contours, resulting from the extraction of Longwalls 37 and 38 are shown in Drawing No. MSEC533-23. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, within the Study Area after the extraction of each of the proposed longwalls, is provided in Table 4.2.

**Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of Each of the Proposed Longwalls**

| Longwalls | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| After LW37 | 1150 | 6.5 | 0.08 | 0.12 |
| After LW38 | 1150 | 6.5 | 0.08 | 0.12 |

The predicted tilts provided in the above table are the maxima after the completion of each of the proposed longwalls. The predicted curvatures provided in the above table are the maxima at any time during or after the extraction of each of the proposed longwalls.

The maximum predicted conventional tilt is 6.5 mm/m (i.e. 0.65 %), which represents a change in grade of 1 in 155. The maximum predicted conventional curvatures are 0.08 $km^{-1}$ hogging and 0.12 $km^{-1}$ sagging, which represent minimum radii of curvature of 12.5 kilometres and 8.3 kilometres, respectively.

The predicted conventional subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the overburden geology, depths of cover, longwall geometry and extraction heights. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Line 1 and Prediction Line 2, the locations of which are shown in Drawings Nos. MSEC533-23 and MSEC533-24.

The predicted profiles of conventional subsidence, tilt and curvature along Prediction Line 1 and Prediction Line 2, resulting from the extraction of the proposed longwalls, are shown in Fig. E.01 and Fig. E02 respectively, in Appendix E. The predicted incremental profiles along the prediction lines, due to the extraction of each of the proposed longwalls, are shown as dashed black lines. The predicted total profiles along the prediction line, after the extraction of each of the proposed longwalls, are shown as solid blue lines. The range of predicted curvatures in any direction to the prediction line, at any time during or after the extraction of the proposed longwalls, is shown by the grey shading.

The reliability of the predictions of subsidence, tilt and curvature, obtained using the Incremental Profile Method, is discussed in Sections 3.6.

## 4.3. Comparison of Maximum Predicted Conventional Subsidence, Tilt and Curvature

The comparison of the maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls with those provided in the Part 3A Application is provided in Table 4.3. The Part 3A Layout included longwalls covering a greater extent than the Extraction Plan Layout. For example, the proposed width of Longwall 37 in the Part 3A Application was 310 metres, whilst the proposed width of Longwall 37 in this report has been reduced to 282 metres. So as to allow comparisons, the parameters provided in Table 4.3 for the Part 3A Layout are the maxima which occur within the extent of the Study Area for the currently proposed longwalls.

**Table 4.3 Comparison of Maximum Predicted Conventional Subsidence Parameters over Longwalls 29 to 38 based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.5 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 1150 | 6.5 | 0.08 | 0.12 |

It can be seen from the above table, that the maximum predicted subsidence, tilt and curvature, based on the Extraction Plan Layout, are similar to but slightly less than those predicted based on the Part 3A Layout.

The comparison of the maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls with those predicted for longwall layouts in Appin Area 3, Appin Area 4, Appin Area 7 and West Cliff Area 5 is provided in Table 4.4.

**Table 4.4 Comparison of Maximum Predicted Conventional Subsidence Parameters**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Appin Area 3 LW301 and 302 | 800 | 6.5 | 0.07 | 0.13 |
| Appin Area 4 LW401 to LW409 | 1600 | 7.5 | 0.07 | 0.14 |
| Appin Area 7 LW705 to LW710 | 1500 | 8.0 | 0.09 | 0.15 |
| West Cliff Area 5 LW34 to LW36 | 1250 | 6.0 | 0.07 | 0.13 |
| West Cliff Area 5 Longwalls 37 and 38 (Report No. MSEC533) | 1150 | 6.5 | 0.08 | 0.12 |

It can be seen from the above table, that the maximum predicted subsidence parameters, resulting from the extraction of the proposed longwalls, are similar to, if not, slightly less than those predicted for the longwalls in Appin Area 4, Appin Area 7 and West Cliff Area 5. The maximum predicted subsidence for the proposed longwalls, however, is greater than that predicted for the longwalls in Appin Area 3, which had narrower longwalls panel widths.

Further comparisons between the predicted and observed subsidence parameter movements over the Appin, Tower and West Cliff Collieries are provided in Section 3.6.

## 4.4. Predicted Strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In previous MSEC subsidence reports, predictions of conventional strain were provided based on the best estimate of the average relationship between curvature and strain. Similar relationships have been proposed by other authors. The reliability of the strain predictions was highlighted in these reports, where it was stated that measured strains can vary considerably from the predicted conventional values.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains.

The maximum predicted conventional strains resulting from the extraction of Longwalls 37 and 38, based on applying a factor of 15 to the maximum predicted total curvatures, are 1.2 mm/m tensile and 1.8 mm/m compressive.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this report, therefore, we have provided a statistical approach to account for the variability, instead of just providing a single predicted conventional strain.

The range of potential strains above the proposed longwalls has been determined using monitoring data from the previously extracted longwalls in the Southern Coalfield. The monitoring data was used from Appin Colliery, as well as the nearby Tower, West Cliff and Tahmoor Collieries, where the overburden geology and mining geometry are reasonably similar to the proposed longwalls. The range of strains measured during the extraction of these longwalls should, therefore, provide a reasonable indication of the range of potential strains for the proposed longwalls.

The data used in the analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related movements, which are addressed separately in this report. The strains resulting from damaged or disturbed survey marks have also been excluded.

### 4.4.1. Analysis of Strains Measured in Survey Bays

For features that are in discrete locations, such as building structures, farm dams and archaeological sites, it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

The survey database has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls in the Southern Coalfield, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls.

The strain distributions were analysed with the assistance of the centre of Excellence for Mathematics and Statistics of Complex Systems (MASCOS). A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided the best fit to the raw strain data.

The histogram of the maximum observed tensile and compressive strains measured in survey bays above goaf, for monitoring lines from the Southern Coalfield, is provided in Fig. 4.1. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

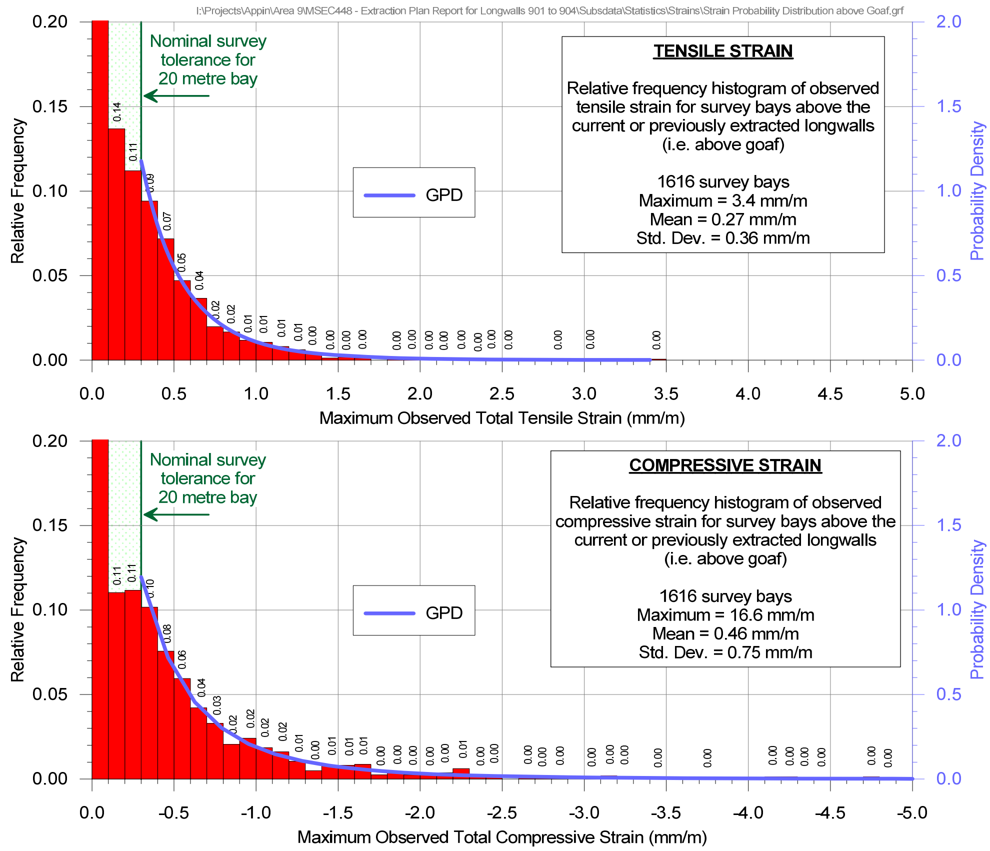



**Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Goaf**

Confidence levels have been determined from the empirical strain data using the GPD. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay per longwall).

A summary of the probabilities of exceedance for tensile and compressive strains for survey bays located above goaf, based on the fitted GPDs, is provided in Table 4.5.

**Table 4.5 Probabilities of Exceedance for Strain for Survey Bays above Goaf**

| Strain (mm/m) | | Probability of Exceedance |
|---|---|---|
| Compression | -6.0 | 1 in 500 |
| | -4.0 | 1 in 175 |
| | -2.0 | 1 in 35 |
| | -1.0 | 1 in 10 |
| | -0.5 | 1 in 3 |
| | -0.3 | 1 in 2 |
| Tension | +0.3 | 1 in 3 |
| | +0.5 | 1 in 6 |
| | +1.0 | 1 in 25 |
| | +2.0 | 1 in 200 |
| | +3.0 | 1 in 1,100 |

The 95 % confidence levels for the maximum total strains that the individual survey bays above goaf experienced at any time during mining were 0.9 mm/m tensile and 1.6 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above goaf experienced at any time during mining were 1.6 mm/m tensile and 3.2 mm/m compressive.

It is noted, that the maximum observed compressive strain of 16.6 mm/m, which occurred along the T-Line at the surface above Appin Longwall 408, was the result of movements along a low angle thrust fault which daylighted above the Cataract Tunnel. All remaining compressive strains were less than 7 mm/m. The inclusion of the strain at the fault above Longwall 408 has a substantial influence on the probabilities of exceeding the strains provided in Table 4.5, particularly at the high magnitudes of strain.

The probabilities for survey bays located above goaf are based on the strains measured anywhere above the previously extracted longwalls in the Southern Coalfield. As described previously, tensile strains are more likely to develop in the locations of hogging curvature and compressive strains are more likely to develop in the locations of sagging curvature.

This is illustrated in Fig. 4.2, which shows the distribution of incremental strains measured above previously extracted longwalls in the Southern Coalfield. The distances have been normalised, so that the locations of the measured strains are shown relative to the longwall maingate and tailgate sides. The approximate confidence levels for the incremental tensile and compressive strains are also shown in this figure, to help illustrate the variation in the data.

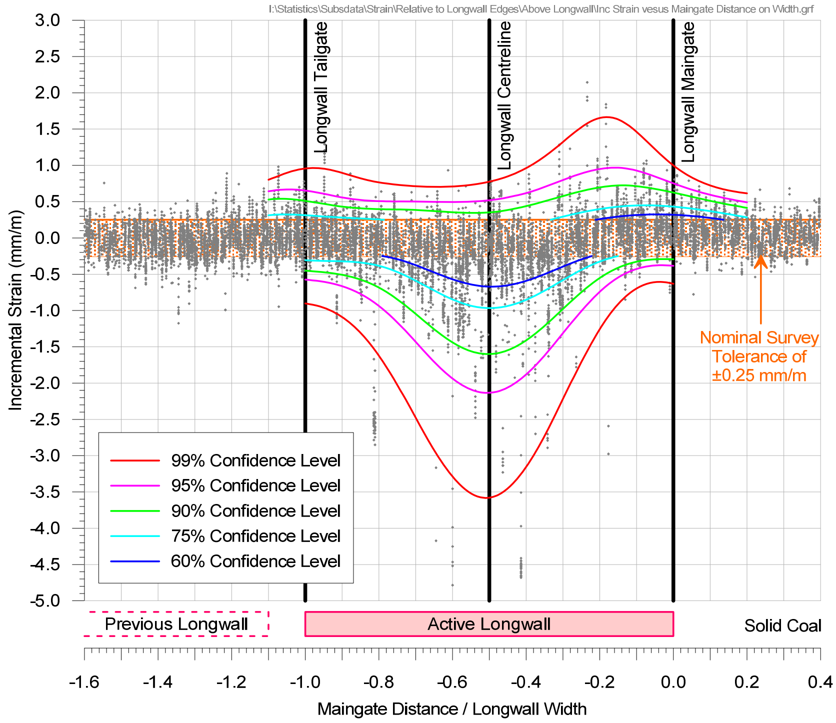



**Fig. 4.2 Observed Incremental Strains versus Normalised Distance from the Longwall Maingate for Previously Extracted Longwalls in the Southern Coalfield**

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls in the Southern Coalfield, for survey bays that were located outside and within 250 metres of the nearest longwall goaf edge, which has been referred to as "*above solid coal*".

The histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal, for monitoring lines in the Southern Coalfield, is provided in Fig. 4.3. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

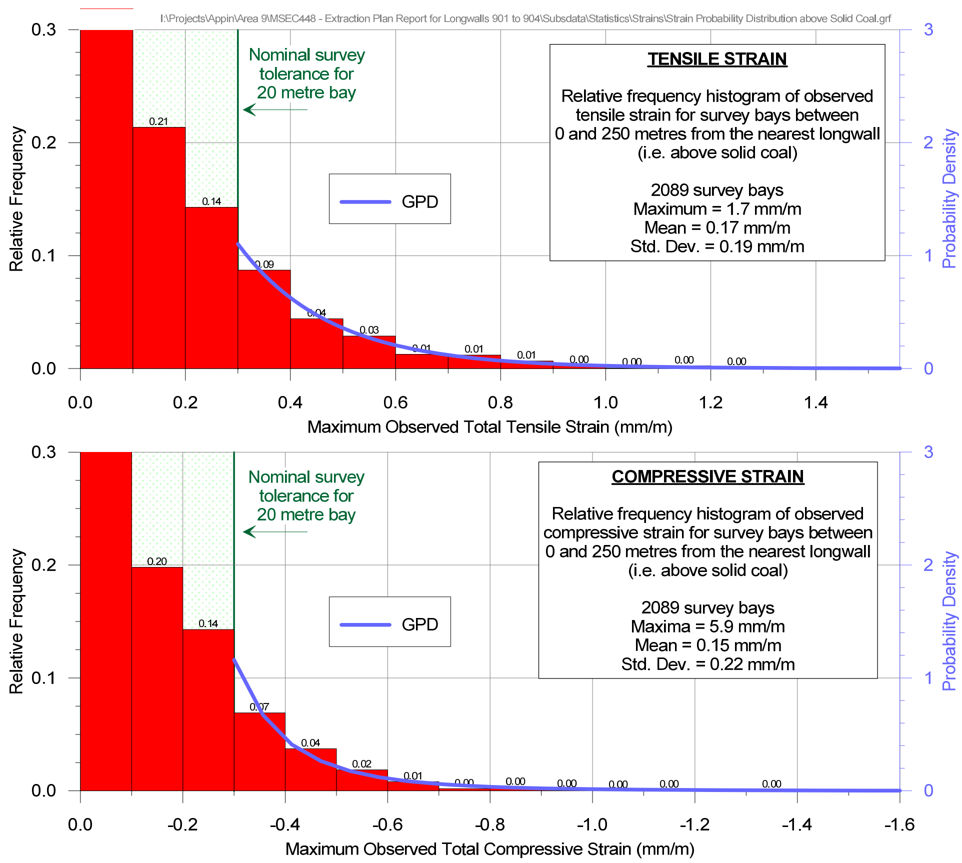



**Fig. 4.3 Distributions of the Measured Maximum Tensile and Compressive Strains during the Extraction of Previous Longwalls in the Southern Coalfield for Bays Located Above Solid Coal**

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

A summary of the probabilities of exceedance for tensile and compressive strains for survey bays located above solid coal, based the fitted GPDs, is provided in Table 4.6.

**Table 4.6 Probabilities of Exceedance for Strain for Survey Bays Located above Solid Coal**

| Strain (mm/m) | | Probability of Exceedance |
|---|---|---|
| Compression | -2.0 | 1 in 2,000 |
| | -1.5 | 1 in 800 |
| | -1.0 | 1 in 200 |
| | -0.5 | 1 in 25 |
| | -0.3 | 1 in 7 |
| Tension | +0.3 | 1 in 5 |
| | +0.5 | 1 in 15 |
| | +1.0 | 1 in 200 |
| | +1.5 | 1 in 2,500 |

The 95 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining were 0.6 mm/m tensile and 0.5 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays above solid coal experienced at any time during mining were 0.9 mm/m tensile and 0.8 mm/m compressive.

### 4.4.2. Analysis of Strains Measured Along Whole Monitoring Lines

For linear features such as roads, cables and pipelines, it is more appropriate to assess the frequency of observed maximum strains along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains anywhere along the monitoring lines, regardless of where the strain actually occurs.

The histogram of maximum observed tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after the extraction of the previous longwalls in the Southern Coalfield, is provided in Fig. 4.4.

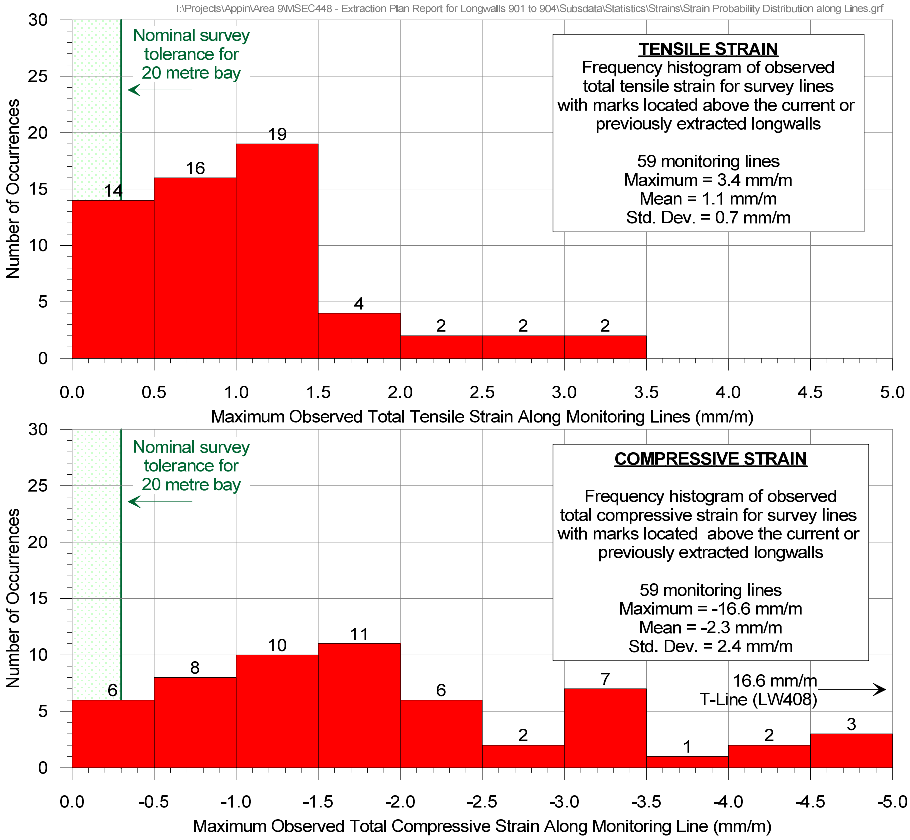



**Fig. 4.4 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines during the Extraction of Previous Longwalls in the Southern Coalfield**

It can be seen from Fig. 4.4,that 30 of the 59 monitoring lines (i.e. 51 %) have recorded maximum total tensile strains of 1.0 mm/m, or less, and that 53 monitoring lines (i.e. 89 %) have recorded maximum total tensile strains of 2.0 mm/m, or less. It can also be seen, that 35 of the 59 monitoring lines (i.e. 59 %) have recorded maximum compressive strains of 2.0 mm/m, or less, and that 51 of the monitoring lines (i.e. 86 %) have recorded maximum compressive strains of 4.0 mm/m, or less.

### 4.4.3. Analysis of Strains Resulting from Valley Closure Movements

The streams within the Study Area are expected to experience compressive strains resulting from valley related movements. The strains resulting from valley related movements are more difficult to predict than strains in flatter terrain, as they are dependent on many additional factors, including the valley shape and valley height, the valley geomorphology and the local geology in the valley base. The development of a prediction method for strains resulting from valley related movements is part of a current ACARP research project.

The predicted strains resulting from valley related movements, for the streams located directly above the proposed longwalls, have been determined using the monitoring data for longwalls which have previously mined directly beneath streams in the Southern Coalfield.

The relationship between total closure strain and total closure movement, based on monitoring data for longwalls which have previously mined directly beneath streams in the Southern Coalfield, is provided in Fig. 4.5. The confidence levels, based on the fitted GPDs, have also been shown in this figure.

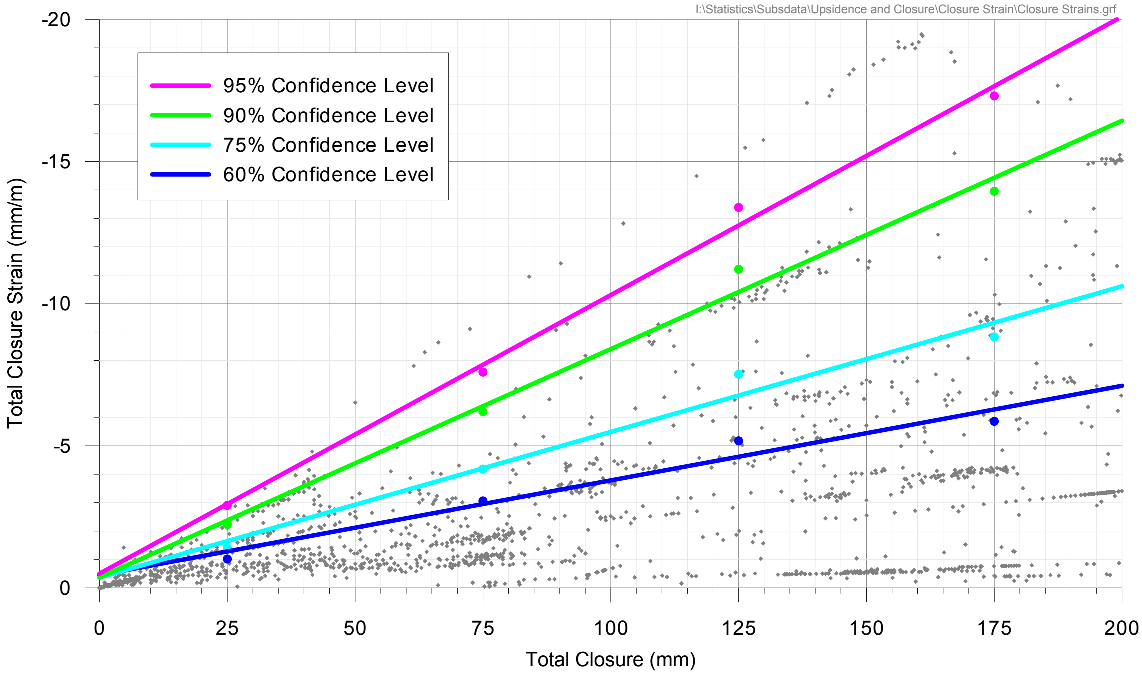



**Fig. 4.5 Total Closure Strain versus Total Closure Movement Based on Monitoring Data for Streams Located Directly Above Longwalls in the Southern Coalfield**

The reliability of the predicted valley related upsidence and closure movements is discussed in Section 3.4.3.

### 4.4.4. Analysis of Shear Strains

As described in Section 3.2, ground strain comprises two components, being normal strain and shear strain, which can be interrelated using Mohr's Circle. The magnitudes of the normal strain and shear strain components are, therefore, dependant on the orientation in which they are measured. The maximum normal strains, referred to as the principal strains, are those in the direction where the corresponding shear strain is zero.

Normal strains along monitoring lines can be measured using 2D and 3D techniques, by taking the change in horizontal distance between two points on the ground and dividing by the original horizontal distance between them. This provides the magnitude of normal strain along the orientation of the monitoring line and, therefore, this strain may not necessarily be the maximum (i.e. principal) normal strain.

Shear deformations are more difficult to measure, as they are the relative horizontal movements perpendicular to the direction of measurement. However, 3D monitoring techniques provide data on the direction and the absolute displacement of survey pegs and, therefore, the shear deformations perpendicular to the monitoring line can be determined. But, in accordance with rigorous definitions and the principles of continuum mechanics, (e.g. Jaeger, 1969), it is not possible to determine horizontal shear strains in any direction relative to the monitoring line using 3D monitoring data from a straight line of survey marks.

As described in Section 3.2, shear deformations perpendicular to monitoring lines can be described using various parameters, including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. In this report, mid-ordinate deviation has been used as the measure for shear deformation, which is defined as the differential horizontal movement of each survey mark, perpendicular to a line drawn between two adjacent survey marks.

The frequency distribution of the maximum mid-ordinate deviation measured at survey marks above goaf, for previously extracted longwalls in the Southern Coalfield, is provided in Fig. 4.6. As the typical bay length was 20 metres, the calculated mid-ordinate deviations were over a chord length of 40 metres. The probability distribution function, based on the fitted GPD, has also been shown in this figure.

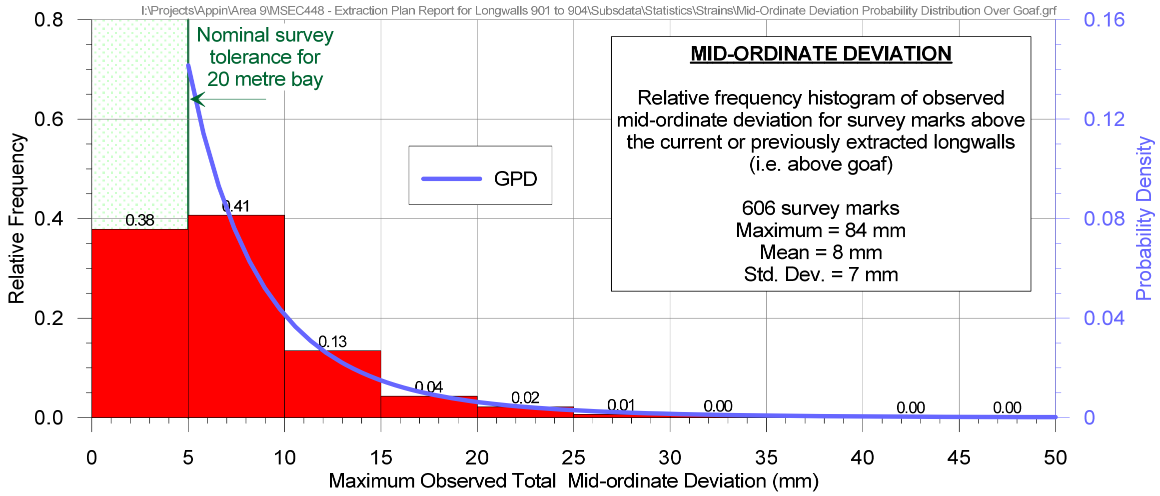



**Fig. 4.6 Distribution of Measured Maximum Mid-ordinate Deviation during the Extraction of Previous Longwalls in the Southern Coalfield for Marks Located Above Goaf**

A summary of the probabilities of exceedance for horizontal mid-ordinate deviation for survey bays located above goaf, based the fitted GPD, is provided in Table 4.7.

**Table 4.7 Probabilities of Exceedance for Mid-Ordinate Deviation for Survey Marks above Goaf for Monitoring Lines in the Southern Coalfield**

| Horizontal Mid-ordinate Deviation (mm) | | Probability of Exceedance |
|---|---|---|
| Mid-ordinate Deviation over 40 metre Chord Length | 10 | 1 in 4 |
| | 20 | 1 in 20 |
| | 30 | 1 in 70 |
| | 40 | 1 in 175 |
| | 50 | 1 in 400 |
| | 60 | 1 in 800 |
| | 70 | 1 in 1,400 |
| | 80 | 1 in 2,300 |

The 95 % and 99 % confidence levels for the maximum total horizontal mid-ordinate deviation that the individual survey marks located above goaf experienced at any time during mining were 20 mm and 35 mm, respectively.

## 4.5. Predicted Conventional Horizontal Movements

The predicted conventional horizontal movements over the proposed longwalls are calculated by applying a factor to the predicted conventional tilt values. In the Southern Coalfield a factor of 15 is generally adopted, being the same factor as that used to determine average strains from curvatures, and this has been found to give a reasonable correlation with measured data. This factor will in fact vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted conventional tilt within the Study Area, at any time during or after the extraction of the proposed longwalls, is 6.5 mm/m. The maximum predicted conventional horizontal movement is, therefore, approximately 98 mm, i.e. 6.5 mm/m multiplied by a factor of 15.

Conventional horizontal movements do not directly impact on natural features or items of surface infrastructure, rather impacts occur as the result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of strain on the natural features and items of surface infrastructure are addressed in the impact assessments for each feature, which have been provided in Chapters 5 through to 11.

## 4.6. Predicted Far-field Horizontal Movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to the proposed longwalls, and the predicted valley related movements along the creeks, it is also likely that far-field horizontal movements will be experienced during the extraction of the proposed longwalls.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data primarily from the Southern Coalfield, from Collieries including Appin, Bellambi, Dendrobium, Douglas, Newstan, Tower and West Cliff. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwall. At very low levels of far-field horizontal movements, however, there was a high scatter in the orientation of the observed movements.

The observed incremental far-field horizontal movements, resulting from the extraction of longwalls in the Southern Coalfield, are provided in Fig. 4.7. The confidence levels, based on fitted GPDs, have also been shown in this figure to illustrate the spread of the data.

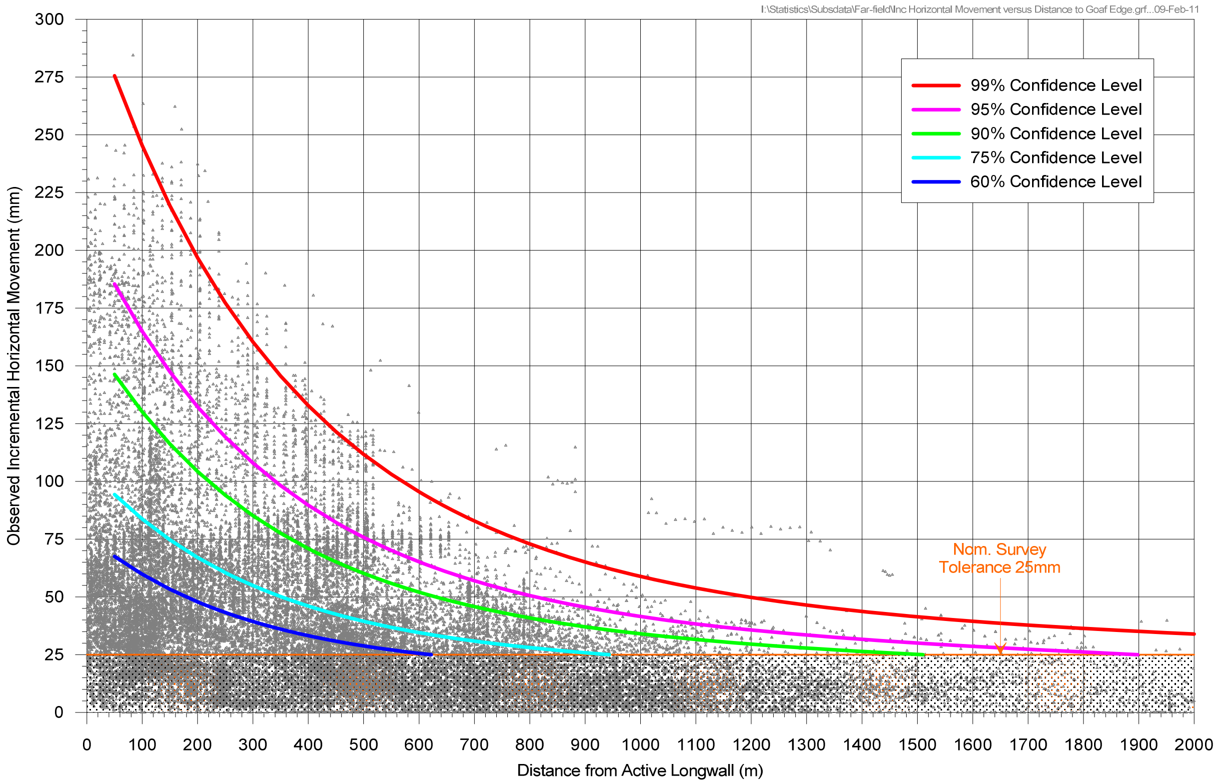



**Fig. 4.7 Observed Incremental Far-Field Horizontal Movements from the Southern Coalfield**

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements decrease. This is possibly due to the fact that once the in-situ stresses within the strata has been redistributed around the collapsed zones above the first few extracted longwalls, the potential for further movement is reduced. The total far-field horizontal movement is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls are very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally less than 0.1 mm/m. The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the vicinity of the Study Area are not expected to be significant, except where they occur at structures which are sensitive to small differential movements, which may include the transmission towers and gas pipeline to the west of Longwall 37.

## 4.7. Non-Conventional Ground Movements

It is likely non-conventional ground movements will occur within the Study Area, due to near surface geological conditions, steep topography and valley related movements, which were discussed in Section 3.4. These non-conventional movements are often accompanied by elevated tilts and curvatures which are likely to exceed the conventional predictions.

Specific predictions of upsidence, closure and compressive strain due to the valley related movements are provided for the streams in Sections 5.2 and 5.3. The impact assessments for the streams are based on both the conventional and valley related movements. The potential for non-conventional movements associated with steep topography is discussed in the impact assessments for the steep slopes provided in Section 5.11.

In most cases, it is not possible to predict the exact locations or magnitudes of the non-conventional anomalous movements due to near surface geological conditions. For this reason, the strain predictions provided in this report are based on a statistical analysis of measured strains in the Southern Coalfield, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.4. In addition to this, the impact assessments for the natural features and items of surface infrastructure, which are provided in Chapters 5 through to 11, include historical impacts resulting from previous longwall mining which have occurred as the result of both conventional and non-conventional subsidence movements.

The largest known case of non-conventional movement in the Southern Coalfield occurred above Appin Longwall 408. In this case, a low angle thrust fault was re-activated in response to mine subsidence movements, resulting in differential vertical and horizontal movements across the fault. Observations at the site showed that the non-conventional movements developed gradually and over a period of time. Regular ground monitoring across the fault indicated that the rate of differential movement was less than 0.5 mm per day at the time non-conventional movements could first be detected. Subsequently as mining progressed, the rate of differential movement increased to a maximum of 28 mm per week.

The development of strain at the low angle thrust fault, as measured along the T-Line during the extraction of Longwall 408, is illustrated in Fig. 4.8. Photographs of the anomalous ground movements associated with this fault are provided in the photographs in Fig. 4.9 and Fig. 4.10.

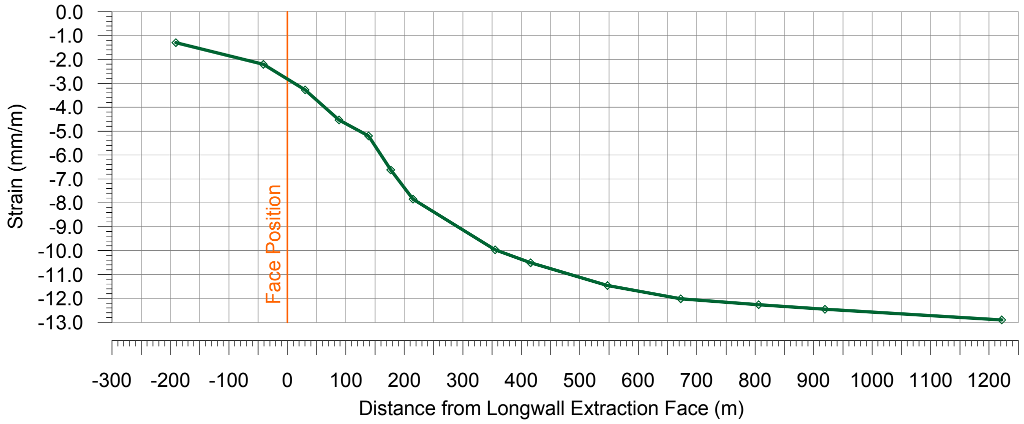



**Fig. 4.8 Development of Strain at the Low Angle Thrust Fault Measured along the T-Line during the Extraction of Appin Longwall 408**

**Fig. 4.9 Surface Compression Humping due to Low Angle Thrust Fault**

**Fig. 4.10 Surface Compression Humping due to Low Angle Thrust Fault**

The developments of strain at anomalies identified in the Southern Coalfield and elsewhere, excluding the low angle thrust fault discussed previously, are illustrated in Fig. 4.11. It can be seen from this figure, that the non-conventional movements develop gradually. For these cases, the maximum rate of development of anomalous strain was 2 mm/m per week. Based on the previous experience of longwall mining in the Southern Coalfield and elsewhere, it has been found that non-conventional anomalous movements can be detected early by regular ground monitoring and visual inspections.

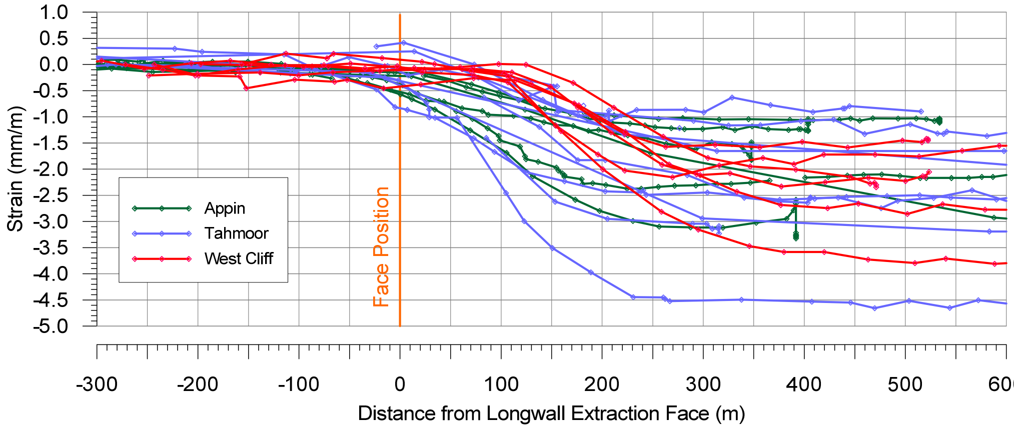



**Fig. 4.11 Development of Non-Conventional Anomalous Strains in the Southern Coalfield**

A study of the majority of ground survey data within the Southern Coalfield was undertaken in 2006 by MSEC. Forty-one (41) monitoring lines were examined for anomalies, which represent a total of 58.2 kilometres of monitoring lines, and approximately 2,980 survey pegs. The monitoring lines crossed over 75 longwalls. The selected lines represented all the major lines over the subsided areas, and contained comprehensive information on subsidence, tilt and strain measurements. A total of 20 anomalies were detected, of which 4 were considered to be significant. The observed anomalies affected 41 of the approximately 2,980 survey pegs monitored. This represented a frequency of 1.4 %.

The above estimates are based on ground survey data that crossed only a small proportion of the total surface area affected by mine subsidence. Recent mining beneath urban and semi-rural areas at Tahmoor and Thirlmere by Tahmoor Colliery Longwalls 22 to 25 provides valuable “whole of panel” information. A total of approximately 35 locations (not including valleys) have been identified over the four extracted longwalls. The surface area directly above the longwalls is approximately 2.56 $km^2$. This equates to a frequency of 14 sites per square kilometre or one site for every 7 hectares.

## 4.8. General Discussion on Mining Induced Ground Deformations

Longwall mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

Faults and joints in bedrock develop during the formation of the strata and from subsequent de-stressing associated with movement of the strata. Longwall mining can result in additional fracturing in the bedrock, which tends to occur in the tensile zones, but fractures can also occur due to buckling of the surface beds in the compressive zones. The incidence of visible cracking at the surface is dependent on the pre-existing jointing patterns in the bedrock as well as the thickness and inherent plasticity of the soils that overlie the bedrock.

Surface cracking in soils as the result of conventional subsidence movements is not commonly observed where the depths of cover are greater than 400 metres, such as the case in West Cliff Area 5, and any cracking that has been observed has generally been isolated and of a minor nature.

Cracking is found more often in the bases of stream valleys due to the compressive strains associated with upsidence and closure movements. The likelihood and extent of cracking along the streams within the Study Area are discussed in Sections 5.2 and 5.3. Cracking can also occur at the tops and on the sides of steep slopes as the result of downslope movements, which is discussed in Section 5.11.

Surface cracks are more readily observed in built infrastructure such as road pavements. In the majority of these cases no visible ground deformations can be seen in the natural ground adjacent to the cracks in the road pavements. In rare instances more noticeable ground deformations, such as humping or stepping of the ground can be observed at thrust faults. Examples of ground deformations previously observed in the Southern Coalfield, where the depths of cover exceed 400 metres, are provided in the photographs in Fig. 4.12 to Fig. 4.15 below.

**Fig. 4.12 Surface Compression Buckling Observed in a Pavement**

**Fig. 4.13 Surface Tension Cracking along the Top of a Steep Slope**

**Fig. 4.14 Surface Tension Cracking along the Top of a Steep Slope**

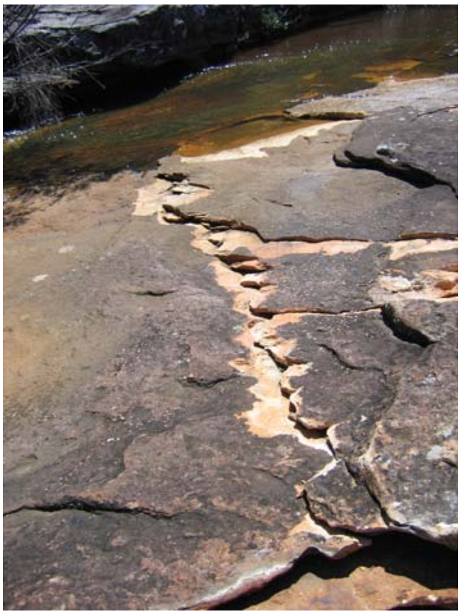


**Fig. 4.15 Fracturing and Bedding Plane Slippage in Sandstone Bedrock in the Base of a Stream**

Localised ground buckling and shearing can occur wherever faults, dykes and abrupt changes in geology occur near the ground surface. The identified geological structures within the Study Area are discussed in Section 1.5. Discussions on irregular ground movements were provided in Section 4.7.

## 4.9. Estimated Height of the Fractured Zone

The extraction of longwalls results in mining induced deformations throughout the overburden strata. To appreciate what has been observed it should be recognised that the terminology used by different authors to describe the strata deformation zones above extracted longwalls varies considerably and caution should be taken when comparing the recommendations from differing authors.

Peng and Chiang (1984) recognised only three zones as reproduced in Fig. 4.16. Forster (1995) noted that most studies have recognised four separate zones, as shown in Fig. 4.17, with some variations in the definitions of each zone.

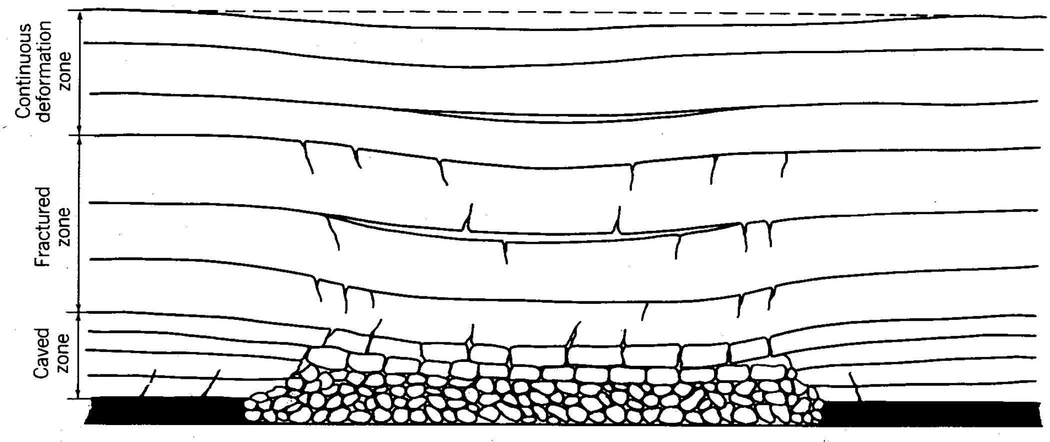



**Fig. 4.16 Zones in the Overburden According to Peng and Chiang (1984)**

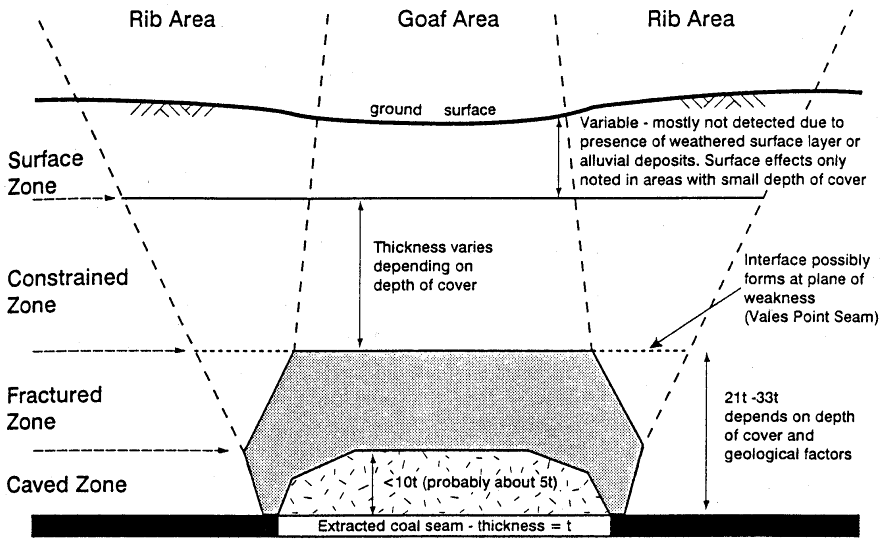



**Fig. 4.17 Zones in the Overburden according to Forster (1995)**

McNally et al (1996) recognised three zones, which they referred to as the caved zone, the fractured zone and the elastic zone. Kratzsch (1983) identified four zones, but named them the immediate roof, the main roof, the intermediate zone and the surface zone.

For the purpose of these discussions, the following zones, as described by Singh and Kendorski (1981) and proposed by Forster (1995), as shown in Fig. 4.17, have been adopted:-

- *Caved or Collapsed Zone* comprises loose blocks of rock detached from the roof and occupying the cavity formed by mining. This zone can contain large voids. It should be noted, that some authors note primary and secondary caving zones.
- *Disturbed* or *Fractured Zone* comprises in-situ material lying immediately above the caved zone which have sagged downwards and consequently suffered significant bending, fracturing, joint opening and bed separation. It should be noted, that some authors include the secondary caving zone in this zone.
- *Constrained* or *Aquiclude Zone* comprises confined rock strata above the disturbed zone which have sagged slightly but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present as well as some discontinuous vertical cracks, usually on the underside of thick strong beds, but not of a degree or nature which would result in connective cracking or significant increases in vertical permeability. Some increases in horizontal permeability can be found. Weak or soft beds in this zone may suffer plastic deformation.
- *Surface Zone* comprises unconfined strata at the ground surface in which mining induced tensile and compressive strains may result in the formation of surface cracking or ground heaving.

Just as the terminology differs between authors, the means of determining the extents of each of these zones has also varied from author to author. Therefore it can be appreciated that some of the difficulties in establishing the heights of the various zones of disturbance above extracted longwalls stem from the imprecise definitions of the fractured and constrained zones, the differing zone names, the use of different groundwater testing methods and differing interpretations of extensometer readings.

Some authors interpret the collapsed and fractured zones to be the zone from which groundwater or water in boreholes could be lost into the mine and, hence, look for the continuing existence of aquiclude or aquitard layers above this height to confirm whether surface water would or would not be lost into the mine. Other authors have solely assumed the heights of the collapsed and fractured zones from borehole extensometer monitoring without being able to check their conclusions with groundwater level or pressure recordings.

The heights of the collapsed and fractured zones above extracted longwalls are affected by a number of factors, which include the:-

- widths of extraction,
- heights of extraction,
- depths of cover,
- types of previous workings, if any, above the current extractions,
- interburden thicknesses to previous workings,
- presence of pre-existing natural joints within each strata layer,
- thickness, geology, geomechanical properties and permeability of each strata layer,
- angle of break of each strata layer,
- spanning capacity of each strata layer, particularly those layers immediately above the collapsed and fractured zones,
- bulking ratios of each of strata layer within the collapsed zone, and the
- presence of aquiclude or aquitard zones.

Some authors have suggested simple equations to estimate the heights of the collapsed and fractured zones based solely on the extracted seam height, others have suggested equations based solely on the widths of extraction, whilst others have suggested equations based on the width-to-depth ratios of the extractions. As this is a complex issue, MSEC understand that at this time no simple geometrical equation can properly estimate the heights of the collapsed and fractured zones and a number of research projects are underway to investigate this issue further.

While there are many factors that may influence the height of fracturing and dilation, various authors, e.g. Gale (ACARP C13013, 2008) and Guo et al (ACARP C14033, 2007), believe that an increase in panel width is likely to result in an increase in the height of fracturing and dilation depending on the local geological conditions. Other authors have suggested that the extracted seam thickness is the main variable influencing the height of fracturing and connective cracking.

A theoretical height of the fractured zone can be estimated from the mining geometry, as being equal to the panel width (W) minus the span (w) divided by twice the tangent of the angle of break. These are illustrated in Fig. 4.18.

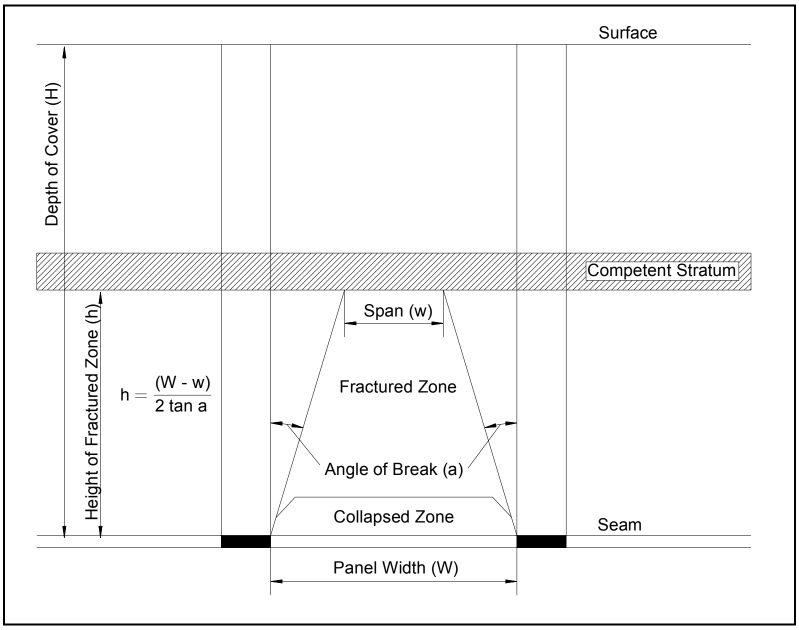


**Fig. 4.18 Theoretical Model Illustrating the Development and Limit of the Fractured Zone**

MSEC has gathered observed data sourced from a number of literature studies. The data points collected to date are shown in Fig. 4.19. The data points are compared with the results of the theoretical model developed by MSEC, using an angle of break of 20 degrees and spanning width of 30 metres. The results are also compared with lines representing factors of 1.0 times and 1.5 times the panel width, which was suggested by Gale (2008).

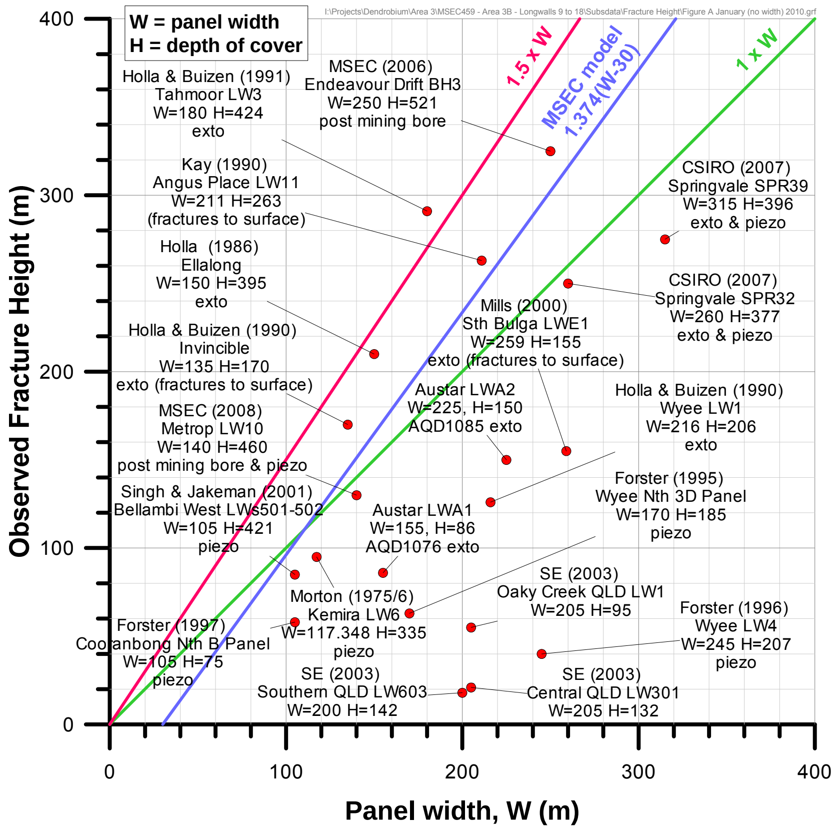



**Fig. 4.19 Observed Fracture Heights versus Panel Width**

It can seen from Fig. 4.19, that the MSEC model and Gale's suggested factors of 1.0 and 1.5 provide similar estimates for the height of fracturing based on panel width. As described previously, however, it is necessary to undertake a detailed review of the site specific geology and permeability before determining whether these heights are reasonable for this site.

In the Southern Coalfield, the upper layers in the overburden strata are relatively strong sandstones. These sandstone strata are particularly strong and would be expected to be capable of spanning at least 30 metres. If an average angle of break of 20 degrees is assumed, with an extracted panel width of 282 metres (LW37) a height of 345 metres would be required above the seam level to reduce the effective span to 30 metres. With an extracted panel width of 305 metres, a height of 375 metres would be required. If an angle of break of 23 degrees is assumed, then heights of 295 metres and 325 metres for extracted panel widths of 282 metres and 305 metres respectively would be required above the seam to reduce the effective span to 30 metres.

The depth of cover directly above the proposed longwalls varies between 450 and 540 metres and, therefore, it is unlikely that the fractured zone would extend up to the surface. It is expected that a *Constrained Zone* or *Continuous Deformation Zone* would occur between the fractured zone and the surface, as illustrated in Fig. 4.16 and Fig. 4.17.

It is noted, that the height of fracturing, based on significant bed separation and vertical dilation, measured by extensometers, does not imply that vertical permeability has increased. It simply means that bed separation and horizontal permeability has increased. The height of fracturing based on this approach may include part of the constrained zone, as defined by Forster (1995), which was shown in Fig. 4.17.

The constrained zone comprises confined rock strata which have sagged slightly, but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present as well as discontinuous vertical cracks (usually on the underside of thick strong beds). Weak or soft beds in this zone may suffer plastic deformation.

# 5.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES WITHIN THE STUDY AREA

The following sections provide the descriptions, predictions of subsidence movements and impact assessments for the natural features within the Study Area. The impact assessments have been made for each natural feature based on these predicted subsidence parameters. The predicted impacts for the Extraction Plan Layout are also compared to the predicted impacts for the Bulli Seam Operations Part 3A Layout.

All significant natural features located outside the Study Area, which may be subjected to far-field movements or valley related movements and may be sensitive to these movements, have also been included as part of these assessments.

## 5.1. Catchment Areas and Declared Special Areas

There are no drinking water catchment areas, or declared special areas within the Study Area. As shown in Drawing No. MSEC533-07 and Drawings Nos. MSEC533-08 and MSEC533-09, the only river within the Study Area is the Georges River. The Creeks that have been identified within the Study Area are;

- Mallaty Creek and its tributaries that have been labelled; MC3, MC4 and MC5,
- Nepean Creek and its tributaries that have been labelled; NC3 and NC5,
- Woodhouse Creek, and
- Various tributaries of the Georges River that have been labelled; GR101, GR102, GR103, GR104, GR105, GR107, GR108, GR108A, GR109, GR110, GR112, GR114, GR114A, GR117 and GR119.

Detailed descriptions of the flows within the Georges River and these creeks are provided in Ecoengineers (2013). The predictions and impact assessments for the river and these creeks are provided in the following sections.

## 5.2. The Georges River

The location of the Georges River is shown in Drawing No. MSEC533-07 and the major stream features are shown in Drawings Nos. MSEC533-08 and MSEC533-09. The predictions and impact assessments for the river are provided in the following sections.

### 5.2.1. Description of the Georges River

The Georges River commences over 8 kilometres to the south east of the Study Area and flows past Sydney's south western suburbs and into Botany Bay.

It can be seen from Drawing No. MSEC533-07 that the proposed longwalls do not mine directly beneath the river. A summary of the minimum distance of the Georges River from each of the proposed longwalls is provided in Table 5.1.

**Table 5.1 Minimum Distances of the Proposed Longwalls from the Georges River**

| Longwall | Minimum Distance from the River Centreline (m) |
|---|---|
| LW37 | 20 |
| LW38 | 45 |

The total length of the Georges River within the Study Area is 2.3 kilometres. The total length of the river within the limit of the mine subsidence movements, which extends to the predicted limits of 20 mm total upsidence and 20 mm total closure, is approximately 3.8 kilometres.

The Georges River forms the eastern boundaries of the South Campbelltown and Appin Mine Subsidence Districts and forms part of the western boundary of the Dharawal State Recreation Area.

The catchment area for the upstream sections of the river includes rural properties to the west, where surface runoff is retained by numerous farm dams. Natural vegetation is dominant within the catchment area on the eastern side of the river.

As detailed in Ecoengineers (2013), the river is a perennial stream with flows derived from catchment areas and licensed discharges from Appin and West Cliff Collieries. In general, the flows along the Georges River within the Study Area are continuous as there is water being discharged into the river for the majority of the time. It is postulated, however, that if the licensed discharges were not released into the river, the water flows would not be continuous along many sections of the river. In times of dry weather, the river has been known to consist of a series of disconnected pools, some of which were completely or partially drained.

During dry periods the licensed discharges from Appin and West Cliff Collieries are the main source of flow for the section of river within the Study Area with recent average discharges the order of 0.3 ML/day and 4 ML/day respectively. The Appin Colliery discharge enters the Georges River via a small tributary upstream of Jutts Crossing. The West Cliff Colliery discharge enters Brennans Creek and is retained by Brennans Creek Dam. Water is released from the dam via a scour valve at its base. This discharge, along with other water that has leaked through the dam wall, is released via the Reclaim Pond (Point 10) into Brennans Creek, which flows into the Georges River. In addition to these flows, Brennans Creek Dam occasionally overtops during large rainfall events.

Summaries of the features along the Georges River in the vicinity of the proposed mining are provided in Table 5.2 and Table 5.3.

**Table 5.2 Rockbars along Georges River and within the Study Area**

| Label | Approximate Size | Approximate size of Upstream Pool | Distance of Closest Point to Mining |
|---|---|---|---|
| GR-RB42 | 19 m long x 20 m wide | 25 m long x 10 m wide | 205 m from LW34, 340 m from LW38 |
| GR-RB43 | 21 m long x 15 m wide | 19 m long x 10 m wide | 218 m from LW35, 304 m from LW38 |
| GR-RB44 | 43 m long x 16 m wide | 36 m long x 16 m wide | 236 m from LW35, 270 m from LW38 |
| GR-RB45 | 63 m long x 11 m wide | 50 m long x 15 m wide | 205 m from LW35, 270 m from LW38 |
| GR-RB47 | 10 m long x 6 m wide | 22 m long x 6 m wide | 265 m from LW35, 155 m from LW38 |
| GR-RB48 | 19 m long x 5 m wide | 100 m long x 10 m wide | 315 m from LW35, 66 m from LW38 |
| GR-RB49 | 80 m long x 7 m wide | 10 m long x 6 m wide | 324 m from LW35, 56 m from LW38 |
| GR-RB51 | 9 m long x 4 m wide | Boulder Field upstream | 255 m from LW35, 120 m from LW38 |
| GR-RB52 | 11 m long x 3 m wide | 150 m long x 12 m wide | 170 m from LW35, 235 m from LW38 |
| GR-RB53 | 5 m long x 5 m wide | 165 m long x 6 m wide | 232 m from LW35, 310 m from LW38 |
| GR-RB59 | 6 m long x 3 m wide | 95 m long x 5 m wide | 210 m from LW35, 300 m from LW37 |
| GR-RB60 | 8 m long x 3 m wide | 150 m long x 5 m wide | 158 m from LW37 |
| GR-RB61 | 15 m long x 18 m wide | 125 m long x 9 m wide | 27 m from LW37 |
| GR-RB62 | 13 m long x 4 m wide | Boulder Field Upstream | 150 m from LW37 |
| GR-RB63 | 5 m long x 3 m wide | 44 m long x 4 m wide | 165 m from LW37 |
| GR-RB64 | 77 m long x 7 m wide | 6 m long x 6 m wide | 205 m from LW37 |
| GR-RB65 | 17 m long x 18 m wide | 337 m long x 7 m wide | 295 m from LW37 |
| GR-RB66 | 9 m long x 15 m wide | 23 m long x 5 m wide | 330 m from LW37 |
| GR-RB67 | 60 m long x 18 m wide | 32 m long x 4 m wide | 340 m from LW37 |

**Table 5.3 Boulderfields along Georges River and within the Study Area**

| Label | Approximate Size | Approximate size of Upstream Pool | Distance of Closest Point to Mining |
|---|---|---|---|
| GR-BF46 | 85 m long x 6 m wide | 42 m long x 7 m wide | 176 m from LW38 |
| GR-BF50 | 10 m long x 3 m wide | 130 m long x 6 m wide | 80 m from LW38 |
| GR-BF51 | 16 m long x 5 m wide | 14 m long x 3 m wide | 103 m from LW38 |
| GR-BF62 | 30 m long x 5 m wide | 320 m long x 5 m wide | 152 m from LW37 |
| GR-BF64 | 12 m long x 3 m wide | Rockbar upstream | 207 m from LW37 |

It can be noted, that the riffle locations shown in Drawings Nos. MSEC533-07 to MSEC533-09 are based on those mapped by IC using GPS during January to March 2012. The locations of riffles are known to change over time, as a result of flooding events and, therefore, the actual locations during the mining period could be different to those shown.

Photographs of some of the stream features are provided in Fig. 5.2 to Fig. 5.7.

**Fig. 5.1 Photograph of Georges River Pool 52 looking Upstream (28th Feb 2011)**

**Fig. 5.2 Photograph of Georges River Pool 57 looking Upstream (28th Feb 2011)**

**Fig. 5.3 Photograph of Georges River Pool 63 looking Downstream (28th Feb 2011)**

**Fig. 5.4 Photograph of Rockbar 64 looking Downstream (3rd Jan 2012)**

**Fig. 5.5 Photograph of Rockbar 60 looking Cross Stream (26th Sep 2011)**

**Fig. 5.6 Photograph of Boulder Field 62 looking Upstream (3rd Jan 2012)**

**Fig. 5.7 Photograph of Boulder Field 50 looking Upstream (3rd Jan 2012)**

The surface mapping and geological modelling undertaken by IC indicate that the base of the river lies within the stratigraphy of the Hawkesbury Sandstone.

The overall height of the Georges River valley is up to around 45 metres within the Study Area. The valley is steeply sided. The descriptions of the cliffs, rock outcrops and steep slopes within the valley are included in Sections 5.9, 5.10 and 5.11 respectively. A cross-section through the valley, adjacent to the finishing (eastern) end of Longwall 37 and over Longwall 38, is provided in Fig. 5.8.

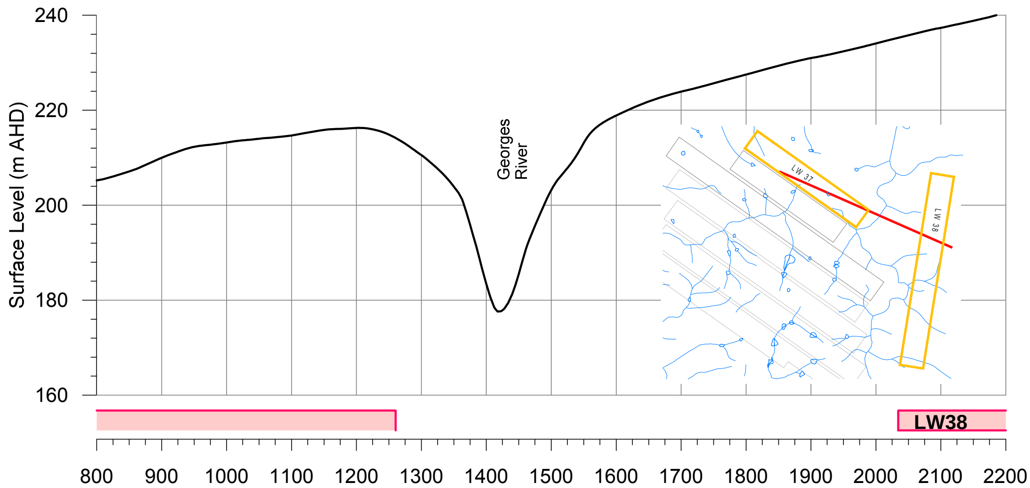



**Fig. 5.8 Surface Cross-section over Longwall 37, across the Georges River and over Longwall 38 (Looking North)**

Within the Study Area surrounding Longwall 37, the average natural gradient of the Georges River is approximately 5 mm/m (i.e. 0.5 %, or 1 in 200). The maximum natural gradient of the Georges River in this area is approximately 140 mm/m (i.e. 14 %, or 1 in 7), which occurs just upstream of Pool 67.

Within the Study Area surrounding Longwall 38, the average natural gradient of the Georges River is approximately 11 mm/m (i.e. 1.1 %, or 1 in 90). The maximum natural gradient of the Georges River in this area is approximately 100 mm/m (i.e. 10 %, or 1 in 100), which occurs just downstream of Pool 43.

### 5.2.2. Predictions for the Georges River

The predicted profiles of incremental and total subsidence, upsidence and closure along the Georges River, after the extraction of each of the proposed longwalls, are shown in Fig. E.03 in Appendix E.

A summary of the maximum predicted values of total subsidence, upsidence and closure along the Georges River within the Study Area, after the extraction of each of the proposed longwalls, is provided in Table 5.4.

**Table 5.4 Maximum Predicted Total Subsidence, Upsidence and Closure at the Georges River Resulting after the Extraction of Longwalls 36, 37 and 38**

| Longwall | Maximum Predicted Total Subsidence (mm) | Maximum Predicted Total Upsidence (mm) | Maximum Predicted Total Closure (mm) |
|---|---|---|---|
| After LW36 | 30 | 120 | 180 |
| After LW37 | 90 | 180 | 210 |
| After LW38 | 100 | 190 | 220 |

The predicted subsidence values provided in the above table are the maximum total values which occur along the Georges River within the Study Area, and include the predicted movements resulting from the extraction of Longwalls 29 to 36.

The predicted upsidence and closure movements in the above table are the maximum total values which occur along the Georges River within the predicted limits of 20 mm additional upsidence and 20 mm additional closure, due to the extraction of Longwalls 37 to 38, but also include the predicted movements resulting from the extraction of Longwalls 29 to 36.

The proposed longwalls do not directly mine beneath the Georges River and this section of the Georges River within the Study Area has not been previously mined beneath. In previous assessments undertaken in the Southern Coalfield, a solid coal factor of 0.7 has been used in calculating the predicted valley related upsidence and closure movements, which is discussed in Section 3.4.3. The application of a solid coal factor is consistent with the recommendations provided in Report No. MSEC404, which supported the Bulli Seam Operations Part 3A Application.

Instead of using a solid coal factor, an equivalent valley height factor of 0.77 was adopted for this section of the Georges River to be compatible with previous reports and to be compatible with previous back analyses of the predicted and observed closures along the Georges River at West Cliff Colliery, refer to Section 5.2.3 below. The equivalent valley height factor was developed to reflect the differences in the shapes of various valleys, since most of the data used to develop the closure model was gathered in the very sharply incised Cataract River and Nepean River Gorges.

The profile of the equivalent valley height along the Georges River that was used to determine the predicted valley related upsidence and closure movements along the River is shown in Fig. E.02. The equivalent valley height is calculated by multiplying the valley height, within a half depth of cover from the valley base, by a factor which reflects the shape of the valley. As described above, a valley height factor of 0.77 has been adopted for the Georges River.

A summary of the maximum predicted values of total subsidence, upsidence and closure movements at each of the mapped rockbars along the Georges River within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table 5.5.

Table 5.5 Maximum Predicted Total Subsidence, Upsidence and Closure at the Mapped Features along the Nepean River after the Extraction of the Longwalls 37 and 38

| Location | Maximum Predicted Subsidence (mm) | Maximum Predicted Upsidence (mm) | Maximum Predicted Closure (mm) |
|---|---|---|---|
| GR-RB42 | 25 | 112 | 151 |
| GR-RB43 | <20 | 107 | 156 |
| GR-RB44 | <20 | 118 | 164 |
| GR-RB45 | <20 | 145 | 169 |
| GR-RB47 | 25 | 103 | 184 |
| GR-RB48 | 67 | 105 | 215 |
| GR-RB49 | 76 | 105 | 218 |
| GR-RB51 | 35 | 98 | 217 |
| GR-RB52 | <20 | 103 | 206 |
| GR-RB53 | <20 | 102 | 191 |
| GR-RB54 | <20 | 110 | 190 |
| GR-RB55 | 25 | 120 | 199 |
| GR-RB56a | 30 | 127 | 216 |
| GR-RB56b | 31 | 127 | 216 |
| GR-RB57 | 28 | 126 | 214 |
| GR-RB59 | 31 | 138 | 214 |
| GR-RB60 | 43 | 149 | 196 |
| GR-RB61 | 89 | 190 | 203 |
| GR-RB62 | <20 | 102 | 150 |
| GR-RB63 | <20 | 88 | 135 |
| GR-RB64 | <20 | 74 | 118 |
| GR-RB65 | <20 | 67 | 78 |
| GR-RB66 | <20 | 63 | 71 |
| GR-RB67 | <20 | 62 | 70 |

### 5.2.3. Comparison of Observed and Predicted Valley Closure Movements along Georges River

The mine subsidence movements across the Georges River valley were measured by IC along seven ground monitoring lines during the extraction of Longwalls 29 to 34, being the G-Line, H-Line, I-Line, J-Line, K-Line, L-Line and M-Line. The locations of these 2D monitoring lines are shown in Drawing No. MSEC533-07 to MSEC533-09.

The predicted closure movements at the Georges River, resulting from the extraction of Longwalls 34 to 36, were provided in Report No. MSEC326. These predictions were further revised for the shortened finishing end of Longwall 34 in Report No. MSEC444.

It should be noted, that the actual closure movements at the Georges River cross lines could be greater than those measured, as the monitoring lines do not extend to the tops of the valley sides. In most cases however it has been found that strains concentrate near the valley base and, therefore, it is likely that the majority of these movements are recorded by these short cross lines.

A summary of the predicted and observed total closure movements for each of the Georges River cross lines is provided in Table 5.6.

Table 5.6 Summary of the Predicted and Observed Closure Movements at the Georges River Cross Lines

| Location | Total Observed Closure | Latest Survey Date | Longwalls Extracted during Survey Line Monitoring | Predicted Total Closure after the extraction of Longwall 34 (as approved) |
|---|---|---|---|---|
| G-Line | 139 | 27-Oct-11 | LW29, 31B, 32, 33, 34 | 135 |
| H-Line | 111 | 27-Oct-11 | LW32, 33, 34 | 103 |
| I-Line | 16 | 17-Nov-11 | LW32, 33, 34 | 89 |
| J-Line | 28 | 17-Nov-11 | LW33, 34 | 61 |
| K-Line | 17 | 17-Nov-11 | LW33, 34 | 51 |
| L-Line | 24 | 27-Oct-11 | LW34 | 21 |
| M-Line | 22 | 27-Oct-11 | LW34 | 45 |

It can be seen from Table 5.6, that the maximum observed total closure movements at the G-Line, H-Line, I-Line, J-Line, K-Line, L-Line and M-Line, after the completion of Longwall 34, were similar to or less than the maxima predicted.

### 5.2.4. Comparison of Predictions for the Georges River with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters along the Georges River with those provided in the Part 3A Application is provided in Table 5.7. It is noted, that these are the maxima anywhere along the river, not just at the mapped rockbars.

Table 5.7 Comparison of the Maximum Predicted Conventional Subsidence Parameters along the Georges River after the Extraction of Longwall 38

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Upsidence (mm) | Maximum Predicted Total Closure (mm) |
|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 150 | 130 | 220 |
| Extraction Plan Layout (Report No. MSEC533) | 100 | 190 | 220 |

It can be seen from the above table that the maximum predicted total subsidence along the Georges River, based on the Extraction Plan Layout, is less than the maximum predicted subsidence based on the Part 3A Layout. The maximum predicted total upsidence and closure along the Georges River, based on the Extraction Plan Layout, are greater than and equal to the maximum predicted upsidence and closure respectively based on the Part 3A Layout.

### 5.2.5. Impact Assessments for the Georges River

The impact assessments for the Georges River are provided in the following sections. The findings in the following sections should be read in conjunction with the other relevant technical reports attached to the Extraction Plan Application.

The assessments provided in this report should be read in conjunction with the assessments provided in the reports by *Ecoengineers* (2013) and *Geoterra* (2013).

#### 5.2.5.1. The Potential for Changes in Surface Water Levels

The surface water levels in the river are controlled by the restricting stream features, which generally comprise rockbars, boulder fields and riffles.

The maximum predicted subsidence and upsidence due to the extraction of the proposed longwalls are 100 mm and 190 mm, respectively. The predicted net vertical movements are small when compared with the hydraulic grade along the river. The changes in water level resulting from the extraction of the proposed longwalls, are small in comparison with natural fall along the river and, therefore, are not expected to result in any measurable impact.

#### 5.2.5.2. The Potential for Increased Levels of Ponding, Flooding and Scouring

The Georges River is a perennial stream where surface water flows are derived from the catchment areas as well as from the Licensed Discharges from Appin and West Cliff Collieries. The larger pools in the river are permanent and naturally develop upstream of the rock bars, riffles and boulder fields, which are shown in Drawings Nos. MSEC533-08 and MSEC533-09.

Mining can potentially result in increased levels of ponding and some minor flooding of the adjacent riparian areas in locations where the mining induced tilts oppose and are greater than the natural river gradients. Mining can also potentially result in an increased likelihood of scouring of the river banks in the locations where the mining induced tilts considerably increase the natural river gradients.

Since the predicted levels of subsidence are small, the maximum predicted conventional tilts along the Georges River, resulting from the extraction of the proposed longwalls, are also very small. The maximum predicted conventional increasing and decreasing tilts along the Georges River, resulting from the extraction of the proposed longwalls, are 0.6 mm/m and 0.9 mm/m (i.e.: both less than 0.1 %), respectively, or a changes in grade less than 1 in 1,000. The natural gradient of the Georges River within the Study Area varies between a minimum of less than 1 mm/m and a maximum of 140 mm/m, with average natural gradients of approximately 5 mm/m to 11 mm/m.

The maximum predicted increasing and decreasing tilt along the Georges River, resulting from the extraction of the proposed longwalls, is much less than the average natural gradients within the Study Area. It is unlikely, therefore, that there would be any significant increases in the levels of ponding, flooding, or scouring of the river banks resulting from the extraction of the proposed longwalls. It is possible, however, that there could be some very localised small increased levels of ponding or flooding where the predicted maximum tilts coincide with existing pools, steps or cascades along the river, however, any changes are not expected to result in an more than a negligible impact.

#### 5.2.5.3. The Potential for Changes in Stream Alignment

The potential for changes in stream alignment can occur due to changes in the cross-bed gradients resulting from mining-induced conventional or valley related movements. The potential for mining-induced changes in the stream alignment depends upon the mining-induced ground movements, the natural river cross-bed gradients, as well as the depth, velocity and rate of surface water flows.

Changes in stream alignment can potentially impact upon the river if they affect riparian vegetation, or the changes result in additional scouring of the river banks. The potential for changes in stream alignment are generally limited to sections of river where surface flows are confined to shallow streams over a relatively flat river bed.

The maximum predicted conventional tilt across the alignment of the river, resulting from the extraction of the proposed longwalls, is 1.4 mm/m (i.e.: 0.1 %), or a change in cross-bed gradient of 1 in 700, which occurs adjacent to Longwall 38 and near the finishing (eastern) end of Longwall 35.

The maximum predicted total upsidence along the river, resulting from the extraction of the proposed longwalls, is 190 mm, which occurs adjacent to the finishing (eastern) end of Longwall 37. Based on an idealised upsidence profile, as shown in Fig. 1.25 in the background report entitled *General Discussion of Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*, the maximum predicted tilt across the alignment of the riveris approximately 6 mm/m (i.e.: 0.6 %), or a change in cross-bed gradient of 1 in 165.

The predicted changes in the cross-bed gradients are very small and are expected to be an order of magnitude smaller than the natural river cross-bed gradients. The potential impacts associated with changes in the stream alignment, resulting from the extraction of the proposed longwalls are, therefore, not expected to be more than negligible.

The potential impacts of the changes in the stream alignment are expected to be negligible when compared to the changes in the river depth and width that occur during times of high flow in the river. The potential impacts of scouring are also likely to be negligible due to the nature of the sandstone river bed.

In the locations where the river bed comprises sediments and deposited debris, rainfall events could also result in changes in the stream alignment. In a large flow event, even rocks and vegetation can be carried downstream. The increased flow velocities in such events are likely to be an order of magnitude greater than those resulting from mining induced changes to bed gradients.

#### 5.2.5.4. The Potential for Fracturing of Bedrock and Surface Water Flow Diversions

Fractures and joints in bedrock and rock bars occur naturally from erosion and weathering processes and from natural valley bulging movements. Where longwall mining occurs in the vicinity of rivers and creeks, mine subsidence movements can result in additional fracturing or the reactivation of existing joints. The precise causes of these mining-induced fractures are difficult to determine as the mechanisms are complex, although the main mining-related mechanisms are the conventional subsidence and valley related movements.

Diversions of surface water flows also occur naturally from erosion and weathering processes and from natural valley bulging movements. Mining-induced surface water flow diversions into near surface subterranean flows occur where there is an upwards thrust of bedrock, resulting in the redirection of some water flows into the dilated strata beneath the river bed. The water generally reappears further downstream of the fractured zone as the water is only redirected below the river bed for a certain distance.

Mining-induced surface water flow diversions due to rock bar leakage occur in a similar manner to the above mechanism, except that the rock bar is elevated above the rest of the river bed and the near surface watertable. The rate of leakage is dependent, amongst other factors, on the extent of horizontal fracturing over the depth of the rock bar and the water level. Rock bars leak at a higher rate when the pool is full, as there is access to all drainage paths and the water head is at its greatest. As the pool level falls, the drainage rate reduces as the water head falls and access is restricted to drainage paths near the base of the rock bar.

The types of surface water flow diversions mentioned above are illustrated in Fig. 5.9.

**Diagrammatic Representation of Subterranean Flows** | **Diagrammatic Representation of Rock Bar Leakage**

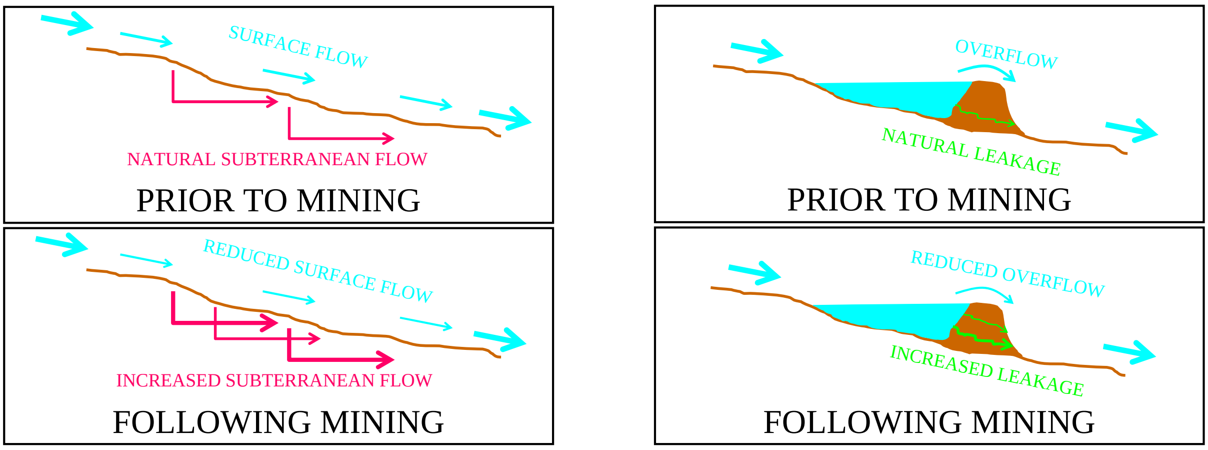



**Fig. 5.9 Types of Surface Water Flow Diversions**

Interactions between the surface water and groundwater systems have been observed along the Georges River and the river is a *losing* system during dry periods, where the predominant movement is from the surface water to the groundwater system (IC, 2004a).

In times of extended drought, the groundwater table can be lowered considerably. In these drought conditions, surface water flows can be naturally diverted through the existing joints into a lower groundwater system and, where mining induced fractures occur, additional surface water diversions can occur into the groundwater system. Following periods of groundwater recharge rain events, the groundwater levels return to higher levels, reducing the diversion of surface water flows into the groundwater system.

The surface water which is diverted into the groundwater system is not drawn upon, utilised or lost from the region and, hence, the diverted surface water is not viewed as a loss of water from the system. Over time, the subterranean flow channels and fractures can become blocked with debris and sediment and, therefore, the diversion of surface water into subterranean flows can reduce over time.

The experience gained from previous longwall mining in the Southern Coalfield indicates that mining-induced fracturing in bedrock and rock bars are commonly found in sections of rivers and creeks that are located directly above extracted longwalls. However, fracturing has also been observed in locations beyond extracted longwall goaf edges, the majority of which have been within the limit of conventional subsidence. In a few isolated cases, fracturing has been observed up to 400 metres outside extracted longwall goaf edges.

While both upsidence and closure movements have been back-predicted for the Georges River, it is our opinion that the most relevant parameter for assessing the potential for significant impacts along the river is the predicted closure movements. This opinion is based on information that is currently available and is made for the following reasons:-

- Closure is the measure of macro valley movements and, therefore, there is less variation in the observed closure movements between adjacent cross-sections within a valley. As a result, there is less scatter in the observed closure movement data in the empirical database.
- Upsidence is the measure of micro valley movements in the base of the valley, which can vary significantly between adjacent cross-sections due to variations in near surface geology, whether failure of the bedrock occurs and the nature of bedrock failure. As a result, there is greater scatter in the observed upsidence movement data in the empirical database.
- The observed upsidence movements in the empirical database are also influenced by the placement of survey pegs, which can miss the point of maximum upsidence within the cross-section and measurements can vary significantly between adjacent cross-sections.

Based on the above points, the predicted closure movements are considered to be more reliable than the predicted upsidence movements. Although fracturing and dilation of underlying strata and, hence, the potential for surface water flow diversions result from upsidence movements, the correlation between closure and upsidence movements allows us to use the predicted closure movements to assess the potential for these impacts.

A summary of the maximum predicted closure at the mapped rock bar locations, after the extraction of Longwalls 37 and 38, is provided in Table 5.5. It can be seen from this table, that three of the 21 rock bars within the Study Area (i.e. 14 %) have predicted closures less than 100 mm, nine rock bars (i.e. 43 %) have predicted closures between 100 mm and 200 mm, and the remaining nine rock bars (i.e. 43 %) have predicted closures between 200 mm and 220 mm.

The potential for the fracturing of bedrock and, hence, the potential for surface water flow diversions along Georges River, resulting from the extraction of Longwalls 37 and 38, has been assessed using the available case studies from the Southern Coalfield where previous longwalls have been mined near to or directly beneath streams.

An empirical database has been developed of pool and rockbar sites in the Southern Coalfield that have experienced mining induced valley related movements. The upsidence and closure movements at these sites have been predicted, using the ACARP Method (Waddington, 2002), at the time when the first pool impact occurred, or after this time, when the pool water loss was first recorded.

In some cases, upsidence and closure movements were also being measured along the streams. However, the monitoring lines were often not located at the impact sites, or the ground movements were measured some time after impacts first occurred. The impacts database has been developed, therefore, using predicted movements, as there is limited ground monitoring data for the available case studies. Adopting the predicted movements using the ACARP Method also allows the mining geometries and valley heights for the case studies to be normalised, such that they can be more readily compared with those for the proposed longwalls.

Descriptions of the observed impacts and the maximum predicted upsidence and closure movements resulting from the previously extracted longwalls at West Cliff Colliery are provided below.Where West Cliff Longwalls 5A1 to 5A4 previously mined directly beneath the Georges River, a number of impacts were observed including:-

- Release of strata gas from the river bed at some locations, including Jutts Crossing and Marhnyes Hole,
- Fractures at rock bars and in the river bed at Pools 8, 9, 14, 15, 16B and 17,
- Reduced water levels in pools with fracturing, including complete draining of Pools 8, 9 and 16B, for short periods of time during low flow conditions, and
- Formation of a spring at Pool 11.

The impacts occurred primarily in the vicinity of Jutts Crossing and Marhnyes Hole and Pools 16B and 17, which are briefly summarised below.

Jutts Crossing (RB10) is located directly above the chain pillar between Longwalls 5A1 and 5A2. No adverse impacts were observed at Jutts Crossing during the extraction of Longwall 5A1. In August 2000, during the extraction of Longwall 5A2, fractures were observed in the bedrock at Jutts Crossing. In November 2000, Pools 8, 9 and 10 upstream of Jutts Crossing were observed to lose water level and then to completely drain during times of low flow. At that stage of mining, the predicted upsidence and closure movements at the rock bar were 220 mm and 235 mm, respectively.

The Marhnyes Hole area consists of two pools along the Georges River, designated Pools 14 and 15, which are separated by Rock Bar 15. The downstream pool, being Pool 15, is contained by Rock Bar 16.

Marhnyes Hole is located above Longwall 5A4. No major impacts were observed at Marhnyes Hole during the extraction of Longwalls 5A1 to 5A3.

Longwall 5A4 mined directly beneath Marhnyes Hole in September 2002 and fracturing was observed when the extraction face was directly beneath the rock bar. The water level in the upstream pool, being Pool 14, began to fall when the longwall face was approximately 140 metres past the rock bar. The water level in the downstream pool, being Pool 15, started to fall shortly after, when the longwall face was approximately 180 metres past. At that stage of mining, the predicted upsidence and closure movements at the rock bar were 185 mm and 210 mm, respectively.

Where West Cliff Longwalls 29 and 31 mined immediately adjacent to the Georges River, gas bubbles were observed in the river. There were no other impacts observed along the Georges River resulting from the extraction of these longwalls. At the completion of these longwalls, the maximum predicted upsidence and closure at the Georges River were 70 mm and 135 mm, respectively.

Minor impacts were observed in the Georges River following extraction of West Cliff Longwall 32 including fracturing in Rock Bar RB36, which is located adjacent to the eastern end of this longwall. Gas realease zones were also observed, which could indicate that additional fracturing may have also occurred in the bed of the river. There were no surface water flow diversions observed along the river due to the extraction of Longwalls 29 to 32. At the completion of Longwall 32, the maximum predicted upsidence and closure at the Georges River were 80 mm and 100 mm, respectively.

Further fracturing was observed in Rock Bar RB36 and fracturing was also observed in RB39 following the extraction of Longwall 33. After the completion of this longwall, the pool water levels upstream of these rock bars were observed to drop more than expected based on the rainfall and flow conditions. At the completion of Longwall 33, the maximum predicted upsidence and closure at the Georges River were 130 mm and 100 mm, respectively.

Minor fracturing in one additional location was observed in the river as a result of the extraction of Longwall 34. No additional changes in pool water levels or gas release zones were observed.

The locations along the Georges River that experienced impacts due to extraction of the Longwall 32, 33 and 34 are generally close to the finishing ends of these longwalls. It can be seen in Fig. E.03 that small additional valley related movements, with predicted closure of approximately 20 mm or less, are predicted to occur along the section of the Georges River adjoining the ends of these Longwalls 32 to 34. The prediction of valley closure is recognised as producing conservative results, particularly at low levels of closure as observed data is affected more by survey tolerance. The small magnitude of the predicted additional closure is considered unlikely to result in new impacts at these locations, however where impacts have occurred from the previously extracted longwalls, the small closure may result in minor movements at existing fractures.

The empirical database also includes other case studies from Appin, Tower, West Cliff, Tahmoor and Metropolitan Collieries. A number of these case studies were described in Report No. MSEC326 (Rev. C), which supported the SMP Application for West Cliff Longwalls 34 to 36.

The observed impacts from the case studies were categorised or defined as three types:-

- Type 1 – where nil or negligible impacts were observed.
- Type 2 – where isolated fracturing, gas releases or iron staining were observed, and
- Type 3 – where pool water levels were observed to drop more than was expected after considering the rainfall and surface and groundwater flow conditions.

The case studies from the Southern Coalfield are illustrated in Fig. 5.10, which shows the type of impacts and the predicted upsidence and predicted closure at the time when impact was first observed. The case studies include those resulting from mining at Appin, Tower, West Cliff, Tahmoor and Metropolitan Collieries.

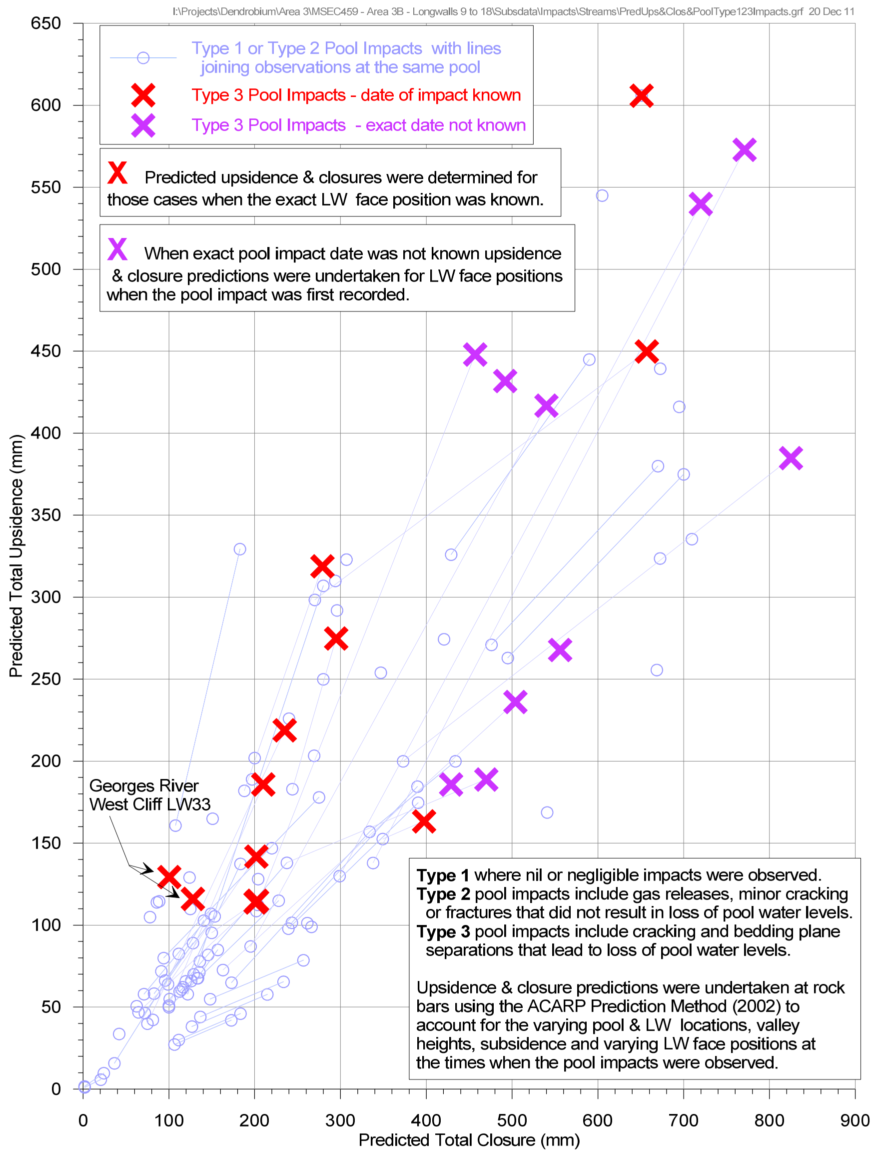



**Fig. 5.10 Case Studies from the Southern Coalfield showing the Predicted Total Upsidence and Predicted Total Closure at the Times when Impacts were First Observed**

It should also be noted, that where the water levels of pools have been observed to fall naturally, during low flow conditions, it is difficult to assess the exact times when mining has affected the water levels of these pools. In these cases, conservative assessments of the times of impact have been adopted in the above assessment.

This correlation does not attempt, at this stage, to differentiate between sites with varying geological or topographical conditions, but, this analysis is the focus of a current ACARP funded research program on the effects of geology on upsidence and closure. It is considered that pool sites with wider or higher rockbars, or sites with thin or brittle surface strata layers, or sites with highly jointed surface strata layers would be more likely to experience increased valley closure and water loss than pools and rockbar sites with short, strong and unjointed surface strata layers.

It can be seen from Fig. 5.10, that only two Type 3 impacts (i.e. 4 % of the currently available database) have been observed, to date, where the predicted total closure was less than 200 mm. These both occurred in the Georges River after the extraction of West Cliff Longwall 33, where pool water levels were observed to drop more than expected based on the rainfall and flow conditions. Assessing or categorising the impacts at these pools was difficult, since pre-mining natural flow diversions were observed at both of these pools. It can also be seen from this figure, that six Type 3 impacts (i.e. 11 % of the currently available database) have been observed once the total predicted closure was 215 mm.

An analysis of impact rates has been undertaken using the currently available database of pool and rockbar case studies. This database is being continually developed and, to date, research has mainly concentrated on collating knowledge on the known pool and rockbar impact sites, whilst less data has been included for sites that had no impacts as a result of mining. The proportion of sites which experienced Type 3 impacts, as a function of the total predicted closure, is illustrated in Fig. 5.11.

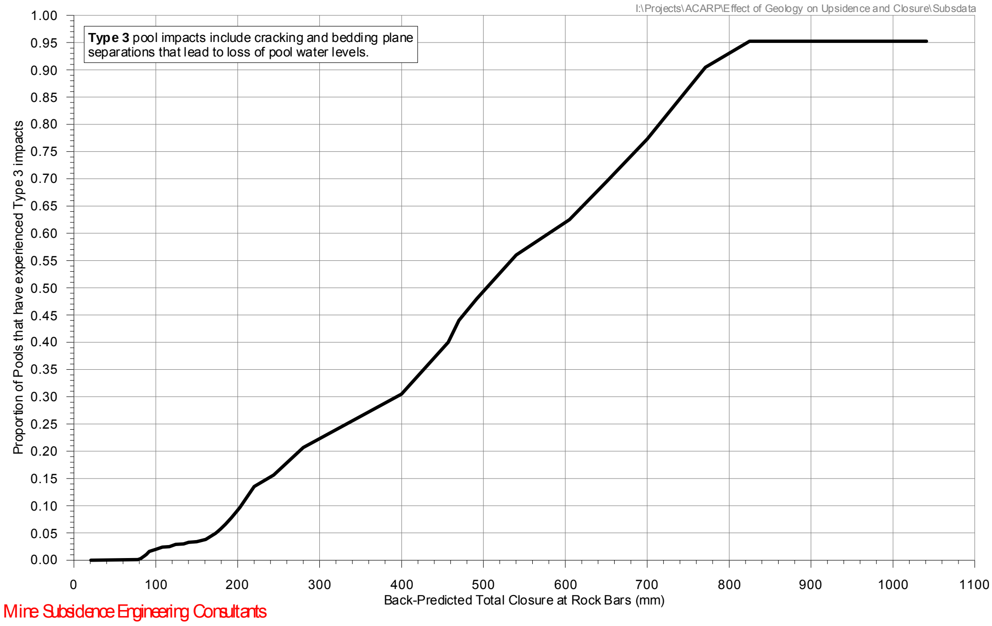



**Fig. 5.11 Proportion of Type 3 Impacts versus Predicted Total Closure for Case Studies**

It can be seen from Fig. E.03 that the maximum predicted total closure along the Georges River is 220 mm. The predicted total closure is less than 200 mm in all but two sections of the Georges River, representing approximately 600 metres and 400 metres lengths of the river. Based on the maximum predicted total closure of 220 mm, the proportion of Type 3 impacts experienced by pools for case studies as presented in Fig. 5.11 is less than 15 %.

It has been assessed, therefore, that there is a low likelihood that significant fracturing or surface water flow diversions would occur along Georges River as a result of the extraction of the proposed Longwalls 37 and 38. This assessment has been based on limiting the predicted closure at the mapped rockbars and riffles to less than 220 mm and, as a result, the proposed longwalls have been setback more than 50 metres from the majority of the mapped rockbars.

It should be noted, however, that fracturing could still occur in the bed of the Georges River as a result of the extraction of the proposed longwalls. Based on previously observed fractures in the beds of streams adjacent to longwall mining in the Southern Coalfield, it is possible that fractures could occur within 400 metres from the proposed longwalls. Any fracturing that does occur in the bed of the creek would be expected to be isolated and not result in more than minor surface water flow diversions.

The proposed Longwalls 37 to 38 mine close to, but not beneath the Georges River. The maximum predicted total conventional hogging and sagging curvature at the Georges River, resulting from the extraction of the proposed longwalls, are 0.02 $km^{-1}$ and less than 0.01 $km^{-1}$, respectively, with associated radii of curvature of 50 kilometres and more than 100 kilometres. The maximum predicted conventional tensile and compressive strains, based on applying a factor of 15 to the maximum predicted conventional curvatures, are both less than 0.5 mm/m.

The fracturing of sandstone due to conventional subsidence movements has generally not been observed in the Southern Coalfield where the conventional tensile and compressive strains have been less than 0.5 mm/m and 2 mm/m, respectively. It is unlikely, therefore, that the maximum predicted conventional strains at the Georges River, resulting from the extraction of the proposed longwalls, would be of sufficient magnitude to result in any significant fracturing in the sandstone bedrock or result in more than minor surface water flow diversions. Further discussion on conventional strains for features located over solid coal are provided in Section 4.4.1.

Elevated compressive strains across the alignment of the Georges River are likely to result from the valley related movements. The maximum predicted total upsidence and closure movements at the river, resulting from the extraction of the proposed longwalls, are 190 mm and 220 mm respectively. The compressive strains resulting from valley related movements are more difficult to predict than conventional strains, especially where rivers and creeks are located above solid coal, i.e.: outside the areas located directly above extracted longwalls, such as the case for the Georges River. The monitoring lines along the Georges River show observed closure strains of up to 8.2 mm/m at the G-Line and 8.3 mm/m at the H-Line, with observed total closure of 139 mm and 111 mm respectively. The remaining Georges River cross lines have experienced observed total closure strains of less than 2 mm/m, with observed total closures of less than 30 mm. Based on these results, it is expected that total compressive strains due to valley closure movements would be greater than 2 mm/m over much of the length of the Georges River after the extraction of the proposed longwalls.

It should be noted that the predicted and back-predicted upsidence and closure movements made using the ACARP Method use very conservative prediction curves. The observed valley related movements, therefore, are typically found to be much less than those predicted using this method. Comparisons between predicted and observed upsidence and closure movements in the valley related movements database are provided in Fig. 5.12 and Fig. 5.13, respectively.

It has been found, in the majority of cases, that the observed valley related movements are typically between 50 % and 100 % of those predicted and in some cases the observed movements are less than 25 % of those predicted. In rare cases, it has been found that the observed movements exceed those predicted, which is generally the result of weak near surface geology.

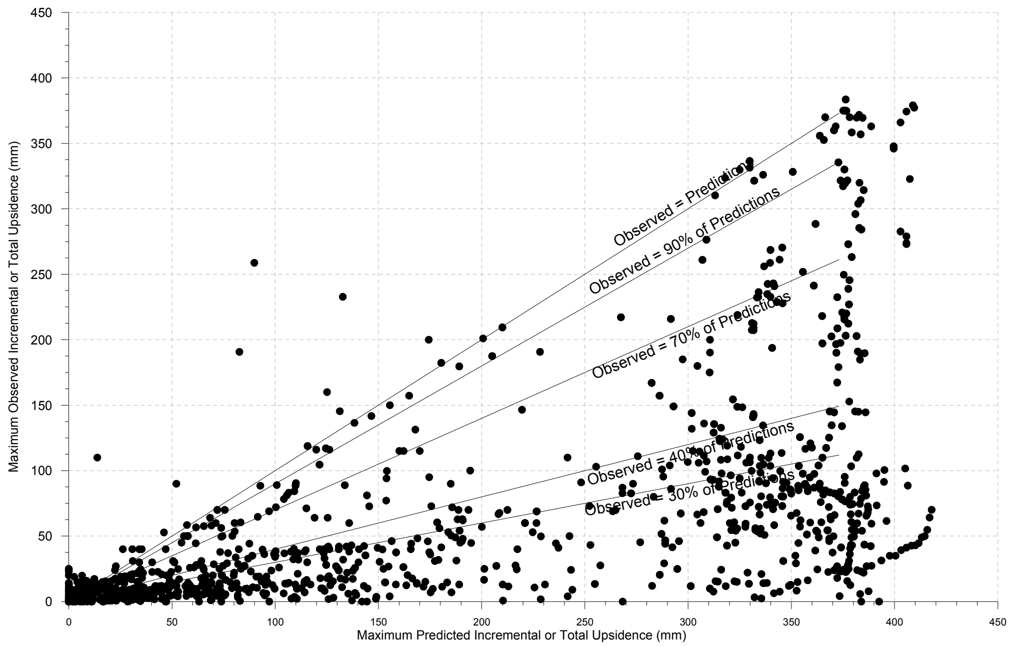



**Fig. 5.12 Comparison of Predicted and Observed Upsidence Movements in Database**

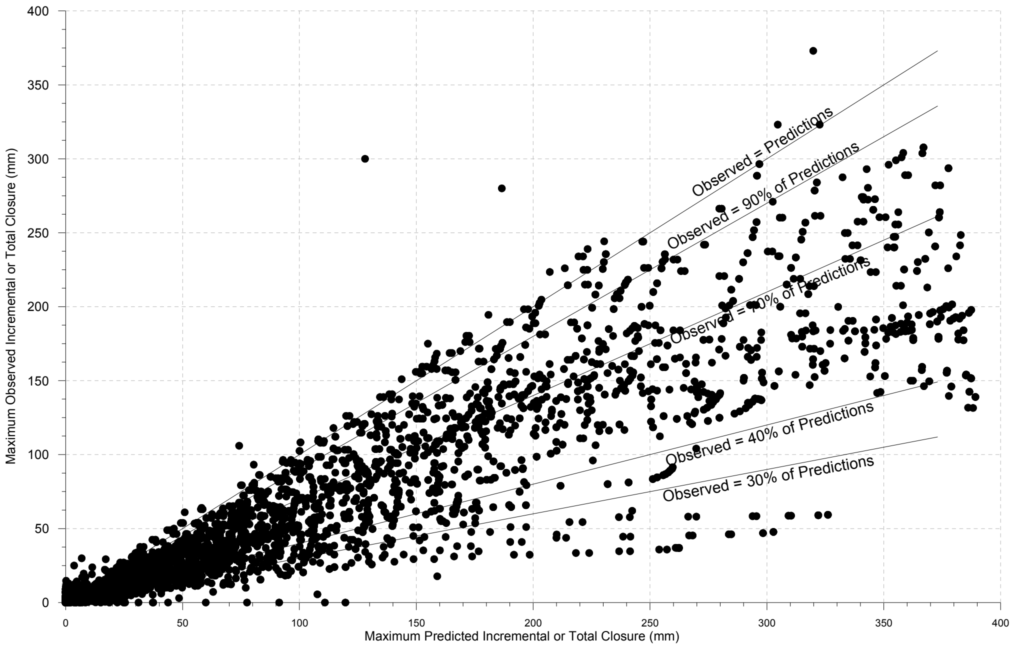



**Fig. 5.13 Comparison of Predicted and Observed Closure Movements in Database**

It can be seen from Fig. 5.10, that the maximum predicted closure movements along the Georges River and at the identified rockbars, resulting from the extraction of proposed Longwalls 37 to 38, are generally less than those back-predicted for most case studies which had observed significant impacts.

As described previously, predicted closure is considered to be the more reliable parameter for assessing impacts along rivers and creeks. The case studies, therefore, indicate that a maximum predicted closure of approximately 220 mm indicates that there is a low likelihood (i.e. less than 15 %) of significant impacts on the Georges River. Similar case studies have also been assessed for rivers and creeks located over previously extracted longwalls at other Collieries within the Southern Coalfield and similar results have been found.

It should be noted that the case studies occurred during a time of severe drought and the surface water and groundwater levels around the rivers and creeks are likely to have been at lower levels and, hence, the rate of surface water diversion would have been much greater than during normal periods. In this regard, the selected limit for surface water flow diversions is considered to be conservative and represents significant protection against flow diversions, even in drought periods.

It has been assessed, therefore, that minor fracturing could occur along the Georges River as a result of the extraction of the proposed longwalls. While it is possible for fracturing to occur anywhere along the river, the most likely areas are the stretch of the Georges River adjacent to and approximately parallel with the Longwall 38 tailgate and the stretch of the Georges River adjacent to the Longwall 35 maingate (i.e. locations with highest predicted total closure movements). It is possible that minor fractures could occur up to 400 metres from the proposed longwalls.

Given that any fracturing of the river bed is likely to be localised in nature, it is unlikely that any remediation would be required following mining. In the unlikely event that any surface fractures were to occur that resulted in pool water loss, it is recommended that they be sealed. Successful remediation has occurred in the Georges River at rock bars that have been directly mined beneath by previous longwalls.

As described above, natural flow diversions have been observed along sections of the Georges River which have not been affected by mining. It is therefore possible, therefore, that the extraction of the proposed longwalls could increase the current rate of surface water flow diversions in the river.

The depth of surface water flow diversions as a result of longwall mining has been estimated to be less than 10 to 15 metres. Recent studies into the depth of dilation of the near-surface strata due to upsidence and closure have been reported by Mills and Huuskes (2004). Extensometer readings were taken at five depths up to a maximum of 27.2 metres across a creek valley with a valley height of approximately 60 metres. The valley was directly mined beneath by a series of longwalls. Maximum incremental subsidence across a nearby monitoring line was approximately 500 mm, with maximum observed total subsidence of approximately 1300 mm. In this case, extensometer readings indicated that the bedrock had dilated vertically from deeper strata by 140 mm at the surface, but the dilation extended to a depth of only 9 metres from the surface.

The depth of dilation at Marhnyes Hole was measured during the extraction of Longwall 5A4 and has been reported by SCT (2003). Extensometer readings were taken at six depths up to a maximum of 39 metres adjacent to Rock Bar 15 and at Rock Bar 16. The extensometer readings at Rock Bar 16 indicated that the bedrock had dilated to a depth of 20 metres and was essentially uniform throughout the strata, but was slightly higher between the depths of 10 and 16 metres. The vertical dilation of the strata at Rock Bar 15 was largely influenced by the 20 metre deep stress relieving slot, which prevented dilation of the strata up to a depth of 15 metres. The extensometer readings at Rock Bar 15 indicated that the bedrock had dilated to a depth of 28 metres, but was mainly concentrated between the depths of 15.5 and 23 metres. It is difficult to infer what the dilation at Rock Bar 15 would have been without the stress relieving slot.

A number of Collieries in the Southern Coalfield have undertaken field investigations into the location and extent of surface water flow diversions during and following longwall mining operations that have occurred in the vicinity of rivers and creeks. These include West Cliff Colliery beneath or near the Georges River, Tower and Appin Colliery beneath or near the Cataract River, and Tahmoor Colliery beneath or near the Bargo River.

The following comments are made from these observations:-

- The rate of natural surface water flow diversions (or pre-mining surface water flow diversions) has not been well understood due to the limited pre-mining investigations that were undertaken. Knowledge in this area is presently increasing. Surface water flow diversions have been recently observed in sections of the Cataract, Georges and Bargo Rivers that have not been affected by previous mining.
- Observations indicate that mining-induced surface water flow diversions are generally limited to sections of river that are located within the limit of subsidence.

- Pools that are located near the ends of Longwalls 29 and 31 in the Georges River have not been observed to completely or even partially drain under periods of low flow. Some pools further downstream from the end of Longwall 29 have been observed to drain, although it is considered likely that these are due to natural rock bar leakages.
- Periodic monitoring of surface water flows in the Georges River during the extraction of Longwalls 5A1 to 5A4 indicate that surface water flow diversions did not begin until the longwalls passed directly beneath the river.
  - No surface water flow diversions were observed during the extraction of Longwall 5A1.
  - Surface water flow diversions were not observed during the extraction of Longwall 5A2 until the longwall had passed directly beneath the river, when Pools 8, 9 and 10 were observed to drain during low flows.
  - Surface water flow diversions were not observed at Marhnyes Hole until Longwall 5A4 had passed directly beneath the river. The water levels in the pools were not observed to fall until the longwall had passed directly beneath and progressed beyond the river by 100 to 180 metres (IC, 2002, IC, 2004a). It was found that the pools in the Georges River above Longwalls 5A2 to 5A4 could remain full with flows of 1.9 ML/day (IC, 2002).
- In the Cataract River, the only known location of surface water flow diversion beyond the goaf area was observed near the commencing end of Longwall 405. Flow diversions of approximately 2 ML/day have been observed in this location and approximately 7 metres of the rock bar, including a waterfall, have been observed to stop flowing during very low flows. However, while the amount of pre-mining investigations was limited, subterranean flows were observed through a rock pool prior to mining. It is difficult to determine whether the flow diversion had increased as a result of mining.
- Dry sections were observed in the Bargo River following a prolonged period of very low flows. The furthest distance of observed surface water flow diversions from the extracted longwalls was approximately 125 metres.

Baseline pool depth monitoring indicates that pools may fully or partially drain if the licensed discharges were reduced. It appears, however, that the pools remain full or at least retain water when there is some flow. Upon examination of baseline entry flows into the river, not including periods when remediation works were undertaken, it appears that discharges of less than 0.3 ML/day occurred less than 15 % of the time (Ecoengineers 2012).

Whilst significant increases in flow diversions are not likely to occur as a result of the extraction of the proposed longwalls, it is possible that sections of river may become dry, depending on the rate of the licensed discharges from Appin and West Cliff Collieries, particularly during times of low rainfall. This is because pre-existing flow diversions are already known to exist in the river. It is suspected that the river would consist of a series of disconnected or drained pools during periods of low rainfall if the licensed discharges did not enter the river.

It is recommended that current flow conditions be maintained during the mining period so that field monitoring can determine whether any increased flow diversions occur as a result of the extraction of the proposed longwalls. It is further recommended that water flow and quality monitoring be continued prior to, during and following the mining period.

It is recommended that any flow diversions be restored by remediation. With the current flow regime within the Georges River and with the implementation of remediation works similar to those previously undertaken along the river, it is unlikely that there would be any more than a minor impact on the Georges River resulting from the extraction of the proposed longwalls.

#### 5.2.5.5. The Potential for Ground Water Inflows

Details of the groundwater seepages identified within the Study Area, are provided in a report by Ecoengineers (2013). No springs developed along the Georges River during the extraction of Longwalls 29 to 34, which did not mine directly beneath the river. A spring, however, developed along the Georges River at Pool 11, which is located directly above Longwall 5A2, after the river was directly mined beneath by this longwall.

Although the proposed longwalls do not mine directly beneath the Georges River, it is possible that mining induced springs could develop following the extraction of the proposed longwalls. The chemical characteristics of mining induced springs suggest that the water passes through upland Wianamatta Shale and permeates through natural or mining-induced fractures in the Hawkesbury Sandstone before emerging in the Georges River (Ecoengineers 2012).

Vertical dilation between the Wianamatta Shale and Hawkesbury Sandstone is possible along the tributaries to the Georges River, particularly if the thickness of the Shale is less than 10 to 15 metres, as field studies suggest that the vertical dilation in creeks and rivers extend, as a maximum, to these depths (Mills and

Huuskes, 2004). Where these tributaries flow into the Georges River, however, the vertical dilation is expected to be small as they are located at the ends of the proposed longwalls.

Further discussion on the likely impacts of springs is provided in a report by Ecoengineers (2013).

#### 5.2.5.6. The Potential Impacts on Water Quality

Mine subsidence can potentially impact on the quality of water in the river due to leaching of minerals from freshly fractured bedrock and from increased inputs from groundwater to surface water flow. Such impacts tend to be temporary, localised and associated with low flow conditions. An investigation into the potential impacts of mine subsidence on water quality in the Georges River and creeks has been undertaken and described in the report by Ecoengineers (2013).

#### 5.2.5.7. The Potential Impacts on Flora and Fauna

Mine subsidence can potentially impact on flora and fauna within rivers and creeks. Flora could be adversely affected by the emission of gas at the surface and habitats can be affected by the fracturing of bedrock and the cracking of soils. The potential impact of mine subsidence on flora and fauna are provided in the reports by The Ecology Lab (2013) and by Niche (2013a).

### 5.2.6. Impact Assessments for the Georges River Based on Increased Predictions

If the predicted conventional tilts along the Georges River were increased by factors of up to 2 times, the maximum predicted changes in grade along the river would be 1.8 mm/m (i.e.: 0.2 %), or a change in grade of 1 in 550. The maximum predicted changes in grade would still be significantly less than average natural river gradients, which are approximately 5 mm/m to 11 mm/m within the Study Area and unlikely, therefore, to result in more than a negligible impact.

If the predicted conventional curvatures at the Georges River were increased by factors of up to 2 times, the maximum predicted hogging and sagging curvature would be 0.04 $km^{-1}$ and less than 0.01 $km^{-1}$ respectively with associated radii of curvature of 25 kilometres and greater than 100 kilometres. The maximum predicted conventional tensile and compressive strains, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.6 mm/m and less than 0.5 mm/m respectively. There is a slightly greater chance of minor fracturing occurring along the river where the maximum predicted tensile strain exceeds 0.5 mm/m. The increased maximum predicted conventional tensile and compressive strains are only marginally greater than 0.5 mm/m and the majority would still be less than 0.5 mm/m and unlikely, therefore, to result in any significant fracturing in the river bed.

If the predicted valley related upsidence and closure movements were increased by factors of up to 2 times, it is likely that fracturing and dilation of the river bed would occur, which could result in some surface water flow diversions. It should be noted, however, that the method used to predict the valley related movements adopts very conservative prediction curves and it is considered unlikely, therefore, that these movements would be exceeded by any more than 15 %.

### 5.2.7. Recommendations for the Georges River

It is recommended that Georges River is monitored during the extraction of the proposed Longwalls 37 to 38. It is also recommended that management strategies are developed for the river, such that any impacts can be identified and remediated accordingly. With these strategies in place, it is unlikely that there would be any more than a neglibible impact on the river resulting from the extraction of the proposed longwalls.

## 5.3. Drainage Lines

The locations of the drainage lines within the Study Area are shown in Drawing No. MSEC533-07, 08 and 09. The predictions and impact assessments for the major drainage lines are provided in the following sections. The Creeks that have been identified within the Study Area are;

- Mallaty Creek and its tributaries that have been labelled; MC3, MC4 and MC5,
- Nepean Creek and its tributaries that have been labelled; NC3 and NC5,
- Woodhouse Creek, and
- Various tributaries of the Georges River that have been labelled; GR101, GR102, GR103, GR104, GR105, GR107, GR108, GR108A, GR109, GR110, GR112, GR114, GR114A, GR117 and GR119.

Mallaty Creek is an ephemeral creek which is located directly above Longwalls 32 to 37. The creek generally flows in a westerly direction until it joins Ousedale Creek, approximately 1.2 kilometres south-west of Longwall 32. The natural gradient of the creek within the Study Area varies between 10 mm/m and 100 mm/m, with an average gradient of approximately 30 mm/m.

Nepean Creek is an ephemeral creek which is located directly above Longwall 37. The creek generally flows in a north-westerly direction until it joins Menangle Creek approximately 3.2 kilometres north west of the Study Area. The natural gradient of the creek within the Study Area varies between 10 mm/m and 150 mm/m, with an average gradient of approximately 40 mm/m.

There are also a number of tributaries within the Study Area, the locations of which are shown in Drawing No. MSEC533-07. The tributaries are located directly above and across the extents of the proposed longwalls.

The average natural gradients along Woodhouse Creek and selected tributaries within the Study Area are provided in Table 5.8. Typical photographs of the tributaries are provided in Fig. 5.14 and Fig. 5.15.

**Table 5.8 Summary of Gradients along selected Tributaries within the Study Area**

| Tributary Name | Approximate Range of Gradients along the Tributary (mm/m) | Average Gradient along the Tributary (mm/m) |
|---|---|---|
| Woodhouse Creek | 0 to 45 | 15 |
| GR103 | 25 to 200 | 100 |
| GR104 | 5 to 60 | 40 |
| GR105 | 0 to 100 | 40 |
| GR107 | 10 to 110 | 100 |
| GR108 | 5 to 140 | 90 |
| GR110 | 20 to 250 | 70 |
| GR114 | 10 to 70 | 45 |


**Fig. 5.14 Typical Stretch of Georges River Tributary GR110 within the Study Area**


**Fig. 5.15 Typical Stretch of the Nepean Creek within the Study Area**

#### 5.3.1. Predictions for the Drainage Lines

The predicted profiles of incremental and total subsidence, upsidence and closure along Mallaty Creek and Nepean Creek and various other tributaries, resulting from the extraction of the proposed longwalls, are shown in Figs. E.04, to E.13, respectively, in Appendix E.

A summary of the maximum predicted values of total subsidence, upsidence and closure anywhere along these drainage lines within the Study Area, after the extraction of Longwalls 36, 37 and 38, is provided in Table 5.9, Table 5.10 and Table 5.11 .

**Table 5.9 Maximum Predicted Total Subsidence, Upsidence and Closure at the Drainage Lines after the Extraction of Longwalls 36**

| Stream | Predictions after LW36 (mm) | | |
|---|---|---|---|
| | Subsidence | Upsidence | Closure |
| Mallaty Creek (incl. MC5) | 1125 | 650 | 725 |
| Nepean Creek (incl. NC3) | 425 | 75 | 50 |
| Woodhouse Creek | <20 | 25 | 25 |
| Tributary GR103 | <20 | 20 | 20 |
| Tributary GR104 | 75 | 90 | 140 |
| Tributary GR105 | 1120 | 210 | 220 |
| Tributary GR107 | <20 | 60 | 80 |
| Tributary GR108 | <20 | 20 | 40 |
| Tributary GR110 | <20 | 30 | 50 |
| Tributary GR114 | 50 | 90 | 70 |

**Table 5.10 Maximum Predicted Total Subsidence, Upsidence and Closure at the Drainage Lines after the Extraction of Longwalls 37**

| Stream | Predictions after LW37 (mm) | | |
|---|---|---|---|
| | Subsidence | Upsidence | Closure |
| Mallaty Creek (incl. MC5) | 1125 | 675 | 725 |
| Nepean Creek (incl. NC3) | 800 | 130 | 75 |
| Woodhouse Creek | 20 | 50 | 75 |
| Tributary GR103 | <20 | 40 | 60 |
| Tributary GR104 | 790 | 190 | 200 |
| Tributary GR105 | 1120 | 240 | 230 |
| Tributary GR107 | <20 | 60 | 90 |
| Tributary GR108 | <20 | 20 | 40 |
| Tributary GR110 | <20 | 30 | 50 |
| Tributary GR114 | 50 | 90 | 70 |

**Table 5.11 Maximum Predicted Total Subsidence, Upsidence and Closure at the Drainage Lines after the Extraction of Longwalls 38**

| Stream | Predictions after LW38 (mm) | | |
|---|---|---|---|
| | Subsidence | Upsidence | Closure |
| Mallaty Creek (incl. MC5) | 1125 | 675 | 725 |
| Nepean Creek (incl. NC3) | 850 | 130 | 75 |
| Woodhouse Creek | 25 | 50 | 75 |
| Tributary GR103 | 95 | 70 | 110 |
| Tributary GR104 | 830 | 190 | 210 |
| Tributary GR105 | 1120 | 240 | 230 |
| Tributary GR107 | 550 | 100 | 190 |
| Tributary GR108 | 640 | 140 | 220 |
| Tributary GR110 | 660 | 140 | 210 |
| Tributary GR114 | 325 | 110 | 90 |

The maximum predicted upsidence and closure movements in the above tables are the maximum values which occur within the predicted limits of 20 mm additional upsidence and 20 mm additional closure, due to the extraction of Longwalls 37 to 38, but also include the predicted movements resulting from the extraction of Longwalls 29 to 36.

The profiles of the equivalent valley heights that were used to determine the predicted valley related upsidence and closure movements along the drainage lines are shown in Figs. E.04 to E.13. An equivalent valley height factor varying between 0.5 and 0.85 were adopted for the drainage lines.

A summary of the maximum predicted values of total tilt anywhere along these drainage lines within the Study Area, after the extraction of Longwall 38, is provided in Table 5.12

**Table 5.12 Maximum Predicted Total Tilt at the Drainage Lines after the Extraction of Longwalls 38**

| Stream | Maximum Predicted Total Tilt after LW38 (mm/m) |
|---|---|
| Mallaty Creek (incl. MC5) | 4.9 |
| Nepean Creek (incl. NC3) | 3.9 |
| Woodhouse Creek | 0.1 |
| Tributary GR103 | 1.2 |
| Tributary GR104 | 3.6 |
| Tributary GR105 | 6.0 |
| Tributary GR107 | 3.6 |
| Tributary GR108 | 4.1 |
| Tributary GR110 | 4.0 |
| Tributary GR114 | 2.0 |

### 5.3.2. Impact Assessments for the Drainage Lines

The maximum predicted conventional tilts along the alignments of Mallaty Creek, Nepean Creek, and Woodhouse Creek are 4.9 mm/m (i.e.: 0.5 %), 3.9 mm/m (i.e.: 0.4 %) and 0.1 mm/m (i.e.: <0.1 %), respectively, or changes in grade of 1 in 200, 1 in 260 and greater than 1 in 1,000, respectively. The maximum predicted conventional tilt along the alignments of the other tributaries within the Study Area is 6.0 mm/m (i.e.: 0.6 %), or a change in grade of 1 in 170.

The natural grade along the alignment of Mallaty Creek within the Study Area varies between a minimum of 10 mm/m and a maximum of 100 mm/m, with an average natural grade of 30 mm/m. The natural grade along the alignment of Nepean Creek within the Study Area varies between a minimum of 10 mm/m and a maximum of 150 mm/m, with an average natural grade of 40 mm/m. The average grades of Woodhouse Creek and the tributaries within the Study Area are 15 mm/m and approximately 40 mm/m to 100 mm/m respectively.

The predicted conventional tilts along the alignments of the drainage lines are small when compared to the existing natural grades and are unlikely, therefore, to result in any significant increases in the levels of ponding, flooding or scouring.

It is possible that there could be very localised areas along the drainage lines which could experience a small increase in the levels of ponding and flooding, where the predicted maximum tilts occur at locations with small natural gradients. As the predicted maximum conventional tilts are less than 1 %, however, any changes are expected to be minor and not result in a significant impact on the drainage lines.

The stream features are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Fracturing of the uppermost bedrock has been observed in the past where the conventional tensile strains have been greater than 0.5 mm/m. Buckling and dilation of the uppermost bedrock has been observed in the past where the compressive strains have been greater than 2 mm/m. It is likely, therefore, that some fracturing, bulking and dilation would occur in the uppermost bedrock based on the distribution of conventional tensile and compressive strains. Where the drainage lines have natural soil beds above the bedrock, it is unlikely that the fracturing resulting from the conventional tensile strains would be seen at the surface.

Surface cracking as the result of conventional subsidence movements at depths of cover greater than 500 metres, such as at West Cliff Colliery, has generally been observed in the past to be isolated and of a minor nature. It has also been observed in the past, that surface cracking as the result of conventional subsidence movements only occurs within the top few metres of the surface soils or bedrock and tends to be filled with the natural soil materials during subsequent flow events.

Elevated compressive strains across the alignments of the drainage lines are likely to result from the valley related movements. The maximum predicted closure movement at Mallaty Creek is 725 mm. The maximum predicted closure movements at Nepean Creek and Woodhouse Creek are both 75 mm. The maximum predicted closure movement at the tributaries within the Study Area are less than 230 mm.

The compressive strains resulting from valley related movements are more difficult to predict than conventional strains. The relationship between closure movements and compressive strains due to closure movements, based on previous mining directly beneath creeks and rivers in the Southern Coalfield, is provided in Fig. 4.5. It can be seen from this figure that the compressive strains due to closure movements at the drainage lines which are directly mined beneath by the proposed Longwalls 37 and 38 are expected to exceed 2 mm/m.

It is possible, therefore, that some compressive buckling and dilation of the uppermost bedrock could occur along the alignments of Mallaty Creek and, to a lesser extent, along the alignments of Nepean Creek and the tributaries within the Study Area. It has been observed in the past, that the depth of buckling and dilation of the uppermost bedrock, resulting from valley related movements, is generally less than 10 to 15 metres.

Where the drainage lines have natural surface soil beds above the sandstone bedrock, it is unlikely that fracturing in the bedrock would be seen at the surface. In the event that surface cracking occurs in these locations within the alignments of the drainage lines, the cracks are likely to be filled with the natural soils during subsequent flow events.

Where the bases of the drainage lines have exposed bedrock, there may be some diversion of surface water flows into the dilated strata beneath them and the draining of the pools which exist within the alignments. It is unlikely that there would be any net loss of water from the catchment, however, as the depth of dilation in rivers and creeks has generally been observed in the past to be less than 10 to 15 metres and, therefore, any diverted surface water is likely to re-emerge into the catchment further downstream.

The drainage lines are ephemeral and so water typically flows during and for periods of time after each rain event. In times of heavy rainfall, the majority of the runoff would flow over the beds and would not be diverted into the dilated strata below. In times of low flow, however, a larger percentage of the water would be diverted into the dilated strata below the beds and this could affect the quality and quantity of the water flowing in the drainage lines. It is unlikely, however, that this would result in a significant impact on the overall quantity and quality of water flowing from the catchment.

The maximum predicted curvatures and the range of potential strains at the drainage lines, resulting from the extraction of the proposed longwalls, are similar to those typically experienced elsewhere in the Southern Coalfield. Longwalls in the Southern Coalfield have been successfully mined directly beneath drainage lines in the past, and some of these cases are provided in Table 5.13.

**Table 5.13 Examples of Previous Experience of Mining Beneath Drainage Lines in the Southern Coalfield**

| Longwalls | Drainage Lines | Observed Movements | Observed Impacts |
|---|---|---|---|
| Appin Area 3<br>Longwalls 301 and 302 | 2.7 kilometres of drainage lines and tributaries directly mined beneath | 650 mm Subsidence<br>4.5 mm/m Tilt<br>1 mm/m Tensile Strain<br>3 mm/m Comp. Strain<br>(Measured M & N-Lines) | No reported fracturing which resulted in surface water flow diversions |
| Appin Area 4<br>Longwalls 401 to 409 | 3.8 kilometres of drainage lines directly mined beneath, including Creek 2A, Rocky Ponds Creek and Simpsons Creek | 700 mm Subsidence<br>5 mm/m Tilt<br>1 mm/m Tensile Strain<br>2 mm/m Comp. Strain<br>(Measured A6000-Line) | No reported fracturing which resulted in surface water flow diversions |
| Appin Area 7<br>Longwalls 701 to 703 | 1.5 kilometres of drainage lines directly mined beneath | 1000 mm Subsidence<br>7 mm/m Tilt<br>1 mm/m Tensile Strain<br>3 mm/m Comp. Strain<br>(Measured MPR-Line) | No reported fracturing which results in surface water flow diversions |
| West Cliff Area 5<br>Longwalls 29 to 33 | 4.2 kilometres of drainage lines directly mined beneath, including Unnamed, Ousedale and Mallaty Creeks | 1000 mm Subsidence<br>5.5 mm/m Tilt<br>1 mm/m Tensile Strain<br>5.5 mm/m Comp. Strain<br>(Measured B-Line) | Fracturing observed in the base of Mallaty Creek, loss of water holding capacity in one pool. |

Based on the previous experience of mining beneath drainage lines in the Southern Coalfield, it is likely that some fracturing will occur along the drainage lines, particularly those located directly above or adjacent to the proposed longwalls. It is unlikely, however, that there would be any net loss of water from the catchment. The predicted mine subsidence movements and, hence, the assessed impacts for the drainage lines are similar to or less than that assessed in the Bulli Seam Operations Environmental Assessment.

Further discussions on the potential impacts of surface cracking and changes in surface water flows are provided in the reports by Ecoengineers (2013), *Cardno Ecology Lab* (2013) and *Niche* (2013a).

***Potential Impacts on Water Quality***

Mine subsidence can potentially impact on the quality of water in streams due to leaching of minerals from freshly fractured bedrock and from increased inputs from groundwater to surface flow. Such impacts tend to be temporary, localised and associated with low flow conditions. An investigation into the potential impacts of mine subsidence on water quality in the creeks has been undertaken and described in the report by *Ecoengineers* (2013).

***Potential Impacts on Flora and Fauna***

Mine subsidence can potentially impact on flora and fauna within the alignments of streams. Flora could be adversely affected by the emission of gas at the surface and habitats can be affected by the fracturing of bedrock and the cracking of soils. The potential impact of mine subsidence on flora and fauna are provided in the reports by *Cardno Ecology Lab* (2013) and *Niche* (2013a).

### 5.3.3. Impact Assessments for the Drainage Lines Based on Increased Predictions

If the predicted conventional tilts along the alignments of the drainage lines were increased by factors of up to 2 times, the maximum predicted changes in gradient would be in the order of 1 %, which is still small when compared to the existing natural gradients. It is possible that there could be localised areas along the drainage lines which could experience a small increase in the levels of ponding and flooding, however, any changes are expected to be minor and not result in a significant impact on the drainage lines.

If the predicted conventional strains at the drainage lines were increased by factors of up to 2 times, the likelihood and extent of cracking in the beds and the likelihood and extent of fracturing and dilation in the bedrock would increase accordingly directly above the proposed longwalls. The predicted conventional strains would still be less than those predicted along the drainage lines above Dendrobium Longwalls 1 and 2, where minor fracturing was observed in only one of the six drainage lines directly mined beneath.

If the predicted valley related movements at the drainage lines were increased by factors of up to 2 times, the likelihood and extent of fracturing and dilation of the uppermost bedrock would increase accordingly directly above and adjacent to the proposed longwalls. It should be noted, however, that the method used to predict the valley related movements adopts very conservative prediction curves and it is unlikely, therefore, that these movements would be exceeded by any more than 15 %.

#### 5.3.4. Recommendations for the Drainage Lines

It is recommended that the drainage lines are visually monitored during the extraction of the proposed longwalls. It is also recommended that management strategies are developed for the drainage lines, such that any impacts can be identified and managed accordingly. With these strategies in place, it is unlikely that there would be a significant impact on the drainage lines resulting from the extraction of the proposed longwalls.

## 5.4. Aquifers and Known Groundwater Resources

There are no *Ground Water Management Areas*, as defined by the Department of Environment, Climate Change and Water, within the Study Area. There are, however, groundwater resources within the Study Area, which are extracted using groundwater bores, the locations of which are shown in Drawing No. MSEC533-22 and details provided in Section 8.11. Further discussions on the groundwater within the Study Area are provided in the report by *Geoterra* (2013).

## 5.5. Springs

No natural springs or groundwater seeps have been identified along the Georges River or along the drainage lines within the Study Area. Further details on the surface and groundwater within the Study Area are provided in the reports by *Ecoengineers* (2013) and *Geoterra* (2013).

## 5.6. Sea or Lake

There are no seas, or lakes within the Study Area.

## 5.7. Shorelines

There are no shorelines within the Study Area.

## 5.8. Natural Dams

There are no natural dams within the Study Area. There are, however, a number of farm dams within the Study Area, which are described in Section 8.10.

## 5.9. Cliffs

The locations of the cliffs within the Study Area are shown in Drawing No. MSEC533-10. The descriptions, predictions and impact assessments for the cliffs are provided in the following sections.

#### 5.9.1. Descriptions of the Cliffs

For the purposes of this report, a cliff has been defined as a continuous rockface having a minimum height of 10 metres and a minimum slope of 2 to 1, i.e. having a minimum angle to the horizontal of 63°. The locations of cliffs within the Study Area were determined from site investigations, from the orthophotograph and from the 1 metre surface level contours which were generated from an aerial laser scan of the area.

The cliffs within the Study Area are generally located within the valley of the Georges River and associated tributaries. There are also rock outcrops which are located along the Georges River, which are discussed in Section 5.10.

The cliffs have formed from the Hawkesbury Sandstone Sedimentary Group. The locations of the cliffs within the vicinity of the Study Area are shown in Drawing No. MSEC533-10 and details are provided in Table 5.14.

**Table 5.14 Details of Cliffs within Vicinity of the Study Area**

| Cliff Ref. | Overall Length (m) | Maximum Height (m) | Description |
|---|---|---|---|
| GR-CL01 | 65 | 15 | Along Georges River approximately 250 metres west of Longwall 38 and 180 metres south east of Longwall 35 |
| GR-CL02 | 80 | 10 | Along Georges River approximately 14 metres south east of Longwall 37 |

### 5.9.2. Predictions for the Cliffs

A summary of the maximum predicted total conventional subsidence parameters at the cliffs, resulting from the extraction of the proposed longwalls, is provided in Table 5.15.

**Table 5.15 Maximum Predicted Total Conventional Subsidence Parameters Cliffs Resulting from the Extraction of the Proposed Longwalls**

| Cliff Ref. | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| GR-CL01 | 25 | <0.5 | <0.01 | <0.01 |
| GR-CL02 | 125 | 1.3 | 0.02 | <0.01 |

The predicted tilts and curvatures provided in the above table are the maxima at any time during or after the extraction of each of the proposed longwalls.

The cliffs are located along the Georges River valley and are outside the extents of longwall mining and, therefore, the strains are expected to be in the range of those measured above solid coal during previous longwall mining. The distribution of strain measured in survey bays located above solid coal during the mining of previous longwalls in the Southern Coalfield is illustrated in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous and valley related movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the cliffs, based on applying a factor of 15 to the maximum predicted conventional curvatures, are less than the order of survey tolerance (i.e. less than 0.2 mm/m).

### 5.9.3. Comparison of Predictions for the Cliffs with those provided in the Part 3A Application

There were no cliffs identified in the West Cliff Area 5 domain during preparation of the Part 3A Application report. The cliffs shown in Drawing No. MSEC533-10 were identified at a later date.

### 5.9.4. Impact Assessments for the Cliffs

The identified cliffs are not located above the proposed longwalls. The cliff closest to the proposed longwalls is Cliff Ref. GR-CF02, which is located approximately 25 metres south-east of the finishing end of the Longwall 37.

The maximum predicted conventional tilt at the cliffs, resulting from the extraction of the proposed longwalls, is 1.3 mm/m (i.e. 0.1 %), or a change in grade of 1 in 770, which occurs at Cliff Ref. GR-CF02.

Tilt does not directly induce differential movements along cliffs, which is the main cause of cliff instabilities. Tilt, however, can increase the overturning moments in steep or overhanging cliffs which, if of sufficient magnitude, could result in toppling type failures. The predicted maximum tilts at the cliffs within the Study Area are very small in comparison to the existing slopes of the cliff faces and are unlikely, therefore, to result in toppling type failures in these cases.

It is possible, however, that if the conventional curvatures and strains are of sufficient magnitude, sections of rock could fracture along existing bedding planes or joints and become unstable, resulting in sliding or toppling type failures along the cliffs, especially during or after heavy rainfall events.

The maximum predicted ground curvature at the cliffs, resulting from the extraction of the proposed longwalls, is 0.02 $km^{-1}$, which represent a minimum radius of curvature of greater than 50 kilometres.

The cliffs could also be subjected to valley related movements resulting from the extraction of the proposed longwalls. The predicted profiles of the upsidence and closure movements along the Georges River, resulting from the extraction of the proposed longwalls, are shown in Fig. E.03, in Appendix E.

The maximum predicted upsidence and compressive strain due to closure movements occur in the bases of the valleys and are unlikely, therefore, to result in impacts on the cliffs, which are located up the valley sides. Closure movements tend to be bodily movements of the valley sides, however, stresses can be induced in the strata where differential closure movements occur around bends in the river valley. It can be seen from Drawing No. MSEC533-10, however, that the cliffs in the vicinity of the proposed longwalls are relatively straight.

It is extremely difficult to assess the likelihood of cliff instabilities based upon predicted ground movements. The likelihood of a cliff becoming unstable is dependent on a number of factors which are difficult to fully quantify. These factors include jointing, inclusions, weaknesses within the rock mass, groundwater pressure and seepage flow behind the rockface. Even if these factors could be determined, it would still be difficult to quantify the extent to which these factors may influence the stability of a cliff naturally or when it is exposed to mine subsidence movements. It is therefore possible that cliff instabilities may occur during mining that may be attributable to either natural causes, mine subsidence or both.

The likelihood of cliff instabilities within the Study Area can be assessed using case studies where previous longwall mining has occurred close to but not directly beneath cliffs. Although rock falls have been observed over solid coal outside the extracted goaf areas of longwall mining in the Southern Coalfield, there have been no recorded cliff instabilities outside the extracted goaf areas of longwall mining in the Southern Coalfield. This statement is based on the following observations:-

- *Appin Longwalls 301 and 302 near the Cataract River*

  Appin Longwalls 301 and 302 mined adjacent to a number of cliff lines located along the Cataract River gorge. A total of 68 cliffs were identified within a 35 degree angle of draw from the longwalls. The cliffs had continuous lengths ranging between 5 metres and 230 metres, overall heights ranging between 10 metres and 37 metres and had been formed within the Hawkesbury Sandstone.

  Appin Longwalls 301 and 302 have void widths of 260 metres, solid chain pillar widths of 40 metres and were extracted from the Bulli Seam at a depth of cover of 500 metres.

  Appin Longwalls 301 and 302 mined to within 50 metres of the identified locations of the cliffs along the Cataract River valley.

  There were no cliff instabilities observed as a result of the extraction of Appin Longwalls 301 and 302. There were, however, five minor rock falls or disturbances which occurred during the mining period, of which, three were considered likely to have occurred due to a significant rainfall event and natural instability of the cliff/overhang. The width of cliff line disturbed as a result of the extraction of Appin Longwalls 301 and 302 was, therefore, estimated to be less than 1 % of the total plan length of cliff line within the area.

- *Tower Longwalls 18 to 20 and Appin Longwalls 701 and 702 near the Nepean River*

  Tower Longwalls 18 to 20 and Appin Longwalls 701 and 702 mined adjacent to a number of cliff lines located along the Nepean River valley. A total of 45 cliffs were identified within a 35 degree angle of draw from the longwalls. The cliffs had continuous lengths ranging between 5 metres and 225 metres, overall heights ranging between 10 metres and 40 metres and had been formed within the Hawkesbury Sandstone.

  Appin Longwalls 701 and 702 have void widths of 320 metres, solid chain pillar widths of 40 metres and were extracted from the Bulli Seam at a depth of cover of 500 metres.

  Appin Longwalls 701 and 702 mined to within 75 metres of the identified locations of the cliffs along the Nepean River valley. Tower Longwall 20 mined directly beneath some cliffs located at the confluence of Elladale Creek and the Nepean River.

  There were no cliff instabilities observed as a result of the extraction of Tower Longwalls 18 to 20 and Appin Longwalls 701 and 702.

Based on the history of mining at Appin and Tower Collieries, it is possible that isolated rock falls could occur as a result of the extraction of the proposed longwalls. It is not expected, however, that any large cliff instabilities would occur as a result of the extraction of the longwalls, as the longwalls are not proposed to be extracted directly beneath the cliffs.

While the risk of cliff instability is extremely low, some risk remains and attention must therefore be paid to any structures or roads that may be located in the vicinity of the cliffs. There is an access track located in the vicinity cliff GR-CF02 along the Georges River, which is shown in Drawing No. MSEC533-11. Given the potential for severe consequences from any rock falls, it is recommended that IC, in consultation with landowners, develop management measures to ensure that their properties remain safe and serviceable throughout the mining period. The management plan may require input from structural, geotechnical and subsidence engineers. The management measures may include:-

- Avoidance of use during the active mining period,
- Site investigation of the cliffs and structures by qualified structural and geotechnical engineers,
- Consideration and possible implementation of mitigation measures to reduce the potential for impacts,
- Detailed monitoring of absolute and differential movements of the ground and the structures,
- Regular review and assessment of the monitoring data, and
- Implementation of planned responses if triggered by monitoring and inspections.

#### 5.9.5. Impact Assessments for the Cliffs Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the cliffs would be 2.6 mm/m (i.e. 0.3 %), or a change in grade of 1 in 390. The tilts at the cliffs would still be extremely small in comparison with the existing slopes of the rockfaces, which exceed 2 to 1. In addition to this, tilt does not directly induce differential movements along cliffs, which is the main cause of cliff instabilities and, therefore, the potential for impacts would not be expected to significantly increase.

If the actual curvatures exceeded those predicted by a factor of 2 times, the maximum curvature at the cliffs would be 0.04 $km^{-1}$, which represents a minimum radius of curvature of 25 kilometres. The curvatures at the cliffs would still be small and, therefore, the likelihood of cliff instabilities would not be expected to increase significantly.

While the predicted ground movements are important parameters when assessing the potential impacts on the cliffs, it is noted that the impact assessments for cliff instabilities have primarily been based on historical observations from previous longwall mining in the Southern Coalfield. The overall levels of impact on the cliffs, resulting from the extraction of the proposed longwalls, are expected to be similar to those observed where longwalls have previously mined close to but not directly beneath the cliffs in the Southern Coalfield.

In any case, the levels of impact on the cliffs within the Study Area are expected to be much less than that observed where previous longwall mining has occurred directly beneath cliffs in the Southern Coalfield. An example of this is Tower Longwalls 1 to 17, which were mined beneath approximately 5 kilometres of cliffline within the Cataract River and Nepean River gorges. There were a total of 10 cliff instabilities recorded along these valleys which represents approximately 4 % of the total length of the clifflines directly mined beneath.

#### 5.9.6. Recommendations for the Cliffs

It is recommended that appropriate management strategies are put in place to ensure the safety of people that may be within the vicinity of the cliffs during the mining period. With these measures in place, it is unlikely that there would be a significant impact associated with the cliffs resulting from the extraction of the proposed longwalls.

It is recommended that the cliffs should be visually monitored during the mining period from a safe location. It is also recommended that the existing condition of cliffs within the Study Area should be documented and photographed prior to mining.

### 5.10. Rock Outcrops

The descriptions, predictions and impact assessments for the rock outcrops are provided in the following sections.

#### 5.10.1. Descriptions of the Rock Outcrops

There are rock outcrops located across the Study Area predominantly within the stream valleys, particularly the Georges River. The central and western parts of the Study Area surrounding Longwall 37 comprise predominantly shales and sandstones of the Wianamatta Group and rock outcrops in this area are uncommon. For the purposes of this report, a rock outcrop has been defined as an isolated rockface having a height of less than 10 metres. Rockfaces with heights between 5 metres and 10 metres have been identified along the Georges River and are shown in Drawing No. MSEC533-10. Rockfaces having minimum heights of 10 metres and minimum slopes of 2 to 1 have been defined as cliffs in this report, which are discussed in Section 5.9.

#### 5.10.2. Predictions for the Rock Outcrops

The rock outcrops located above the proposed and existing longwalls are expected to experience the full range of subsidence movements. The rock outcrops located outside the longwall footprints are expected to experience low level subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The rock outcrops are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the rock outcrops, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.2 mm/m tensile and 1.8 mm/m compressive.

#### 5.10.3. Impact Assessments for the Rock Outcrop

The extraction of the proposed longwalls is likely to result in some fracturing of the rock outcrops predominantly where the rock outcrops are located above the existing and proposed longwalls and, where the rock is marginally stable, could then result in instabilities. Previous experience in the Southern Coalfield indicates that the percentage of rock outcrops that are likely to be impacted by mining is very small. The potential for isolated rockfalls, however, could result in a public safety risk where houses or infrastructure are located beneath large rock outcrops.

#### 5.10.4. Impact Assessments for the Rock Outcrops Based on Increased Predictions

If the actual subsidence movements exceeded those predicted by a factor of 2 times, the extent of fracturing and, hence, the incidence of impacts would increase for the rock outcrops located directly above the proposed longwalls. The incidence of impacts on the rock outcrops (i.e. not including the large cliff lines) was small at Dendrobium Mine, where the predicted curvatures and ground strains were 2 to 5 times those predicted within the Study Area. Based on this previous experience, it would be expected that the incidence of impacts on the rock outcrops in the Study Area would still be small if the actual movements exceeded those predicted.

#### 5.10.5. Recommendations for the Rock Outcrops

It is recommended that appropriate management strategies are put in place to ensure the safety of people that may be within the vicinity of the rock outcrops during the mining period. With these measures in place, it is unlikely that there would be a significant impact associated with the rock outcrops resulting from the extraction of the proposed longwalls.

### 5.11. Steep Slopes

The locations of the steep slopes within the Study Area are shown in Drawing No. MSEC533-07. The descriptions, predictions and impact assessments for the steep slopes are provided in the following sections.

#### 5.11.1. Descriptions of the Steep Slopes

For the purposes of this report, a steep slope has been defined as an area of land having a natural gradient greater than 1 in 3 (i.e. a grade of 33 %, or an angle to the horizontal of 18°). The reason for identifying steep slopes is to highlight areas in which existing ground slopes may be marginally stable.

The steep slopes within the Study Area were identified from the 1 metre surface contours which were generated from an airborne laser scan of the area. The areas identified as having steep slopes are shown in Drawing No. MSEC533-07. It can be seen from this drawing that the steep slopes are predominantly located along the alignment of the Georges River and its tributaries. Isolated steep slopes have been identified over the existing Longwalls 35 and 36.

### 5.11.2. Predictions for the Steep Slopes

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature at the steep slopes, resulting from the extraction of the proposed longwalls, is provided in Table 5.16.

**Table 5.16 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature at the Steep Slopes Resulting from the Extraction of the Proposed Longwalls**

| Location | Longwall | Maximum Predicted Conventional Subsidence (mm) | Maximum Predicted Conventional Tilt (mm/m) | Maximum Predicted Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|---|
| Over LW35 and LW36 | After LW37 | 1130 | 5.9 | 0.07 | 0.11 |
| | After LW38 | 1130 | 5.9 | 0.07 | 0.11 |
| Along Georges River and Tributaries | After LW37 | 780 | 5.4 | 0.05 | 0.11 |
| | After LW38 | 820 | 5.6 | 0.05 | 0.12 |

The predicted tilts provided in the above table are the maxima after the completion of each of the proposed longwalls. The predicted curvatures provided in the above table are the maxima at any time during or after the extraction of each of the proposed longwalls.

The steep slopes are planar features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines above previous longwall mining. The analysis of strains along whole monitoring lines during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4 and the results are provided in Fig. 4.4.

Non-conventional movements can also occur and have occurred in NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the steep slopes, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.2 mm/m tensile and 1.8 mm/m compressive.

### 5.11.3. Comparison of Predictions for the Steep Slopes with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for steep slopes with those provided in the Part 3A Application is provided in Table 5.17.

**Table 5.17 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Steep Slopes Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 1130 | 5.9 | 0.07 | 0.12 |

It can be seen from the above table, that the maximum predicted mine subsidence movements at the steep slopes, based on the Extraction Plan Layout, are similar to or slightly less than those predicted based on the Part 3A Layout.

### 5.11.4. Impact Assessments for the Steep Slopes

The maximum predicted tilt at the steep slopes, resulting from the extraction of the proposed longwalls, is 5.9 mm/m (i.e. 0.6 %), which represents a change in grade of 1 in 165.

The predicted changes in grade are small when compared to the natural grades of the steep slopes, which are greater than 1 in 3 and, therefore, the tilts are unlikely to result in any significant impact on the stability of the steep slopes.

The steep slopes are more likely to be impacted by ground curvatures and strains. The potential impacts would generally result from the down slope movement of the soil, causing tension cracks to appear at the tops and on the sides of the slopes and compression ridges to form at the bottoms of the slopes.

The maximum predicted ground curvatures for the steep slopes, resulting from the extraction of the proposed longwalls, are 0.07 $km^{-1}$ hogging and 0.12 $km^{-1}$ sagging, which represent minimum radii of curvature of 14 kilometres and 8 kilometres, respectively. The maximum predicted ground curvatures at the steep slopes are similar to those typically experienced in the Southern Coalfield. The potential impacts on the steep slopes within the Study Area, therefore, are expected to be similar to those previously observed in the Southern Coalfield.

No large-scale slope failures have been observed along steep slopes in the Southern Coalfield, even where longwalls have been mined directly beneath them. Although no large-scale slope failures have been observed in the Southern Coalfield, tension cracking has been observed at the tops and on the sides of steep slopes as the result of downslope movements.

Cracks resulting from downslope movements at depths of cover greater than 400 metres, such as the case in the Study Area, are generally isolated and narrow, typically having maximum widths in the order of 50 mm. Larger cracks have been observed at the tops of very steep slopes and adjacent to large rock formations, where maximum crack widths in the order of 100 mm to 150 mm have been observed at depths of cover greater than 400 metres, such as the case in the Study Area. A photograph of a tension crack near the top of a steep slope is provided in Fig. 5.16.

**Fig. 5.16 Example of Surface Tension Cracking along the Top of a Steep Slope**

The majority of the steep slopes along the Georges River valley and associated tributaries are not directly mined beneath by the proposed longwalls. It is likely, therefore, that only minor cracking would occur near the tops of these steep slopes.

If tension cracks were to develop, as the result of the extraction of the proposed longwalls, it is possible that soil erosion could occur if these cracks were left untreated. It is possible, therefore, that some remediation might be required, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the slopes in the longer term.

While in most cases, impacts on steep slopes are likely to consist of surface cracks, there remains a low probability of large-scale downslope movements. Experience indicates that the probability of mining induced large-scale slippages is extremely low due to the significant depth of cover within the Study Area.

While the risk is extremely low, some risk remains and it is recommended any features or items of infrastructure that are located in the vicinity of steep slopes directly above the proposed longwalls are monitored. Features which should be monitored include:-

- Houses,

- Local roads,
- Low voltage powerlines, and
- The optical fibre cable and copper cables.

The locations of the surface infrastructure in the vicinity of steep slopes are shown in Drawing No. MSEC533-11 to MSEC533-15. The risks associated with the proximity of the steep slopes are discussed in the impact assessments for each item of infrastructure.

#### 5.11.5. Impact Assessments for the Steep Slopes Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the steep slopes would be 12 mm/m (i.e. 1.2 %), which represents a change in grade of 1 in 85. The tilts at the steep slopes would still be small in comparison with the existing natural grades, which exceed 1 in 3.

If the actual curvatures exceeded those predicted by a factor of 2 times, the maximum curvature at the steep slopes would be 0.24 $km^{-1}$, which represents a minimum radius of curvature of 4 kilometres. The curvature at the steep slopes would still be less than those predicted to have occurred as the result of the extraction of the longwalls in Dendrobium Areas 1 and 2, which mined directly beneath ridgelines having natural steep slopes up to 1.2 in 1. Whilst large tensile cracks were observed near the tops of the steep slopes, in the order of 300 mm, there were no reports of slope instabilities.

Any surface cracking which could lead to erosion or other impacts could be remediated by infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. In some cases, additional erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the slopes in the longer term.

#### 5.11.6. Recommendations for the Steep Slopes

It is recommended that appropriate management strategies are put in place to ensure protection of the soil surface from erosion and the safety of people that may be within the vicinity of the steep slopes during the mining period. With these measures in place, it is unlikely that there would be a significant impact associated with the steep slopes resulting from the extraction of the proposed longwalls.

## 5.12. Escarpments

There are no escarpments located within the Study Area.

## 5.13. Land Prone to Flooding and Inundation

There are areas prone to flooding or inundation within the Georges River valley. Discussions on the increased likelihoods of ponding and flooding along the river are provided in Section 5.2.

## 5.14. Swamps, Wetlands and Water Related Ecosystems

There are no swamps or wetlands within the Study Area. There are water related ecosystems within the Study Area associated with the major watercourses, including the Georges River and the major tributaries. Discussions on the water related ecosystems are provided in the reports by *Niche* (2013a) and *Cardno Ecology Lab* (2013).

## 5.15. Threatened, Protected Species or Critical Habitats

There are no lands within the Study Area that have been declared as critical habitat under the *Threatened Species Conservation Act 1995*. There are, however, threatened and protected species within the Study Area which are described in the report by *Niche* (2013a) and *Cardno Ecology Lab* (2013).

## 5.16. National Parks or Wilderness Areas

There are no National Parks nor any land identified as wilderness under the Wilderness Act 1987 within the Study Area.

## 5.17. State Recreational or Conservation Areas

The Dharawal State Recreation Area is located above the central part of the proposed Longwall 38 as shown on Drawing No. MSEC533-01. The Dharawal State Recreation Area is bounded to the west by the Georges River and to the north and south by private land.

## 5.18. Natural Vegetation

The extent of natural vegetation can be seen from the aerial photograph provided in Fig. 1.1. The locations of the *Endangered Ecological Communities* are indicated on Drawing No. MSEC533-07. A survey of the natural vegetation within the Study Area has been undertaken and details are provided in the report by *Niche* (2013a).

### 5.18.1. Areas of Significant Geological Interest

There are no areas of significant geological interest within the Study Area.

### 5.18.2. Any Other Natural Feature Considered Significant

There are no other natural features considered significant within the Study Area.

## 6.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC UTILITIES

The following sections provide the descriptions, predictions and impact assessments for the Public Utilities within the Study Area.

### 6.1. Railways

There are no railways located with the Study Area. The nearest railway is the Main Southern Railway which is over 4km to the west of the commencing end of Longwall 37.

### 6.2. Appin Road

The location of Appin Road is shown in Drawing No. MSEC533-11. The predictions and impact assessments for the road are provided in the following sections.

#### 6.2.1. Predictions for Appin Road

The predicted profiles of incremental and total conventional subsidence, tilt and curvature along the alignment of Appin Road, resulting from the extraction of the proposed longwalls, are shown in Fig. E.14 in Appendix E. A summary of the maximum predicted values of incremental and total conventional subsidence, tilt and curvature along the alignment of the road within the Study Area, resulting from the extraction of Longwall 37, are provided in Table 6.1. Longwall 38 is approximately 900 metres to the west of Appin Road at the southern end of the longwall and approximately 1300 metres from Appin Road at the northern end. At these distances, there are no significant predicted conventional subsidence movements due to the extraction of Longwall 38, therefore prediction results for Longwall 37 only have been presented.

**Table 6.1 Maximum Predicted Incremental and Total Conventional Subsidence, Tilt and Curvature along the Alignment of Appin Road Resulting from the Extraction of Longwall 37**

| | Maximum Predicted Subsidence (mm) | Maximum Predicted Tilt (mm/m) | Maximum Predicted Hogging Curvature ($km^{-1}$) | Maximum Predicted Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| Predicted Incremental Parameters Due to LW37 | 760 | 5.5 | 0.06 | 0.11 |
| Predicted total Parameters After LW37 | 1080 | 6.2 | 0.07 | 0.12 |

The values provided in the above table are the maximum predicted incremental and total conventional subsidence parameters along Appin Road within the Study Area. The maximum predicted incremental conventional subsidence of 760 mm occurs above the proposed Longwall 37. The maximum predicted total conventional subsidence of 1080 mm occurs above Longwall 36 and the additional predicted subsidence due to Longwall 37 at this location is approximately 290 mm.

The predicted tilts provided in the above table are the maxima after the completion of each of the proposed longwalls. The maximum predicted incremental and total conventional tilt occur above Longwall 37. The predicted curvatures provided in the above table are the maxima at any time during or after the extraction of each of the proposed longwalls. The maximum predicted incremental and total conventional curvatures occur above Longwall 37.

The road will also be subjected to travelling tilts and curvatures as the extraction faces of the proposed longwall passes beneath it. A summary of the maximum predicted travelling tilts and strains at the road, during the extraction of proposed longwall, is provided in Table 6.2.

**Table 6.2 Maximum Predicted Travelling Tilt and Curvature along the Alignment of Appin Road Resulting from the Extraction of Longwall 37**

| | Maximum Predicted Travelling Tilt (mm/m) | Maximum Predicted Travelling Hogging Curvature ($km^{-1}$) | Maximum Predicted Travelling Sagging Curvature ($km^{-1}$) |
|---|---|---|---|
| Predicted Travelling Parameters Due to LW37 | 2.7 | 0.03 | 0.02 |

Appin Road follows a ridgeline within the Study Area and does not cross any significant drainage lines. It is unlikely, therefore, that the road would be subjected to any significant valley related upsidence or closure movements resulting from the extraction of the proposed longwalls.

#### 6.2.2. Comparison of Predictions for Appin Road with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for Appin Road with those provided in the Part 3A Application is provided in Table 6.5.

**Table 6.3 Comparison of the Maximum Predicted Conventional Subsidence Parameters for Appin Road Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt Along Alignment (mm/m) | Maximum Predicted Total Conventional Hogging Curvature in Any Direction ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature in Any Direction ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1100 | 5.8 | 0.06 | 0.10 |
| Extraction Plan Layout (Report No. MSEC533) | 1080 | 6.2 | 0.07 | 0.12 |

It can be seen from the above table, that the maximum predicted mine subsidence movements at Appin Road, based on the Extraction Plan Layout, are similar to those predicted based on the Part 3A Layout.

#### 6.2.3. Impact Assessments for Appin Road

The maximum predicted conventional tilt along Appin Road within the Study Area, at any time during or after the extraction of Longwall 37, is 6.2 mm/m (i.e.: 0.6 %), or a change in grade of 1 in 160. The existing gradients along the alignment of the road within the Study Area vary up to approximately 50 mm/m (i.e.: 5 %), with an average existing gradient of approximately 15 mm/m (i.e.: 1.5 %).

It is unlikely, therefore, that the predicted conventional tilts along the road would result in significant changes in surface water drainage, as the maximum predicted change in grade is less than 1 % and is much less than the typical existing gradients along the alignment of the road within the Study Area.

The maximum predicted conventional hogging and sagging curvature along the road within the Study Area, at any time during or after the extraction of the proposed longwalls, are 0.07 $km^{-1}$ and 0.12 $km^{-1}$, respectively. The minimum radii of curvatures associated with the maximum predicted hogging and sagging curvatures are 14 kilometres and 8 kilometres, respectively.

The road is of flexible construction with a bitumen seal and is likely to tolerate curvatures of these magnitudes without significant impact. It is possible that minor cracking could occur in some places along the road, due to localised concentrations of tensile strains, and that minor rippling of the road surface could occur in other places, due to localised concentrations of compressive strains.

As the magnitudes of the maximum predicted curvatures are relatively low, any such impacts are likely to be infrequent occurrences and of a minor nature. It is recommended that any impacts are remediated using normal road maintenance techniques. With these remediation measures implemented, it is expected that the road can be maintained in a safe and serviceable condition throughout the mining period.

Previous Longwalls 32, 33 and 34 have been successfully extracted beneath Appin Road providing examples of the types of impacts that may be experienced due to the extraction of Longwall 37. The void width of Longwall 37 is slightly narrower (23 metres less) than these previously extracted longwalls but the incremental values of the predicted subsidence, tilt and curvature for Longwall 37 are of a similar order of magnitude to these previously extracted longwalls.

The surface impacts resulting from the extraction of the previous Longwalls 32, 33 and 34 included small compression bumps in the road pavement, and the opening of minor cracks along and across the road surface. Some spalling and buckling of a concrete gutter was also observed. Photographs of the types of impacts are provided in Fig. 6.1 to Fig. 6.4.

The impacts that required remedial measures consisted of humps in the road surface which formed at the locations of irregular movements. Remedial measures comprised milling and resheeting of the road surface for the impacts during the extraction of Longwalls 32 and 33. The section of the northbound lane of Appin

Road over longwall 34 was reported to contain Heavily Bound Basecourse (HBB). As a result of this type of construction, the addition of slots, cut across the longitudinal direction of the road pavement were included with the remedial measures undertaken during the extraction of Longwall 34. It is understood that the HBB layer was constructed over the length of the overtaking lane along this section of Appin Road in order to widen the road, and therefore extends over the footprint of Longwall 34 and part way into the Longwall 35 footprint.

The monitored subsidence that occurred during the extraction of Longwalls 32 and 33 was similar to but less than predicted. The monitored subsidence monitored during the extraction of Longwalls 34 was greater than the predicted subsidence by up to approximately 20 %. Whilst the irregular movements cannot be predicted, they occurred consistently during the extraction of Longwalls 32, 33 and 34. It is reasonable to therefore anticipate that similar irregular movements may occur during the extraction of Longwall 37.

**Fig. 6.1 Transverse Cracking (Photograph Courtesy of Colin Dove)**


**Fig. 6.2 Small compression bump (Photograph Courtesy of Colin Dove)**

**Fig. 6.3 Spalling of concrete kerb (Photograph Courtesy of Colin Dove)**

**Fig. 6.4 Shear cracking (Photograph Courtesy of Colin Dove)**

### 6.2.4. Impact Assessments for Appin Road Based on Increased Predictions

If the predicted conventional tilts were increased by factors of up to 2 times, the maximum predicted tilt at the road within the Study Area would be 12.4 mm/m (i.e.: 1.2 %), or a change in grade of 1 in 80. It would still be unlikely that the predicted tilts would result in significant changes in surface water drainage, as the maximum predicted change in gradient is still less than the typical existing gradients along the alignment of the road within the Study Area.

If the maximum predicted conventional curvatures were increased by factors of up to 2 times, the likelihood and extent of cracking in the road surface would increase. As the magnitudes of the maximum predicted curvature are relatively low, however, it would still be expected that any impacts could be easily repaired using normal road maintenance techniques. With these remediation measures implemented, it is expected that the road can be maintained in a safe and serviceable condition throughout the mining period.

The irregular movements encountered during monitoring along Appin Road during the extraction of Longwall 34 resulted in a maximum observed tilt approximately 2 times the maximum predicted tilt and a maximum observed compressive strain approximately 4 times the maximum predicted compressive strain. The pavement was maintained in a safe and serviceable condition during the extraction of Longwall 34.

### 6.2.5. Recommendations for Appin Road

It is recommended that the road be inspected on a regular basis as the proposed longwalls are mined beneath it so that any impacts can be identified and remediated accordingly. In this way, the road can be maintained in a safe and serviceable condition throughout the mining period. It is unlikely that the traffic signs and other road infrastructure would suffer any impact due to mine subsidence, however it is recommended that thes items are monitored along with the road pavement.

A management plan has been established for the public roads for Longwalls 34 to 36. It is recommended that the existing management plan be reviewed, in consultation with the Roads and Maritime Services and the Wollondilly Shire Council, and that amendments are made to the plan, where necessary, to include the predicted movements resulting from the extraction of Longwall 37.

## 6.3. The Local Roads

The locations of local roads within the Study Area are shown in Drawing No. MSEC553-11. The descriptions, prediction and impact assessments for the local roads within the Study Area are provided in the following sections.

The descriptions, predictions and impact assessments for the local road drainage culverts are provided in Section 6.6. The descriptions, predictions and impact assessments for Appin Road are provided in Section 6.2.

### 6.3.1. Descriptions of the Local Roads

Appin Road is the only public road and the only sealed road in the portion of the Study Area surrounding Longwall 37. There are three sealed public roads within the portion of the Study Area surrounding Longwall 38 which are shown in Drawing No. MSEC553-11.

The main local road within the Study Area Lysaght/Minerva Road which is located at the eastern edge of the Study Area and is approximately 230 metres to the east of Longwall 38 at its nearest point. Two smaller roads, Exley and Blackburn Roads, cross over the footprint of Longwall 38 and are approximately perpendicular to the longitudinal axis of the longwall. The local roads have single carriageways with bitumen seals and no kerb and gutter.

### 6.3.2. Predictions for the Local Roads

The predicted profiles of conventional subsidence, tilt and curvature along the alignment of Exley Road and Blackburn Road will be similar to the predicted profiles for Prediction Line 2, which is discussed in Section 4.2. The predicted profiles of conventional subsidence, tilt and curvature along Prediction Line 2, resulting from the extraction of the proposed longwalls, are shown in Fig. E02, in Appendix E.

A summary of the maximum predicted total conventional subsidence parameters for Prediction Line 2, after the extraction of the proposed longwalls, is provided in Table 6.4.

**Table 6.4 Maximum Predicted Total Conventional Subsidence Parameters for Prediction Line 2 after the Extraction of Each of the Proposed Longwalls**

| Location | Maximum Predicted Subsidence (mm) | Maximum Predicted Tilt Along Alignment (mm/m) | Maximum Predicted Hogging Curvature in Any Direction ($km^{-1}$) | Maximum Predicted Sagging Curvature in Any Direction ($km^{-1}$) |
|---|---|---|---|---|
| Prediction Line 2 | 630 | 4.0 | 0.03 | 0.07 |

The predicted tilts provided in the above table are the maxima along the alignment of the road after the completion of the proposed longwalls. The predicted curvatures provided in the above table are the maxima in any direction at any time during or after the extraction of the proposed longwalls.

Lysaght/Minerva Road is located outside the predicted 20 mm subsidence contour and as a result is expected to experience only minimal subsidence movements.

The local roads are linear features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines above previous longwall mining. The analysis of strains along whole monitoring lines during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4 and the results are provided in Fig. 4.4.

Non-conventional movements can also occur and have occurred in NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the local roads, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and 1 mm/m compressive.

### 6.3.3. Comparison of Predictions for the Roads with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for the local roads with those provided in the Part 3A Application is provided in Table 6.5.

**Table 6.5 Comparison of the Maximum Predicted Conventional Subsidence Parameters for Menangle Road Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt Along Alignment (mm/m) | Maximum Predicted Total Conventional Hogging Curvature in Any Direction ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature in Any Direction ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1300 | 7.0 | 0.09 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 630 | 4.0 | 0.03 | 0.07 |

It can be seen from the above table, that the maximum predicted mine subsidence movements at the local roads, based on the Extraction Plan Layout, are less than those predicted based on the Part 3A Layout.

### 6.3.4. Impact Assessments for the Local Roads

The maximum predicted conventional tilt along the alignment of Exley and Blackburn Roads, resulting from the extraction of the proposed longwalls, is 4.0 mm/m (i.e. 0.4 %), which represents a change in grade of 1 in 250.

The predicted tilts are less than 1 % and are unlikely, therefore, to result in any significant impacts on the serviceability or surface water drainage for the local roads. If any additional ponding or adverse changes in surface water drainage were to occur as the result of mining, the roads could be repaired using normal road maintenance techniques.

The maximum predicted conventional hogging and sagging curvatures at Exley and Blackburn Roads, resulting from the extraction of the proposed longwalls, are 0.03 $km^{-1}$ and 0.07 $km^{-1}$, respectively, which equate to minimum radii of curvatures of 35 kilometres and 14 kilometres, respectively.

The maximum predicted ground curvatures and the range of potential strains at the local roads, resulting from the extraction of the proposed longwalls, are less than those predicted for Appin Road which has been successfully mined beneath in the past.

The impacts to Appin Road are discussed in Section 6.2. These impacts did not present a public safety risk and were remediated using normal road maintenance techniques.

The predicted mine subsidence movements at the local roads within the Study Area are less than those observed and predicted at Appin Road which has been mined directly beneath by previously extracted longwalls. The overall levels of impact on the local roads in the Study Area are, therefore, expected to be significantly less than those observed along Appin Road from the previously extracted longwalls. It is expected, therefore, that the local roads can be maintained in a safe and serviceable condition throughout the mining period using normal road maintenance techniques.

### 6.3.5. Impact Assessments for the Local Roads Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the local roads would be 8 mm/m (i.e. 0.8 %), or a change in grade of 1 in 125. The potential impacts on the serviceability and surface water drainage of the roads would not be expected to significantly increase, as the maximum change in grade would still be less than 1 %. If any additional ponding or adverse changes in surface water drainage were to occur as the result of mining, the local roads could be repaired using normal road maintenance techniques.

If the actual curvatures exceeded those predicted by a factor of 2 times, the maximum curvature at the local roads would be 0.14 $km^{-1}$, which represents a minimum radius of curvature of 7 kilometres. In this case, the incidence of cracking, stepping and heaving of the local road surfaces would increase directly above the proposed longwalls. It would still be expected that any impacts could be repaired using normal road maintenance techniques.

While the predicted ground movements are important parameters when assessing the potential impacts on the local roads, it is noted that the impact assessments were primarily based on historical observations from previous longwall mining beneath Appin Road. The overall levels of impact on the local roads, resulting from the extraction of the proposed longwalls, are expected to be less than or similar to those observed where longwalls have previously mined directly beneath Appin Road.

### 6.3.6. Recommendations for the Roads

A management plan has been established for the public roads for Longwalls 34 to 36. It is recommended that the existing management plan be reviewed, in consultation with the Roads and Maritime Services and the Wollondilly Shire Council, and that amendments are made to the plan, where necessary, to include the local roads within the Study Area. With the implementation of these management strategies, it would be expected that the local roads could be maintained in safe and serviceable conditions during and after the extraction of the proposed longwalls.

## 6.4. Bridges

There are no bridges within the Study Area.

## 6.5. Tunnels

There are no tunnels within the Study Area.

## 6.6. Local Road Drainage Culverts

### 6.6.1. Descriptions of the Drainage Culverts

There are no identified drainage culverts on public land within the Study Area. There are, however, drainage culverts on private land. These drainage culverts could be subjected to the full range of predicted conventional subsidence movements.

### 6.6.2. Predictions for the Drainage Culverts

The maximum predicted conventional tilt within the Study Area is 6.5 mm/m (i.e.: 0.7 %), or a change in grade of 1 in 155. The maximum predicted conventional hogging and sagging curvatures within the Study Area, resulting from the extraction of the proposed longwalls, are 0.08 $km^{-1}$ and 0.12 $km^{-1}$, respectively, which equate to minimum radii of curvatures of 13 kilometres and 8 kilometres, respectively.

The drainage culverts are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in NSW Coalfields as a result of, among other things, valley related upsidence and closure movements and anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the drainage culverts anywhere across the Study Area, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.2 mm/m tensile and 1.8 mm/m compressive. The strains resulting from valley related movements are discussed separately in the following sections.

### 6.6.3. Comparison of Predictions for the Local Road Drainage Culverts with those provided in the Part 3A Application

Comparisons of the maximum predicted subsidence parameters, based on the Part 3A Layout, with those predicted based on the Extraction Plan Layout, are provided in Section 4.3.

### 6.6.4. Impact Assessments for the Local Road Drainage Culverts

The maximum predicted conventional tilt within the Study Area is 6.5 mm/m (i.e.: 0.7 %), or a change in grade of 1 in 155. It is expected that the local road drainage culverts will generally experience tilts less than this maximum, as the result of the variations in the predicted tilts across the Study Area and the orientations of the culverts relative to the subsidence trough.

The predicted changes in grade are small, less than 1 % and, therefore, are unlikely to result in any significant impacts on the serviceability of the local road drainage culverts. If the flow of water through any drainage culverts were to be adversely affected, as a result of the extraction of the proposed longwalls, this could be easily remediated by relevelling the affected culverts.

The maximum predicted ground curvatures within the Study Area, resulting from the extraction of the proposed longwalls, are 0.08 $km^{-1}$ and 0.12 $km^{-1}$, respectively, which equate to minimum radii of curvatures of 13 kilometres and 8 kilometres, respectively. It is expected that the local road drainage culverts will generally experience curvatures less than these maxima, as the result of variations in the predicted curvatures across the Study Area and the orientations of the culverts relative to the subsidence trough.

Previously extracted longwalls throughout NSW Coalfields have mined directly beneath drainage culverts. The incidence of impacts on drainage culverts has been found to be low, where the depths of cover were greater than 400 metres, such as the case within the Study Area. Impacts have generally been limited to cracking in the concrete headwalls which can be readily remediated. In some cases, however, cracking in the culvert pipes occurred which required the culverts to be replaced.

With remedial measures implemented, it is expected that the drainage culverts within the Study Area could be maintained in a serviceable condition throughout the mining period.

### 6.6.5. Impact Assessments for the Local Road Drainage Culverts Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the drainage culverts would be 13 mm/m (i.e. 1.3 %), or a change in grade of 1 in 80. The potential impacts on the serviceability and surface water drainage through the culverts would not be expected to significantly increase, as the maximum change in grade would still be small, in the order of 1 %. If any ponding or adverse changes in surface water drainage were to occur as the result of mining, the affected culverts could be replaced.

If the actual curvatures exceeded those predicted by a factor of 2 times, the maximum curvature at the local road drainage culverts would be 0.24 $km^{-1}$, which represents a minimum radius of curvature of 4 kilometres. In this case, the incidence of cracking in the culverts would increase, however, it would not be expected to affect the structural capacity or stability of the culverts. If any culverts were adversely impacted as a result of mining, the affected culverts could be replaced.

### 6.6.6. Recommendations for the Local Road Drainage Culverts

IC has developed a *Public Road Management Plan* for the longwalls at West Cliff and Appin Area 7 so as to manage the potential impacts on road drainage culverts. The potential impacts on the drainage culverts within the Study Area can be managed by periodic visual monitoring and the implementation of any necessary remedial measures. The ground movements will occur gradually as mining progresses, which will provide adequate time to repair or replace the culverts at the appropriate time, should these works be required.

It is recommended that the existing Public Road Management Plan be reviewed and, where required, revised to incorporate the culverts within the Study Area. With the implementation of these management strategies, it would be expected that the local road drainage culverts could be maintained in a safe and serviceable condition during and after the extraction of the proposed longwalls.

## 6.7. Macarthur Water Supply System

The 1200 mm diameter treated water gravity main, which forms part of the Macarthur Water Supply System, is located to the west of the Study Area and is approximately 690 metres from the commencing end of Longwall 37 at its nearest point. The location of the 1200 mm diameter water pipeline is shown on Drawing No. MSEC533-12. At this distance the water pipeline is unlikely to be subjected to significant conventional subsidence movements resulting from the extraction of the proposed longwalls but may experience minor far field effects resulting from the extraction of Longwall 37. Far field movements are discussed in Section 4.6.

The 1200 mm diameter water pipeline forms part of the Macarthur Water Supply System which was designed and constructed in 1994 to the Mine Subsidence Board's design requirements, which are summarised in Table 6.6.

**Table 6.6 Mine Subsidence Board Design Requirements for the 1200 mm Diameter Pipeline**

| Subsidence Parameter | Mine Subsidence Board Design Requirements |
|---|---|
| Vertical Subsidence (mm) | 1250 |
| Tilt (mm/m) | 8.0 |
| Tensile Strain (mm/m) | 1.5 |
| Compressive Strain (mm/m) | 2.5 |

### 6.7.1. Predictions for the 1200mm Diameter Water Pipeline

At 690 metres distance from Longwall 37 the water pipeline is unlikely to be subjected to any significant conventional subsidence movements resulting from the extraction of the proposed longwalls but may experience minor valley far field effects resulting from the extraction of Longwall 37. Far field movements are discussed in Section 4.6.

The pipeline crosses a number of streams and could be subjected to upsidence and closure movements at these locations, however at a distance of 690 metres, the predicted upsidence and closure movements are negligible. The locations of the stream crossings are shown in Drawing No. MSEC533-12.

### 6.7.2. Impact Assessments for the 1200 mm Diameter Water Pipeline

The 1200 mm diameter water pipeline forms part of the Macarthur Water Supply System which was designed and constructed in 1994 to the Mine Subsidence Board's design requirements, which are summarised in Table 6.6.

The pipeline has been successfully mined beneath by Longwalls 30 to 35 at West Cliff. The potential valley related and far field effects at the location of the water pipeline resulting from the extraction of Longwall 37 would be negligible and much less than the parameters used for the design of the pipeline and those experienced from the previously extracted longwalls.

Mitigative measures have been undertaken by United Utilities so that the water pipeline is able to accommodate the predicted movements at the Mallaty Creek crossing resulting from the extraction of Longwalls 29 to 38, based on a previous layout of Longwalls 34 to 36.

It is recommended that the predicted movements at the stream crossings are provided to United Utilities, so that an assessment of the pipeline can be undertaken based on the predicted movements resulting from the proposed longwalls. With the implementation of any necessary mitigative measures, it is expected that the pipeline can be maintained in a safe and serviceable condition throughout the mining period.

### 6.7.3. Impact Assessments for the 1200 mm Diameter Water Pipeline Based on Increased Predictions

If the predicted valley related movements were increased by a factor of 2, the maximum predicted upsidence and closure at the streams would still be less than 5 mm and much less than the MSB minimum design requirements. It would be unlikely, therefore, that the pipeline would experience a significant impact.

### 6.7.4. Recommendations for the 1200 mm Diameter Water Pipeline

A management plan has been established for the 1200 mm water pipeline for Longwalls 34 to 36. It is recommended that the existing management plan be reviewed, in consultation with United Utilities, and amendments are made to the plan, where necessary, to include the predicted movements resulting from Longwalls 37 and 38.

## 6.8. Sydney Water Infrastructure

The locations of the Sydney Water owned infrastructure within the Study Area are shown in Drawing No. MSEC533-12. The descriptions, predictions and impact assessments for the water infrastructure are provided in the following sections.

### 6.8.1. Descriptions of the Sydney Water Infrastructure

The Sydney Water infrastructure within the Study Area comprises a rising sewer main between Appin and Rosemeadow which is currently under construction. The rising sewer main forms part of a pressure sewer reticulation network for Appin Township. The alignment of the rising sewer main is along Appin Road as shown in Drawing No. MSEC533-12. The section of pipeline within the Study Area will comprise a 225 mm diameter polyethylene pipe.

Recommended design parameters for the pipeline were provided in a report prepared by MSEC (MSEC421) in September 2009. The recommended design parameters for the sewer pipeline in the vicinity of the Study Area are summarised in Table 6.7.

**Table 6.7 Recommended Design Parameters the 225 mm Diameter Rising Sewer Main**

| Subsidence Parameter | Recommended Design Requirements |
|---|---|
| Vertical Subsidence (mm) | 1900 mm |
| Tilt (mm/m) | 10 mm/m |
| Tensile Strain (mm/m) | 1.4 mm/m |
| Compressive Strain (mm/m) | 2.9 mm/m |

### 6.8.2. Predictions for the Sydney Water Infrastructure

A summary of the maximum predicted total conventional subsidence parameters for the sewer pipeline is provided in Table 6.8. Longwall 38 is more than 900 metres to the east of the rising sewer main location at the southern end of the longwall and approximately 1300 metres at the northern end. At these distances, there are no significant predicted conventional subsidence movements due to the extraction of Longwall 38, therefore prediction results for Longwall 37 only have been presented.

**Table 6.8 Maximum Predicted Incremental and Total Conventional Subsidence Parameters for the Rising Sewer Main after the Extraction of Each of the Proposed Longwall 37**

| | Maximum Predicted Subsidence (mm) | Maximum Predicted Tilt Along Alignment (mm/m) | Maximum Predicted Hogging Curvature Along Alignment ($km^{-1}$) | Maximum Predicted Sagging Along Alignment ($km^{-1}$) |
|---|---|---|---|---|
| Predicted Incremental Parameters Due to LW37 | 760 | 5.5 | 0.06 | 0.11 |
| Predicted Total Parameters After LW37 | 1080 | 6.2 | 0.07 | 0.12 |

The predicted tilts provided in the above table are the maxima along the alignment of the pipeline after the completion of each of the proposed longwalls. The predicted curvatures provided in the above table are the maxima along the alignments of the pipelines at any time during or after the extraction of each of the proposed longwalls.

The sewer pipeline is a linear feature and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines above previous longwall mining. The analysis of strains along whole monitoring lines during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4 and the results are provided in Fig. 4.4.

Non-conventional movements can also occur and have occurred in NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the sewer pipeline, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.1 mm/m tensile and 1.8 mm/m compressive. The pipeline does not cross any stream valleys within the Study Area and will therefore not experience valley related movements.

### 6.8.3. Comparison of Predictions for the Sydney Water Infrastructure with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for Appin Road with those provided in the Part 3A Application is provided in Table 6.9.

**Table 6.9 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Rising Sewer main Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt Along Alignment (mm/m) | Maximum Predicted Total Conventional Hogging Curvature in Any Direction ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature in Any Direction ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1100 | 5.8 | 0.06 | 0.10 |
| Extraction Plan Layout (Report No. MSEC533) | 1080 | 6.2 | 0.07 | 0.12 |

It can be seen from the above table, that the maximum predicted mine subsidence movements based on the Extraction Plan Layout, are similar to those predicted based on the Part 3A Layout.

### 6.8.4. Impact Assessments for the Sydney Water Infrastructure

The rising sewer main is a pressure main and is unlikely, therefore, to be affected to any great extent by changes in gradient due to subsidence or tilt.

The maximum predicted conventional hogging and sagging curvatures at the water infrastructure, resulting from the extraction of the proposed longwalls, are 0.07 $km^{-1}$ and 0.12 $km^{-1}$, respectively, which equate to minimum radii of curvatures of 15 kilometres and 8 kilometres, respectively.

The predicted maximum conventional tensile and compressive strains of 1.1 mm/m and 1.8 mm/m respectively are less than the recommended parameters provided in Table 6.7.

The pipeline comprises a 225 mm diameter polyethylene pipe which can typically accommodate large movements. Provided the pipeline has been designed using the recommended parameters provided in Table 6.7, risk of impact to the pipeline resulting from the extraction of the proposed longwalls is considered to be very low.

### 6.8.5. Impact Assessments for the Sydney Water Infrastructure Based on Increased Predictions

If the conventional subsidence movements exceeded those predicted by a factor of 2 times, the maximum predicted tilt along the pipeline 12.0 mm/m (i.e. 1.2 %), or a change in grade of 1 in 80. The sewer pipeline is a pressure mains and unlikely, therefore, to be affected to any great extent by changes in gradient due to subsidence or tilt.

If the conventional subsidence movements exceeded those predicted by a factor of 2 times, the maximum predicted hogging and sagging curvature along the pipeline would be 0.14 $km^{-1}$ and 0.24 $km^{-1}$, respectively which represents a minimum radius of curvature of 7 kilometres and 4 kilometres. The maximum predicted conventional strains for the sewer pipeline, based on applying a factor of 15 to the maximum predicted conventional curvatures, would be 2.1 mm/m tensile and 3.6 mm/m compressive.

The increased predicted strains would be slightly greater than the recommended design parameters provided in Table 6.7 and would therefore result in a higher risk of impact to the pipeline.

Some examples of previous experiences of mining beneath much less flexible pipelines are summarised in Table 6.10.

**Table 6.10 Examples of Previous Experience of Mining Beneath Water Pipelines in the Southern Coalfield**

| Colliery and LWs | Pipelines | Observed Movements | Observed Impacts |
|---|---|---|---|
| Appin LW301 & LW302 | 0.6 km of 150 dia DICL<br>0.6 km of 300 dia CICL<br>0.6 km of 1200 dia SCL | 650 mm Subsidence<br>4.5 mm/m Tilt<br>1 mm/m Tensile Strain<br>2 mm/m Comp. Strain<br>(Measured M & N-Lines) | Leakage of the 150 mm and 300 mm CICL pipelines at a creek crossing; elsewhere no other reported impacts |
| Tahmoor LW22 to LW25 | 2.7 km DICL pipes<br>7.3 km CICL pipes | 1200 mm Subsidence<br>6 mm/m Tilt<br>1.5 mm Tensile Strain<br>2.0 mm (typ.) and up to 5.0 mm/m Comp. Strain<br>(Extensive street monitoring) | One reported impact to the distribution network and a very small number of minor leaks in the consumer connection pipes |
| West Cliff LW5A3, LW5A4 & LW29 to LW33 | 2.3 km of 100 dia CICL pipe directly mined beneath | 1000 mm Subsidence<br>5.5 mm/m Tilt<br>1 mm/m Tensile Strain<br>5.5 mm/m Comp. Strain<br>(Measured B-Line) | No reported impacts |

It can be seen from the above table, that the incidence of impacts on water pipelines is small. Based on this experience, and the nature of the much more flexible polyethylene pipeline for the rising sewer main, it is expected that if the conventional subsidence movements exceeded thos predicted by a factor of 2 times, the risk of impact to the pipeline would be low. Impacts are more likely to occur in locations of non-conventional movements.

### 6.8.6. Recommendations for the Sydney Water Infrastructure

Management strategies have already been developed by IC, in consultation with Sydney Water, to manage the impacts on water infrastructure in Appin Areas 3 and 7 and at West Cliff Colliery. It is recommended that these management strategies are extended to include the proposed Longwalls 37 and 38.

## 6.9. Sydney Catchment Authority Infrastructure

There is no Sydney Catchment Authority Infrastructure within the Study Area.

## 6.10. Sewerage Pipelines and Sewage Treatment Works

There are no sewage treatment works within the Study Area. A rising sewer main between Appin and Rosemeadow is currently under construction and is discussed in Section 6.8. The properties within the Study Area have local connections to on-site waste water systems and these are discussed in Section 11.7.

## 6.11. Gas Pipelines

There are no gas pipelines within the Study Area. There are three gas pipelines which cross the Longwall 30 to 36, to the west of the Study Area. The pipelines are approximately 720 metres from the proposed Longwall 37 at its nearest point. All three pipelines are located within an easement, which crosses over the western ends of the Longwalls 30 to 36, as shown in Drawing No. MSEC533-12.

At 720 metres distance from Longwall 37 the gas pipelines are unlikely to be subjected to any significant conventional subsidence movements resulting from the extraction of the proposed longwalls but may experience minor far field effects resulting from the extraction of Longwall 37. Far field movements are discussed in Section 4.6.

The gas pipelines cross a number of streams and could be subjected to upsidence and closure movements at these locations however at a distance of 720 metres, the predicted upsidence and closure movements are negligible. The locations of the stream crossings are shown in Drawing No. MSEC533-12.

The pipeline has been successfully mined beneath by Longwalls 30 to 35 at West Cliff. The potential valley related and far field effects at the location of the gas pipelines resulting from the extraction of Longwall 37 would be negligible and much less than the parameters used for the design of the pipelines and those experienced from the previously extracted longwalls.

Mitigative measures have been undertaken so that the gas pipelines are able to accommodate the predicted movements at the Mallaty Creek crossing resulting from the extraction of Longwalls 29 to 38, based on a previous layout of Longwalls 34 to 36.

With the implementation of any necessary mitigative measures, it is expected that the pipeline can be maintained in a safe and serviceable condition throughout the mining period.

A management plan has been established for the gas pipelines for Longwalls 34 to 36. It is recommended that the existing management plan be reviewed, in consultation with the utility owners, and amendments are made to the plan, where necessary, to include the potential movements resulting from Longwalls 37 and 38.

## 6.12. Liquid Fuel Pipelines

There are no liquid fuel pipelines within the Study Area.

## 6.13. Electrical Infrastructure

The locations of the electrical infrastructure within the Study Area are shown in Drawing No. MSEC533-13. The descriptions, predictions and impact assessments for the electrical infrastructure are provided in the following sections.

### 6.13.1. Descriptions of the Electrical Infrastructure

The electrical infrastructure within the Study Area comprises 11 kV powerlines, which follow the local roads through the Study Area. The powerlines consist of aerial copper cables supported on timber poles as shown in Drawing No. MSEC533-13.

There is a 66kV powerline and 330kV transmission line located outside the Study Area and over the western ends of Longwalls 31 to 36. The lines are approximately 780 metres from the proposed Longwall 37 at its nearest point. The locations of the lines are shown in Drawing No. MSEC533-13.

### 6.13.2. Predictions for the Electrical Infrastructure

At 850 metres distance from Longwall 37 the 66kV powerline and 330kV transmission line are unlikely to be subjected to any significant conventional subsidence movements resulting from the extraction of the proposed longwalls but may experience minor far field effects resulting from the extraction of Longwall 37. Far field movements are discussed in Section 4.6.

The 11kV aerial powerlines will not be directly affected by the ground strains, as the cables are supported by poles above ground level. The cables may, however, be affected by changes in the bay lengths, i.e. the distances between the poles at the levels of the cables, resulting from differential subsidence, horizontal movements, and tilt at the pole locations. The stabilities of the poles may also be affected by conventional tilt, and by changes in the catenary profiles of the cables.

The 11 kV powerlines are located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

### 6.13.3. Comparison of Predictions for the Electrical Infrastructure with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for the 11 kV powerlines with those provided in the Part 3A Application is provided in Table 6.11.

**Table 6.11 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the 11 kV Powerlines**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Tilt in Any Direction (mm/m) |
|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 |
| Extraction Plan Layout (Report No. MSEC533) | 1150 | 6.5 |

It can be seen from the above table, that the maximum predicted mine subsidence movements at the electrical infrastructure, based on the Extraction Plan Layout, are generally similar to or slightly less than those predicted based on the Part 3A Layout.

### 6.13.4. Impact Assessments for the Electrical Infrastructure

The maximum predicted tilt at the powerlines is 6.5 mm/m (i.e. 0.7 %), which represents a change in verticality of 1 in 155. It is expected that the power poles within the Study Area will generally experience tilts less than this maximum, as the result of the variations in the predicted tilts across the Study Area.

The maximum predicted subsidence and tilts at the powerlines, resulting from the extraction of the proposed longwalls, are similar to those typically experienced elsewhere in the Southern Coalfield. Longwalls in the Southern Coalfield have been successfully mined directly beneath powerlines in the past, and some of these cases are provided Table 6.12

**Table 6.12 Examples of Previous Experience of Mining Beneath Powerlines in the Southern Coalfield**

| Colliery and LWs | Length of Powerlines Directly Mined Beneath (km) | Observed Maximum Movements at Powerlines | Observed Impacts |
|---|---|---|---|
| Appin LW1 to LW12 | 5.2 km of 11 kV<br>104 power poles | 850 mm Subsidence<br>6 mm/m Tilt<br>(Measured WX-Line) | No significant impacts |
| Appin LW14 to LW29 | 1.0 km of 66 kV<br>4.6 km of 11 kV<br>76 power poles | 1200 mm Subsidence<br>7 mm/m Tilt<br>(Measured A-Line) | No significant impacts |
| Appin LW301 and LW302 | 0.6 km of 66 kV<br>0.2 km of 11 kV<br>14 power poles | 650 mm Subsidence<br>4.5 mm/m Tilt<br>(Measured M & N-Lines) | No significant impacts |
| Appin LW401 to LW409 | 3.4 km of 66 kV<br>0.6 km of 33 kV<br>2.9 km of 11 kV<br>96 power poles | 700 mm Subsidence<br>5 mm/m Tilt<br>(Measured A-Line) | No significant impacts |
| Appin LW702 | 1.5 km of 11 kV<br>19 power poles | 550 mm Subsidence<br>3.5 mm/m Tilt<br>(Measured MPR-Line) | No significant impacts |
| Dendrobium LW3 and LW5 | 1.2 km of 33 kV powerline | 1100 mm Subsidence<br>40 mm/m Tilt<br>(Measured D2000-Line) | No significant impacts |
| Tahmoor LW22 to LW25 | Approx. 22 km of electrical cables and 595 power poles | 1200 mm Subsidence<br>6 mm/m Tilt<br>(Extensive street monitoring) | Minor adjustments to cable catenaries, pole tilts and consumer cables required. |
| Tower LW1 to LW10 | 6.0 km of 66 kV<br>4.3 km of 11 kV<br>112 power poles | 400 mm Subsidence<br>3 mm/m Tilt<br>(Measured T & TE-Lines) | No significant impacts |
| West Cliff LW5A3 to LW5A4 & LW29 to LW33 | 0.8 km of a 66 kV<br>3.7 km of 11 kV<br>113 power poles | 950 mm Subsidence<br>5 mm/m Tilt<br>(Measured B-Line) | No significant impacts |

It can be seen from the above table, that there have been only very minor impacts on powerlines which have been directly mined beneath by previously extracted longwalls in the Southern Coalfield. Some remedial measures were required, which included adjustments to cable catenaries, pole tilts and to consumer cables which connect between the powerlines and houses. The incidence of these impacts was very low.

Based on this experience, it is likely that the extraction of the proposed longwalls would result in only minor impacts on the powerlines within the Study Area. It is expected that the remedial measures would include some adjustments of the cable catenaries, pole tilts and the consumer cables, as has been undertaken in the past, but any other impacts are expected to be relatively infrequent and easily repaired.

The 66 kV powerline and 330 kV transmission line have been successfully mined beneath by Longwalls 31 to 35 at West Cliff. Mitigative measures include a cruciform based constructed at one of the 330kV towers which is a tension tower. With the implementation of any necessary mitigative measures, it is expected that the 66 kV powerline and 330 kV transmission line can be maintained in a safe and serviceable condition throughout the mining period.

#### 6.13.5. Impact Assessments for the Electrical Infrastructure Based on Increased Predictions

If the actual subsidence movements exceeded those predicted by a factor of 2 times, the maximum tilt at the powerlines would be 13 mm/m (i.e. 1.3 %), or a change in verticality of 1 in 80. In this case, the incidence of impacts would increase in the locations of greatest tilt, such as adjacent to the active longwall maingate and adjacent to the ends of the proposed longwalls. It would still be expected that any impacts could be remediated, including some adjustments of the cable catenaries, pole tilts and the consumer cables, as has been undertaken in the past.

While the predicted ground movements are important parameters when assessing the potential impacts on the powerlines, it is noted that the impact assessments were primarily based on historical observations from previous longwall mining in the Southern Coalfield. The overall levels of impact on the powerlines, resulting from the extraction of the proposed longwalls, are expected to be similar to those observed where longwalls have previously mined directly beneath powerlines in the Southern Coalfield.

#### 6.13.6. Recommendations for the Electrical Infrastructure

A management plan has been established for the electrical infrastructure for Longwalls 34 to 36. It is recommended that the existing management plan be reviewed, in consultation with the infrastructure owners, and that amendments are made to the plan, where necessary, to include the electrical infrastructure within the Study Area. With the implementation of these management strategies, it would be expected that the electrical infrastructure could be maintained in a safe and serviceable condition during and after the extraction of the proposed longwalls.

### 6.14. Telecommunications Infrastructure

The locations of the telecommunications infrastructure within the Study Area are shown in Drawing No. MSEC533-14. The descriptions, predictions and impact assessments for the telecommunications infrastructure are provided in the following sections.

#### 6.14.1. Description of the Telecommunications Infrastructure

The telecommunications infrastructure within the Study Area comprises a direct buried optical fibre cable, aerial and direct buried copper cables. A summary of the telecommunications cables within the Study Area is provided in Table 6.13.

**Table 6.13 Summary of Telecommunications Infrastructure within the Study Area**

| Type | Location | Total Length of Cable within Study Area (km) | Total Length of Cable Located Directly above Proposed Longwalls (km) |
|---|---|---|---|
| Optical Fibre Cables | Above 37 along the alignment of Appin Road | 1.4 | 0.3 |
| Copper Cables | Above LW37 and 38 | 8.0 | 1.9 |

The telecommunications cables within the Study Area are owned and maintained by Telstra.

### 6.14.2. Predictions for the Telecommunications Infrastructure

A summary of the maximum predicted total conventional subsidence parameters for the optical fibre cables is provided in Table 6.14. Longwall 38 is more than 900 metres to the east of the optical fibre cable location at the southern end of the longwall and approximately 1300 metres at the northern end. At these distances, there are no significant predicted conventional subsidence movements due to the extraction of Longwall 38, therefore prediction results for Longwall 37 only have been presented.

**Table 6.14 Maximum Predicted Incremental and Total Conventional Subsidence Parameters for the Optical Fibre Cable after the Extraction of Each of the Proposed Longwall 37**

| | Maximum Predicted Subsidence (mm) | Maximum Predicted Tilt Along Alignment (mm/m) | Maximum Predicted Hogging Curvature Along Alignment ($km^{-1}$) | Maximum Predicted Sagging Along Alignment ($km^{-1}$) |
|---|---|---|---|---|
| Predicted Incremental Parameters Due to LW37 | 760 | 5.5 | 0.06 | 0.11 |
| Predicted Total Parameters After LW37 | 1080 | 6.2 | 0.07 | 0.12 |

The predicted tilts provided in the above table are the maxima along the alignment of the optical fibre cable after the completion Longwall 37. The predicted curvatures provided in the above table are the maxima along the alignment of the optical fibre cable at any time during or after the extraction of Longwall 37.

The copper telecommunications cables are located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The telecommunications cables are linear features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines above previous longwall mining. The analysis of strains along whole monitoring lines during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4 and the results are provided in Fig. 4.4.

Non-conventional movements can also occur and have occurred in NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the optical fibre cable, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.1 mm/m tensile and 1.8 mm/m compressive. The maximum predicted conventional strains for the copper cables, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.2 mm/m tensile and 1.8 mm/m compressive.

### 6.14.3. Comparison of Predictions for the Telecommunications Cables with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for optical fibre cables with those provided in the Part 3A Application is provided in Table 6.15. The comparison of the maximum predicted subsidence parameters for copper telecommunications cables with those provided in the Part 3A Application is provided in Table 6.16

**Table 6.15 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Optical Fibre Cable on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt Along Alignment (mm/m) | Maximum Predicted Total Conventional Hogging Curvature in Any Direction ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature in Any Direction ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1100 | 5.8 | 0.06 | 0.10 |
| Extraction Plan Layout (Report No. MSEC533) | 1080 | 6.2 | 0.07 | 0.12 |

**Table 6.16 Comparison of the Maximum Predicted Conventional Subsidence Parameters for Copper Telecommunications Cables Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt Along Alignment (mm/m) | Maximum Predicted Total Conventional Hogging Curvature in Any Direction ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature in Any Direction ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 1150 | 6.5 | 0.08 | 0.12 |

It can be seen from the above tables, that the maximum predicted mine subsidence parameters for the optical fibre cable, based on the Extraction Plan Layout, are similar to those predicted based on the Part 3A Layout.

### 6.14.4. Impact Assessments for the Optical Fibre Cable

The optical fibre cables are direct buried and are unlikely, therefore, to be impacted by tilt. The cables are also unlikely to be impacted by curvature, as the cable are flexible and would be expected to tolerate the predicted minimum radius of curvature within the Study Area of 8 kilometres.

The optical fibre cables could, however, be affected by the ground strains resulting from the extraction of the proposed longwalls. The greatest potential for impacts will occur as a result of localised ground strains due to non-conventional ground movements.

The tensile strains in the optical fibre cables could be higher than predicted, where the cables connect to the support structures, which may act as anchor points, preventing any differential movements that may have been allowed to occur in the ground. Tree roots have also been known to anchor cables to the ground. The extent to which the anchor points affect the ability of the cables to tolerate the mine subsidence movements depends on the cable size, type, age, installation method and ground conditions.

In addition to this, optical fibre cables contain additional fibre lengths over the sheath lengths, where the individual fibres are loosely contained within tubes. Compression of the sheaths can transfer to the loose tubes and fibres and result in “micro-bending” of the fibres constrained within the tubes, leading to higher attenuation of the transmitted signal. If the maximum predicted compressive strains were to be fully transferred into the optical fibre cables, the strains could be of sufficient magnitude to result in the reduction in capacities of the cables or transmission loss.

The strains transferred into the optical fibre cables can be monitored using Optical Time Domain Reflectometer (OTDR), which can be used to notify the infrastructure owners of strain concentrations due to non-conventional ground movements.

Longwalls in the Coalfields of New South Wales have been successfully mined directly beneath optical fibre cables in the past. A summary of some of these cases is provided in Table 6.17.

Table 6.17 Examples of Mining Beneath Optical Fibre Cables

| Colliery and LWs | Length of Optical Fibre Cables Directly Mined Beneath (km) | Observed Maximum Movements at Optical Fibre Cables | Pre-Mining Mitigation, Monitoring and Observed Impacts |
|---|---|---|---|
| Appin LW301 and LW302 | 0.8 | 650 mm Subsidence 0.7 mm/m Tensile Strain 2.8 mm/m Comp. Strain | 600 metre aerial cable on standby. Ground survey, visual, OTDR. No reported impacts. |
| Tahmoor LW22 to LW25 | 1.2 | 775 mm Subsidence 0.8 mm/m Tensile Strain 1.9 mm/m Comp. Strain | Ground survey, visual, OTDR, SBS. No reported impacts. |
| Tower LW1 to LW10 | 1.7 | 400 mm Subsidence 3 mm/m Tilt 0.5 mm/m Tensile Strain 1.0 mm/m Comp. Strain | No reported impacts |
| West Cliff LW5A3, LW5A4 and LW29 to LW33 | 2.3 | 950 mm Subsidence 1 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line) | Survey, visual, OTDR, SBS. No reported impacts. |
| West Wallsend LW27 | 0.2 | 350 mm Subsidence 1.3 mm/m Tensile Strain 1.7 mm/m Comp. Strain | Cut over clear of Longwall 27. Ground survey, visual, OTDR. No reported impacts. |

It can be seen from the above table, that optical fibre cables have been successfully mined directly beneath by previously extracted longwalls in the Coalfields of New South Wales, with the implementation of suitable management strategies. It is recommended that the predicted movements are reviewed by the infrastructure owners, to assess the potential impacts and to develop appropriate management strategies.

### 6.14.5. Impact Assessments for the Copper Telecommunications Cables

The direct buried copper telecommunications cables are unlikely to be impacted by tilt. The cables are also unlikely to be impacted by curvature, as the cables are flexible and would be expected to tolerate the predicted minimum radius of curvature within the Study Area of 8 kilometres.

The direct buried copper cables could, however, be affected by the ground strains resulting from the extraction of the proposed longwalls. The copper cables are more likely to be impacted by tensile strains rather than compressive strains. It is possible, that the direct buried cables could experience higher tensile strains where they are anchored to the ground by associated infrastructure, or by tree roots. The cables could also experience higher compressive strains at the creek crossings as the result of valley related movements.

Aerial copper telecommunications cables are generally not affected by ground strains, as they are supported by the poles above ground level. The aerial cables, however, could be affected by the changes in bay lengths, i.e. the distances between the poles at the levels of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the poles due to tilting of the poles. The stability of the poles can also be affected by mining induced tilts and by changes in the catenary profiles of the cables.

Longwalls in the Southern Coalfield of New South Wales have been successfully mined directly beneath copper telecommunications cables in the past, where the magnitudes of the predicted mine subsidence movements were similar to those predicted within the Study Area. Some of these cases have been summarised in Table 6.18.

**Table 6.18 Examples of Mining Beneath Copper Telecommunications Cables**

| Colliery and LWs | Copper Cables | Observed Maximum Movements at the Copper Cables | Observed Impacts |
|---|---|---|---|
| Appin<br>LW401 to LW408 | Longwalls have mined beneath 4 km of underground cables and 0.8 km of aerial cables | 700 mm Subsidence<br>5 mm/m Tilt<br>1 mm/m Tensile Strain<br>2 mm/m Comp. Strain<br>(Measured A6000-Line) | No significant impacts |
| Tahmoor<br>LW22 to LW25 | Longwalls have mined beneath 19 km of underground cables and 2.5 km of aerial cables | 1200 mm Subsidence<br>6 mm/m Tilt<br>1.5 mm Tensile Strain<br>2.0 mm (typ.) and up to 5.0 mm/m Comp. Strain<br>(Extensive street monitoring) | No significant impacts to underground cables. Some pole tilts and cable catenaries adjusted. Some consumer cables were re-tensioned as a precautionary measure |
| West Cliff<br>LW29 to LW33 | Longwalls have mined beneath 13 km of underground cables | 950 mm Subsidence<br>1 mm/m Tensile Strain<br>5.5 mm/m Comp. Strain<br>(Measured B-Line) | No significant impacts |

It can be seen from the above table, that there were no reported impacts on the direct buried copper telecommunications cables in the above examples. It is also understood, that there have been no significant impacts on direct buried copper telecommunications cables elsewhere in the NSW Coalfields, where the depths of cover were greater than 400 metres, such as the case above the proposed longwalls.

It can also be seen from the above table, that there have been only minor impacts on aerial copper telecommunications cables in the above examples. Some remedial measures were required, which included adjustments to cable catenaries, pole tilts and consumer cables which connect between the poles and houses. The incidence of these impacts, however, was very low.

Based on this experience, it is unlikely that the extraction of the proposed longwalls would result in any significant impacts on the direct buried or aerial copper telecommunications cables within the Study Area. Any minor impacts on these cables would be expected to be relatively infrequent and easily repaired.

### 6.14.6. Impact Assessments for Telecommunications Infrastructure Based on Increased Predictions

If the actual mine subsidence movements exceeded those predicted by a factor of 2 times, the maximum curvature at the telecommunications cables would be 0.24 $km^{-1}$, which represents a minimum radius of curvature of 4 kilometres. In this case, the predicted conventional strains for the telecommunications cables would be 4 mm/m. It can be seen from Table 6.17 and Table 6.18, that longwalls have been successfully mined beneath optical fibre cables and copper telecommunications cables where the measured strains were up to 5.5 mm/m.

It would still be expected, that the potential for elevated ground strains along the optical fibre cables could be managed using OTDR monitoring. Mitigation measures can be undertaken, such as excavating and exposing the cable, if strain concentrations are detected during the mining period.

### 6.14.7. Recommendations for Telecommunications Infrastructure

IC has developed specific telecommunication infrastructure management plans for the longwalls at Appin Area 7 and West Cliff to manage the potential impacts on copper and optical fibre cables owned by Telstra, Optus, NextGen and PowerTel. The Management Plans were developed in consultation with telecommunications experts and the infrastructure owners. It is recommended that these plans are reviewed and, where required, revised to incorporate the telecommunications infrastructure within the Study Area. With the implementation of these management strategies, it would be expected that the telecommunications infrastructure can be maintained in a safe and serviceable condition during and after the extraction of the proposed longwalls.

## 6.15. Water Tanks, Water and Sewage Treatment Works

There are no public water or sewage treatment works within the Study Area.

## 6.16. Dams, Reservoirs or Associated Works

There are no public dams, reservoirs, nor associated works within the Study Area.

## 6.17. Air Strips

There are no air strips within the Study Area. Wedderburn Airport is located to the South East of the Study Area and is shown on Drawing No. MSEC533-21. The airport is located over previously extracted Longwalls 20 to 24.

The airport comprises an airstrip approximately 1 kilometre in length and several large sheds to the east of the airstrip. The airstrip is located approximately 390 metres from Longwall 38 at its nearest point.

At 390 metres distance from Longwall 38 the airport is unlikely to be subjected to any significant conventional subsidence movements resulting from the extraction of the proposed longwalls but may experience minor far field effects resulting from the extraction of Longwall 37. Far field movements are discussed in Section 4.6 As discussed in Section 4.6 the impacts of far-field horizontal movements are not expected to be significant, however the far field movements could result in reactivation of the goaf above the previously extracted Longwalls 20 to 24.

It is recommended that a management plan should be established for the airport for Longwalls 37 and 38 in consultation with the airport owners to ensure that the airport remains safe and serviceable during the extraction of the proposed longwalls.

## 6.18. Survey Control Marks

The locations of the survey control marks within and immediately adjacent to the Study Area are shown in Drawing No. MSEC533-22. The locations and details of the survey control marks were obtained from the *Land and Property Management Authority* using the *SCIMS Online* website (SCIMS, 2012).

The survey control marks are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The survey control marks located outside and in the vicinity of the Study Area are also expected to experience small amounts of subsidence and small far-field horizontal movements. It is possible that other survey control marks outside the immediate area could also be affected by far-field horizontal movements, up to 3 kilometres outside the Study Area. Far-field horizontal movements and the methods used to predict such movements are described further in Sections 3.3 and 4.6.

It will be necessary on the completion of the longwalls, when the ground has stabilised, to re-establish any survey control marks that are required for future use. Consultation between the IC and the Department of Lands will be required to ensure that these survey control marks are reinstated at the appropriate time, as required.

## 6.19. Any Other Public Utilities

There are no other public utilities within the Study Area.

# 7.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE PUBLIC AMENITIES

The following sections provide the descriptions, predictions and impact assessments for the Public Amenities within the Study Area.

## 7.1. Hospitals

There are no hospitals within the Study Area.

## 7.2. Places of Worship

There are no places of worship within the Study Area.

## 7.3. Schools

There are no schools within the Study Area.

## 7.4. Shopping Centres

There are no shopping centres within the Study Area

## 7.5. Community Centres

There are no community centres located within the Study Area.

## 7.6. Office Buildings

There are no office buildings within the Study Area.

## 7.7. Swimming Pools

There are no public swimming pools within the Study Area.

## 7.8. Bowling Greens

There are no bowling greens within the Study Area.

## 7.9. Ovals or Cricket Grounds

There are no ovals or cricket grounds located within the Study Area.

## 7.10. Racecourses

There are no racecourses within the Study Area.

## 7.11. Golf Courses

There are no golf courses within the Study Area.

## 7.12. Tennis Courts

There are no public tennis courts within the Study Area.

## 7.13. Any Other Public Amenities

There are no other public amenities identified within the Study Area.

The following sections provide the descriptions, predictions and impact assessments for the farm land and farm facilities within the Study Area.

## 8.1. Agricultural Utilisation

The agricultural land classification types within the Study Area are illustrated in Fig. 8.1.

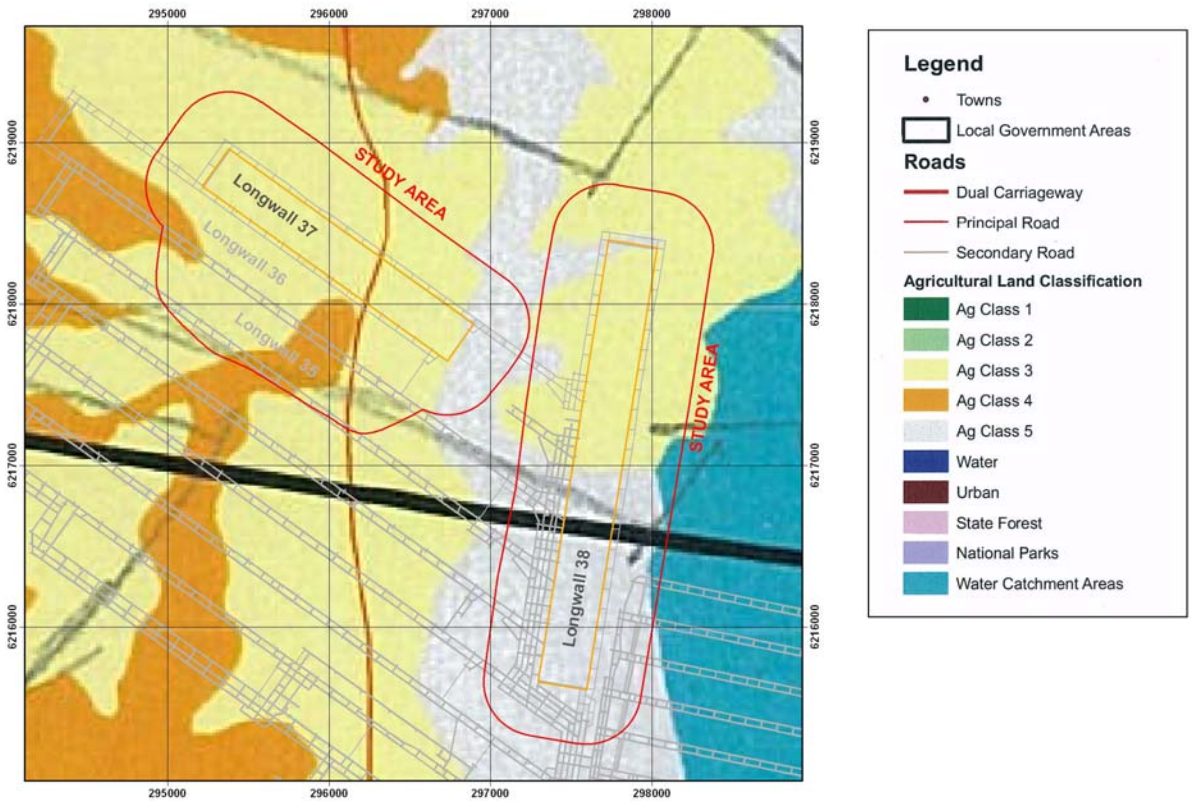



**Fig. 8.1 Agricultural Land Classification within the Study Area (Source NSW DII November 2008)**

It can be seen from the above figure, that there are three main agricultural land classification types within the Study Area, which are:-

- Class 3 – Grazing land or land well suited to pasture improvement,
- Class 4 – Land suitable for grazing but not for cultivation, and
- Class 5 – Land unsuitable for agriculture, or at best suited only to light grazing.

The flatter areas of land within the Study Area form the majority of the Class 3 agricultural land. The more hilly areas within the Study Area, have not been cleared of the natural vegetation.

## 8.2. Rural Building Structures

The locations of the rural building structures within the Study Area are shown in Drawings Nos. MSEC533-15 to MSEC533-21. The descriptions, predictions and impact assessments for these structures are provided in the following sections.

### 8.2.1. Descriptions of the Rural Building Structures

There are 207 rural building structures (Structure Type R) which have been identified within the Study Area, which includes sheds, garages, gazebos, pergolas, greenhouses, playhouses, shade structures and other non-residential building structures.

The locations of the rural building structures are shown in Drawings Nos. MSEC533-16 to MSEC533-21 and details are provided in Table D.03, in Appendix D. The locations, sizes, and details of the rural building structures were determined from an aerial photograph of the area and from kerb side inspections.

### 8.2.2. Predictions for the Rural Building Structures

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at the vertices of each rural building structure, as well as at eight equally spaced points placed radially around the centroid and vertices at a distance of 20 metres. In the case of a rectangular shaped structure, predictions have been made at a minimum of 45 points within and around the structure.

A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each rural building structure within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table D.03, in Appendix D. The predicted tilts provided in this table are the maxima in any direction after the completion of each of the proposed longwalls. The predicted curvatures provided in this table are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the rural building structures within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 8.2 and Fig. 8.3.

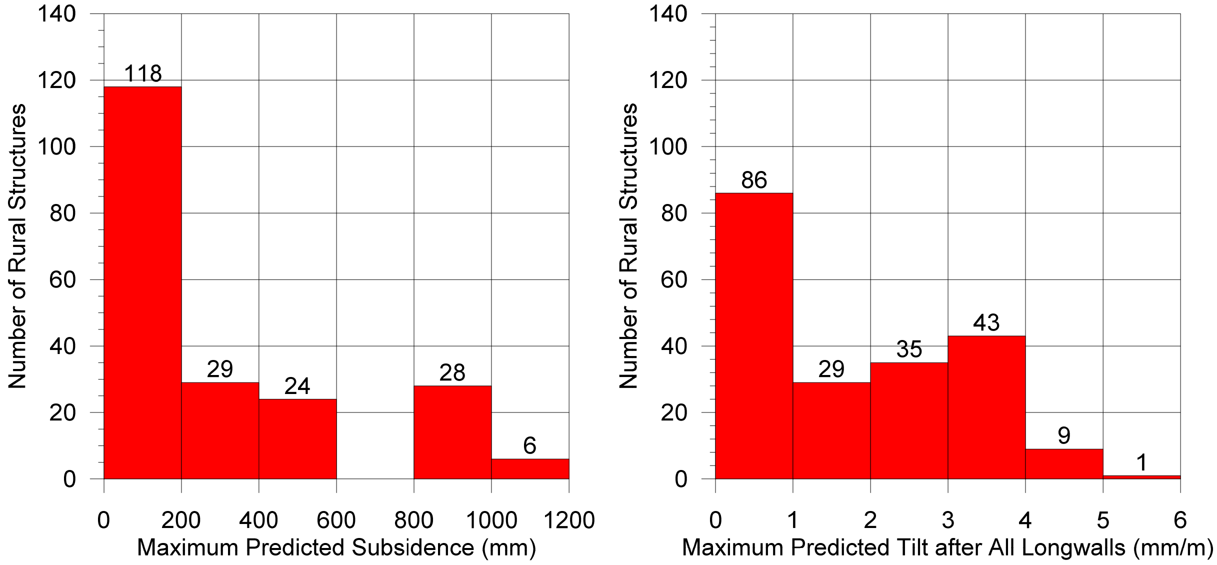



**Fig. 8.2 Maximum Predicted Conventional Subsidence and Tilt for the Rural Building Structures within the Study Area Resulting from the Extraction of the Proposed Longwalls**

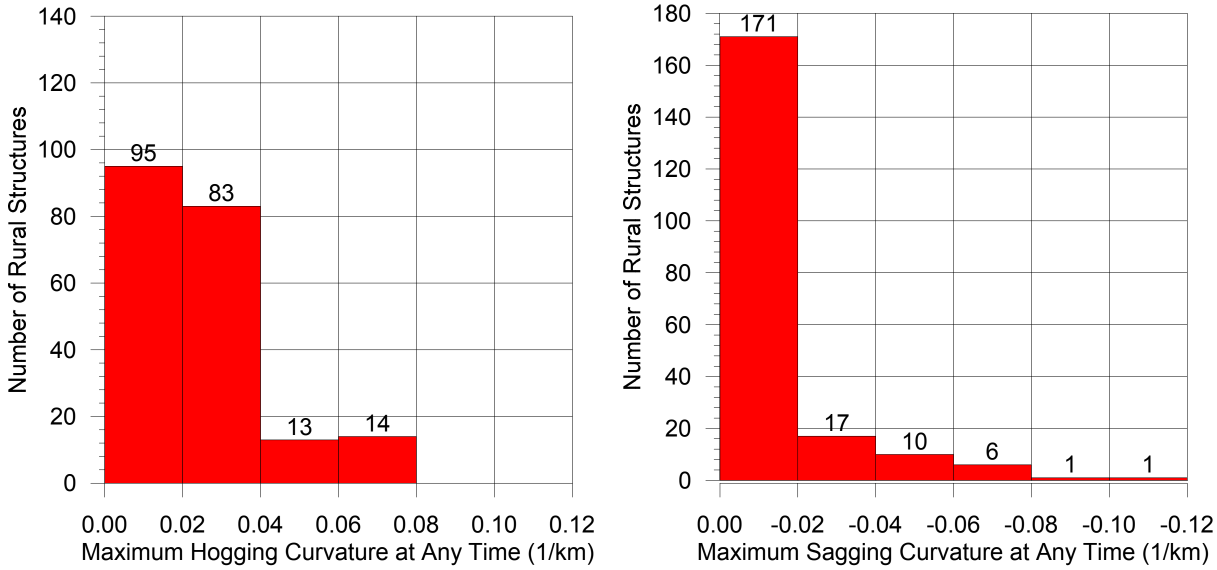



**Fig. 8.3 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Rural Structures Resulting from the Extraction of the Proposed Longwalls**

The rural building structures are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous ground movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the rural building structures, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.1 mm/m tensile and 1.8 mm/m compressive.

#### 8.2.3. Comparison of Predictions for the Rural Building Structures with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for the rural building structures with those provided in the Part 3A Application is provided in Table 8.1.

**Table 8.1 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Rural Building Structures Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 1050 | 6.0 | 0.07 | 0.12 |

It can be seen from the above table, that the maximum predicted mine subsidence movements for the rural building structures, based on the Extraction Plan Layout, are similar to but slightly less than those predicted based on the Part 3A Layout.

#### 8.2.4. Impact Assessments for the Rural Building Structures

The maximum predicted tilt for the rural building structures, resulting from the extraction of the proposed longwalls, is 6 mm/m (i.e. 0.6 %), which represents a change in grade of 1 in 170. The majority of the rural building structures within the Study Area are of lightweight construction. It has been found from past longwall mining experience, that tilts of the magnitudes predicted within the Study Area generally do not result in any significant impacts on rural building structures. Some minor serviceability impacts could occur at the higher levels of predicted tilt, including door swings and issues with roof and pavement drainage, all of which can be remediated using normal building maintenance techniques.

The maximum predicted conventional hogging and sagging curvatures for the rural building structures, resulting from the extraction of the proposed longwalls, are 0.07 $km^{-1}$ and 0.12 $km^{-1}$, respectively, which equate to minimum radii of curvature of 14 kilometres and 8 kilometres, respectively.

The maximum predicted ground curvatures and the range of potential strains at the rural building structures, resulting from the extraction of the proposed longwalls, are similar to those typically experienced elsewhere in the Southern Coalfield. Longwalls in the Southern Coalfield have been successfully mined directly beneath rural building structures in the past, and some of these cases are provided in Table 8.2.

**Table 8.2 Examples of Previous Experience of Mining Beneath Rural Building Structures in the Southern Coalfield**

| Colliery and LWs | Rural Building Structures | Maximum Predicted Movements at the Structures | Observed Impacts |
|---|---|---|---|
| Appin<br>LW301 and LW302 | 4 | 770 mm Subsidence<br>6 mm/m Tilt<br>0.7 mm/m Tensile Strain<br>1.6 mm/m Comp. Strain | No reported impacts |
| Appin<br>LW401 to LW408 | 75 | 1200 mm Subsidence<br>5 mm/m Tilt<br>1.2 mm/m Tensile Strain<br>2.2 mm/m Comp. Strain | No reported impacts |
| Appin<br>LW701 and LW702 | 12 | 1300 mm Subsidence<br>5 mm/m Tilt<br>1.6 mm/m Tensile Strain<br>2.0 mm/m Comp. Strain | No reported impacts |
| Tahmoor<br>LW22 to LW24A | 79 | 850 mm Subsidence<br>5 mm/m Tilt<br>0.8 mm/m Tensile Strain<br>1.7 mm/m Comp. Strain | Impacts reported at three rural building structures |
| West Cliff<br>LW29 to LW33 | 184 | 1200 mm Subsidence<br>6 mm/m Tilt<br>1.4 mm/m Tensile Strain<br>1.8 mm/m Comp. Strain | Impacts to four large chicken sheds due to non-conventional movements. |

There is extensive experience of mining directly beneath rural building structures in the Southern Coalfield which indicates that the incidence of impacts on these structures is very low. This is not surprising as rural building structures are generally small in size and of light-weight construction, which makes them less susceptible to impact than houses which are typically more rigid. In all cases, the rural building structures remained in a safe and serviceable condition.

It is expected, therefore, that all the rural building structures within the Study Area would remain safe, serviceable and repairable during the mining period, provided that they are in sound condition prior to any subsidence movements. The risk of impact is clearly greater if the structures are in poor condition, though the chances of there being a public safety risk remains very low. A number of rural building structures which were in poor condition have been directly mined beneath and these structures have not experienced impacts during mining.

Any impacts on the rural building structures that occur as the result of the extraction of the proposed longwalls are expected to be remediated using well established building techniques. With these remediation measures available, it is unlikely that there would be any significant impacts on rural building structures resulting from the extraction of the proposed longwalls.

### 8.2.5. Impact Assessments for the Rural Building Structures Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the rural building structures would be 12 mm/m (i.e. 1.2 %), or a change in grade of 1 in 85. In this case, the incidence of serviceability impacts, such as door swings and issues with gutter and pavement drainage, would increase in the locations of greatest tilt, such as adjacent to the active longwall maingate and adjacent to the ends of the proposed longwalls. It would still be unlikely that stabilities of these rural building structures would be affected by tilts of these magnitudes.

If the actual curvatures exceeded those predicted by a factor of 2 times, the incidence of impacts would increase for the rural building structures located directly above the longwalls. Since rural building structures are generally small in size and of light-weight construction, they would still be expected to remain safe, serviceable and repairable using normal building maintenance techniques. With the implementation of any necessary remediation measures, it is unlikely that there would be any significant impacts on the rural building structures.

While the predicted ground movements are important parameters when assessing the potential impacts on the rural building structures, it is noted that the impact assessments were primarily based on historical observations from previous longwall mining in the Southern Coalfield. The overall levels of impact on the rural building structures, resulting from the extraction of the proposed longwalls, are expected to be similar to those observed where longwalls have previously mined directly beneath rural building structures in the Southern Coalfield.

#### 8.2.6. Recommendations for the Rural Building Structures

The assessed impacts on the rural building structures within the Study Area, resulting from the extraction of the proposed longwalls, can be managed with the implementation of suitable management strategies.

IC will prepare Property Subsidence Management Plans (PSMP) for all landholders within the Study Area, similar to those which have been prepared for the properties at Appin Area 7 and West Cliff Colliery. The PSMPs will address the management of all surface infrastructure including rural building structures. With the implementation of these management strategies, it would be expected that the rural building structures would be maintained in safe and serviceable conditions during and after the extraction of the proposed longwalls.

### 8.3. Tanks

The locations of the water tanks within the Study Area are shown in Drawings Nos. MSEC533-15 to MSEC533-21. The descriptions, predictions and impact assessments for the tanks are provided in the following sections.

#### 8.3.1. Descriptions of the Tanks

There are 82 water tanks (Structure Type T) which have been identified within the Study Area. The locations of the tanks are shown in Drawing No. MSEC533-16 to MSEC533-21 and details are provided in Table D.05, in Appendix D. The locations and sizes of the tanks were determined from an aerial photograph of the area and kerb side inspections. There are also a number of smaller rainwater tanks associated with the houses which are not shown in these drawings. The existence of any underground tanks or plans to construct new tanks would be discussed with property owners during preparation of PSMPs for each property.

#### 8.3.2. Predictions for the Tanks

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at points located around the perimeter of each tank, as well as at points located at a distance of 20 metres from the perimeter of each tank.

A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each tank within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table D.05, in Appendix D. The predicted tilts provided in this table are the maxima in any direction after the completion of each of the proposed longwalls. The predicted curvatures provided in this table are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the tanks within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 8.4 and Fig. 8.5.

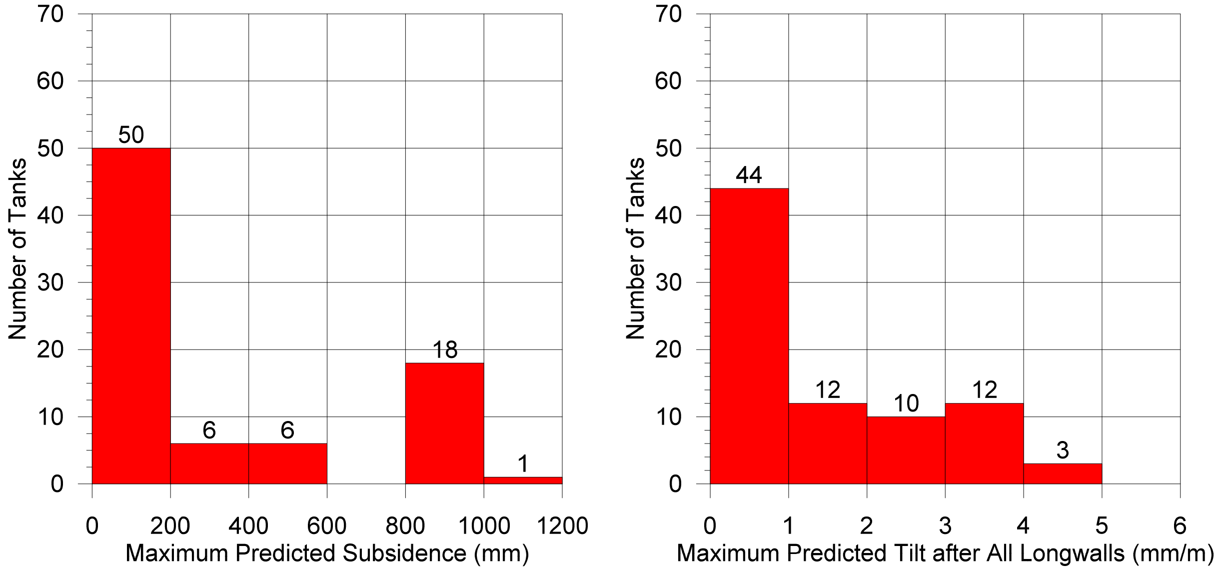



**Fig. 8.4 Maximum Predicted Conventional Subsidence and Tilt for the Tanks within the Study Area Resulting from the Extraction of the Proposed Longwalls**

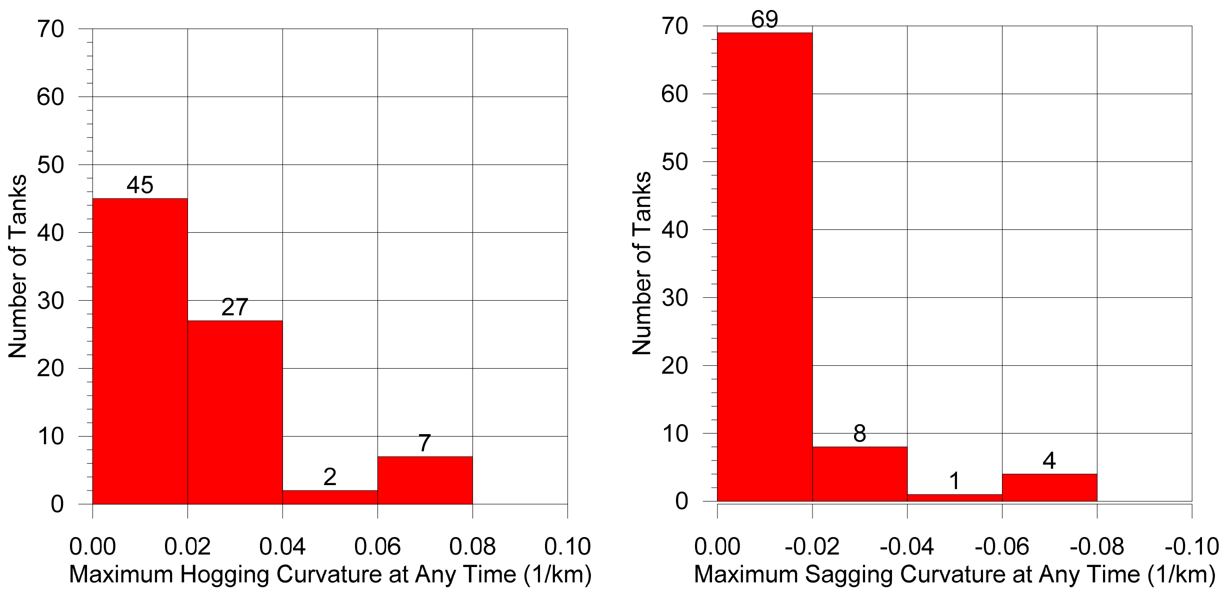



**Fig. 8.5 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Tanks Resulting from the Extraction of the Proposed Longwalls**

The tanks are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the tanks, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.1 mm/m tensile and 0.9 mm/m compressive.

### 8.3.3. Comparison of Predictions for the Tanks with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for the tanks with those provided in the Part 3A Application is provided in Table 8.3.

**Table 8.3 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Tanks Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 1000 | 4.0 | 0.07 | 0.06 |

It can be seen from the above table, that the maximum predicted mine subsidence movements for the tanks, based on the Extraction Plan Layout, are less than those predicted based on the Part 3A Layout.

### 8.3.4. Impact Assessments for the Tanks

Tilt can potentially affect the serviceability of tanks by altering the water levels in the tanks, which can in turn affect the minimum level of water which can be released from the outlets. The maximum predicted conventional tilt for the tanks within the Study Area is 4 mm/m (i.e. 0.4 %), which represents a change in grade of 1 in 250. The predicted changes in grade are small, less than 1 % and unlikely, therefore, to result in any significant impacts on the serviceability of the tanks.

The tanks are typically constructed above ground level and, therefore, are unlikely to experience the curvatures and ground strains resulting from the extraction of the proposed longwalls. It is possible, that any buried tanks or water pipelines associated with the tanks within the Study Area could be impacted by the ground strains, if they are anchored by the tanks, or by other structures in the ground.

Any impacts are expected to be of a minor nature, including leaking pipe joints, and could be easily repaired. With these remedial measures in place, it would be unlikely that there would be any significant impacts on the pipelines associated with the tanks.

### 8.3.5. Impact Assessments for the Tanks Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the tanks would be 8 mm/m (i.e. 0.8 %), or a change in grade of 1 in 125. In this case, the incidence of serviceability impacts, such as changes in the minimum water levels which can be released from the outlets, could increase in the locations of greatest tilt, such as adjacent to the active longwall maingate and adjacent to the ends of the proposed longwalls. Any such impacts would be expected to be easily remediated by relevelling the tanks.

If the actual curvatures exceeded those predicted by a factor of 2 times, the incidence of impacts on the tank structures would not be expected to change significantly, as they are not expected to experience these ground movements. The incidence of impacts on the buried pipelines would, however, be expected to increase in the locations directly above the proposed longwalls. Any impacts would still be expected to be of a minor nature which could be easily repaired. With these remediation measures in place, it would be unlikely that there would be any significant long term impacts on the pipelines associated with the tanks.

### 8.3.6. Recommendations for the Tanks

The assessed impacts on the tanks and associated infrastructure resulting from the extraction of the proposed longwalls are not significant. It is recommended that management strategies for the tanks within the Study Area are addressed in the PSMPs.

## 8.4. Gas and Fuel Storages

A number of the residences within the Study Area are likely to have gas or fuel storages.

The domestic gas and fuel storages could potentially experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The storage tanks are generally elevated above ground level and, therefore, are not susceptible to mine subsidence movements. It is possible, however, that any buried storages or gas pipelines associated with the storage tanks within the Study Area could be impacted by the curvatures and ground strains, if they are anchored by the storage tanks, or by other structures in the ground.

Any impacts are expected to be of a minor nature, including minor gas leaks, which could be easily repaired. It is unlikely that there would be any significant impacts on the pipelines associated with the gas and fuel storage tanks, even if the actual movements exceeded the predictions by a factor of 2 times. It is recommended that the management of any fuel storages are addressed in PSMPs.

## 8.5. Poultry Sheds

No poultry sheds have been identified within the Study Area. It is recommended that the management of any small poultry enclosures identified in the Study Area are addressed in the PSMPs.

## 8.6. Glass Houses

No glass houses have been identified within the Study Area. It is recommended that the management of any small glass enclosures identified in the Study Area are addressed in the PSMPs.

## 8.7. Hydroponic Systems

No hydroponic systems have been identified within the Study Area. It is recommended that the management of any small hydroponic systems identified in the Study Area are addressed in the PSMPs.

## 8.8. Irrigation Systems

No irrigation systems have been identified within the Study Area. It is possible that irrigation systems are present within the Study Area for private use and at the Harland's Fruit Nursery and Landscaping property. The systems are usually constructed from polyethylene pipes which can tolerate ground movements much larger than the predicted mine subsidence movments within the Study Area. Elevated strains can occur in the pipelines where they are anchored to the ground or where they are subjected to non-conventional ground movements. Any impacts are expected to be of a minor nature, including leaking pipe joints, and could be easily repaired.

It is recommended that the management of any small irrigation systems identified in the Study Area are addressed in the PSMPs.

## 8.9. Farm Fences

The fences are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The fences are linear features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines above previous longwall mining. The analysis of strains along whole monitoring lines during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4 and the results are provided in Fig. 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The fences within the Study Area are constructed in a variety of ways, generally using either timber or metal materials.

Wire fences can be affected by tilting of the fence posts and by changes of tension in the fence wires due to strain as mining occurs. These types of fences are generally flexible in construction and can usually tolerate tilts of up to 10 mm/m and strains of up to 5 mm/m without significant impacts. It is likely, therefore, that some of the wire fences within the Study Area would be impacted as the result of the extraction of the proposed longwalls. Any impacts on the wire fences are likely to be of a minor nature and relatively easy to remediate by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

Colorbond and timber paling fences are more rigid than wire fences and, therefore, are more susceptible to impacts resulting from mine subsidence movements. It is possible that these types of fences could be impacted as the result of the extraction of the proposed longwalls. Any impacts on Colorbond or timber paling fences can be remediated or, where necessary, affected sections of the fences replaced.

The management strategies for the fences within the Study Area will be covered in the PSMPs.

## 8.10. Farm Dams

The locations of the farm dams within the Study Area are shown in Drawings Nos. MSEC533-15 to MSEC533-21. The descriptions, predictions and impact assessments for these features are provided in the following sections.

### 8.10.1. Descriptions of the Farm Dams

There are 43 farm dams (Structure Type D) which have been identified within the Study Area. The locations of the farm dams are shown in Drawings Nos. MSEC533-16 to MSEC533-21 and details are provided in Table D.04, in Appendix D. The locations and sizes of the farm dams were determined from an aerial photograph of the area.

The dams are typically of earthen construction and have been established by localised cut and fill operations within the natural drainage lines. The farm dams are generally shallow, with the dam wall heights generally being less than 3 metres. The distributions of the longest lengths and surface areas of the farm dams within the Study Area are shown in Fig. 8.6.

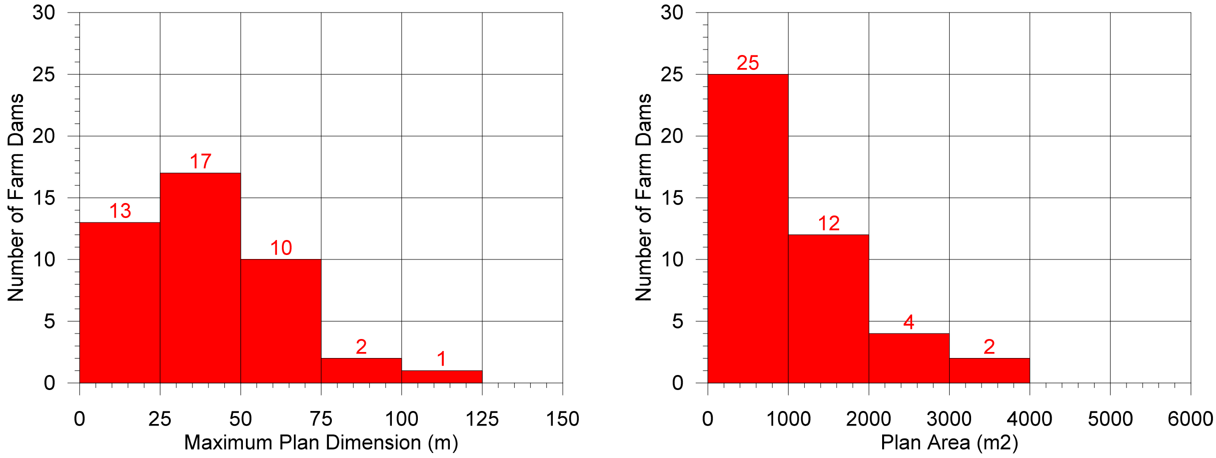



**Fig. 8.6 Distributions of Longest Lengths and Surface Areas of the Farm Dams**

### 8.10.2. Predictions for the Farm Dams

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and around the perimeters of each farm dam. A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each farm dam within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table D.04, in Appendix D.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the farm dams within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 8.7, Fig. 8.8 and Fig. 8.9.

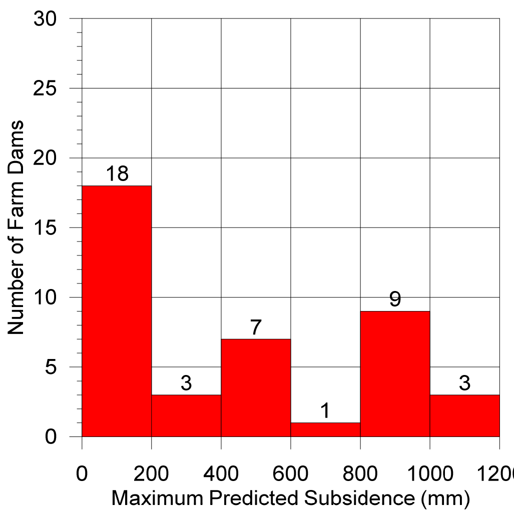


**Fig. 8.7 Maximum Predicted Conventional Subsidence for the Farm Dams within the Study Area Resulting from the Extraction of the Proposed Longwalls**

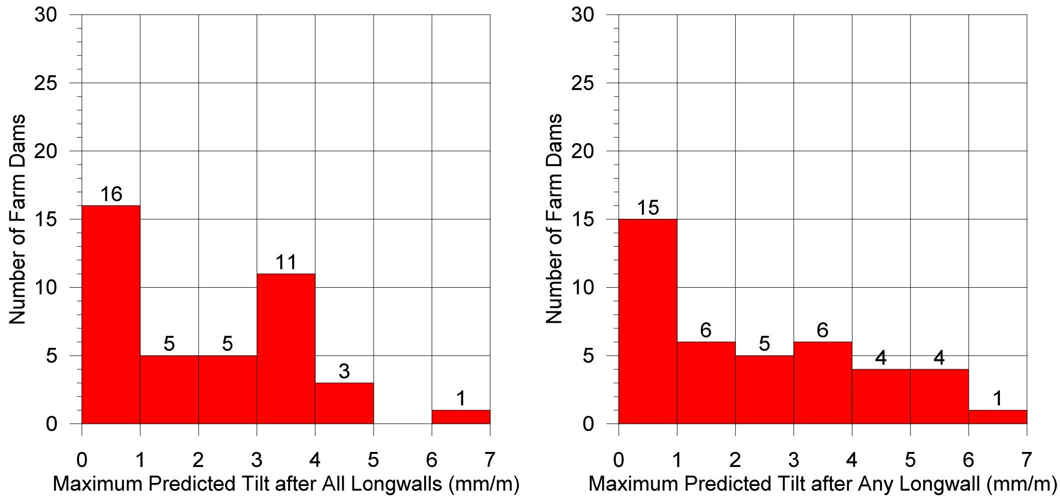



**Fig. 8.8 Maximum Predicted Conventional Tilt after the Extraction of All Longwalls (Left) and after the Extraction of Any Longwall (Right) for the Farm Dams within the Study Area**

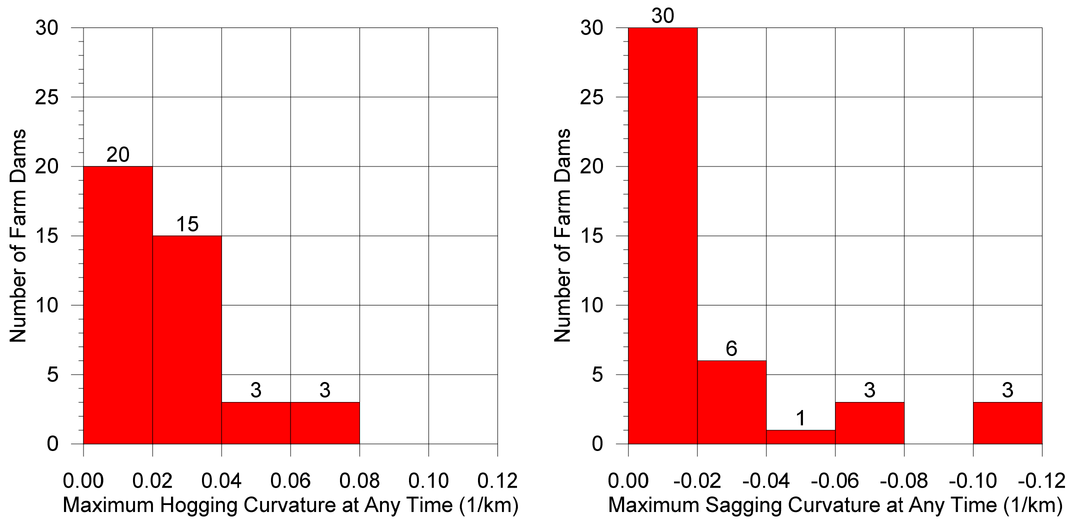



**Fig. 8.9 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Farm Dams Resulting from the Extraction of the Proposed Longwalls**

The dams have typically been constructed within the drainage lines and, therefore, may be subjected to valley related movements resulting from the extraction of the proposed longwalls. The equivalent valley heights at the dams are very small and it is expected, therefore, that the predicted valley related upsidence and closure movements at the dam walls would be much less than the predicted conventional subsidence movements and would not be significant.

The farm dams are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous ground movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the farm dams, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.1 mm/m tensile and 1.8 mm/m compressive. The strains resulting from valley related movements are discussed separately in the following sections.

### 8.10.3. Comparison of Predictions for the Farm Dams with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for the farm dams with those provided in the Part 3A Application is provided in Table 8.4.

**Table 8.4 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Farm Dams Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 1100 | 6.5 | 0.07 | 0.12 |

It can be seen from the above table, that the maximum predicted mine subsidence movements for the farm dams, based on the Extraction Plan Layout, are similar to but slightly less than those predicted based on the Part 3A Layout.

### 8.10.4. Impact Assessments for the Farm Dams

The maximum predicted tilt for the farm dams within the Study Area, at the completion of mining or at any time during the extraction of the proposed longwalls, is 6.5 mm/m (i.e. 0.7 %), which represents a change in grade of 1 in 155.

Mining induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side, and decreasing on the other. Tilt can potentially reduce the storage capacity of farm dams, by causing them to overflow, or can affect the stability of the dam walls.

The predicted changes in freeboard at the farm dams within the Study Area were determined by taking the difference between the maximum predicted subsidence and the minimum predicted subsidence anywhere around the perimeter of each farm dam. The predicted maximum changes in freeboard at the farm dams within the Study Area, after the completion of the proposed longwalls, are provided in Table D.04, in Appendix D, and are illustrated in Fig. 8.10.

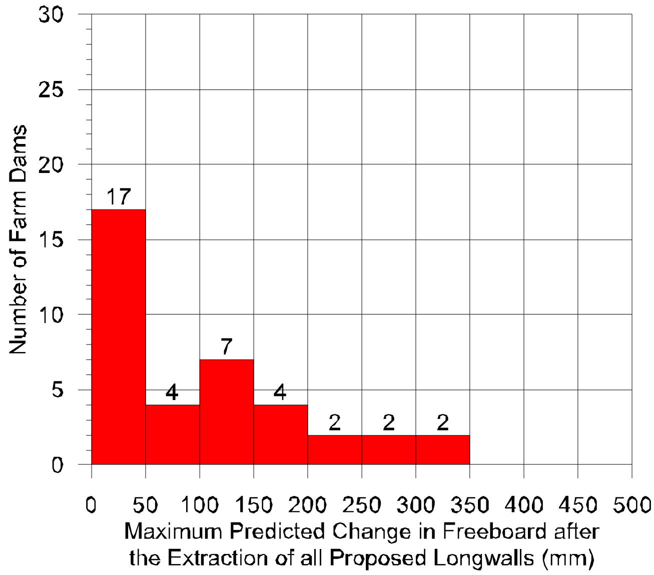



**Fig. 8.10 Predicted Changes in Freeboards for the Farm Dams within the Study Area**

It can be seen from the above figure, that the predicted maximum changes in freeboard at the farm dams within the Study Area are all less than 400 mm and are unlikely, therefore, to have a significant impact on the storage capacities or the stability of the dam walls.

The maximum predicted hogging and sagging curvatures for farm dams, resulting from the extraction of the proposed longwalls, are 0.07 $km^{-1}$ and 0.12 $km^{-1}$, respectively, which represent minimum radii of curvature of 14 kilometres and 8 kilometres, respectively.

The maximum predicted curvatures and the range of potential strains at the farm dams, resulting from the extraction of the proposed longwalls, are similar to those typically experienced elsewhere in the Southern Coalfield. Longwalls in the Southern Coalfield have been successfully mined directly beneath farm dams in the past, and some of these cases are provided in Table 8.5.

**Table 8.5 Examples of Previous Experience of Mining Beneath Farm Dams in the Southern Coalfield**

| Colliery and LWs | Number of Farm Dams Directly Mined Beneath | Predicted Maximum Movements at Dams | Observed Impacts |
|---|---|---|---|
| Appin LW301 and LW302 | 3 | 750 mm Subsidence<br>6 mm/m Tilt<br>0.7 mm/m Tensile Strain<br>1.8 mm/m Comp. Strain | No reported impacts |
| Appin LW401 to LW408 | 49 | 1200 mm Subsidence<br>5 mm/m Tilt<br>1.2 mm/m Tensile Strain<br>2.2 mm/m Comp. Strain | No reported impacts |
| Appin LW701 and LW702 | 11 | 1100 mm Subsidence<br>4 mm/m Tilt<br>0.6 mm/m Tensile Strain<br>1.4 mm/m Comp. Strain | One farm dam reported to drain |
| Tahmoor LW22 to LW24A | 16 | 850 mm Subsidence<br>5 mm/m Tilt<br>1.0 mm/m Tensile Strain<br>1.7 mm/m Comp. Strain | No reported impacts |
| West Cliff LW29 to LW33 | 42 | 1100 mm Subsidence<br>6 mm/m Tilt<br>1.2 mm/m Tensile Strain<br>2.0 mm/m Comp. Strain | No reported impacts |

It can be seen from the above table, that the incidence of impacts on farm dams in the Southern Coalfield is extremely low. The farm dam reported to drain during the extraction of Appin Longwall 702 was of poor, shallow construction and seepage was observed at the base of the dam wall prior to mining. While no impacts were observed on the dam wall itself, the dam was observed to drain following mining of Appin Longwall 702.

It is expected, therefore, that the incidence of impacts on the farm dams within the Study Area, resulting from the extraction of the proposed longwalls, will be extremely low. If cracking or leakage of water were to occur in the farm dam walls, it is expected that this could be easily identified and repaired as required. It is not expected that any significant loss of water will occur from the farm dams, and any loss that did occur would flow into the tributary in which the dam was formed.

### 8.10.5. Impact Assessments for the Farm Dams Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the farm dams, at the completion of mining, would be 13 mm/m (i.e. 1.3 %), or a change in grade of 1 in 80. In this case, the maximum change in freeboard would be around 700 mm, which could be sufficient to reduce the capacities of the farm dams below acceptable levels in the locations of greatest tilt, such as adjacent to the active longwall maingate and adjacent to the ends of the proposed longwalls. It may be necessary, in consultation with the landowner, to restore the capacities of these farm dams at the completion of mining.

If the actual curvatures exceeded those predicted by a factor of 2 times, the likelihood and extent of cracking would increase for the farm dams located directly above the longwalls. Any surface cracking would still be expected to be of a minor nature and could be easily repaired. With any necessary remedial measures implemented, it is unlikely that any significant impact on the farm dams would occur resulting from the extraction of the proposed longwalls.

### 8.10.6. Recommendations for the Farm Dams

The assessed impacts on the farm dams, resulting from the extraction of the proposed longwalls, can be managed by the implementation of suitable management strategies. It is recommended that all water retaining structures be periodically visually monitored during the extraction of the proposed longwalls, to ensure that they remain in a safe and serviceable condition.

It is recommended that the management strategies for the farm dams within the Study Area be addressed in the PSMPs. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the farm dams resulting from the extraction of the proposed longwalls.

## 8.11. Groundwater Bores

The locations of the groundwater bores within the Study Area are shown in Drawing No. MSEC533-22. The descriptions, predictions and impact assessments for the bores are provided in the following sections.

### 8.11.1. Descriptions of the Groundwater Bores

There is one registered groundwater bore within the Study Area, the details of which are provided in Table 8.6.

**Table 8.6 Details of the Groundwater Bore within the Study Area**

| Ref. | Approximate Easting (m) | Approximate Northing (m) | Diameter (mm) | Depth (m) | Authorised Use |
|---|---|---|---|---|---|
| GW072454 | 297710 | 6218063 | 125 | 162 | Domestic Irrigation |

The locations and details of the registered groundwater bores were obtained from the Department of Natural Resources using the *Natural Resource Atlas* website (NRAtlas, 2010).

Further details on the groundwater bores are provided in the report by *Geoterra* (2013).

### 8.11.2. Predictions and Impact Assessments for the Groundwater Bores

A summary of the maximum predicted total conventional subsidence parameters for the groundwater bores, resulting from the extraction of the proposed longwalls, is provided in Table 8.7.

**Table 8.7 Maximum Predicted Total Conventional Subsidence Parameters at the Groundwater Bores Resulting from the Extraction of the Proposed Longwalls**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| GW072454 | 340 | 3.6 | 0.03 | < 0.01 |

The predicted tilts provided in the above table are the maxima in any direction after the completion of any or all of the proposed longwalls. The predicted curvatures provided in the above table are the maxima in any direction at any time during or after the extraction of the proposed longwalls.

The bores are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional ground strains for the bores, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and <0.2 mm/m compressive.

It is likely that the groundwater bores will experience some impacts as the result of mining of the longwalls, particularly those directly above the proposed longwalls. Impacts may include temporary lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality. Such impacts on the groundwater bores can be readily managed.

It should be noted, that there have been no reported significant impacts on the registered groundwater bores which were located above or near the previously extracted Appin Longwalls 401 to 409 and West Cliff Longwalls 29 to 33.

Further discussions on the potential impacts on the groundwater regime, resulting from the extraction of the proposed longwalls, are provided in the report by *Geoterra* (2013).

#### 8.11.3. Recommendations for the Groundwater Bores

It is recommended that the management strategies for the groundwater bores within the Study Area are addressed in the PSMPs.

# 9.0 DESCRIPTIONS, PREDICTIONS AND IMPACT ASSESSMENTS FOR THE INDUSTRIAL, COMMERICAL AND BUSINESS ESTABLISHMENTS

The following sections provide the descriptions, predictions and impact assessments for the industrial, commercial and business establishments within the Study Area.

## 9.1. Factories

There are no factories within the Study Area.

## 9.2. Workshops

There are no commercial workshops within the Study Area.

## 9.3. Business or Commercial Establishments or Improvements

The Harland's Fruit, Nursery and Lanscaping business is located within the Study Area on Blackburn Road. The property grows plants and fruit trees and is located partially over the proposed Longwall 38. The property will experience the full range of predicted incremental subsidence movements from the extraction of Longwall 38 which are summarised in Table 4.1.

It is possible that plants and fruit trees could be affected by changes in the surface and groundwater regime, and surface cracking resulting from the extraction of Longwall 38. Surface cracking in soils above the proposed longwalls is expected to be isolated and of a minor nature as dicussed in Section 4.8. Further discussions on the surface water and groundwater within the Study Area are provided in the report by *Ecoengineers* (2013) and *Geoterra* (2013) respectively.

There are no other businesses or commercial establishments within the Study Area. Any business or commercial establishments identified during the development of the PSMPs will be addressed in those management plans.

## 9.4. Gas or Fuel Storages and Associated Plant

There are no commercial gas or fuel storages within the Study Area.

## 9.5. Waste Storages and Associated Plant

There are no commercial waste storages, or associated plant within the Study Area.

## 9.6. Buildings, Equipment or Operations that are Sensitive to Surface Movements

There are no known buildings, equipment or operations in addition to those already addressed in this report that are sensitive to surface movements within the Study Area.

## 9.7. Surface Mining (Open Cut) Voids and Rehabilitated Areas

There are no surface mining, or rehabilitation areas within the Study Area.

## 9.8. Mine Infrastructure Including Tailings Dams or Emplacement Areas

There are a number of exploration drill holes within the Study Area, the locations of which are shown in Drawing No. MSEC533-32. There is no other mine infrastructure within the Study Area.

## 9.9. Any Other Industrial, Commercial or Business Features

There are no other industrial, or commercial, or business features within the Study Area.

The descriptions, predictions and impact assessments for the archaeological and heritage sites within the Study Area are provided in the following sections.

## 10.1. Aboriginal Archaeological Sites

There are no lands within the Study Area declared as an Aboriginal Place under the *National Parks and Wildlife Act 1974*.

There are five archaeological sites that have been identified within the Study Area, the locations of which are shown in Drawing No. MSEC533-22. There is also one grinding groove archaeological site immediately to the south of the Study Area around Longwall 38 that has been included in the assessment. There are no sites located over the proposed longwalls. A summary is provided in Table 10.1.

**Table 10.1 Archaeological Sites Identified within the Study Area**

| Recording Code | Site Name | Recoding Type |
|---|---|---|
| 52-2-2064 | Sawpit Gully 9 Georges River Appin | Grinding Grooves |
| 52-2-2234 | GEORGES RIVER NO.1 | Shelter with Art |
| 52-2-2241 | GEORGES RIVER NO.5 | Shelter with Art |
| 52-2-2242 | GEORGES RIVER NO.4 | Shelter with Art |
| 52-2-2243 | GEORGES RIVER NO.2 | Shelter with Art and Deposit |
| 52-2-3691 | Bulli Site 11 | Open Site (Artefacts) |

Detailed descriptions of the archaeological sites are provided by *Niche* (2013b).

### 10.1.1. Predictions for the Aboriginal Archaeological Sites

A summary of the maximum predicted values of total conventional subsidence, tilt and curvature for the archaeological sites is provided in Table 10.2. Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at points located around the perimeter of each archaeological site, as well as at points located at a distance of 20 metres from the perimeter of each archaeological site.

**Table 10.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature for the Archaeological Sites Resulting from the Extraction of the Proposed Longwalls**

| Location | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging Curvature ($km^{-1}$) |
|---|---|---|---|---|
| 52-2-2064 | < 20 | < 0.5 | < 0.01 | < 0.01 |
| 52-2-2234 | 25 | < 0.5 | < 0.01 | < 0.01 |
| 52-2-2241 | 125 | 2.0 | 0.03 | < 0.01 |
| 52-2-2242 | 100 | 1.0 | < 0.01 | < 0.01 |
| 52-2-2243 | < 20 | < 0.5 | < 0.01 | < 0.01 |
| 52-2-3691 | 1025 | 2.0 | 0.03 | < 0.01 |

The predicted tilts provided in the above table are the maxima after the completion of any or all of the proposed longwalls. The predicted curvatures provided in the above table are the maxima at any time during or after the extraction of each of the proposed longwalls.

The archaeological sites are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the archaeological sites, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and less than 0.2 mm/m compressive.

### 10.1.2. Comparison of Predictions for the Aboriginal Archaeological Sites with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for the archaeological sites with those provided in the Part 3A Application is provided in Table 10.3.

**Table 10.3 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Archaeological Sites Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 1025 | 2.0 | 0.03 | <0.01 |

It can be seen from the above table, that the maximum predicted mine subsidence movements for the archaeological sites, based on the Extraction Plan Layout, are much less than those predicted based on the Part 3A Layout.

### 10.1.3. Impact Assessments for the Artefact Scatters

There are two sites with artefact scatters included in the assessment. The maximum predicted tilt for the artefact scatter sites is 2 mm/m (i.e. 0.2 %), which represents a change in grade of 1 in 500. It is unlikely that these sites would experience any adverse impacts resulting from the mining induced tilts.

The maximum predicted curvatures for the artefact scatter sites are 0.03 $km^{-1}$ hogging and <0.01 $km^{-1}$ sagging, which represent minimum radii of curvature of 33 kilometres and greater than 100 kilometres, respectively. The maximum predicted conventional strains for these sites, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and less than 0.2 mm/m compressive.

These artefact scatter sites can potentially be affected by cracking of the surface soils as a result of mine subsidence movements. It is unlikely, however, that the scattered artefacts or isolated finds themselves would be impacted by surface cracking. It is possible, however, that if remediation of the surface was required after mining, that these works could potentially impact the sites.

### 10.1.4. Impact Assessments for the Shelters

There are four shelter sites included in the assessment. The maximum predicted tilt for the shelters is 2 mm/m (i.e. 0.2 %), which represents a change in grade of 1 in 500. It is unlikely that these sites would experience any adverse impacts resulting from the mining induced tilts.

The maximum predicted curvature for the artefact scatter sites are 0.03 $km^{-1}$ hogging and <0.01 $km^{-1}$ sagging, which represent minimum radii of curvature of 33 kilometres and greater than 100 kilometres, respectively. The maximum predicted conventional strains for these sites, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 0.5 mm/m tensile and less than 0.2 mm/m compressive.

These types of sites can potentially be impacted by mine subsidence movements including the fracturing of sandstone, rock falls, or water seepage through joints which may affect artwork. The main mechanisms which could potentially result in impact on sandstone shelters are the conventional curvatures.

Tensile strains greater than 0.5 mm/m may be of a sufficient magnitude to result in the fracturing of sandstone. Compressive strains greater than 2 mm/m may be of a sufficient magnitude to result in the underlying strata buckling, which could result in the fracturing of the sandstone bedrock.

It is possible, therefore, that the maximum predicted conventional tensile strains could be of sufficient magnitude to result in fracturing in the sandstone bedrock and, hence, the possibility of impacts to the shelters. Given the low values of predicted curvature at the shelters, however, the risk of impact to the shelters is considered to be very low.

The likelihood of impact on shelters with art located outside of the footprint of the extracted longwalls is considerably less than those which are located directly above extracted longwalls. It has been reported that, where longwall mining has previously been carried out in the Southern Coalfield, beneath 52 shelters, that approximately 10 % of the shelters have been affected by fracturing of the strata or shear movements along bedding planes and that none of the shelters have collapsed (Sefton, 2000). This suggests that the likelihood of significant impacts on the shelters with art, resulting from the extraction of the proposed longwalls, is low.

#### 10.1.5. Impact Assessments for the Grinding Groove Sites

There is one grinding groove site within the Study Area. The maximum predicted tilt for the grinding groove site is less than 0.5 mm/m (i.e. less than 0.1 %), which represents changes in grade of less than 1 in 2,000. It is unlikely that this site would experience any adverse impacts resulting from mining induced tilts of these magnitudes.

The maximum predicted curvature for the grinding groove site is less than 0.01 $km^{-1}$ hogging and sagging, which represents a minimum radius of curvature greater than 100 kilometres. The maximum predicted conventional strains for this site, based on applying a factor of 15 to the maximum predicted conventional curvatures, is less than 0.2 mm/m.

The sites is located in the base of the stream valleys and, therefore, could experience valley related movements. The maximum predicted upsidence and the maximum predicted compressive strains due to the closure movements are expected to occur in the bases of the valleys and could potentially impact the grinding groove sites. Discussions on impacts to the bases of stream valleys are provided in Sections 5.2.5 and 5.3.2. It is possible, therefore, that minor and isolated fracturing could occur in the vicinity of the grinding groove sites. The likelihood of any fracturing being coincident with the sites is considered low. Further assessments of the potential impacts on the grinding groove sites are provided in a report by *Niche* (2013b).

#### 10.1.6. Impact Assessments for the Aboriginal Archaeological Sites Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilts at the artefact scatters, shelters and grinding groove sites would be 4 mm/m (i.e. 0.4 %, or 1 in 250). These types of archaeological sites are not adversely affected by tilt and, therefore, the likelihoods of impact would not be expected to increase.

If the actual curvatures or strains at the artefact scatter sites and shelters exceeded those predicted by a factor of 2 times, the maximum predicted curvature would be 0.06 $km^{-1}$ hogging, which represents a minimum radius of curvature of 16 kilometres. The maximum predicted conventional strains for these sites, based on applying a factor of 15 to the maximum predicted conventional curvatures, is 1 mm/m tensile. The sagging curvature and associated compressive strains would still be minimal and less than levels considered to result in surface impacts. The likelihoods and extents of cracking in the surface soils due to the hogging curvature and associated tensile strain would increase. It would still be unlikely that the artefacts themselves would be impacted by the surface cracking and the methods of remediation, if required, would not be expected to change. It should be noted, however, that the Incremental Profile Method generally provides conservative predictions and that additional conservatism has been provided by taking the maximum predicted systematic subsidence parameters within a 20 metre radius of each archaeological site. It is expected, therefore, that the systematic subsidence parameters at the archaeological sites would not be significantly exceeded.

If the actual curvatures at the grinding groove sites exceeded those predicted by a factor of 2 times, the maximum curvatures and associated conventional tensile strains would still be very low and much less than potential strains generated by valley closure movements. If the actual valley related movements at the grinding groove sites exceeded those predicted by a factor of 2 times, potential frequency of cracking and potential for cracking to coincide with the grinding grooves would also increase. It would still be expected that only minor and isolated fracturing would occur in these locations.

#### 10.1.7. Recommendations for the Aborigial Archaeological Sites

It is recommended that a survey of the Aboriginal archaeological sites be undertaken and a monitoring programme established to record the effects of mine subsidence on these sites.

## 10.2. Heritage Sites

There are no items within the Study Area which are listed on the State Heritage Register. The locations of heritage items outside the Study Area are shown on Drawing No. MSEC533-22. The distances from the heritage items to the nearest goaf edges of the proposed Longwalls 37 and 38 varies from approximately 460 metres to 760 metres. At these distances the heritage sites are unlikely to be subjected to any significant conventional subsidence movements resulting from the extraction of the proposed longwalls but may experience minor far field effects. Far field movements are discussed in Section 4.6.

The Bridge and Road Remains Site (WH1) is located 470 metres to the west of Longwall 38 and consists of eight postholes cut into the sandstone bed of the Georges River. The remains of timber posts and cement packing are present in some of the holes. Since this site is located in the base of a valley it may be subjected to minor valley related movements due to the extraction of Longwall 38. The WH1 site is located on the Georges River Rockbar RB39, which experienced fractures after the completion of Longwall 33, one of which was coincident with one of the post hole remains. The predicted incremental closure due to Longwall 38 at this location along the Georges River is 20 mm and the predicted total closure due to Longwalls 29 to 38 is 130 mm. The prediction of valley closure is recognised as producing conservative results, particularly at low levels of closure as data is affected more by survey tolerance. The predicted additional closure due to the extraction of Longwall 38 is small, however given the rockbar has experienced impacts from the previously extracted longwalls, this closure may cause minor movements at existing fractures in the rockbar. The small magnitude of the predicted additional closure is considered unlikely to result in new impacts.

## 10.3. Items on the Register of the National Estate

There are no items on the Register of National Estate within the Study Area.

## 10.4. Items of Architectural Significance

There are no items of architectural significance within the Study Area.

## 11.1. Houses

The locations of the houses within the Study Area are shown in Drawings Nos. MSEC533-15 to MSEC533-21. The descriptions, predictions and impact assessments for these structures are provided in the following sections.

### 11.1.1. Descriptions of the Houses

There are 33 houses that have been identified within the Study Area. The locations of the houses are shown in Drawing No. MSEC533-15 to MSEC533-21 and details are provided in Table D.01, in Appendix D. The locations, sizes, and details of the houses were determined from an aerial photograph of the area and from kerb side inspections. It is likely that additional houses will be constructed prior to the commencement of mining. There are five houses identified within the Appin Mine Subsidence District, which was proclaimed on the 20th March 1968 and notified on the 19th April 1968. There are a total of 4 houses identified within the South Campbelltown Mine Subsidence District, which was proclaimed on the 30th June 1976 and notified on the 30th July 1976. The *Appin* and the *South Campbelltown* Mine Subsidence Districts are shown in Drawing No. MSEC533-01.

The distribution of the maximum plan dimension and plan area of the houses within the Study Area is provided in Fig. 11.1. The distributions of the wall and footing constructions of the houses within the Study Area are provided in Fig. 11.2.

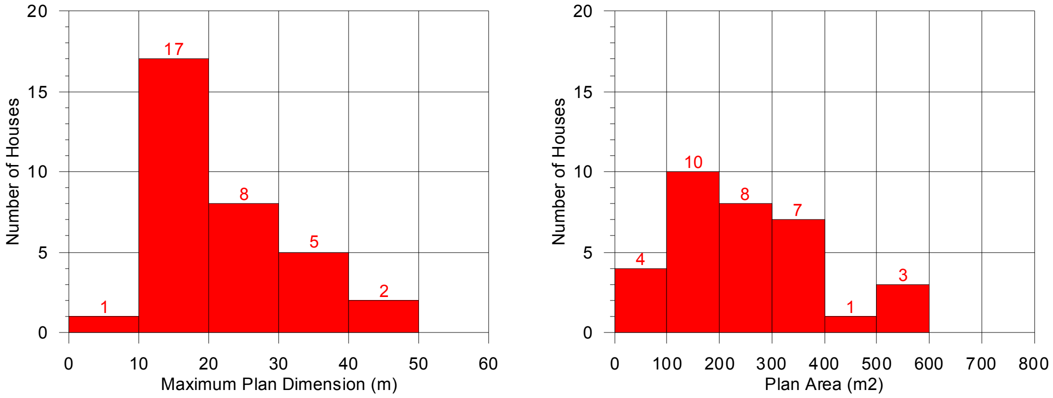



**Fig. 11.1 Distribution of the Maximum Plan Dimension of Houses within the Study Area**

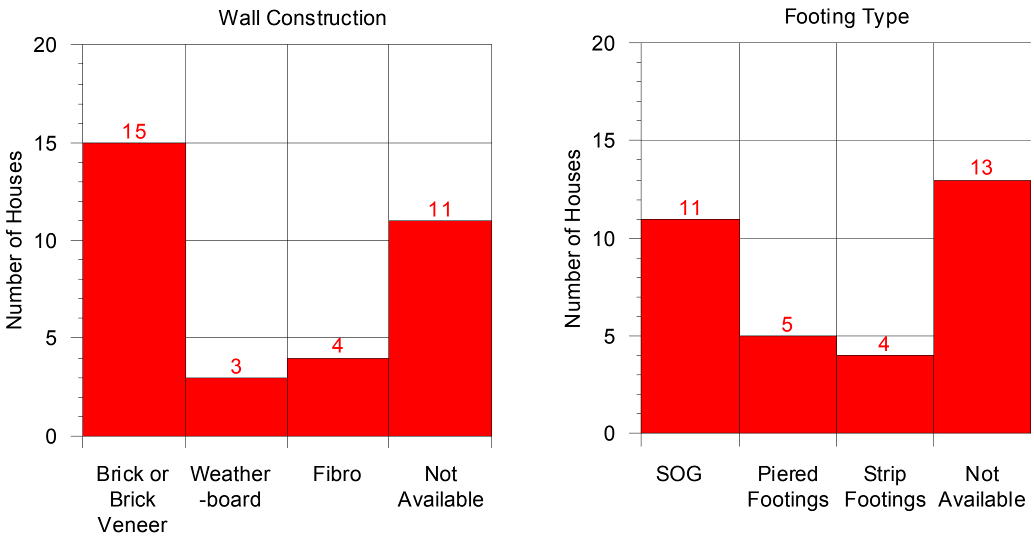



**Fig. 11.2 Distributions of Wall and Footing Construction for Houses within the Study Area**

### 11.1.2. Predictions for the Houses

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at the vertices of each house, as well as eight equally spaced points placed radially around the centroid and vertices at a distance of 20 metres. In the case of a rectangular shaped structure, predictions have been made at a minimum of 45 points within and around the structure.

A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each house within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table D.02, in Appendix D. The predicted tilts provided in this table are the maxima in any direction after the completion of each of the proposed longwalls. The predicted curvatures provided in this table are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

The distribution of the predicted conventional subsidence parameters for the houses within the Study Area are illustrated in Fig. 11.3, Fig. 11.4 and Fig. 11.5 below.

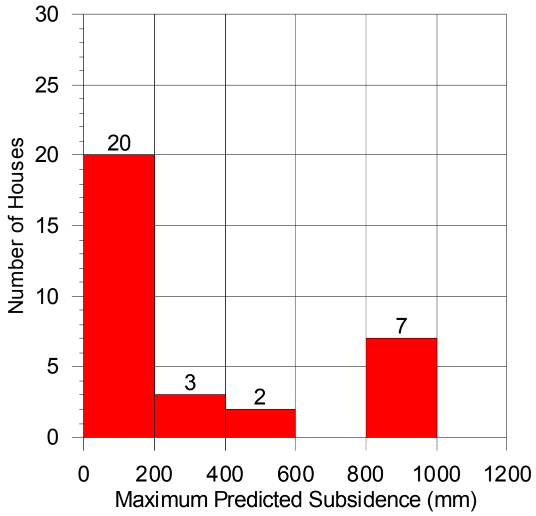
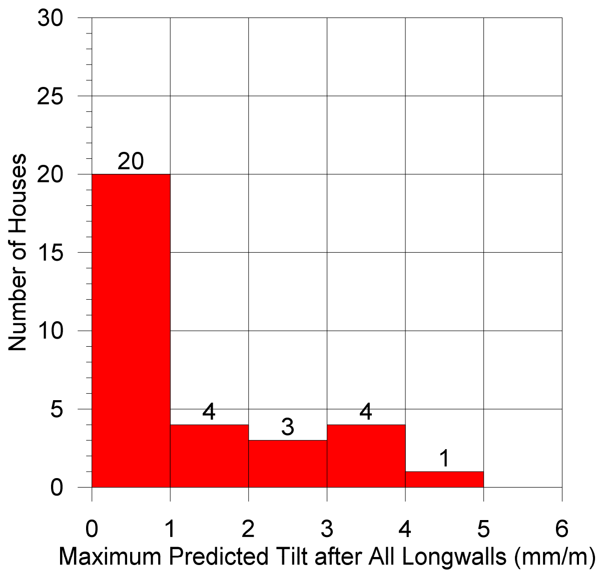



**Fig. 11.3 Maximum Predicted Conventional Subsidence for the Houses within the Study Area Resulting from the Extraction of the Proposed Longwalls**



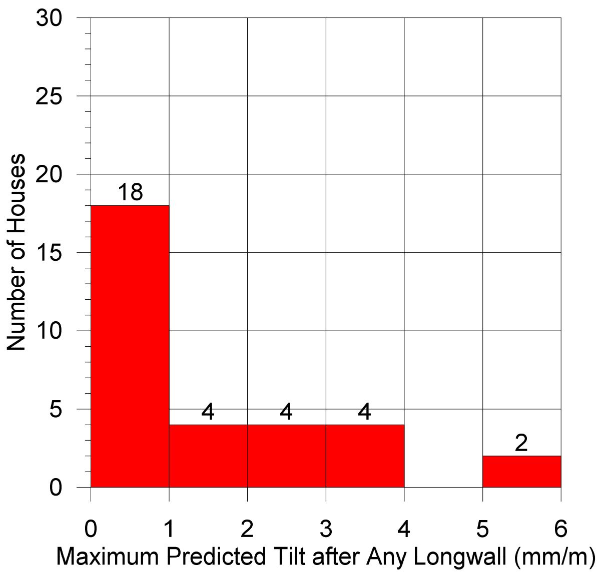




**Fig. 11.4 Maximum Predicted Conventional Tilts After the Extraction of All Longwalls (Left) and Maximum Predicted Conventional Tilts After the Extraction of Any Longwall (Right)**

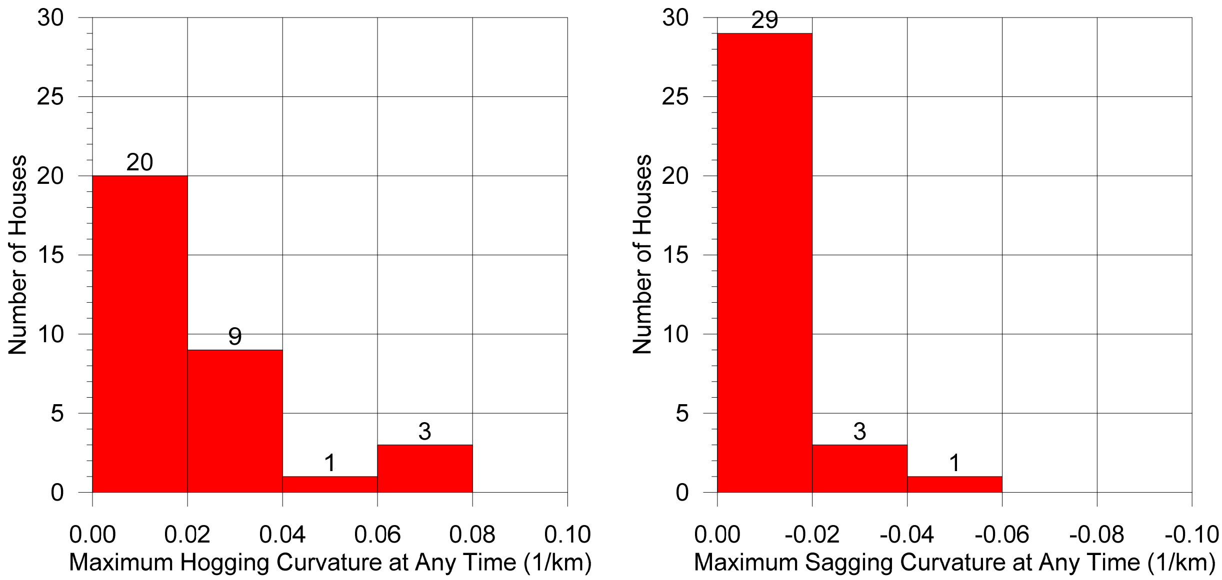



**Fig. 11.5 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses Resulting from the Extraction of the Proposed Longwalls**

The houses are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the houses, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.1 mm/m tensile and 0.8 mm/m compressive.

### 11.1.3. Comparison of Predictions for the Houses with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for the houses with those provided in the Part 3A Application is provided in Table 11.1.

**Table 11.1 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Houses Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 950 | 6.0 | 0.07 | 0.05 |

It can be seen from the above table, that the maximum predicted mine subsidence movements for the houses, based on the Extraction Plan Layout, are similar to but slightly less than those predicted based on the Part 3A Layout.

### 11.1.4. Impact Assessments for the Houses

The following sections provide the impact assessments for the houses within the Study Area.

***Potential Impacts Resulting from Vertical Subsidence***

Vertical subsidence does not directly affect the stability or serviceability of houses. The potential for impacts on houses are affected by differential subsidence, which includes tilt, curvature and ground strain, and the impact assessments based on these parameters are described in the following sections.

Vertical subsidence can, in some cases, affect the heights of the houses above the flood level. The land within the Study Area drains freely into the nearby streams and there are no houses located in areas which would be considered flood prone.

***Potential Impacts Resulting from Tilt***

It has been found from past longwall mining experience that tilts of less than 7 mm/m generally do not result in any significant impacts on houses. Some minor serviceability impacts can occur at these levels of tilt, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques. Tilts greater than 7 mm/m can result in greater serviceability impacts which may require more substantial remediation measures, including the relevelling of wet areas or, in some cases, the relevelling of the building structure.

The maximum predicted tilt for the houses, resulting from the extraction of the proposed longwalls, is 6.0 mm/m (i.e. 0.6 %), which represents a change in grade of 1 in 170. It is expected, therefore, that only minor serviceability impacts would occur at the houses within the Study Area, as the result of tilt, which could be remediated using normal building techniques. It is expected that the houses within the Study Area will remain in a safe and serviceable condition as the result of the mining induced tilts.

***Potential Impacts Resulting from Curvature and Strain***

The methods for predicting and assessing impacts on building structures have developed over time as knowledge and experience has grown. MSEC has provided predictions and impact assessments for the houses within the Study Area using the latest methods available at the time.

*Background to the Method of Impact Assessment for Houses*

Building structures have been directly mined beneath at a number of Collieries throughout the NSW Coalfields. The experience gained has provided substantial information that has been used to continually develop the methods of impact assessment for houses. The assessments provided in this report are based on the latest research, which is summarised in Appendix C. The discussions and the method of assessment provided in this report are based on the experience of mining at depths of cover generally greater than 350 metres, such as the case within the Study Area.

The most extensive data has come from the extraction of Tahmoor Longwalls 22 to 25, where over 1000 residential and significant civil structures have experienced mine subsidence movements. The impacts to houses at Tahmoor Colliery were last analysed in detail following the completion of Longwall 24A. A summary of the observed frequency of impacts for all structures located within the 26½ degree angle of draw from the extents of mining at that time is provided in Table 11.2.

**Table 11.2 Observed Frequency of Impacts for Building Structures Resulting from the Extraction of Tahmoor Longwalls 22 to 24A**

| Group | Repair Category | | | |
|---|---|---|---|---|
| | No Claim or R0 | R1 or R2 | R3 or R4 | R5 |
| All buildings (total of 1099) | 967 (88.0 %) | 92 (8.4 %) | 37 (3.4 %) | 3 (0.3 %) |
| Buildings directly above goaf (total of 669) | 546 (81.6 %) | 84 (12.6 %) | 36 (5.4 %) | 3 (0.4 %) |
| Buildings directly above solid coal (total of 430) | 421 (97.9 %) | 8 (1.9 %) | 1 (0.2 %) | 0 (0.0 %) |

The repair categories R0 to R5 are described in Table C.4 in Appendix C.

The distributions of the maximum predicted conventional hogging and sagging curvatures for the houses, resulting from the extraction of Tahmoor Longwalls 22 to 24A, are provided in Fig. 11.6. It can be seen from this figure, that the houses were predicted to have experienced conventional hogging curvatures of up to 0.10 $km^{-1}$ and conventional sagging curvatures of up to 0.15 $km^{-1}$.

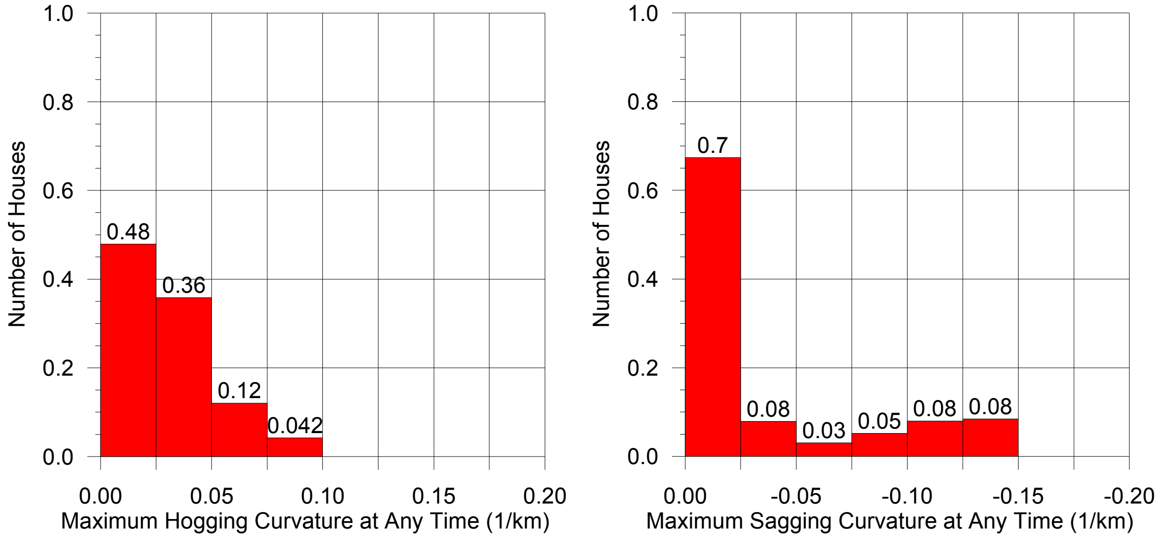



**Fig. 11.6 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses Located Above Tahmoor Longwalls 22 to 24A**

Extensive data has also come from the extraction of Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10, where approximately 500 houses have experienced mine subsidence movements. A summary of the observed frequency of impacts for the houses located within the 26½ degree angle of draw from the extents of mining at these Collieries is provided in Table 11.3.

**Table 11.3 Observed Frequency of Impacts for Houses Resulting from the Extraction of Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10**

| Group | Repair Category | | | |
|---|---|---|---|---|
| | No Claim or R0 | R1 or R2 | R3 or R4 | R5 |
| All houses (total of 494) | 415 (84.0 %) | 51 (10.3 %) | 26 (5.3 %) | 2 (0.4 %) |

The repair categories R0 to R5 are described in Table C.4 in Appendix C.

The distributions of the maximum predicted conventional hogging and sagging curvatures for the houses, resulting from the extraction of Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10, are provided in Fig. 11.7. It can be seen from this figure, that the houses were predicted to have experienced conventional hogging curvatures of up to 0.20 $km^{-1}$ and conventional sagging curvatures of up to 0.25 $km^{-1}$.

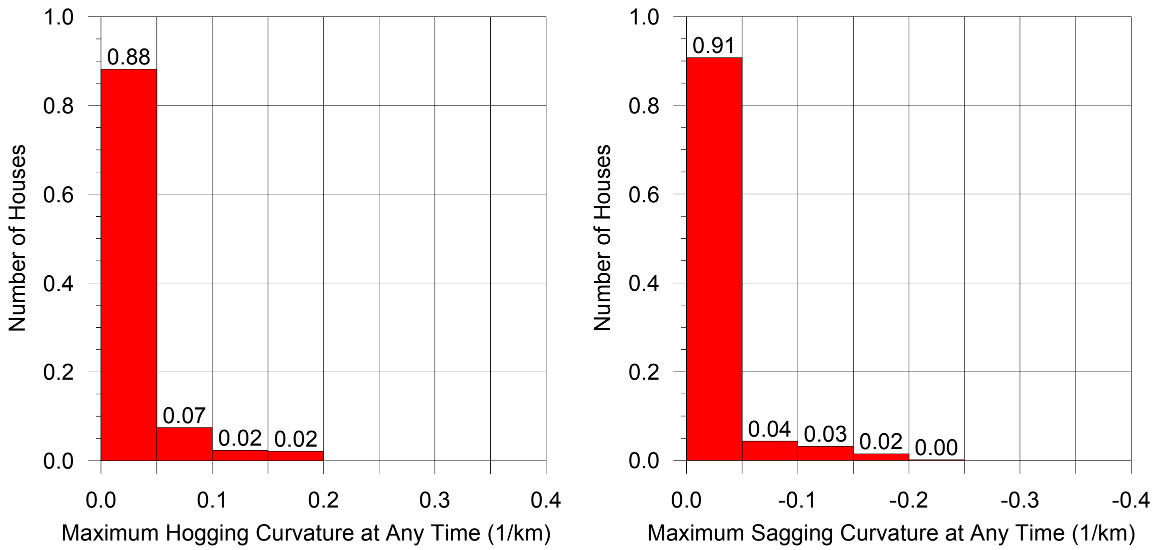



**Fig. 11.7 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses at Teralba, West Cliff and West Wallsend**

The experiences at Tahmoor, Teralba, West Cliff and West Wallsend Collieries indicate that the majority of observed impacts relate to minor effects that are relatively simple to repair, such as sticky doors or windows and cracks to plasterboard linings. In about 5 % of cases, however, substantial or more extensive repairs were required. In less than 1 % of cases, the houses experienced severe impacts, where the Mine Subsidence Board, in consultation with the owners, elected to rebuild the structure as the cost of repair exceeded the cost of replacement.

In all these cases, the residents were not exposed to any immediate and sudden safety hazards as the result of impacts that occurred due to mine subsidence movements. Emphasis is placed on the words "immediate and sudden" as, in rare cases, some structures have experienced severe impacts, but these impacts did not present an immediate risk to public safety as they developed gradually with ample time to manage any increased safety risks.

As part of ACARP Research Project C12015, a detailed analysis was undertaken to identify the trends that linked the frequency and severity of impacts with ground strain, ground curvature, type of construction and structure size. A method for assessment was developed for houses, using the primary parameters of ground curvature and type of construction, and further details of this method are provided in Appendix C. The method of assessment developed as part of the ACARP research project has been used to assess the potential impacts on the houses within the Study Area which is provided below.

*Impact Assessment for Houses within the Study Area*

The maximum predicted conventional hogging and sagging curvatures for the houses, resulting from the extraction of the proposed longwalls, are 0.07 $km^{-1}$ and 0.05 $km^{-1}$, respectively, which equate to minimum radii of curvature of 14 kilometres and 20 kilometres, respectively. It can be seen from Fig. 11.5, that approximately 90 % to 95 % of the houses within the Study Area are predicted to experience hogging and sagging curvatures no greater than 0.05 $km^{-1}$. It is expected, therefore, that the houses within the Study Area will collectively experience a similar range of impacts as has been observed at similar houses during previous longwall mining in the Southern Coalfield.

The probabilities of impacts for each house within the Study Area have been assessed using the method developed as part of ACARP Research Project C12015, which is described in Appendix C. This method uses the primary parameters of ground curvature and type of construction. A summary of the predicted movements and the assessed impacts for each house within the Study Area is provided in Table D.02 in Appendix D. The overall distribution of the assessed impacts for the houses within the Study Area is provided in Table 11.4.

**Table 11.4 Assessed Impacts for the Houses within the Study Area**

| Group | Repair Category | | | |
|---|---|---|---|---|
| | No Claim or R0 | R1 or R2 | R3 or R4 | R5 |
| All houses (total of 33) | 29 (89 %) | 3 (6 %) | 1 (3 %) | ≈ 1 (< 3 %) |
| Houses Directly Above Longwalls (total of 12) | 10 (83 %) | 1 (12 %) | 1 (5 %) | ≈ 0 |
| Houses Directly Above Solid Coal (total of 21) | 19 (92 %) | 1 (7 %) | ≈ 1 (<1 %) | ≈ 0 |

Trend analyses following the mining of Tahmoor Longwalls 22 to 24A indicate that the chance of impact is higher for the following houses:-

- Houses predicted to experience higher strains and curvatures,
- Houses with masonry walls,
- Masonry walled houses that are constructed on strip footings,
- Larger houses, and
- Houses with variable foundations, such as those with extensions added.

The primary risk associated with mining beneath houses is public safety. Residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements in the NSW Coalfields, where the depths of cover were greater than 400 metres, such as the case above the proposed longwalls. This includes the recent experience at Tahmoor Colliery, which included more than 1000 houses, and the experiences at Teralba, West Cliff and West Wallsend Collieries, which included around 500 houses.

All houses within the Study Area are expected to remain safe, serviceable and repairable throughout the mining period, provided that they are in sound structural condition prior to mining. It should be noted that the assessments indicate that the impact to approximately one house with repair category R3, R4 or R5 could occur, however the probability of this occurring is very low.

### 11.1.5. Impact Assessments for the Houses Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the tilts would still be less than 7 mm/m at 30 of the houses (i.e. 91 %) at the completion of mining. It would still be expected that only minor serviceability impacts would occur at these houses, as the result of tilt, which could be remediated using normal building techniques.

The tilts would be between 7 mm/m and 10 mm/m at 2 houses (i.e. 6 %) and would be equal to 12 mm/m at 1 house (i.e. 3 %) at the completion of mining. It would be expected that greater serviceability impacts would occur at these houses which would require more substantial remediation measures including, in some cases, relevelling of the building structures.

A summary of the houses with tilts greater than 7 mm/m, based on a 2 times predicted case, is provided in Table 11.5. The maximum tilt at the completion of mining, based on the 2 times predicted case, is 12 mm/m at House Ref. D08h01, which is located directly above Longwall 37.

**Table 11.5 Houses with Tilts Greater than 7 mm/m Based on a 2 Times Predicted Case**

| Tilt Based on a 2 Times Predicted Case (mm/m) | Number of Houses | House References |
|---|---|---|
| 7 ~ 10 | 2 | D04h01, K17h01 |
| > 10 | 1 | D08h01 |

It is expected, in all cases, that the houses within the Study Area would remain in a safe and serviceable condition as the result of the mining induced tilts.

If the actual curvatures exceeded those predicted by a factor of 2 times, the maximum hogging and sagging curvatures at the houses would be 0.14 $km^{-1}$ and 0.10 $km^{-1}$, respectively, which equate to minimum radii of curvature of 7 kilometres and 10 kilometres, respectively. The distributions of hogging and sagging curvature, based on a 2 times predicted case, are illustrated in Fig. 11.8.

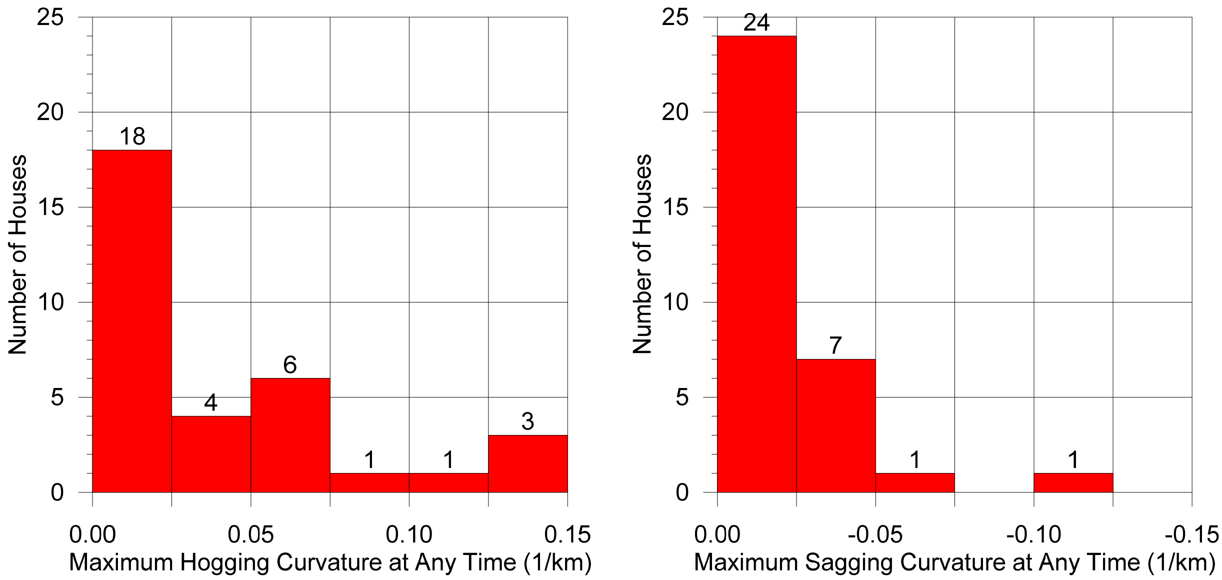



**Fig. 11.8 Distribution of Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses Based on a 2 Times Predicted Case**

It can be seen from the above figure, that the ranges and distributions of hogging and sagging curvature, based on the 2 times predicted case, are similar to those predicted to have occurred for the houses above Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10, which was illustrated in Fig. 11.7.

The overall levels of impact on the houses within the Study Area would, therefore, be expected to be similar to that experienced at Teralba, West Cliff and West Wallsend, which is summarised in Table 11.3. Based on previous experience, it would still be expected that the houses would remain in a safe and serviceable condition. The impacts would develop slowly, allowing preventive measures to be undertaken and, where required, relocation of residence if any structures were deemed to become unsafe.

#### 11.1.6. Recommendations for the Houses

IC has developed a number of management strategies for houses which have been directly mined beneath by previously extracted longwalls at Appin, Tower and West Cliff Collieries. It is recommended that similar management strategies are developed for the houses within the Study Area.

IC will prepare PSMPs for all landholders within the Study Area, similar to those which have been prepared for the properties at Appin Area 7 and West Cliff Colliery. The PSMPs will address the management of all surface infrastructure including the houses. With the implementation of these management strategies, it would be expected that the houses could be maintained in a safe and serviceable condition during and after the extraction of the proposed longwalls.

The management strategies should include the following where access is provided to the property:-

- Inspection of the houses considered to be at higher risk by a structural engineer or a suitably qualified building inspector prior to the longwall mining directly beneath them,
- Consideration of implementing any mitigation measures, where necessary to address specific identified risks to public safety,
- Consideration of undertaking detailed monitoring of ground movements at or around structures, where necessary to address specific identified risks to public safety,
- Periodic inspections of structures that are considered to be at higher risk. These may include:-
    - Structures in close proximity to steep slopes where recommended by a geotechnical or subsidence engineer,
    - Structures identified as being potentially unstable where recommended by a structural or subsidence engineer, and
    - Pool fences.
- Co-ordination and communication with landowners and the Mine Subsidence Board during mining.

It is recommended that the houses are periodically visually monitored during the extraction of the proposed longwalls. With these strategies in place, it is expected that the houses would remain safe and serviceable throughout the mining period.

## 11.2. Flats or Units

There are no flats or units within the Study Area.

## 11.3. Caravan Parks

There are no caravan parks within the Study Area.

## 11.4. Retirement or Aged Care Villages

There are no retirement or aged care villages within the Study Area.

## 11.5. Swimming Pools

The locations of the private swimming pools within the Study Area are shown in Drawings Nos. MSEC533-15 to MSEC533-21. The predictions and impact assessments for the privately owned pools are provided in the following sections. There are no public swimming pools identified within the Study Area.

#### 11.5.1. Descriptions of the Swimming Pools

There are 8 privately owned swimming pools which have been identified within the Study Area. The locations, sizes, and details of the pools were determined from an aerial photograph of the area.

### 11.5.2. Predictions for the Swimming Pools

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at points located around the perimeter of each pool, as well as at points located at a distance of 20 metres from the perimeter of each pool.

A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each pool within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table D.06, in Appendix D. The predicted tilts provided in this table are the maxima in any direction after the completion of each of the proposed longwalls. The predicted curvatures provided in this table are the maxima in any direction at any time during or after the extraction of each of the proposed longwalls.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the pools within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 11.9 and Fig. 11.10.

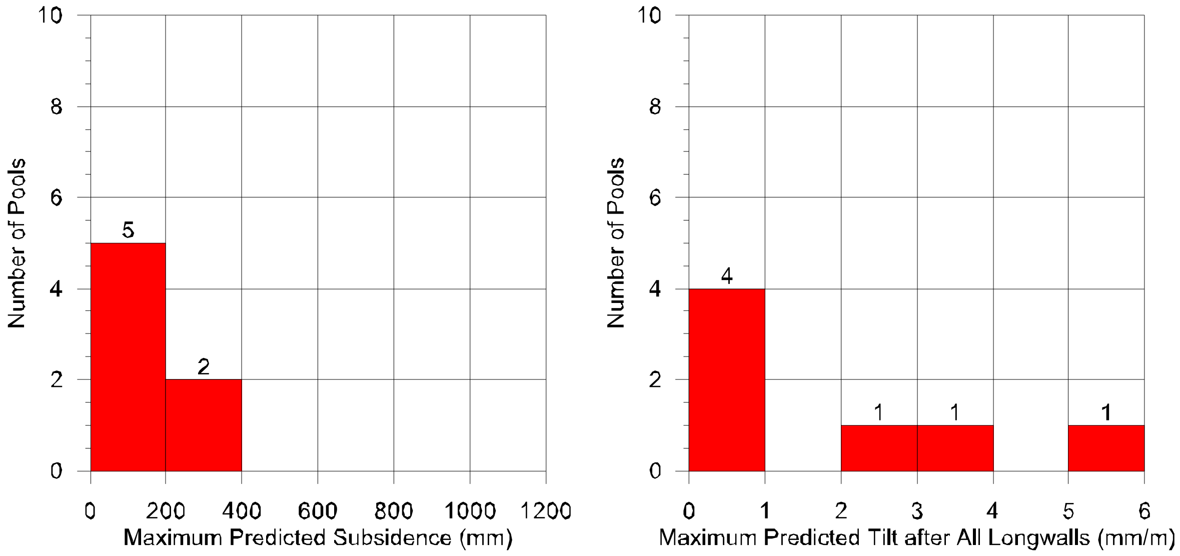



**Fig. 11.9 Maximum Predicted Conventional Subsidence and Tilt for the Pools within the Study Area Resulting from the Extraction of the Proposed Longwalls**

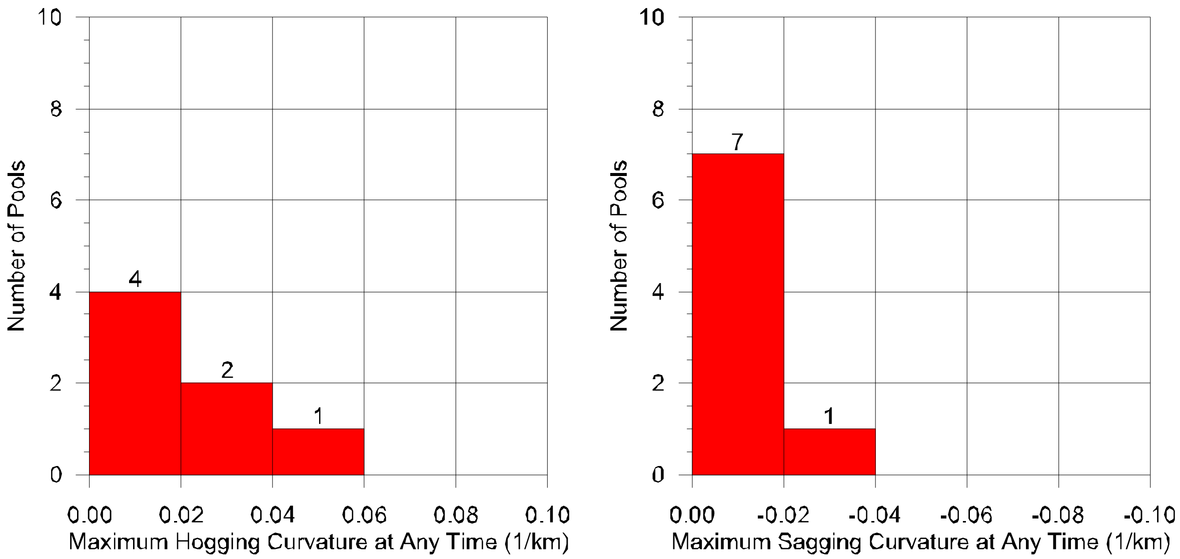



**Fig. 11.10 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Pools Resulting from the Extraction of the Proposed Longwalls**

The pools are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the pools, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1 mm/m tensile and 0.5 mm/m compressive.

### 11.5.3. Comparison of Predictions for the Pools with those provided in the Part 3A Application

The comparison of the maximum predicted subsidence parameters for the pools with those provided in the Part 3A Application is provided in Table 11.6.

**Table 11.6 Comparison of the Maximum Predicted Conventional Subsidence Parameters for the Pools Based on the Part 3A and Extraction Plan Layouts**

| Layout | Maximum Predicted Total Conventional Subsidence (mm) | Maximum Predicted Total Conventional Tilt (mm/m) | Maximum Predicted Total Conventional Hogging Curvature ($km^{-1}$) | Maximum Predicted Total Conventional Sagging ($km^{-1}$) |
|---|---|---|---|---|
| Part 3A Layout (Report No. MSEC404) | 1200 | 6.3 | 0.08 | 0.14 |
| Extraction Plan Layout (Report No. MSEC533) | 400 | 5.0 | 0.06 | 0.03 |

It can be seen from the above table, that the maximum predicted mine subsidence movements for the pools, based on the Extraction Plan Layout, are similar to or less than those predicted based on the Part 3A Layout.

### 11.5.4. Impact Assessments for the Swimming Pools

Mining-induced tilts are more noticeable in pools than other structures due to the presence of the water line and the small gap to the edge coping, particularly when the pool lining has been tiled. Skimmer boxes are also susceptible of being lifted above the water line due to mining tilt.

The Australian Standard AS2783-1992 (Use of reinforced concrete for small swimming pools) requires that pools be constructed level ± 15 mm from one end to the other. This represents a tilt of approximately 3.3 mm/m for pools that are 10 metres in length. Australian Standard AS/NZS 1839:1994 (Swimming pools – Pre-moulded fibre-reinforced plastics – Installation) also requires that pools be constructed with a tilt of 3 mm/m or less.

It can be seen from Table D.06, that 7 of the 8 pools within the Study Area are predicted to experience tilts of 3 mm/m or less, at the completion of the proposed longwalls, which is similar to or less than the Australian Standard. There is one pool (Ref. D08p01) within the Study Area which is predicted to experience a tilt greater than 3 mm/m, at the completion of the proposed longwalls, which may require some remediation of the pool copings. The predicted tilt at this pool, at the completion of mining, is 5 mm/m (i.e. 0.5 %).

The maximum predicted hogging and sagging curvatures at the pools within the Study Area, resulting from the extraction of the proposed longwalls, are both 0.06 $km^{-1}$ and 0.03 $km^{-1}$ respectively, which represent minimum radius of curvature of 16 kilometres and 33 Kilometres. It can be seen from Fig. 11.10, that the ranges and distributions of hogging and sagging curvature for the pools within the Study Area are similar to or less than those predicted to have occurred for the houses and, hence, the pools above Tahmoor Longwalls 22 to 24A, which is illustrated in Fig. 11.6. The incidence and levels of impacts on the pools in the Study Area, therefore, are expected to be similar to or less than those experienced at Tahmoor Colliery.

Observations during the mining of Tahmoor Colliery Longwalls 22 to 25 have shown that pools, particularly in-ground pools, are more susceptible to severe impacts than houses and other structures. Pools cannot be easily repaired and most of the impacted pools were replaced in order to restore them to pre-mining condition or better.

As of May 2009, a total of 108 pools have experienced mine subsidence movements during the mining of Tahmoor Colliery Longwalls 22 to 25, of which 80 were located directly above the extracted longwalls. A total of 14 pools have reported impacts, all of which were located directly above the extracted longwalls. This represents an impact rate of approximately 18 %. A higher proportion of impacts have been observed for in-ground pools, particularly fibreglass pools. The majority of the impacts related to tilt or cracking, though in a small number of cases the impacts were limited to damage to skimmer boxes or the edge coping.

The observed levels of impact on the pools at Tahmoor should provide a reasonable guide to the potential levels of impact on the pools within the Study Area.

#### 11.5.5. Impact Assessments for the Swimming Pools Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the tilts would still be less than 3 mm/m at five or the eight pools at the completion of mining. The tilts would exceed 3 mm/m at three pools at the completion of mining, which may require some remediation of the pool copings.

If the actual curvatures exceeded those predicted by a factor of 2 times, the maximum hogging and sagging curvatures at the houses would be 0.12 $km^{-1}$ and 0.06 $km^{-1}$ respectively, which represents a minimum radius of curvature of 8 kilometres and 17 kilometres. The ranges of hogging and sagging curvature, based on the 2 times predicted case, are similar to those predicted to have occurred for the houses and, hence, the pools above Tahmoor Longwalls 22 to 24A, which is illustrated in Fig. 11.6. In this case, the potential impacts on the pools within the Study Area would be expected to be similar to those experienced at Tahmoor Colliery.

#### 11.5.6. Recommendations for the Swimming Pools

A number of pool gates have been impacted as the result of the previous extraction of longwalls beneath pools. While the gates can be easily repaired, the consequence of breaching pool fence integrity is considered to be severe. As a result, it is recommended that regular inspections of the integrity of pool fences during the active subsidence period be included in the development of any Management Plan for properties that have pools or are planning to construct a pool during the mining period.

IC will prepare PSMPs for all landholders within the Study Area, similar to those which have been prepared for the properties at Appin Area 7 and West Cliff Colliery. The PSMPs will address the management of all surface infrastructure including the pools and pool fences.

### 11.6. Tennis Courts

There are no tennis courts within the Study Area.

### 11.7. On-Site Waste Water Systems

The residences on the rural properties within the Study Area have on-site waste water systems.

The on-site waste systems are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The on-site waste water systems are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains in survey bays during the mining of previous longwalls in the Southern Coalfield is discussed in Section 4.4.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.5. The results for survey bays above solid coal are provided in Fig. 4.3 and Table 4.6.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, among other things, anomalous ground movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted conventional strains for the on-site waste water systems, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.2 mm/m tensile and 1.8 mm/m compressive.

The maximum predicted change in grade for the on-site waste water systems within the Study Area are less than 1 %. It is unlikely, therefore, that the maximum predicted tilts would result in any significant impacts on the systems. The maximum predicted conventional tilts could, however, be of sufficient magnitude to affect the serviceability of the buried pipes between the houses and the on-site waste water systems, if the existing grades of these pipes are very small, say less than 1 %.

The on-site waste water system tanks are generally small, typically less than 3 metres in diameter, are constructed from reinforced concrete, and are usually bedded in sand and backfilled. It is unlikely, therefore, that the maximum predicted curvatures and ground strains would be fully transferred into the tank structures.

It is possible, however, that the buried pipelines associated with the on-site waste water tanks could be impacted by the ground strains if they are anchored by the tanks or other structures in the ground. Any impacts are expected to be of a minor nature, including leaking pipe joints, and could be easily repaired.

With the implementation of these remedial measures, it would be unlikely that there would be any significant impacts on the pipelines associated with the on-site waste water systems.

It is recommended that IC prepare PSMPs for all landholders within the Study Area, similar to those which have been prepared for the properties at Appin Area 7 and West Cliff Colliery. The PSMPs will address the management of all surface infrastructure including the on-site waste water systems.

## 11.8. Rigid External Pavements

Adverse impacts on rigid external pavements are often reported to the Mine Subsidence Board in the NSW Coalfields. This is because pavements are typically thin relative to their length and width. The design of external pavements is also not regulated by Council or the Mine Subsidence Board.

A study by MSEC of 120 properties at Tahmoor and Thirlmere indicated that 98 % of the properties with external concrete pavements demonstrated some form of cracking prior to mining. These cracks are sometimes difficult to distinguish from cracks caused by mine subsidence.

Residential concrete pavements are typically constructed with tooled joints which do not have the capacity to absorb compressive movements. It is possible that some of the smaller concrete footpaths or pavements within the Study Area, in the locations of the larger compressive ground strains, could buckle upwards if there are insufficient movement joints in the pavements. It is expected, however, that the buckling of footpaths and pavements would not be common, given the magnitudes of the predicted ground strains, and could be easily repaired.

It is recommended that IC prepare PSMPs for all landholders within the Study Area, similar to those which have been prepared for the properties at Appin Area 7 and West Cliff Colliery. The PSMPs will address the management of all surface infrastructure including the rigid external pavements.

## 11.9. Fences

The predictions and impact assessments for fences are provided in Section 8.3.

## 11.10. Any Other Residential Feature

There are no other significant residential features within the Study Area.

# APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

# Glossary of Terms and Definitions

Some of the more common mining terms used in the report are defined below:-

| | |
|---|---|
| **Angle of draw** | The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence). |
| **Chain pillar** | A block of coal left unmined between the longwall extraction panels. |
| **Cover depth (H)** | The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel. |
| **Closure** | **T**he reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill movements and other possible strata mechanisms. |
| **Critical area** | The area of extraction at which the maximum possible subsidence of one point on the surface occurs. |
| **Curvature** | The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave). |
| **Extracted seam** | The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel. |
| **Effective extracted** | The extracted seam thickness modified to account for the percentage of coal |
| **seam thickness (T)** | left as pillars within the panel. |
| **Face length** | The width of the coalface measured across the longwall panel. |
| **Far-field movements** | The measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. |
| **Goaf** | The void created by the extraction of the coal into which the immediate roof layers collapse. |
| **Goaf end factor** | A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel. |
| **Horizontal displacement** | The horizontal movement of a point on the surface of the ground as it settles above an extracted panel. |
| **Inflection point** | The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max. |
| **Incremental subsidence** | The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel. |
| **Panel** | The plan area of coal extraction. |
| **Panel length (L)** | The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib. |

| | |
|---|---|
| **Panel width (Wv)** | The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side. |
| **Panel centre line** | An imaginary line drawn down the middle of the panel. |
| **Pillar** | A block of coal left unmined. |
| **Pillar width (Wpi)** | The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib. |
| **Shear deformations** | The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. |
| **Strain** | The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation.<br><br>**Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines. |
| **Sub-critical area** | An area of panel smaller than the critical area. |
| **Subsidence** | The vertical movement of a point on the surface of the ground as it settles above an extracted panel, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured. |
| **Super-critical area** | An area of panel greater than the critical area. |
| **Tilt** | 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 horizontal 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 %, or 1 in 1000. |
| **Uplift** | An increase in the level of a point relative to its original position. |
| **Upsidence** | Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain. |

# APPENDIX B. REFERENCES

# References

APCRC (1997). *Geochemical and isotopic analysis of soil, water and gas samples from Cataract Gorge*. George, S. C., Pallasser, R. and Quezada, R. A., APCRC Confidential Report No. 282, June 1997.

Australian Standards Association, AS 2870 - 1996, *Residential Slabs and Footings – Construction.*

Cardno Ecology Lab (2013). *West Cliff Longwalls 37-38, Aquatic Flora and Fauna Assessment,* January 2013.

Christie, D., (2006). *Inspection of Cuttings on the Main South Line affected by LW's 701 to 704*. June, 2006.

Department of Land and Water Conservation. (2000). *Cataract River: Assessment of the effectiveness of grouting trial at Bubble Pool*. Resource Information Unit, Sydney South Coast Region, Department of Land and Water Conservation, June, 2000.

Ecoengineers (2013). *Assessment of Water Quality Effects and Water Quality Monitoring Plan – West Cliff Colliery, Longwalls 37 and 38 Extraction Plan*, January 2013

Forster, I.R., (1995). *Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW*. Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

Geoterra (2013). *West Cliff Longwalls 37 and 38 Groundwater Assessment*, 24 May 2013

Grainger, M.A. (1993). *Effects of mining on railway infrastructure and developments in their control*. Proceedings of the Institution of Civil Engineers, Transport, 100, May, pp. 83-93.

Hinchliffe, D., Matthew, P., Pillai-McGarry, U., So, H.B., and Mulligan, D., (2003) Effect of longwall mine subsidence on plant production on cropping land. ACARP Project C8018

Holla, L. and Armstrong, M., (1986). *Measurement of Sub-Surface Strata Movement by Multi-wire Borehole Instrumentation*. Proc. Australian Institute of Mining and Metallurgy, 291, pp. 65-72.

Holla, L., (1991). *Reliability of Subsidence Prediction Methods for Use in Mining Decisions in New South Wales.* Conference on Reliability, Production and Control in Coal Mines, Wollongong.

Holla, L. and Barclay, E., (2000). *Mine Subsidence in the Southern Coalfield, NSW, Australia.* Published by the Department of Mineral Resources, NSW.

Holla, L. & Buizen, M., (1991). *The Ground Movement, Strata Fracturing and Changes in Permeability Due to Deep Longwall Mining*. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr. Vol 28, No. 2/3, pp.207-217, 1991.

Kapp (1982). *Subsidence from Deep Longwall Mining of Coal Overlain by Massive Sandstones*. Kapp, W.A. Proc. Australasian Ins. Min. Met., 7/1 – 7/9.

Kratzsch, H., (1983). *Mining Subsidence Engineering*, Published by Springer - Verlag Berlin Heidelberg New York.

Lea, K.R., (1991). *Technical Considerations with respect to Longwall Mining beneath Railways in particular panels 9 & 10 from Teralba Colliery*. Report to State Rail Authority of New South Wales, Cityrail.

McNally, et al (1996). *Geological Factors influencing Longwall-Induced Subsidence*. McNally, G.H., Willey, P.L. and Creech, M. Symposium on Geology in Longwall mining, 12-13 November 1996, Eds G.H. McNally and C.R. Ward, pp 257-267.

Moelle, et al (1995). *On mechanical aspects of coal outbursts in underground coal mines.* Moelle, K.H.R., Li, G., Dean-Jones, G.L., Philips, R.N. Proceedings of the International Symposium on Management and Control of High Gas Emissions and Outbursts in Underground Coal Mines, Wollongong Australia, pp 593-601.

Niche (2013a). West Cliff Longwalls 37 and 38 Extraction Plan, Terrestrial Flora and Fauna Assessment. Prepared for BHP Billiton Illawarra Coal, 29 May 2013

Niche (2013b). Heritage Assessment, West Cliff Longwalls 37 and 38 Extraction Plan, May 2013

NRAtlas, (2010). *Natural Resource Atlas* website, viewed 23rd April 2010. The Department of Natural Resources. http://nratlas.nsw.gov.au/

Patton and Hendron (1972). *General Report on Mass Movements*. Patton F.D. & Hendron A.J.. Proc. 2nd Intl. Congress of International Association of Engineering Geology, V-GR1-V-GR57.

Peng and Chiang (1984). *Longwall Mining*. Wiley, Peng S.S. & Chiang H.S. New York, pg 708.

Reid, P., (1991). *Coal Mining Beneath Dams in NSW Australia.* 1991 ASDSO Annual Conference, September 1991, San Diego, USA pp 240-245.

Sefton (2000). *Overview of the Monitoring of Sandstone Overhangs for the Effects of Mining Subsidence Illawarra Coal Measures, for Illawarra Coal.* C.E. Sefton Pty Ltd, 2000.
Report No. BHC2404C, SCT, December 2003.

SCIMS (2012). *SCIMS Online* website, viewed April 2012. The Land and Property Management Authority. http://www.lands.nsw.gov.au/survey_maps/scims_online

Singh and Kendorski (1981). *Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments*. Singh, M.M. & Kendorski, F.D. Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

Sloan and Allman (1995). *Engineering Geology of the Newcastle-Gosford Region*. Sloan, S.W. and Allman, M.A. The University of Newcastle NSW, 5-7 February 1995, Australian Geomechanics Society, 1995. pp 14-19.

Smart R, Lamb D, O'Brien D, Mitchell A, Frazier P (2006) *Vines, wines and mines can they happily coexist?* Wine Industry Journal 21, 20-24.

Trotter T, Frazier P, (2009) *Monitoring the effect of longwall mining on agricultural environments-Interim report.* ACARP Project C15013

Waddington, A.A. and Kay, D.R., (2002). *Management Information Handbook on the Undermining of Cliffs, Gorges and River Systems*. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Whittaker and Reddish (1989). *Subsidence – Occurrence, Prediction and Control.* Whittaker, B.N. and Reddish, D.J. Elsevier.

# APPENDIX C. METHOD OF IMPACT ASSESSMENTS FOR HOUSES

# APPENDIX C METHOD OF IMPACT ASSESSMENT FOR HOUSES

## C.1. Introduction

The methods for predicting and assessing impacts on building structures have developed over time as knowledge and experience has grown. MSEC has provided predictions and impact assessments for the building structures within the Study Area using the latest methods available at this time.

Longwall mining has occurred directly beneath building structures at a number of Collieries in the Southern Coalfield, including Appin, West Cliff, Tower and Tahmoor Collieries. The most extensive data has come from extraction of Tahmoor Colliery Longwalls 22 to 24A, where more than 1000 residential and significant civil structures have experienced subsidence movements. The experiences gained during the mining of these longwalls, as well as longwalls at other Collieries in the Southern and Newcastle Coalfields, have provided substantial additional information that has been used to further develop the methods.

The information collected during the mining of Tahmoor Colliery Longwalls 22 to 24A has been reviewed in two parallel studies, one as part of a funded ACARP Research Project C12015, and the other at the request of Industry and Investment NSW (I&I).

The outcomes of these studies include:-

- Review of the performance of the previous method,
- Recommendations for improving the method of Impact Classification, and
- Recommendations for improving the method of Impact Assessment.

A summary is provided in the following sections.

## C.2. Review of the Performance of the Previous Method

The most extensive data on house impacts has come from extraction of Tahmoor Colliery Longwalls 22 to 25 and a comparison between predicted and observed impacts is provided in Table C.1. The comparison is based on pre-mining predictions that were provided in SMP Applications for these longwalls and the observations of impacts using the previous method of impact classification. The comparison is based on information up to 30 November 2008. At this point in time, the length of extraction of Longwall 25 was 611 metres.

A total of 1037 houses and civil structures were affected by subsidence due to the mining of Tahmoor Colliery Longwalls 22 to 25 at this time. A total of 175 claims have been received by the Mine Subsidence Board (not including claims that have been refused) of which 14 claims do not relate to the main residence or civil structure.

**Table C.1 Summary of Comparison between Observed and Predicted Impacts for each Structure**

| Strain Impact Category | Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 0 | Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 1 | Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 2 | Total |
|---|---|---|---|---|
| No impact | 483 | 373 | 20 | 876 |
| Cat 0 | 31 | 70 | 6 | 107 |
| Cat 1 | 8 | 9 | 1 | 18 |
| Cat 2 | 7 | 11 | 2 | 20 |
| Cat 3 | 2 | 2 | 0 | 4 |
| Cat 4 | 3 | 5 | 0 | 8 |
| Cat 5 | 3 | 1 | 0 | 4 |
| Total | 537 | 471 | 29 | 1037 |
| **% claim** | **10 %** | **21 %** | **31 %** | 16 % |
| **% Obs > Pred** | **4 %** | **4 %** | **0 %** | - |
| **% Obs <= Pred** | **96 %** | **96 %** | **100 %** | - |

*Note*: Predicted impacts due to conventional subsidence only, as described in the SMP Application.

Given that observed impacts are less than or equal to predicted impacts in 96 % of cases, it is considered that the previous methods are generally conservative even though non-conventional movements were not taken into account in the predictions and assessments. However, when compared on a house by house basis, the predictions have been substantially exceeded in a small proportion of cases.

The majority, if not all, of the houses that have experienced Category 3, 4 or 5 impacts are considered to have experienced substantial non-conventional subsidence movements. The consideration is based on nearby ground survey results, where upsidence bumps are observed in subsidence profiles and high localised strain is observed. The potential for impact from non-conventional movements were discussed generally and not included in the specific impact assessments for each structure.

The inability to specify the number or probability of impacts due to the potential for non-conventional movements is a shortcoming of the previous method. It is considered that there is significant room for improvement in this area and recommendations are provided later in this report.

The comparison shows a favourable observation that the overall proportion of claims increased for increasing predicted impact categories. This suggests that the main parameters currently used to make impact assessments (namely predicted conventional curvature and maximum plan dimension of each structure) are credible. Please note that we have stated predicted conventional curvature rather than strain, as predictions of strain were directly based on predictions of conventional curvature.

A significant over-prediction is observed at the low end of the spectrum of impacts (Category 0 and 1). A number of causes and/or possible causes for the deviations have been identified:

- Construction methods and standards may mitigate against small differential ground movements.
- The impacts may have occurred but the residents have not made a claim for the following reasons:-
  - All structures contain some existing, pre-mining defects. A pre-mining field investigation of 119 structures showed that it is very rare for all elements of a building to be free of cracks. Cracks up to 3 mm in width are commonly found in buildings. Cracks up to 1 mm in width are very common. There is a higher incidence of cracking in brittle forms of construction such as masonry walls and tiled surfaces.
  - In light of the above, additional very slight Category 0 and 1 impacts may not have been noticed by residents. A forensic investigation of all structures before or after mining may reveal that the number of actual impacts is greater than currently known.
  - Similarly, impacts have been noticed but some residents may consider them to be too trivial to make a claim. While difficult to prove statistically, it is considered that the frequency of claims from tenanted properties is less than the frequency of claims from owner-occupied properties.
- The impacts have been noticed but some residents are yet to make a claim at this stage. It has been observed that there is a noticeable time lag between the moment of impact and the moment of making a claim. More claims are therefore expected to be received in the future within areas that have already been directly mined beneath.
- The predictive method is deliberately conservative in a number of ways.
  - Predicted subsidence movements for each structure are based on the maximum predicted subsidence movements within 20 metres of the structure.
  - An additional 0.2 mm/m of strain was added
  - Maximum strains were applied to the maximum plan dimension, regardless of the maximum predicted strain orientation.
  - The method of impact assessment does not provide for “nil impacts”. The minimum assessed level of impact is Category 0.
  - The impact data was based on double-storey full masonry structures in the UK.

Finally, it is considered that the previous method impact classification has masked the true nature and extent of impacts. It is recommended that an improved method of classification be adopted before embarking on any further analysis. This is discussed in the next chapter of this report.

## C.3. Method of Impact Classification

### C.3.1. Previous Method

The impacts to structures were previously classified in accordance with Table C1 of Australian Standard 2870-1996, but the Table has been extended by the addition of Category 5 and is reproduced below.

**Table C.2 Classification of Damage with Reference to Strain**

| Impact Category | Description of typical damage to walls and required repair | Approximate crack width limit |
|---|---|---|
| 0 | Hairline cracks. | < 0.1 mm |
| 1 | Fine cracks which do not need repair. | 0.1 mm to 1.0 mm |
| 2 | Cracks noticeable but easily filled. Doors and windows stick slightly | 1 mm to 5 mm |
| 3 | Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weather-tightness often impaired | 5 mm to 15 mm, or a number of cracks 3 mm to 5 mm in one group |
| 4 | Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window or door frames distort. Walls lean or bulge noticeably. Some loss of bearing in beams. Service pipes disrupted. | 15 mm to 25 mm but also depends on number of cracks |
| 5 | As above but worse, and requiring partial or complete rebuilding. Roof and floor beams lose bearing and need shoring up. Windows broken with distortion. If compressive damage, severe buckling and bulging of the roof and walls. | > 25 mm |

Note 1 of Table C1 states that *"Crack width is the main factor by which damage to walls is categorized. The width may be supplemented by other factors, including serviceability, in assessing category of damage.*

Impacts relating to tilt were classified according to matching impacts with the description in Table C.3, not the observed actual tilt. This is because many houses that have experience tilts greater than 5 mm have not made a claim to the MSB.

**Table C.3 Classification of Damage with Reference to Tilt**

| Impact Category | Tilt (mm/m) | Description |
|---|---|---|
| A | < 5 | Unlikely that remedial work will be required. |
| B | 5 to 7 | Adjustment to roof drainage and wet area floors might be required. |
| C | 7 to 10 | Minor structural work might be required to rectify tilt. Adjustments to roof drainage and wet area floors will probably be required and remedial work to surface water drainage and sewerage systems might be necessary. |
| D | > 10 | Considerable structural work might be required to rectify tilt. Jacking to level or rebuilding could be necessary in the worst cases. Remedial work to surface water drainage and sewerage systems might be necessary. |

### C.3.2. Need for Improvement to the Previous Method of Impact Classification

It is very difficult to design a method of impact classification that covers all possible scenarios and permutations. The application of any method is likely to find some instances that do not quite fit within the classification criteria.

Exposure to a large number of affected structures has allowed the mining industry to appreciate where improvements can be made to all aspects including the identification of areas for improvement in the previous method of impact classification.

A number of difficulties have been experienced with the previous method during the mining period. The difficulty centres on the use of crack width as the main classifying factor, as specified in Table C1 of Australian Standard 2870-1996.

A benefit of using crack width as the main factor is that it provides a clear objective measure by which to classify impact. However, experience has shown that crack width is a poor measure of the overall impact and extent of repair to a structure. The previous method of impact classification may be useful for assessing impact to newly built structures in a non-subsidence environment but further improvement and clarification is recommended before it can be effectively applied to houses impacted by mine subsidence.

The following aspects highlight areas where the previous classification system could be improved.-

- *Slippage on Damp Proof Course*

  Approximately 30 houses have experienced slippage along the damp proof course in Tahmoor. Slippage on some houses is relatively small (less than 10 mm) though substantial slippage has been observed in a number of cases, such as shown in Fig. C.1 below.


**Fig. C.1 Example of slippage on damp proof course**

  Under the previous classification method, the “crack” width of the slippage may be very small (Category 1) but the distortion in the brickwork is substantial. Moreover, the extent of work required to repair the impact is substantial as it usually involves re-lining the whole external skin of the structure. Such impacts would be considered Category 4 based on extent of repair but only Category 1 or 2 based on maximum crack width.

  There is no reference to slippage of damp proof course in the previous method of impact classification. However, if the extent of repair was used instead of using crack width as the main factor, the impact category would be properly classified as either Category 4 or Category 5.

  It was recommended that slippage of damp proof courses be added to the previous impact classification table.

- *Cracks to brickwork*

  In some cases, cracks are observed in mortar only. For example, movement joints in some structures have been improperly filled with mortar instead of a flexible sealant, as shown in Fig. C.2. In these situations, the measured crack width may be significant but the impact is relatively simple to repair regardless of the crack width.

**Fig. C.2 Example of crack in mortar only**

In other cases, a small number of isolated bricks have been observed to crack or become loose. This is usually straightforward to repair. Under the previous impact classification method, a completely loose brick could be strictly classified as Category 5 as the crack width is infinitely large. This is clearly not the intention of the previous method but clarification is recommended to avoid confusion.

If a panel of brickwork is cracked, the method of repair is the same regardless of the width. While it is considered reasonable to classify large and severe cracks by its width, it is recommended that cracks less than 5 mm in width be treated the same rather than spread across Categories 0, 1 and 2.

If a brick lined structure contains many cracks of width less than 3 mm, the impact would be classified as no more than Category 2 under the previous method of impact classification. The extent of repair may be substantially more than a house that has experienced only one single 5 mm crack. However, it is recognised that it is very difficult to develop a simple method of classifying impacts based on multiple cracks in wall panels. How many cracks are needed to justify an increase in impact category?

- *Structures without masonry walls*

  Timber framed structures with lightweight external linings such weatherboard panels and fibro sheeting are not referenced in the previous classification table. If crack widths were strictly adopted to classify impacts, it may be possible to classify movement in external wall linings beyond Category 3 when in reality the repairs are usually minor.

  It was recommended that the impact classification table be extended to include structures with other types of external linings.

- *Minor impacts such as door swings*

  Experience has shown that one of the earliest signs of impact is the report of a sticking door. In some instances, the only observed impact is one or two sticking doors. It takes less than half an hour to repair a sticking door and impact is considered negligible.

  Such an impact would be rightly classified as Category 0 based on the previous method of impact classification as there is no observed crack. However, the previous classification table suggests that sticking doors and windows occur when Category 2 crack widths develop. It was recommended that the impact classification table be amended in this respect.

### C.3.3. Broad Recommendations for Improvement of Previous Method of Impact Classification

It was recommended that crack width no longer be used as the main factor for classifying impacts. This does not mean that the use of crack width should be abandoned altogether. Crack width remains a good indicator of the severity of impacts and should be used to assist classification, particularly for impacts that are moderate or greater.

By focussing on crack width, the previous impact classification table appears to be classifying impacts from a structural stability perspective. It was recommended that a revised impact classification table be more closely aligned with all aspects of a building, including its finishes and services. Residents who are affected by impacts are concerned as much about impacts to internal linings, finishes and services as they are about cracks to their external walls and a revised impact classification method should reflect this.

With crack width no longer used as the main factor, it was recommended that the wording of the descriptions of impact in the classification table be extended to cover impacts to more elements of buildings. In keeping with the previous method of assessment, the level of impact should distinguish between cosmetic, serviceability and stability related impacts:-

- Low impact levels should relate to cosmetic impacts that do affect the structural integrity of the building and are relatively straight-forward to repair,
- Mid-level impact categories should relate to impacts to serviceability and minor structural issues, and
- High level impacts should be reserved for structural stability issues and impacts requiring extensive repairs.

### C.3.4. Revised Method of Impact Classification

The following revised method of impact classification has been developed.

**Table C.4 Revised Classification based on the Extent of Repairs**

| Repair Category | Extent of Repairs |
|---|---|
| **Nil** | No repairs required |
| **R0**<br>**Adjustment** | One or more of the following, where the damage does not require the removal or replacement of any external or internal claddings or linings:-<br>- **Door** or **window** jams or swings, or<br>- Movement of **cornices**, or<br>- Movement at external or internal **expansion joints**. |
| **R1**<br>**Very Minor Repair** | One or more of the following, where the damage can be repaired by filling, patching or painting without the removal or replacement of any external or internal brickwork, claddings or linings:-<br>- Cracks in **brick mortar** only, or isolated cracked, broken, or loose **bricks** in the external façade, or<br>- Cracks or movement < 5 mm in width in any external or internal wall **claddings**, **linings**, or **finish**, or<br>- Isolated cracked, loose, or drummy floor or wall **tiles**, or<br>- Minor repairs to any **services** or **gutters**. |
| **R2**<br>**Minor Repair** | One or more of the following, where the damage affects a small proportion of external or internal claddings or linings, but does not affect the integrity of external brickwork or structural elements:-<br>- Continuous cracking in **bricks** < 5 mm in width in one or more locations in the total external façade, or<br>- Slippage along the **damp proof course** of 2 to 5 mm anywhere in the total external façade, or<br>- Cracks or movement ≥ 5 mm in width in any external or internal wall **claddings**, **linings**, **finish**, or<br>- Several cracked, loose or drummy floor or wall **tiles**, or<br>- Replacement of any **services**. |
| **R3**<br>**Substantial Repair** | One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or affects the stability of isolated structural elements:-<br>- Continuous cracking in **bricks** of 5 to 15 mm in width in one or more locations in the total external façade, or<br>- Slippage along the **damp proof course** of 5 to 15 mm anywhere in the total external façade, or<br>- Loss of bearing to isolated walls, piers, columns, or other load-bearing elements, or<br>- Loss of stability of isolated structural elements. |
| **R4**<br>**Extensive Repair** | One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or the replacement or repair of several structural elements:-<br>- Continuous cracking in **bricks** > 15 mm in width in one or more locations in the total external façade, or<br>- Slippage along the damp proof course of 15 mm or greater anywhere in the total external façade, or<br>- Relevelling of building, or<br>- Loss of stability of several structural elements. |
| **R5**<br>**Re-build** | Extensive damage to house where the MSB and the owner have agreed to rebuild as the cost of repair is greater than the cost of replacement. |

As discussed at the start of this chapter, it is very difficult to design a method of impact classification that covers all possible scenarios and permutations. While the method has been floated among some members of the mining industry, it is recommended that this table be reviewed broadly.

The recommended method has attempted to follow the current Australian Standard in terms of the number of impact categories and crack widths for Categories 3 and 4. The method is based on the extent of repairs required to repair the physical damage that has occurred, and does not include additional work that is occasionally required because replacement finishes cannot match existing damaged ones. It is therefore likely that the actual cost of repairs will vary greatly between houses depending on the nature of the existing level and type of finishes used.

The impacts experienced at Tahmoor Colliery have been classified in accordance with the revised method of classification with good results. The method allowed clearer trends to be found when undertaking statistical analyses.

A comparison between the previous and revised methods is shown in Fig. C.3.

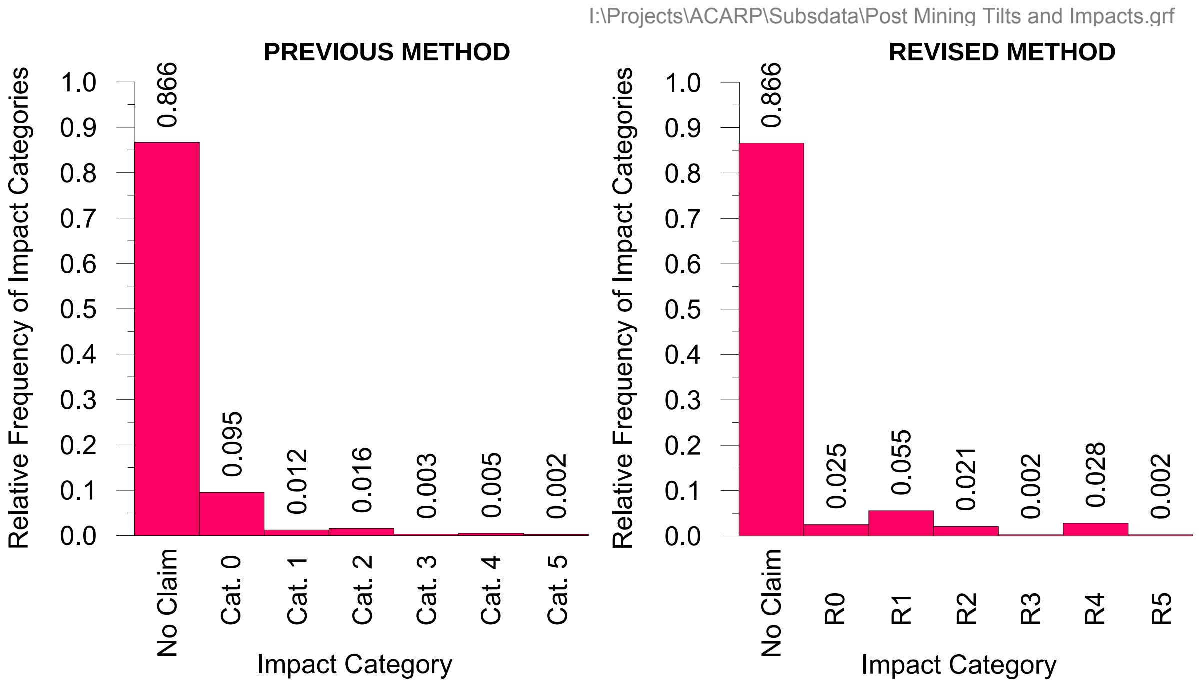



**Fig. C.3 Comparison between Previous and Revised Methods of Impact Classification**

It can be seen that there was an increased proportion in the higher impact categories using the revised method. This is brought about mainly by the recorded slippage on damp proof courses, which are classified as either Category 3 or Category 4 when they were previously classified as Category 1 or 2.

There was also a noticeable reduction in proportion of Category 0 impacts and noticeable increase in proportion of Category 1 impacts using the revised method. This is because the revised method reserves Category 0 impacts for impacts that did not result in cracking any linings, while the previous method allows hairline cracking to occur.

The consistent low proportion of Category 3 impacts under both the previous and current methods raises questions as to whether this category should be merged with Category 4.

## C.4. Method of Impact Assessment

### C.4.1. Need for Improvement of the Previous Method

The previous method of impact assessment provided specific quantitative predictions based on predicted conventional subsidence movements and general qualitative statements concerning the potential for impacts due to non-conventional movements. These non-conventional movements are additional to the predicted conventional movements.

This message was quite complex and created the potential for confusion and misunderstanding among members of the community who may easily focus on numbers and letters in a table that deal specifically with their house and misunderstand the message contained in the accompanying words of caution about the low level of reliability concerning predictions of conventional strain and potential for non-conventional movements.

This was unfortunately a necessary shortcoming of the previous method at the time as there was very little statistical information available to quantify the potential for impacts due to non-conventional movement. However, a great deal of statistical information is now available following the mining of Tahmoor Colliery Longwalls 22 to 24A and the method and message to the community can be improved.

While additional statistical information is now available, there remains limited knowledge at this point in time to accurately predict the locations of non-conventional movement. Substantial gains are still to be made in this area.

In the meantime, therefore, a probabilistic method of impact assessment has been developed. The method combines the potential for impacts from both conventional and non-conventional subsidence movement.

### C.4.2. Factors that Could be Used to Develop a Probabilistic Method of Prediction

Trend analyses have highlighted a number of factors that could be used to develop a probabilistic method. The trends examined were:-

- *Ground tilt*

  This was found to be an ineffective parameter at Tahmoor Colliery as ground tilts have been relatively benign and a low number of claims have been made in relation to tilt.

- *Ground strain*

  There appears to be a clear link between ground strain and impacts, particularly compressive strain. The difficulty with adopting ground strain as a predictive factor lies in the ability to accurately predict ground strain at a point.

  Another challenge with using strain to develop a probabilistic method is that there is limited information that links maximum observed strains with observed impacts at a structure. Horizontal strain is a two-dimensional parameter and it has been measured along survey lines that are oriented in one direction only.

  The above issues are less problematic for curvature and the statistical analysis on the relationship between strain and curvature shows that the observed frequency of high strains increased with increasing observed curvature.

- *Ground curvature*

  Curvature appears to be the most effective subsidence parameter to develop a probabilistic method. The trend analysis showed that the frequency of impacts increased with increasing observed curvature.

  It should be noted that we are referring to conventional curvature and not curvatures that have developed as a result of non-conventional subsidence behaviour. This is because conventional curvature can be readily predicted with reasonable correlation with observations. It is also a relatively straight-forward exercise to estimate the observed smoothed or “conventional” curvature provided some ground monitoring is undertaken across and along extracted longwalls.

  Non-conventional curvature cannot be predicted prior to mining and is accounted for by using a probabilistic method of impact assessment.

  It has also been shown that the observed frequency of high strains increased with increasing observed curvature.

- *Position of structure relative to longwall*

  A clear trend was understandably found that structures located directly above goaf were substantially more likely to experience impact. The calculated probabilities may be applicable for mining conditions that are similar to those experienced at Tahmoor Colliery but will be less applicable for other mining conditions. An effective probabilistic method should create a link between the magnitude of differential subsidence movements and impact.

- *Construction type*

  Two trends have been observed. Not surprisingly, structures constructed with lightweight flexible external linings are able to accommodate a far greater range of subsidence movements than brittle inflexible linings such as masonry. The analyses merely quantified what was already well known. The second observation was that houses constructed with strip footings were noticeably more likely to experience impacts than houses constructed with a ground slab, particularly in relation to higher levels of impact. This is because houses with strip footings are more susceptible to slippage along the damp proof course.

- *Structure size*

  Trend analysis showed that larger structures attract a higher likelihood of impact. This is understandable as the chance of impacts increases with increasing footprint area. However, it is noted that the probability of severe impacts was not substantially greater for larger structures even though this would be expected if considering probabilities theoretically rather than empirically. It may be worthwhile including structure size as a factor in the development of a probabilistic method, though it is considered that it is a third order effect behind subsidence movements and construction type.

- *Structure age*

  The trend analysis for structure age did not reveal any noticeable trends.

- *Extensions, variable foundations and building joints*

  There is a clear trend of a higher frequency of impacts for structures that include extensions, variable foundations and building joints. The increased frequency appears to be related mainly to lower impact categories.

- *Urban or rural setting*

  While trends were observed, it is considered that they can be explained by other factors. However, consideration can be made to provide a more conservative estimate of probabilities in rural areas if structure size has not been taken into account.

### C.4.3. Revised Method of Impact Assessment

A revised method of impact assessment has been developed. The method is probabilistic and currently includes conventional ground curvature and construction type as input factors.

Because of the relatively low number of buildings that suffered damage, the trends in the data were difficult to determine within small ranges of curvature. A decision was therefore taken to analyse the data in a limited number of curvature ranges, so that where possible a reasonable sample size would be available in each range. The ranges of curvature chosen were 5 to 15 kilometres, 15 to 50 kilometres and greater than 50 kilometres.

Because the incidence of damage for different construction types showed strong trends and because the sample size was reasonable for each type of structure, the data were analysed to determine the effect of radius of curvature on the incidence of damage for each of the three structure types and for each of the three curvature ranges.

The following probabilities are proposed in Table C.5.

**Table C.5 Probabilities of Impact based on Curvature and Construction Type based on the Revised Method of Impact Classification**

| R (km) | Repair Category | | | |
|---|---|---|---|---|
| | No Repair or R0 | R1 or R2 | R3 or R4 | R5 |
| **Brick or brick-veneer houses with Slab on Ground** | | | | |
| > 50 | 90 ~ 95 % | 3 ~ 10 % | 1 % | < 0.1 % |
| 15 to 50 | 80 ~ 85 % | 12 ~ 17 % | 2 ~ 5 % | < 0.5 % |
| 5 to 15 | 70 ~ 75 % | 17 ~ 22 % | 5 ~ 8 % | < 0.5 % |
| **Brick or brick-veneer houses with Strip Footing** | | | | |
| > 50 | 90 ~ 95 % | 3 ~ 10 % | 1 % | < 0.1 % |
| 15 to 50 | 80 ~ 85 % | 7 ~ 12 % | 2 ~ 7 % | < 0.5 % |
| 5 to 15 | 70 ~ 75 % | 15 ~ 20 % | 7 ~ 12 % | < 0.5 % |
| **Timber-framed houses with flexible external linings of any foundation type** | | | | |
| > 50 | 90 ~ 95 % | 3 ~ 10 % | 1 % | < 0.1 % |
| 15 to 50 | 85 ~ 90 % | 7 ~ 13 % | 1 ~ 3 % | < 0.5 % |
| 5 to 15 | 80 ~ 85 % | 10 ~ 15 % | 3 ~ 5 % | < 0.5 % |

The results have been expressed as a range of values rather than a single number, recognising that the data had considerable scatter within each curvature range. While structure size and building extensions have not been included in the predictive tables, it is recommended to adopt percentages at the higher end of the range for larger structures or those with building extensions.

The percentages stated in each table are the percentages of building structures of that type that would be likely to be damaged to the level indicated within each curvature range. The levels of damage in the tables are indicated with reference to the repair categories described in the damage classification given in Table C.4.

To place these values in context, Table C.6 shows the actual percentages recorded at Tahmoor Colliery for all buildings within the sample.

**Table C.6 Observed Frequency of Impacts observed for all buildings at Tahmoor Colliery**

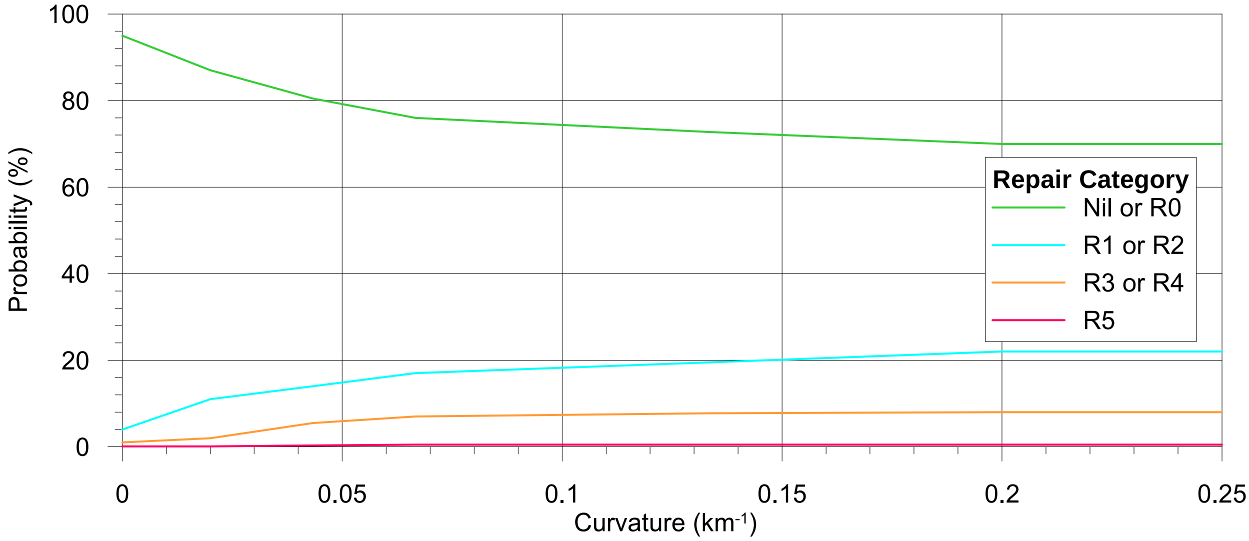
| R (km) | Repair Category | | | |
|---|---|---|---|---|
| | No Claim or R0 | R1 or R2 | R3 or R4 | R5 |
| > 50 | 94 % | 4 % | 1 % | 0 % |
| 15 to 50 | 86 % | 9 % | 4 % | 0.7 % |
| 5 to 15 | 76 % | 17 % | 7 % | 0 % |

It can be seen that the proposed probabilities for the higher impact categories have been increased compared to those observed to date. These have been deliberately increased, because it has been noticed that some of the claims for damage have been submitted well after the event and it is possible that the numbers damaged in this category could be increased as further claims are received and investigated. These numbers are particularly sensitive to change because the sample size is very small. In light of the above, it is recommended that the probabilities be revisited in the future as mining progresses.

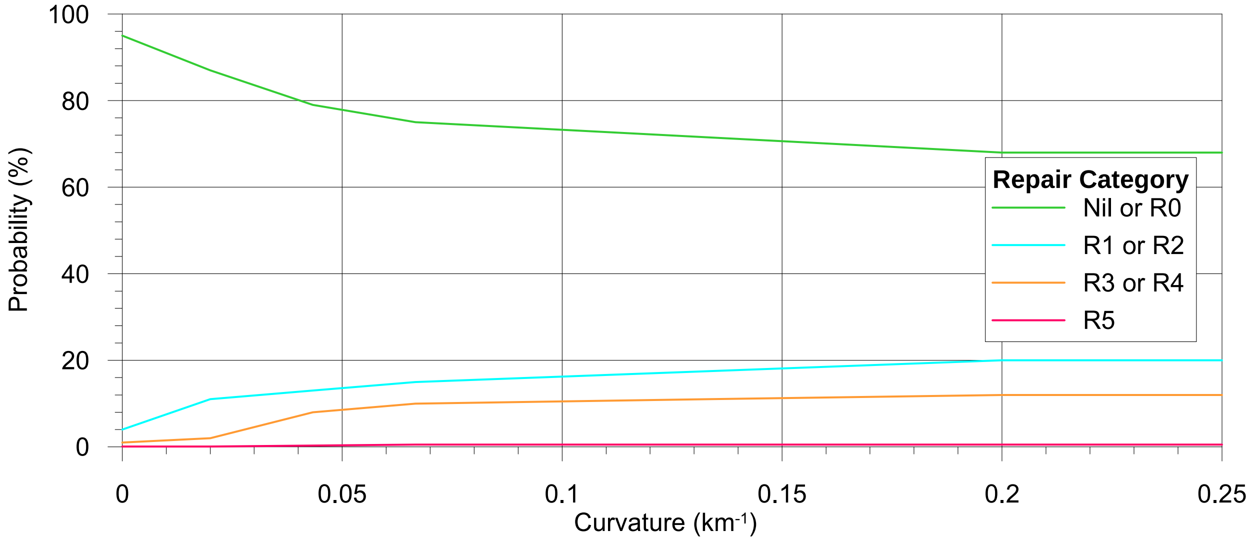
The ranges provided in Table C.5 have been converted into a set of probability curves to remove artificial discontinuities that are formed by dividing curvatures into three categories. These are shown in Fig. C.4. The probability curves are applicable for all houses and civil structures.

I:\Projects\Tahmoor\MSEC355 - SMP Report for LW27 to LW30\Subsdata\Impacts\Structures\Structure Probability Curves.grf

**Brick or Brick-Veneer Buildings with Slab on Ground**




**Brick or Brick-Veneer Buildings with Strip Footing**




**Weatherboard or Fibro Buildings**

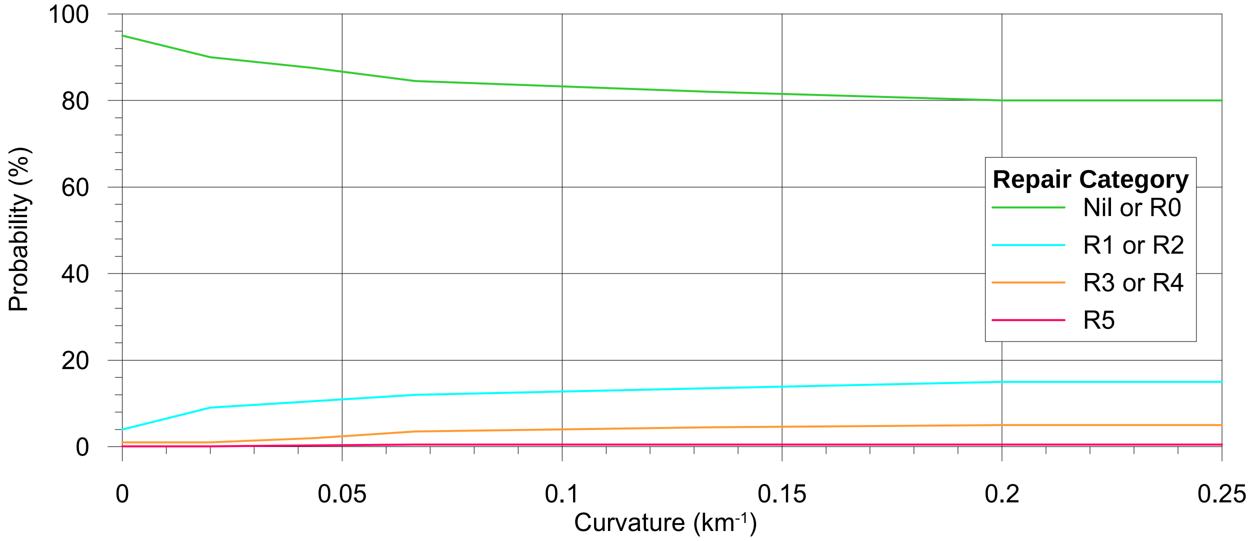



**Fig. C.4 Probability Curves for Impacts to Buildings**

# APPENDIX D.   TABLES

# Table D.01 - Details of the Houses within the Study Area

| House Ref. | Mine Subsidence District | Maximum Plan Dimension (m) | Planar Area (m2) | Number of Stories | Wall Construction | Footing Construction | Wall and Footing Construction | Roof Construcftion | House Located Above Goaf after LW35 | House Located Above Goaf after LW36 | House Located Above Goaf after LW37 | House Located Above Goaf after LW38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C07h01 | Sth Camp. | 10.35 | 66 | 0 | Other | Unknown | Other | Metal | | 1 | 1 | 1 |
| C08h01 | Appin | 9.37 | 81 | 1 | Fibro | Piers | Weatherboard or Fibro | Metal | | 1 | 1 | 1 |
| C12h01 | 0 | 11.42 | 82 | 0 | Other | Unknown | Other | Metal | | | | |
| D03h01 | 0 | 11.74 | 122 | 1 | Weatherboard | Piers | Weatherboard or Fibro | Tiled | | 1 | 1 | 1 |
| D04h01 | 0 | 17.18 | 153 | 1 | Brick or Brick-Veneer | Strip Footings | Brick on Strip | Tiled | | 1 | 1 | 1 |
| D05h01 | 0 | 34.54 | 457 | 1 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Metal | | 1 | 1 | 1 |
| D06h01 | 0 | 14.3 | 165 | 1 | Fibro | Strip Footings | Weatherboard or Fibro | Tiled | | | 1 | 1 |
| D07h01 | 0 | 14.16 | 113 | 1 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Metal | | | 1 | 1 |
| D08h01 | 0 | 18.38 | 204 | 1 | Brick or Brick-Veneer | Strip Footings | Brick on Strip | Metal | | | 1 | 1 |
| J07h02 | 0 | 18.9 | 222 | 0 | Other | Unknown | Other | Metal | | | | |
| K01h02 | 0 | 23.17 | 365 | 0 | Other | Unknown | Other | Metal | | | | |
| K04h01 | 0 | 41.57 | 390 | 0 | Other | Unknown | Other | Metal | | | | |
| K05h01 | 0 | 17.65 | 166 | 0 | Other | Unknown | Other | Metal | | | | |
| K05h02 | 0 | 11.27 | 100 | 2 | Brick or Brick-Veneer | Unknown | Other | Metal | | | | |
| K07h02 | 0 | 23.04 | 214 | 1 | Weatherboard | Strip Footings | Weatherboard or Fibro | Metal | | | | |
| K08h01 | 0 | 14.86 | 183 | 2 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Metal | | | | |
| K09h01 | 0 | 33.62 | 541 | 0 | Other | Unknown | Other | Metal | | | | 1 |
| K10h01 | 0 | 44.39 | 596 | 1 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Metal | | | | 1 |
| K11h01 | 0 | 19.59 | 309 | 2 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Tiled | | | | |
| K12h01 | 0 | 23.3 | 322 | 2 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Metal | | | | |
| K13h01 | 0 | 32.77 | 359 | 0 | Other | Unknown | Other | Tiled | | | | |
| K14h01 | 0 | 23.43 | 285 | 0 | Other | Unknown | Other | Metal | | | | |
| K15h01 | 0 | 19.44 | 253 | 1 | Brick or Brick-Veneer | Piers | Brick on Piers | Tiled | | | | |
| K16h01 | 0 | 12.45 | 115 | 1 | Fibro | Slab on Ground | Weatherboard or Fibro | Metal | | | | |
| K16h02 | 0 | 39.76 | 574 | 1 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Tiled | | | | 1 |
| K17h01 | 0 | 20.37 | 250 | 0 | Other | Unknown | Other | Metal | | | | 1 |
| K18h01 | 0 | 16.78 | 149 | 2 | Brick or Brick-Veneer | Unknown | Other | Metal | | | | |
| K19h01 | 0 | 25.82 | 357 | 1 | Weatherboard | Piers | Weatherboard or Fibro | Metal | | | | |
| K19h02 | 0 | 13.88 | 129 | 1 | Fibro | Piers | Weatherboard or Fibro | Metal | | | | |
| K20h01 | 0 | 33.5 | 400 | 1 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Metal | | | | |
| K23h01 | 0 | 14.77 | 171 | 0 | Other | Unknown | Other | Metal | | | | |
| K25h01 | 0 | 25.22 | 287 | 1 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Tiled | | | | |
| K28h01 | 0 | 25.4 | 292 | 1 | Brick or Brick-Veneer | Slab on Ground | Brick on SOG | Metal | | | | |

# Table D.02 - Predictions and Impact Assessments for Houses within the Study Area

| House Ref. | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Maximum Predicted Tilt at the Completion of Any or All the Longwalls (mm/m) |
|---|---|---|---|---|---|---|---|
| C07h01 | 425 | 850 | 875 | 5.0 | 3.0 | 3.0 | 5.0 |
| C08h01 | 325 | 775 | 800 | 4.0 | 1.5 | 1.5 | 4.0 |
| C12h01 | < 20 | 75 | 75 | < 0.5 | 0.5 | 1.0 | 1.0 |
| D03h01 | 700 | 950 | 950 | 3.0 | 3.5 | 3.5 | 3.5 |
| D04h01 | 575 | 925 | 950 | 5.5 | 4.0 | 4.0 | 5.5 |
| D05h01 | 200 | 800 | 825 | 2.5 | 0.5 | 1.0 | 2.5 |
| D06h01 | 100 | 800 | 825 | 1.0 | < 0.5 | < 0.5 | 1.0 |
| D07h01 | 75 | 800 | 850 | 0.5 | < 0.5 | < 0.5 | 0.5 |
| D08h01 | 25 | 500 | 525 | < 0.5 | 6.0 | 6.0 | 6.0 |
| J07h02 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K01h02 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K04h01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K05h01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K05h02 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K07h02 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K08h01 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | 1.5 |
| K09h01 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | 3.0 |
| K10h01 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 2.0 | 2.0 |
| K11h01 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 1.0 | 1.0 |
| K12h01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K13h01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K14h01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K15h01 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 1.0 | 1.0 |
| K16h01 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | 1.5 |
| K16h02 | < 20 | < 20 | 275 | < 0.5 | < 0.5 | 3.0 | 3.0 |
| K17h01 | < 20 | < 20 | 400 | < 0.5 | < 0.5 | 3.5 | 3.5 |
| K18h01 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | 2.0 |
| K19h01 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 0.5 | 0.5 |
| K19h02 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K20h01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K23h01 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | 2.5 |
| K25h01 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |
| K28h01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.5 |

# Table D.02 - Predictions and Impact Assessments for Houses within the Study Area

| House Ref. | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) | Predicted Probability of Nil or Category R0 Impact due to Proposed Longwalls (%) | Predicted Probability of Category R1 or R2 Impact due to Proposed Longwalls (%) | Predicted Probability of Category R3 or R4 Impact due to Proposed Longwalls (%) | Predicted Probability of Category R5 Impact due to Proposed Longwalls (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| C07h01 | 0.05 | 0.07 | 0.07 | 0.01 | 0.01 | 0.01 | 74.8 | 15.1 | 10.0 | < 0.5 |
| C08h01 | 0.05 | 0.07 | 0.07 | < 0.01 | 0.02 | 0.02 | 84.4 | 12.1 | 3.5 | < 0.5 |
| C12h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 91.4 | 7.2 | 1.5 | < 0.1 |
| D03h01 | 0.01 | 0.01 | 0.01 | 0.05 | 0.05 | 0.05 | 86.6 | 10.9 | 2.4 | < 0.4 |
| D04h01 | 0.05 | 0.07 | 0.07 | 0.02 | 0.02 | 0.02 | 74.8 | 15.1 | 10.1 | < 0.5 |
| D05h01 | 0.04 | 0.04 | 0.04 | < 0.01 | 0.02 | 0.02 | 81.6 | 13.5 | 4.9 | < 0.3 |
| D06h01 | 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 | 89.4 | 9.4 | 1.2 | < 0.1 |
| D07h01 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 | 85.1 | 11.9 | 3.0 | < 0.2 |
| D08h01 | < 0.01 | 0.06 | 0.06 | < 0.01 | 0.01 | 0.01 | 76.2 | 14.4 | 9.4 | < 0.4 |
| J07h02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 94.9 | 4.1 | 1.0 | < 0.1 |
| K01h02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 94.9 | 4.1 | 1.0 | < 0.1 |
| K04h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 94.9 | 4.1 | 1.0 | < 0.1 |
| K05h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 94.9 | 4.1 | 1.0 | < 0.1 |
| K05h02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 94.5 | 4.4 | 1.1 | < 0.1 |
| K07h02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 94.7 | 4.3 | 1.0 | < 0.1 |
| K08h01 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 | 88.5 | 9.7 | 1.8 | < 0.1 |
| K09h01 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.03 | 83.5 | 11.9 | 4.6 | < 0.2 |
| K10h01 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 | 88.8 | 9.4 | 1.8 | < 0.1 |
| K11h01 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 | 90.7 | 7.8 | 1.5 | < 0.1 |
| K12h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 93.2 | 5.6 | 1.2 | < 0.1 |
| K13h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 91.8 | 6.8 | 1.4 | < 0.1 |
| K14h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 94.6 | 4.4 | 1.1 | < 0.1 |
| K15h01 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 | 90.1 | 8.3 | 1.6 | < 0.1 |
| K16h01 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 | 89.9 | 9.0 | 1.0 | < 0.1 |
| K16h02 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 | 85.2 | 11.8 | 3.0 | < 0.2 |
| K17h01 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.01 | 84.7 | 11.6 | 3.7 | < 0.2 |
| K18h01 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 | 85.3 | 11.4 | 3.2 | < 0.1 |
| K19h01 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 | 92.5 | 6.5 | 1.0 | < 0.1 |
| K19h02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 93.7 | 5.3 | 1.0 | < 0.1 |
| K20h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 94.9 | 4.1 | 1.0 | < 0.1 |
| K23h01 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 | 84.9 | 11.5 | 3.5 | < 0.2 |
| K25h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 93.5 | 5.3 | 1.2 | < 0.1 |
| K28h01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 91.3 | 7.3 | 1.5 | < 0.1 |

# Table D.03 - Predictions for the Rural Building Structures within the Study Area

| Structure Ref. | Maximum Length (m) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A39r01 | 11.27 | 1000 | 1050 | 1050 | 1.5 | 1.5 | 1.5 | 0.03 | 0.03 | 0.03 | 0.07 | 0.07 | 0.07 |
| A39r02 | 4.43 | 1000 | 1050 | 1050 | 1.5 | 1.5 | 1.5 | 0.03 | 0.03 | 0.03 | 0.05 | 0.05 | 0.05 |
| A39r03 | 4.56 | 1000 | 1050 | 1050 | 1.5 | 1.5 | 1.5 | 0.03 | 0.03 | 0.03 | 0.05 | 0.05 | 0.05 |
| A39r04 | 3.79 | 1000 | 1050 | 1050 | 2.5 | 2.0 | 2.0 | 0.03 | 0.03 | 0.03 | 0.11 | 0.11 | 0.11 |
| C07r01 | 9.44 | 525 | 925 | 950 | 5.5 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.01 | 0.01 | 0.01 |
| C07r02 | 17.52 | 550 | 925 | 950 | 6.0 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.01 | 0.01 | 0.01 |
| C08r01 | 6.59 | 325 | 775 | 800 | 4.0 | 1.5 | 1.5 | 0.05 | 0.07 | 0.07 | < 0.01 | 0.02 | 0.02 |
| C08r02 | 9.42 | 325 | 800 | 825 | 4.0 | 2.0 | 2.0 | 0.05 | 0.07 | 0.07 | < 0.01 | 0.02 | 0.02 |
| C12r01 | 7.36 | < 20 | 25 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r02 | 4.66 | < 20 | 75 | 75 | < 0.5 | 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r03 | 3.69 | < 20 | 75 | 75 | < 0.5 | 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r04 | 4.08 | < 20 | 100 | 100 | < 0.5 | 1.0 | 1.0 | < 0.01 | 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r07 | 17.15 | < 20 | 50 | 50 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r08 | 17.39 | < 20 | 50 | 50 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r09 | 17.39 | < 20 | 50 | 50 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r10 | 6.31 | < 20 | 75 | 75 | < 0.5 | 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r11 | 3.58 | < 20 | 75 | 100 | < 0.5 | 1.0 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r12 | 2.29 | < 20 | 75 | 75 | < 0.5 | 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12r13 | 2.61 | < 20 | 50 | 50 | < 0.5 | < 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| D01r01 | 10.29 | 375 | 475 | 475 | 3.0 | 3.0 | 3.0 | 0.05 | 0.05 | 0.05 | < 0.01 | < 0.01 | < 0.01 |
| D01r02 | 3.53 | 350 | 450 | 450 | 2.5 | 2.5 | 3.0 | 0.03 | 0.03 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| D01r03 | 7.83 | 350 | 450 | 450 | 2.5 | 2.5 | 2.5 | 0.04 | 0.04 | 0.04 | < 0.01 | < 0.01 | < 0.01 |
| D01r04 | 2.7 | 350 | 450 | 450 | 3.0 | 2.5 | 2.5 | 0.05 | 0.05 | 0.05 | < 0.01 | < 0.01 | < 0.01 |
| D01r05 | 6.1 | 225 | 325 | 325 | 1.5 | 2.0 | 2.0 | 0.02 | 0.02 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| D01r06 | 14.98 | 225 | 325 | 325 | 1.5 | 2.0 | 2.0 | 0.02 | 0.02 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| D01r07 | 7.82 | 350 | 450 | 450 | 2.5 | 2.5 | 3.0 | 0.04 | 0.04 | 0.04 | < 0.01 | < 0.01 | < 0.01 |
| D02r01 | 9.93 | 275 | 475 | 500 | 3.0 | 3.5 | 3.5 | 0.04 | 0.04 | 0.04 | < 0.01 | < 0.01 | < 0.01 |
| D02r02 | 4.19 | 275 | 500 | 500 | 3.0 | 3.5 | 4.0 | 0.04 | 0.04 | 0.04 | < 0.01 | < 0.01 | < 0.01 |
| D02r03 | 4.68 | 300 | 525 | 525 | 3.5 | 4.0 | 4.0 | 0.04 | 0.04 | 0.04 | 0.02 | 0.02 | 0.02 |
| D02r04 | 3.14 | 275 | 500 | 500 | 3.0 | 4.0 | 4.0 | 0.04 | 0.04 | 0.04 | < 0.01 | < 0.01 | < 0.01 |
| D02r05 | 2.96 | 300 | 500 | 525 | 3.5 | 4.0 | 4.0 | 0.04 | 0.04 | 0.04 | 0.01 | 0.01 | 0.01 |
| D03r01 | 12.02 | 700 | 975 | 1000 | 2.5 | 3.0 | 3.0 | 0.01 | 0.01 | 0.01 | 0.08 | 0.08 | 0.08 |
| D03r02 | 7.34 | 650 | 875 | 900 | 3.5 | 3.5 | 3.5 | < 0.01 | < 0.01 | < 0.01 | 0.03 | 0.04 | 0.04 |
| D03r03 | 6.14 | 625 | 850 | 875 | 3.5 | 4.0 | 4.0 | < 0.01 | < 0.01 | < 0.01 | 0.03 | 0.04 | 0.04 |
| D04r01 | 6.7 | 600 | 950 | 975 | 5.5 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.03 | 0.03 | 0.03 |
| D04r02 | 3.23 | 625 | 975 | 1000 | 5.5 | 4.0 | 4.0 | 0.05 | 0.06 | 0.07 | 0.05 | 0.05 | 0.05 |
| D04r03 | 11.19 | 625 | 975 | 1000 | 5.5 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.05 | 0.05 | 0.05 |
| D04r04 | 7.64 | 650 | 975 | 1000 | 5.5 | 4.0 | 4.0 | 0.05 | 0.06 | 0.07 | 0.06 | 0.06 | 0.06 |
| D04r05 | 8.98 | 575 | 950 | 950 | 5.5 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.03 | 0.03 | 0.03 |
| D04r06 | 7.88 | 475 | 875 | 875 | 5.5 | 4.0 | 3.5 | 0.05 | 0.07 | 0.07 | 0.01 | 0.02 | 0.02 |
| D04r07 | 4.01 | 500 | 875 | 900 | 5.5 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.02 | 0.02 | 0.02 |
| D04r08 | 5.56 | 650 | 1000 | 1000 | 5.5 | 4.0 | 4.0 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| D04r09 | 10.99 | 575 | 925 | 950 | 5.5 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.02 | 0.02 | 0.02 |

# Table D.03 - Predictions for the Rural Building Structures within the Study Area

| Structure Ref. | Maximum Length (m) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D04r10 | 4.31 | 475 | 875 | 875 | 5.5 | 4.0 | 3.5 | 0.05 | 0.07 | 0.07 | 0.02 | 0.02 | 0.02 |
| D06r01 | 9.7 | 100 | 800 | 850 | 1.0 | < 0.5 | < 0.5 | 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06r02 | 6.69 | 75 | 800 | 850 | 1.0 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06r03 | 4.24 | 75 | 800 | 850 | 0.5 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06r04 | 6.73 | 50 | 800 | 850 | 0.5 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06r05 | 6.08 | 50 | 800 | 850 | 0.5 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06r06 | 7.97 | 125 | 800 | 825 | 1.5 | < 0.5 | 0.5 | 0.02 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06r07 | 4.31 | 75 | 800 | 850 | 1.0 | < 0.5 | < 0.5 | 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06r08 | 4.3 | 50 | 800 | 850 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.05 | 0.05 |
| D06r09 | 4.88 | 25 | 800 | 850 | < 0.5 | 3.5 | 3.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.12 | 0.12 |
| D07r01 | 6.71 | 75 | 800 | 850 | 1.0 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D07r02 | 5.08 | 75 | 800 | 850 | 1.0 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D07r03 | 4.81 | 75 | 800 | 850 | 0.5 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D07r04 | 6.75 | 75 | 800 | 850 | 0.5 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D08r01 | 6.5 | 25 | 475 | 500 | < 0.5 | 6.0 | 6.0 | < 0.01 | 0.06 | 0.06 | < 0.01 | 0.01 | 0.01 |
| D08r02 | 12.62 | < 20 | 325 | 350 | < 0.5 | 4.0 | 4.5 | < 0.01 | 0.06 | 0.06 | < 0.01 | < 0.01 | < 0.01 |
| D08r03 | 12.91 | < 20 | 450 | 475 | < 0.5 | 5.5 | 6.0 | < 0.01 | 0.06 | 0.06 | < 0.01 | 0.01 | 0.01 |
| D08r04 | 9.66 | 25 | 500 | 500 | < 0.5 | 6.0 | 6.0 | < 0.01 | 0.06 | 0.06 | < 0.01 | 0.01 | 0.01 |
| J07r03 | 8.53 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| J07r04 | 6.82 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| J07r06 | 5.1 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| J07r07 | 4.33 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| J07r08 | 4.22 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01r01 | 11.44 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01r02 | 23.96 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01r03 | 20.21 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01r04 | 12.49 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01r05 | 10.72 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01r06 | 15.25 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01r09 | 12.52 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K04r01 | 5.96 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K05r01 | 8.75 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K05r02 | 14.5 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K05r03 | 3.34 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K05r04 | 11.32 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07r08 | 3.26 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07r09 | 18.21 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07r10 | 6.62 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07r11 | 4.79 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07r12 | 7.57 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07r13 | 7.99 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07r14 | 7.57 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K08r01 | 17.66 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |

# Table D.03 - Predictions for the Rural Building Structures within the Study Area

| Structure Ref. | Maximum Length (m) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K08r02 | 2.09 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K08r03 | 2.45 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K09r01 | 13.8 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.02 |
| K09r02 | 7.53 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.03 |
| K09r03 | 8.97 | < 20 | < 20 | 225 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.02 |
| K09r04 | 2.96 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.02 |
| K10r01 | 12.94 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K11r01 | 9.77 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K11r02 | 9.64 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K11r03 | 9.69 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K11r04 | 11.39 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K12r01 | 15.82 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K12r02 | 10.03 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K12r03 | 17.61 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K12r04 | 12.36 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K12r05 | 5.01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K13r01 | 9.38 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K13r02 | 7.33 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K13r03 | 3.06 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K13r04 | 6.5 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K13r05 | 4.2 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14r01 | 15.04 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14r02 | 10.8 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14r03 | 5.85 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14r04 | 17.74 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14r05 | 7.12 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14r06 | 2.02 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K15r01 | 5.94 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K15r02 | 5.87 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K15r03 | 3.64 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16r01 | 6.81 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16r02 | 11.08 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16r03 | 3.57 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16r04 | 6.46 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16r05 | 4.08 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16r06 | 3.55 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16r07 | 9.84 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K16r08 | 8.15 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K16r09 | 8.89 | < 20 | < 20 | 275 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K16r10 | 13.77 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K16r11 | 7.15 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K16r12 | 4.36 | < 20 | < 20 | 325 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K16r13 | 9.05 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |

# Table D.03 - Predictions for the Rural Building Structures within the Study Area

| Structure Ref. | Maximum Length (m) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K17r01 | 6.13 | < 20 | < 20 | 575 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K17r02 | 5.2 | < 20 | < 20 | 550 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K17r03 | 16.99 | < 20 | < 20 | 525 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.05 |
| K17r04 | 2.53 | < 20 | < 20 | 525 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.05 |
| K17r05 | 9.71 | < 20 | < 20 | 300 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K17r06 | 20.28 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K17r07 | 9.78 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r01 | 4.62 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r02 | 11.44 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r03 | 5.44 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r04 | 8.92 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r05 | 9.39 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r06 | 9.52 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r07 | 9.39 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r08 | 9.51 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r09 | 9.14 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r10 | 4.62 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r11 | 11.14 | < 20 | < 20 | 225 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r12 | 4.98 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r13 | 15.1 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r14 | 15.02 | < 20 | < 20 | 225 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r15 | 2.97 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r16 | 1.87 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r17 | 5 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r18 | 2.69 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r19 | 1.86 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r20 | 4.15 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r21 | 2.27 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r22 | 1.79 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r23 | 1.86 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r24 | 2.95 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r25 | 4.7 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r26 | 3.32 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r27 | 3.15 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18r28 | 3.05 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18r29 | 6.84 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K19r01 | 9.94 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19r02 | 9.77 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19r03 | 5.11 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 0.5 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r01 | 6.32 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r02 | 11.95 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r03 | 2.28 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r04 | 7.71 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |

# Table D.03 - Predictions for the Rural Building Structures within the Study Area

| Structure Ref. | Maximum Length (m) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K20r05 | 34.65 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r06 | 4.85 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r07 | 4.34 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r08 | 3.81 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r09 | 8.11 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r10 | 4.65 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r11 | 4.48 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r12 | 5.4 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20r13 | 4.84 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K23r01 | 20.8 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r02 | 12.44 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r03 | 18.4 | < 20 | < 20 | 225 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r04 | 11.83 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r05 | 8.74 | < 20 | < 20 | 300 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r06 | 7.51 | < 20 | < 20 | 325 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r07 | 10.5 | < 20 | < 20 | 425 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.01 |
| K23r08 | 4.58 | < 20 | < 20 | 550 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K23r09 | 9.84 | < 20 | < 20 | 350 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r10 | 22.39 | < 20 | < 20 | 350 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r11 | 23.14 | < 20 | < 20 | 350 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r12 | 23.14 | < 20 | < 20 | 350 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r13 | 11.2 | < 20 | < 20 | 275 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r14 | 6.07 | < 20 | < 20 | 400 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.01 |
| K23r15 | 2.41 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23r16 | 1.49 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K24r01 | 2.02 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K27r01 | 11.49 | < 20 | < 20 | 575 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K27r02 | 12.81 | < 20 | < 20 | 550 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K27r03 | 5.96 | < 20 | < 20 | 575 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K27r04 | 3.19 | < 20 | < 20 | 350 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K27r05 | 3.41 | < 20 | < 20 | 325 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K27r06 | 2.19 | < 20 | < 20 | 425 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.02 |
| K28r01 | 11.84 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K28r02 | 5.25 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K28r03 | 8.48 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |

# Table D.04 - Predictions for the Farm Dams within the Study Area

| Dam Ref. | Maximum Length (m) | Plannar Area (m2) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) |
|---|---|---|---|---|---|---|---|---|
| A39d01 | 48 | 1260 | 900 | 925 | 925 | 1.5 | 1.5 | 1.5 |
| A39d02 | 13 | 106 | 925 | 975 | 975 | 1.5 | 1.5 | 1.5 |
| C06d02 | 19 | 187 | 850 | 925 | 925 | 4.5 | 4.0 | 4.0 |
| C07d01 | 61 | 2095 | 550 | 950 | 975 | 6.0 | 4.0 | 4.0 |
| C07d02 | 67 | 2343 | 750 | 950 | 975 | 1.0 | 1.5 | 1.5 |
| C07d03 | 52 | 1379 | 1025 | 1100 | 1100 | 3.5 | 3.0 | 3.0 |
| C07d05 | 23 | 162 | 725 | 1050 | 1075 | 5.5 | 4.0 | 4.0 |
| C07d06 | 21 | 159 | 675 | 1000 | 1025 | 5.5 | 4.0 | 4.0 |
| C09d01 | 66 | 1971 | 500 | 825 | 825 | 5.0 | 4.0 | 4.0 |
| C09d02 | 19 | 154 | 50 | 550 | 600 | 0.5 | 4.0 | 4.0 |
| C11d01 | 36 | 713 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| C12d02 | 51 | 1379 | < 20 | 25 | 25 | < 0.5 | < 0.5 | < 0.5 |
| C12d03 | 20 | 285 | < 20 | 175 | 200 | < 0.5 | 2.0 | 2.5 |
| C12d04 | 42 | 1151 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| C12d05 | 21 | 220 | 125 | 800 | 825 | 1.5 | < 0.5 | < 0.5 |
| C13d01 | 41 | 591 | 75 | 800 | 850 | 0.5 | < 0.5 | < 0.5 |
| C13d02 | 65 | 1709 | < 20 | 25 | 25 | < 0.5 | < 0.5 | < 0.5 |
| D01d01 | 14 | 138 | 375 | 400 | 425 | 4.5 | 4.0 | 4.0 |
| D02d01 | 24 | 197 | 250 | 375 | 375 | 2.0 | 2.5 | 2.5 |
| D08d01 | 58 | 1393 | 50 | 800 | 850 | < 0.5 | 6.0 | 6.5 |
| D09d01 | 36 | 829 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| D10d01 | 34 | 550 | 50 | 725 | 750 | 0.5 | 2.5 | 2.5 |
| J07d01 | 57 | 1083 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| J07d02 | 13 | 93 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| K05d01 | 16 | 137 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| K07d02 | 49 | 782 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 |
| K08d01 | 47 | 1249 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 0.5 |
| K10d01 | 61 | 1319 | < 20 | < 20 | 250 | < 0.5 | < 0.5 | 3.0 |
| K11d01 | 45 | 666 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| K14d01 | 35 | 795 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| K15d01 | 22 | 327 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 |
| K16d01 | 68 | 2021 | < 20 | < 20 | 325 | < 0.5 | < 0.5 | 3.5 |
| K17d01 | 45 | 901 | < 20 | < 20 | 550 | < 0.5 | < 0.5 | 3.5 |
| K17d02 | 27 | 345 | < 20 | < 20 | 575 | < 0.5 | < 0.5 | 3.5 |
| K19d01 | 34 | 492 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 |
| K20d01 | 43 | 742 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |
| K21d01 | 33 | 465 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 |
| K23d01 | 22 | 357 | < 20 | < 20 | 425 | < 0.5 | < 0.5 | 3.5 |
| K24d01 | 97 | 3245 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 |
| K24d02 | 48 | 1479 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 |
| K27d01 | 89 | 3486 | < 20 | < 20 | 475 | < 0.5 | < 0.5 | 3.5 |
| K27d02 | 42 | 1086 | < 20 | < 20 | 575 | < 0.5 | < 0.5 | 3.5 |
| L04d04 | 114 | 2986 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 |

# Table D.04 - Predictions for the Farm Dams within the Study Area

| Dam Ref. | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) | Predicted Change in Freeboard after LW36 (mm) | Predicted Change in Freeboard after LW37 (mm) | Predicted Change in Freeboard after LW38 (mm) |
|---|---|---|---|---|---|---|---|---|---|
| A39d01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 100 | 150 | 150 |
| A39d02 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 150 | 150 | 150 |
| C06d02 | 0.07 | 0.07 | 0.07 | 0.01 | 0.01 | 0.01 | 400 | 150 | 150 |
| C07d01 | 0.05 | 0.07 | 0.07 | 0.02 | 0.02 | 0.02 | 50 | 150 | 150 |
| C07d02 | 0.04 | 0.04 | 0.04 | 0.02 | 0.02 | 0.02 | 100 | 50 | 50 |
| C07d03 | 0.03 | 0.03 | 0.03 | 0.10 | 0.10 | 0.10 | 350 | 200 | 200 |
| C07d05 | 0.03 | 0.05 | 0.05 | 0.10 | 0.10 | 0.10 | < 50 | 100 | 100 |
| C07d06 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 | < 50 | < 50 | < 50 |
| C09d01 | 0.05 | 0.06 | 0.06 | 0.02 | 0.03 | 0.03 | < 50 | < 50 | < 50 |
| C09d02 | < 0.01 | 0.01 | 0.01 | < 0.01 | 0.03 | 0.03 | < 50 | 100 | 100 |
| C11d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| C12d02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 50 | < 50 | < 50 |
| C12d03 | < 0.01 | 0.03 | 0.03 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| C12d04 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| C12d05 | 0.02 | 0.02 | 0.02 | < 0.01 | 0.02 | 0.02 | 150 | 150 | 150 |
| C13d01 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.04 | 0.04 | 100 | 100 | 100 |
| C13d02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | 350 | 350 |
| D01d01 | 0.06 | 0.06 | 0.06 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| D02d01 | 0.03 | 0.03 | 0.03 | < 0.01 | < 0.01 | < 0.01 | < 50 | 150 | 150 |
| D08d01 | < 0.01 | 0.03 | 0.04 | < 0.01 | 0.11 | 0.12 | < 50 | < 50 | < 50 |
| D09d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| D10d01 | < 0.01 | 0.02 | 0.02 | < 0.01 | 0.02 | 0.02 | < 50 | < 50 | < 50 |
| J07d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| J07d02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| K05d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | 250 |
| K07d02 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| K08d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| K10d01 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.02 | < 50 | < 50 | < 50 |
| K11d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | 250 |
| K14d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | 300 |
| K15d01 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | 150 |
| K16d01 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| K17d01 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 | < 50 | < 50 | < 50 |
| K17d02 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 | < 50 | < 50 | < 50 |
| K19d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | 200 |
| K20d01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | 50 |
| K21d01 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | 150 |
| K23d01 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.01 | < 50 | < 50 | 300 |
| K24d01 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | 100 |
| K24d02 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |
| K27d01 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.04 | < 50 | < 50 | < 50 |
| K27d02 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.07 | < 50 | < 50 | < 50 |
| L04d04 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 50 | < 50 | < 50 |

# Table D.05 - Predictions for the Tanks within the Study Area

| Structure Ref. | Maximum Length (m) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A36t04 | 3.86 | 400 | 500 | 500 | 3.0 | 3.0 | 3.0 | 0.05 | 0.06 | 0.06 | < 0.01 | < 0.01 | < 0.01 |
| C07t01 | 3.55 | 450 | 875 | 900 | 5.5 | 3.5 | 3.5 | 0.05 | 0.07 | 0.07 | 0.01 | 0.01 | 0.01 |
| C08t01 | 1.82 | 325 | 775 | 800 | 4.0 | 1.5 | 1.5 | 0.05 | 0.07 | 0.07 | < 0.01 | 0.01 | 0.01 |
| C08t02 | 3.85 | 300 | 775 | 800 | 4.0 | 1.5 | 1.5 | 0.05 | 0.07 | 0.07 | < 0.01 | 0.02 | 0.02 |
| C12t02 | 3.38 | < 20 | 50 | 50 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| C12t03 | 2.1 | < 20 | 50 | 50 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| D03t01 | 2.48 | 675 | 925 | 925 | 3.0 | 3.5 | 3.5 | < 0.01 | < 0.01 | < 0.01 | 0.03 | 0.04 | 0.04 |
| D03t03 | 4.19 | 675 | 925 | 925 | 3.0 | 3.0 | 3.0 | < 0.01 | < 0.01 | < 0.01 | 0.03 | 0.04 | 0.04 |
| D04t01 | 2.27 | 500 | 900 | 900 | 5.5 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.02 | 0.02 | 0.02 |
| D04t02 | 3.42 | 650 | 1000 | 1000 | 5.5 | 4.0 | 4.0 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| D04t03 | 1.7 | 575 | 950 | 975 | 5.5 | 4.0 | 4.0 | 0.05 | 0.07 | 0.07 | 0.03 | 0.03 | 0.03 |
| D04t05 | 1.7 | 450 | 850 | 875 | 5.5 | 3.5 | 3.5 | 0.05 | 0.07 | 0.07 | 0.01 | 0.02 | 0.02 |
| D05t01 | 6.6 | 150 | 800 | 825 | 1.5 | 0.5 | 0.5 | 0.02 | 0.02 | 0.02 | < 0.01 | 0.02 | 0.02 |
| D05t02 | 1.6 | 125 | 800 | 825 | 1.5 | 0.5 | 0.5 | 0.02 | 0.02 | 0.02 | < 0.01 | 0.02 | 0.02 |
| D05t03 | 1.59 | 125 | 800 | 825 | 1.5 | 0.5 | 0.5 | 0.02 | 0.02 | 0.02 | < 0.01 | 0.02 | 0.02 |
| D05t04 | 2.13 | 200 | 775 | 800 | 2.5 | 0.5 | 1.0 | 0.03 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06t01 | 3.09 | 125 | 800 | 825 | 1.0 | < 0.5 | < 0.5 | 0.02 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06t02 | 3.29 | 100 | 800 | 825 | 1.0 | < 0.5 | < 0.5 | 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06t03 | 3.29 | 75 | 800 | 850 | 0.5 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D06t05 | 2.35 | 100 | 800 | 825 | 1.0 | < 0.5 | < 0.5 | 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D07t04 | 5.44 | 50 | 800 | 850 | < 0.5 | 0.5 | 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.06 | 0.06 |
| D07t05 | 2.35 | 75 | 800 | 850 | 0.5 | < 0.5 | < 0.5 | < 0.01 | 0.03 | 0.03 | < 0.01 | 0.02 | 0.02 |
| D08t02 | 3.15 | < 20 | 300 | 325 | < 0.5 | 4.0 | 4.0 | < 0.01 | 0.06 | 0.06 | < 0.01 | < 0.01 | < 0.01 |
| J07t01 | 7.06 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01t01 | 6.86 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01t02 | 3.01 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01t03 | 4.07 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01t04 | 5.32 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01t05 | 2.14 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01t06 | 2.14 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K01t07 | 1.57 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K05t01 | 3.27 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K05t02 | 2.05 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07t04 | 3.03 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K07t05 | 3.39 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K08t01 | 3.74 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K08t02 | 2.02 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K08t03 | 3.74 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K09t01 | 7.87 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.01 |
| K09t02 | 2.84 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.02 |
| K09t03 | 2.84 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.02 |
| K10t01 | 7.15 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K11t01 | 6.9 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K13t01 | 6.67 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |

# Table D.05 - Predictions for the Tanks within the Study Area

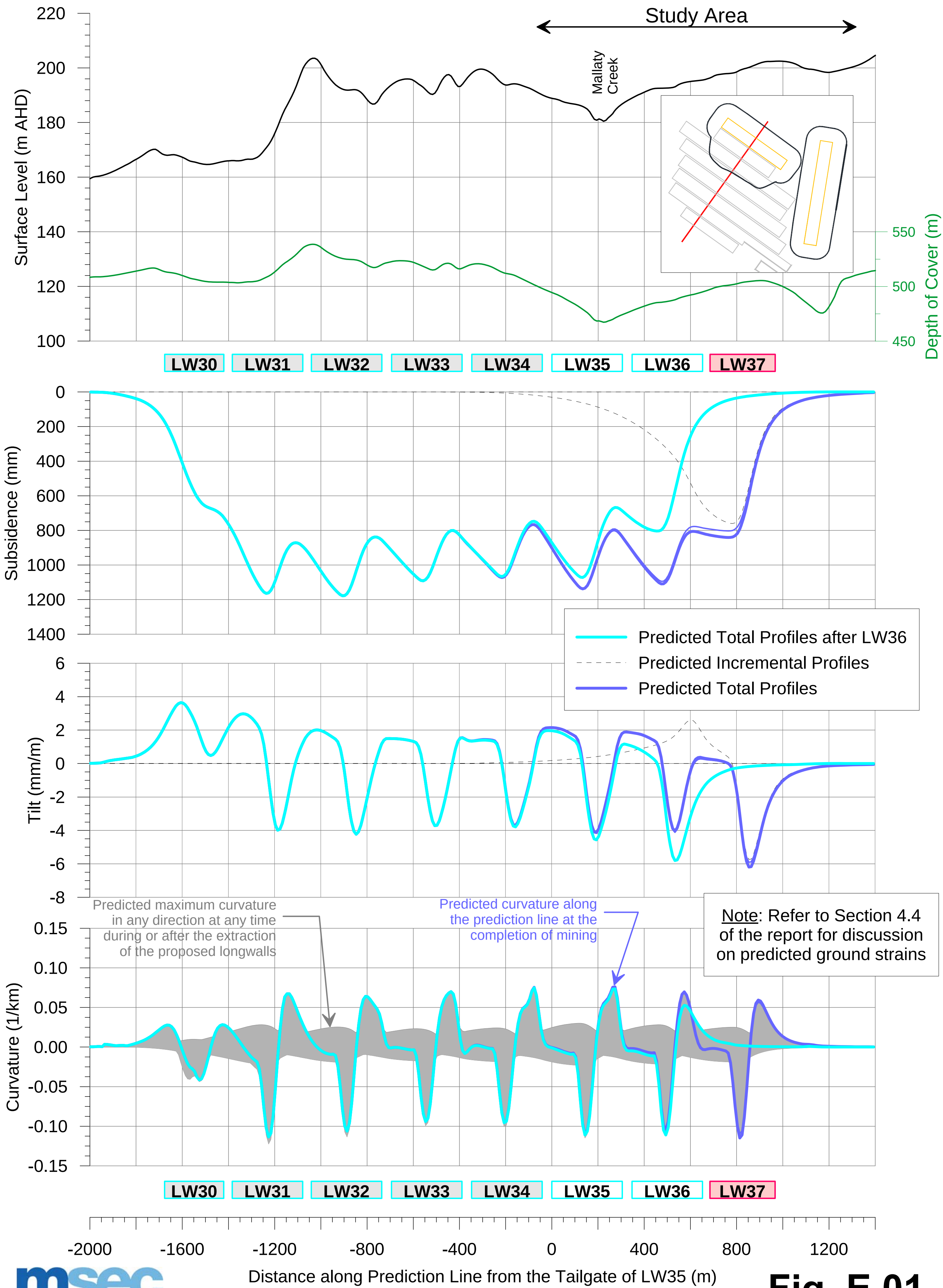
| Structure Ref. | Maximum Length (m) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| K13t02 | 3.45 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14t01 | 3.33 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14t02 | 3.33 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K15t01 | 7.02 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K16t01 | 3.16 | < 20 | < 20 | 100 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16t02 | 9.38 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16t03 | 3.2 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K16t04 | 2.18 | < 20 | < 20 | 325 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K17t01 | 2.11 | < 20 | < 20 | 400 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.01 |
| K17t02 | 1.77 | < 20 | < 20 | 375 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18t01 | 1.97 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18t02 | 1.97 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18t03 | 1.45 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18t04 | 2.11 | < 20 | < 20 | 125 | < 0.5 | < 0.5 | 1.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K18t05 | 2.11 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K18t06 | 2.11 | < 20 | < 20 | 175 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K19t01 | 9.03 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t02 | 1.77 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t03 | 1.77 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t04 | 3.06 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t05 | 1.77 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t06 | 1.77 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t07 | 1.66 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t08 | 2.57 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t09 | 2.81 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K19t10 | 2.61 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K200t2 | 2.39 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K20t01 | 8.23 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K23t01 | 5.19 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K23t02 | 2.08 | < 20 | < 20 | 400 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.01 |
| K24t01 | 1.04 | < 20 | < 20 | 75 | < 0.5 | < 0.5 | 1.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | < 0.01 |
| K25t01 | 2.39 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K27t01 | 3.41 | < 20 | < 20 | 575 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K27t02 | 2.04 | < 20 | < 20 | 575 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K27t03 | 2.04 | < 20 | < 20 | 575 | < 0.5 | < 0.5 | 3.0 | < 0.01 | < 0.01 | 0.02 | < 0.01 | < 0.01 | 0.06 |
| K27t04 | 2.82 | < 20 | < 20 | 300 | < 0.5 | < 0.5 | 3.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K28t01 | 7.69 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K28t02 | 2.25 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |

# Table D.06 - Predictions for the Pools within the Study Area

| Pool Ref. | Maximum Length (m) | Predicted Total Subsidence after LW36 (mm) | Predicted Total Subsidence after LW37 (mm) | Predicted Total Subsidence after LW38 (mm) | Predicted Total Tilt after LW36 (mm/m) | Predicted Total Tilt after LW37 (mm/m) | Predicted Total Tilt after LW38 (mm/m) | Predicted Total or Travelling Hogging Curvature after LW36 (1/km) | Predicted Total or Travelling Hogging Curvature after LW37 (1/km) | Predicted Total or Travelling Hogging Curvature after LW38 (1/km) | Predicted Total or Travelling Sagging Curvature after LW36 (1/km) | Predicted Total or Travelling Sagging Curvature after LW37 (1/km) | Predicted Total or Travelling Sagging Curvature after LW38 (1/km) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D08p1 | 10.3 | < 20 | 375 | 400 | < 0.5 | 5.0 | 5.0 | < 0.01 | 0.06 | 0.06 | < 0.01 | < 0.01 | < 0.01 |
| K09p1 | 9.49 | < 20 | < 20 | 200 | < 0.5 | < 0.5 | 2.5 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | 0.02 |
| K11p1 | 14.37 | < 20 | < 20 | 50 | < 0.5 | < 0.5 | 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K12p1 | 6.64 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K14p1 | 9.05 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K16p1 | 10.14 | < 20 | < 20 | 150 | < 0.5 | < 0.5 | 2.0 | < 0.01 | < 0.01 | 0.03 | < 0.01 | < 0.01 | < 0.01 |
| K20p1 | 9.73 | < 20 | < 20 | < 20 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| K25p1 | 6.9 | < 20 | < 20 | 25 | < 0.5 | < 0.5 | < 0.5 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |

# APPENDIX E. FIGURES

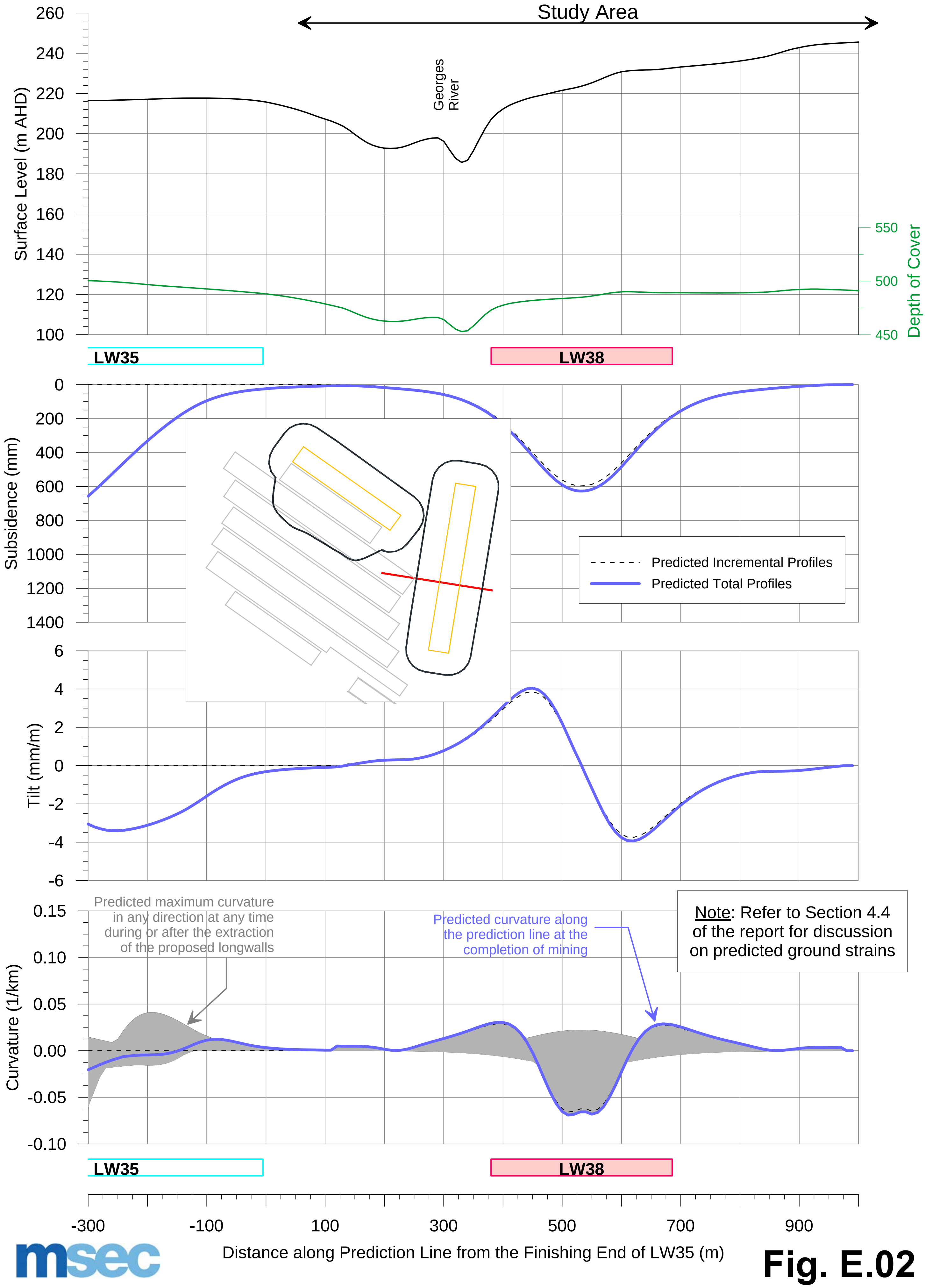
# Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 Resulting from the Extraction of Longwalls 29 to 38




msec

**Fig. E.01**

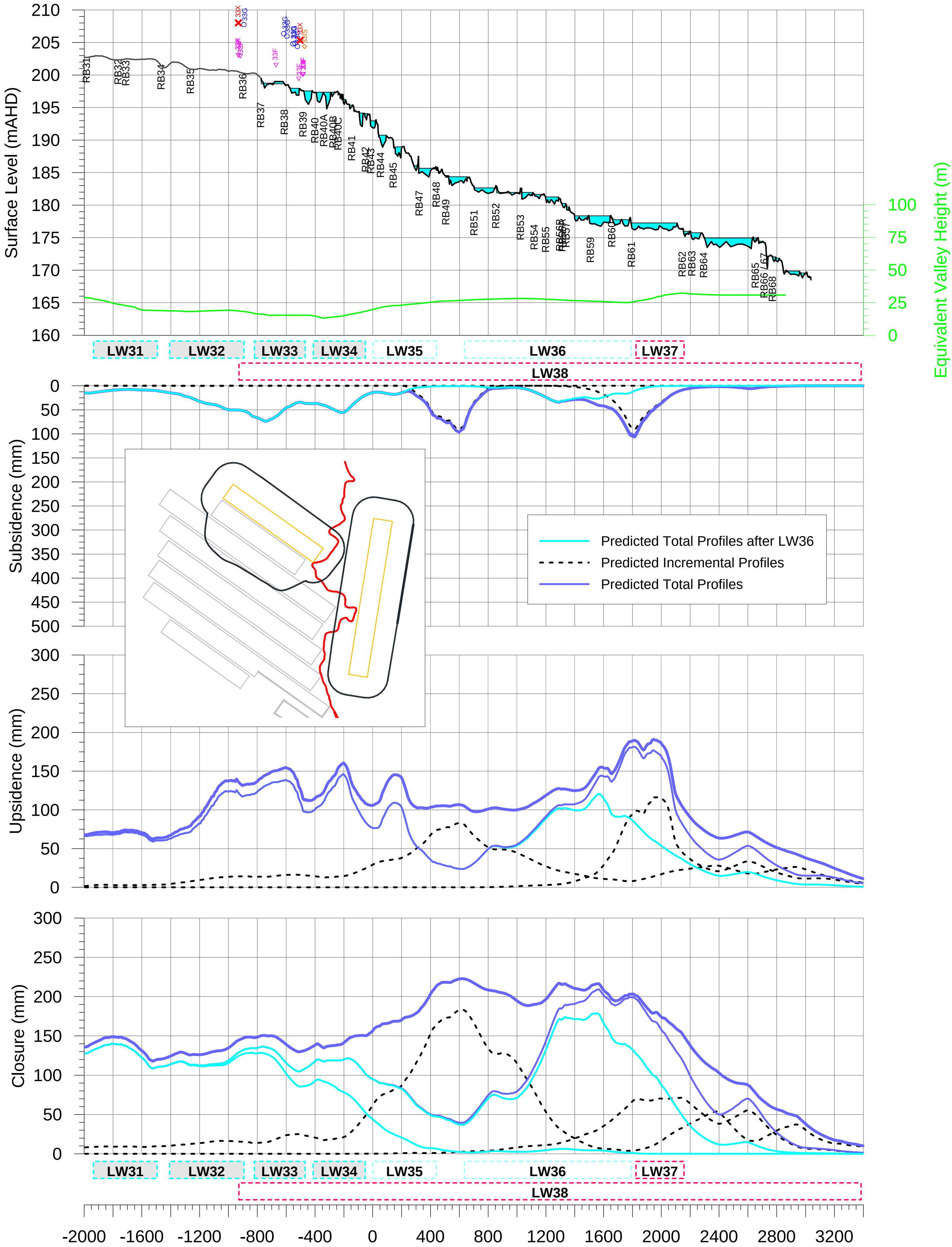
# Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 Resulting from the Extraction of Longwalls 29 to 38




msec

Fig. E.02

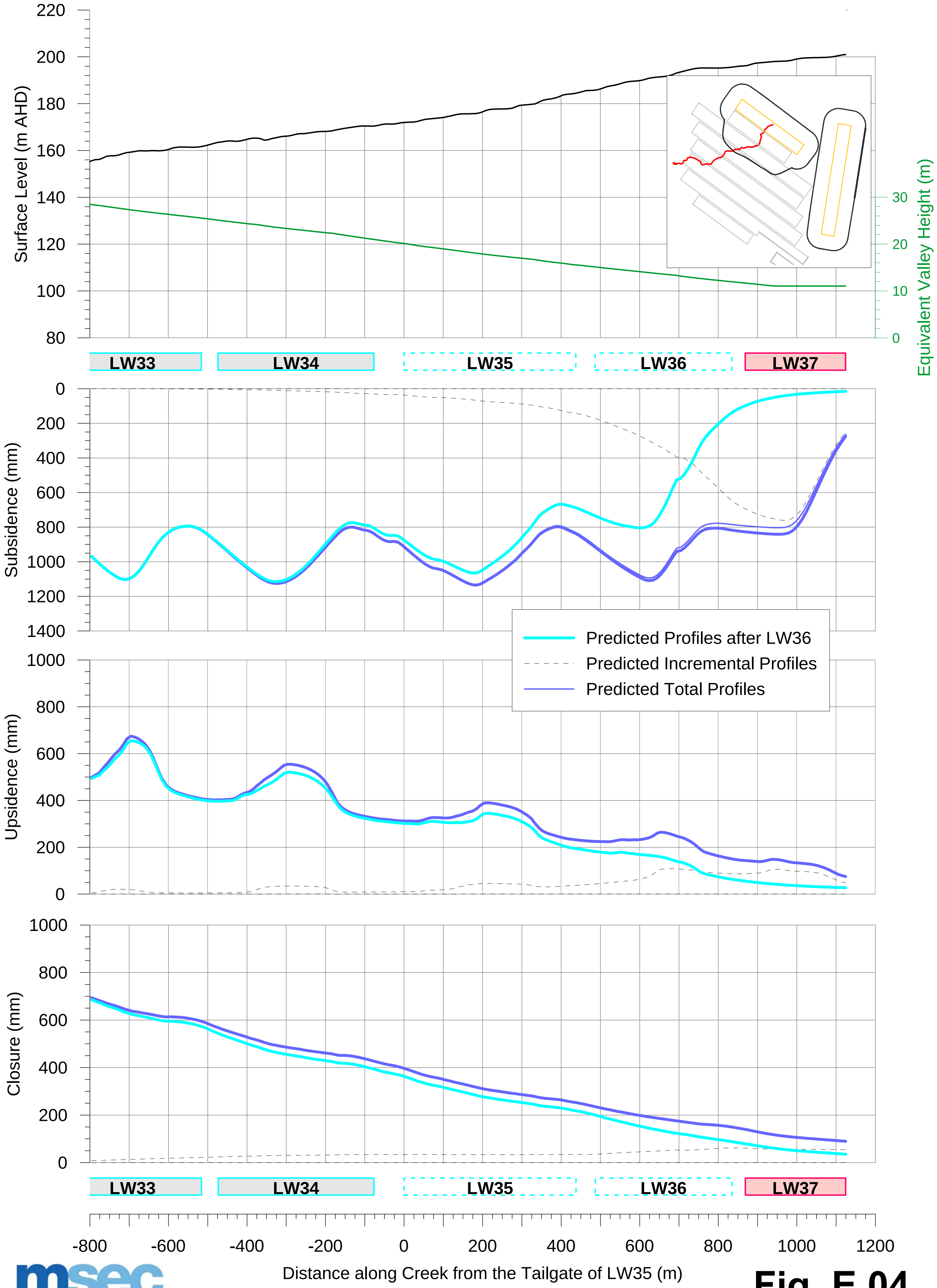
# Predicted Profiles of Subsidence, Upsidence and Closure along the Georges River Resulting from the Extraction of Longwalls 37 and 38




msec

**Fig. E.03**

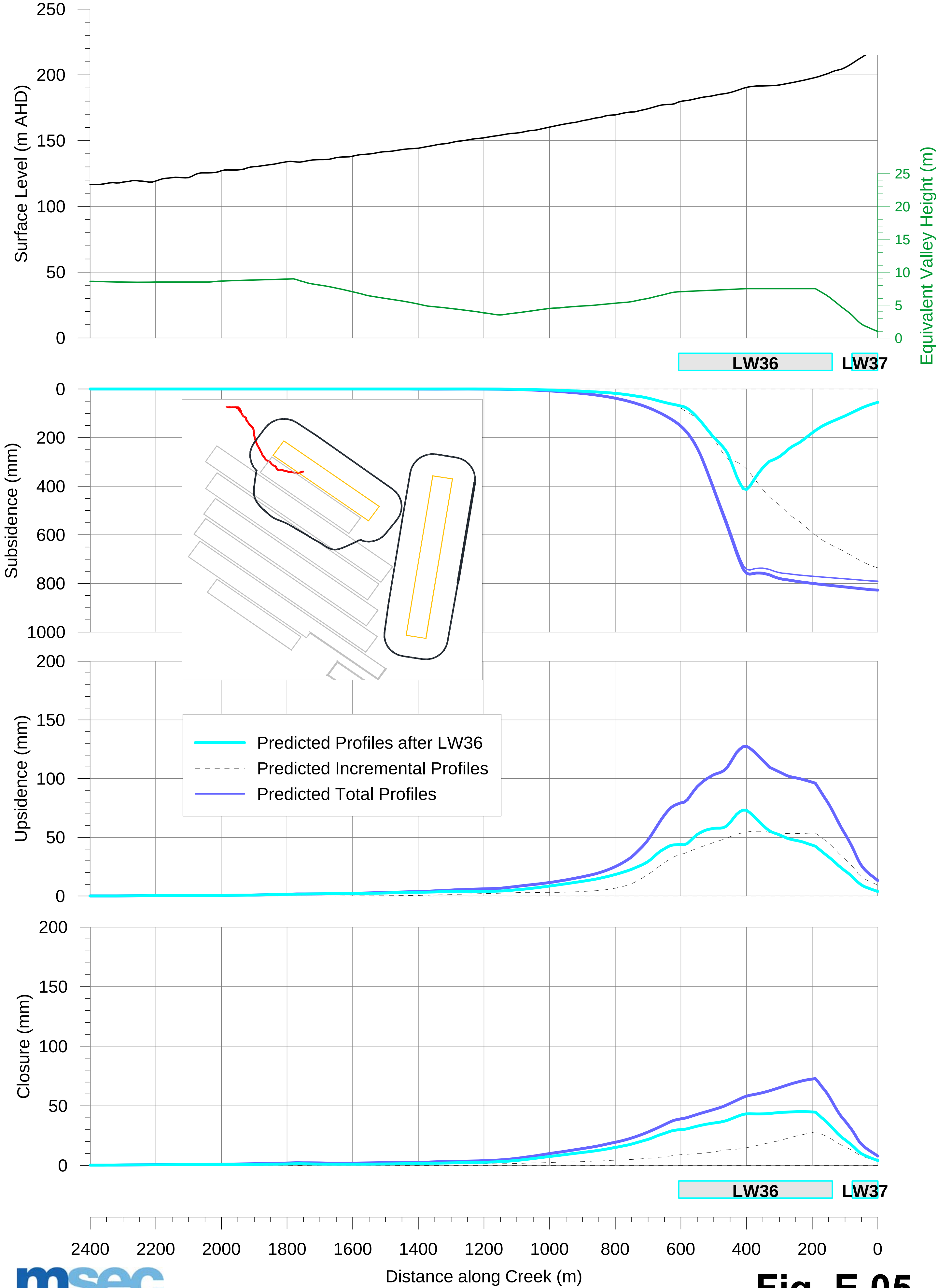
# Predicted Profiles of Subsidence, Upsidence and Closure along Mallaty Creek Resulting from the Extraction of Longwalls 29 to 38




msec

**Fig. E.04**

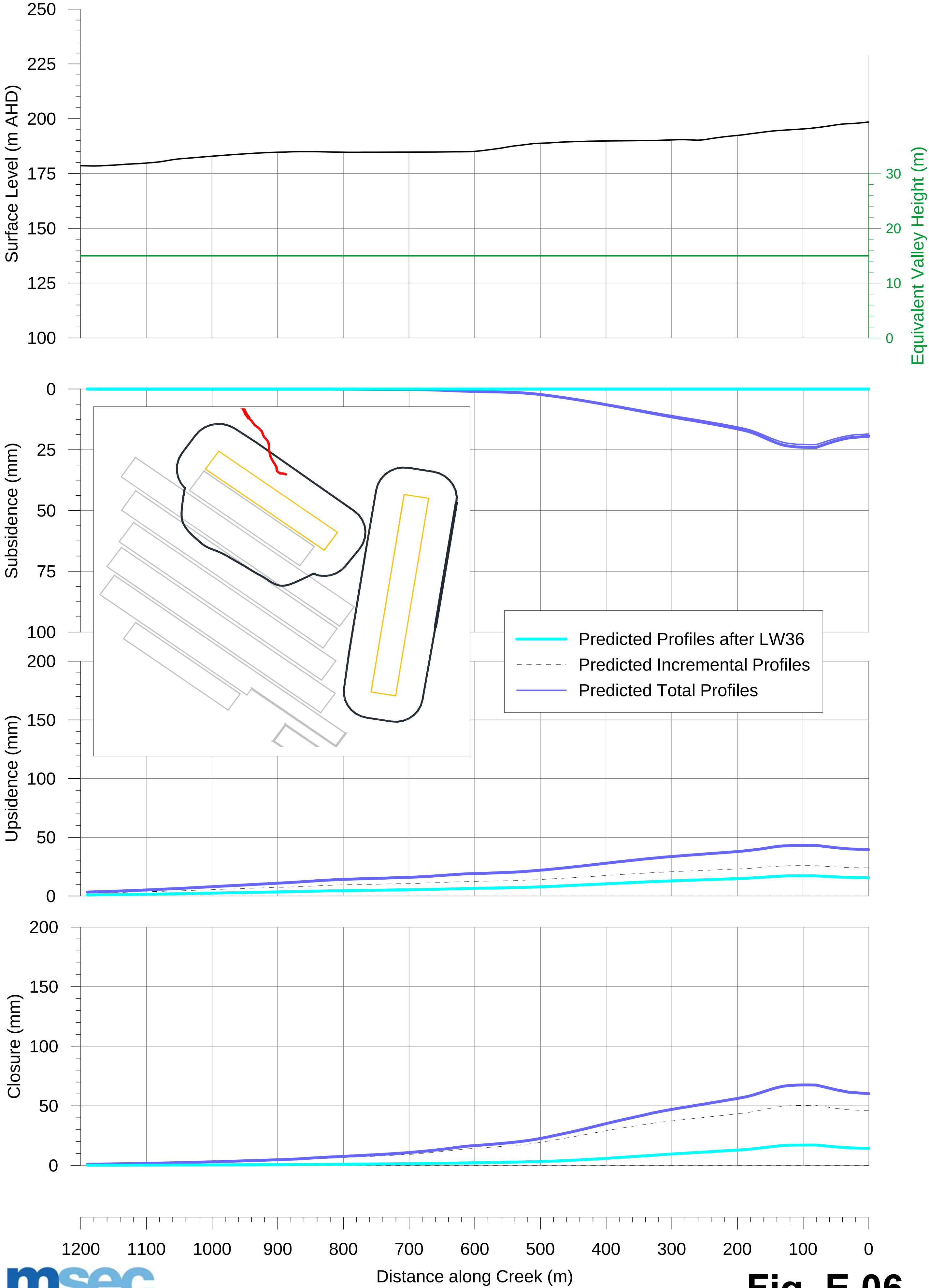
# Predicted Profiles of Subsidence, Upsidence and Closure along Nepean Creek Resulting from the Extraction of Longwalls 29 to 38




msec

Fig. E.05

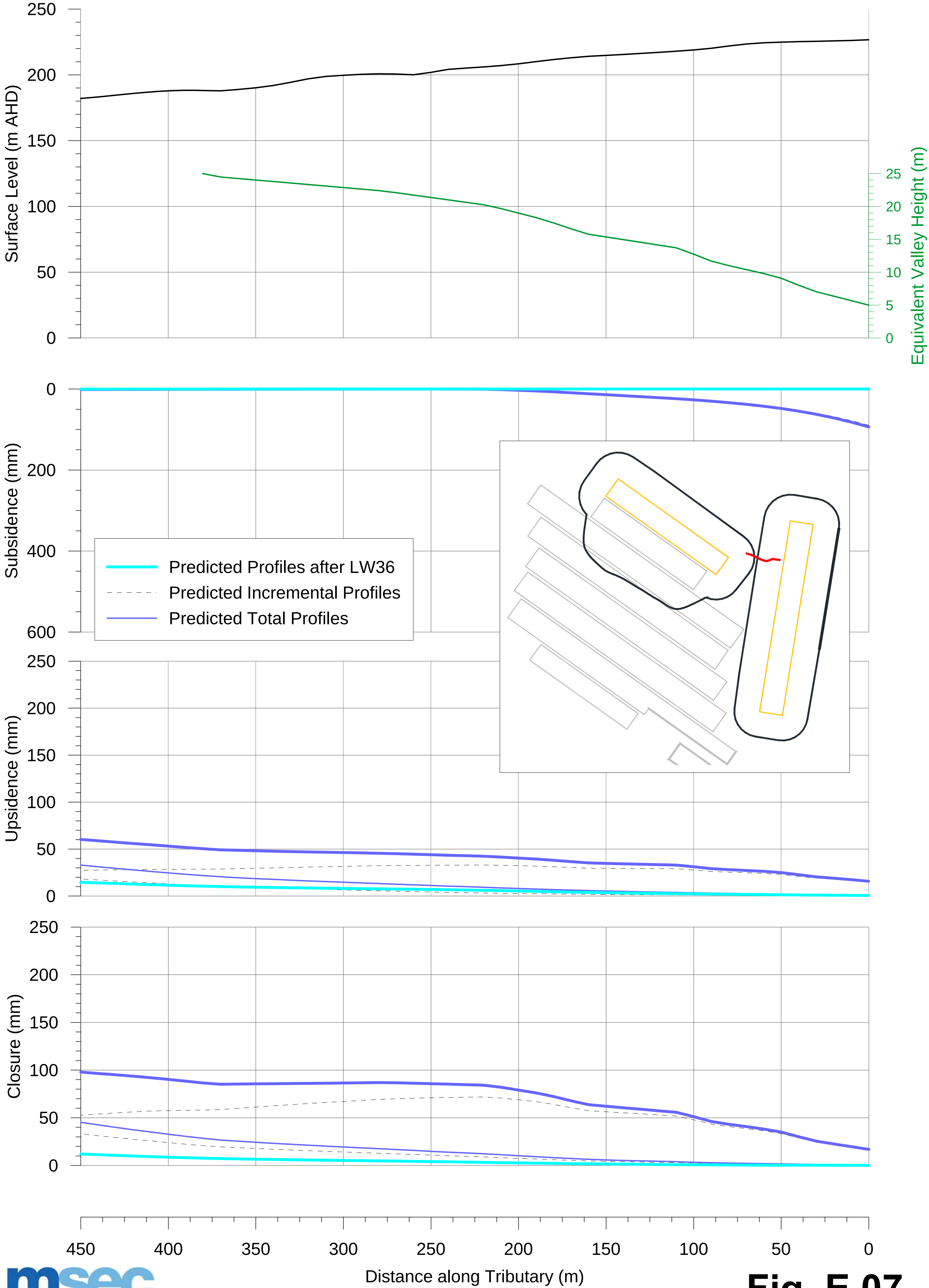
# Predicted Profiles of Subsidence, Upsidence and Closure along Woodhouse Creek Resulting from the Extraction of Longwalls 29 to 38




msec

Fig. E.06

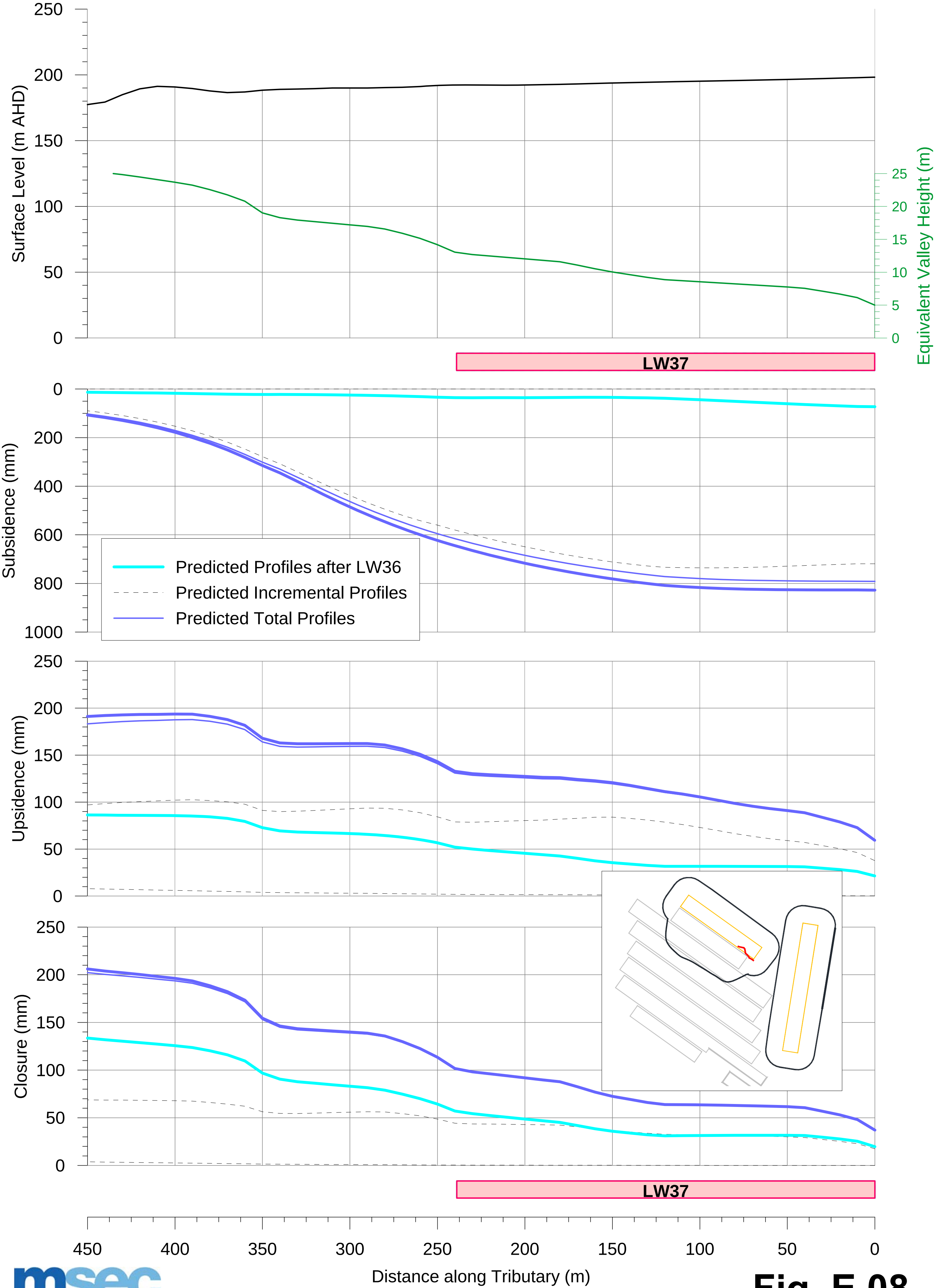
# Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR103 due to Longwalls 29 to 38




msec

**Fig. E.07**

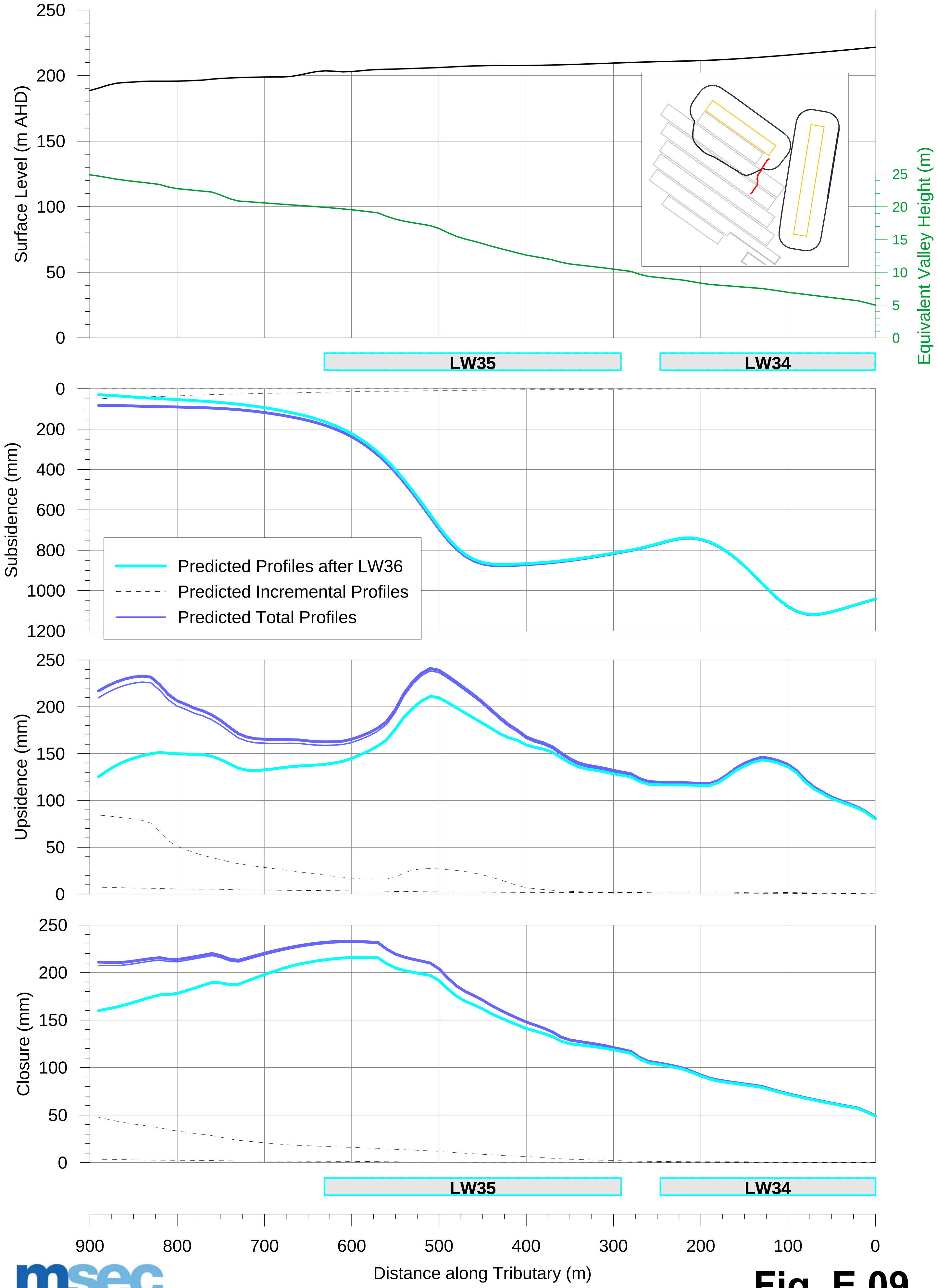
# Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR104 due to Longwalls 29 to 38




msec

**Fig. E.08**

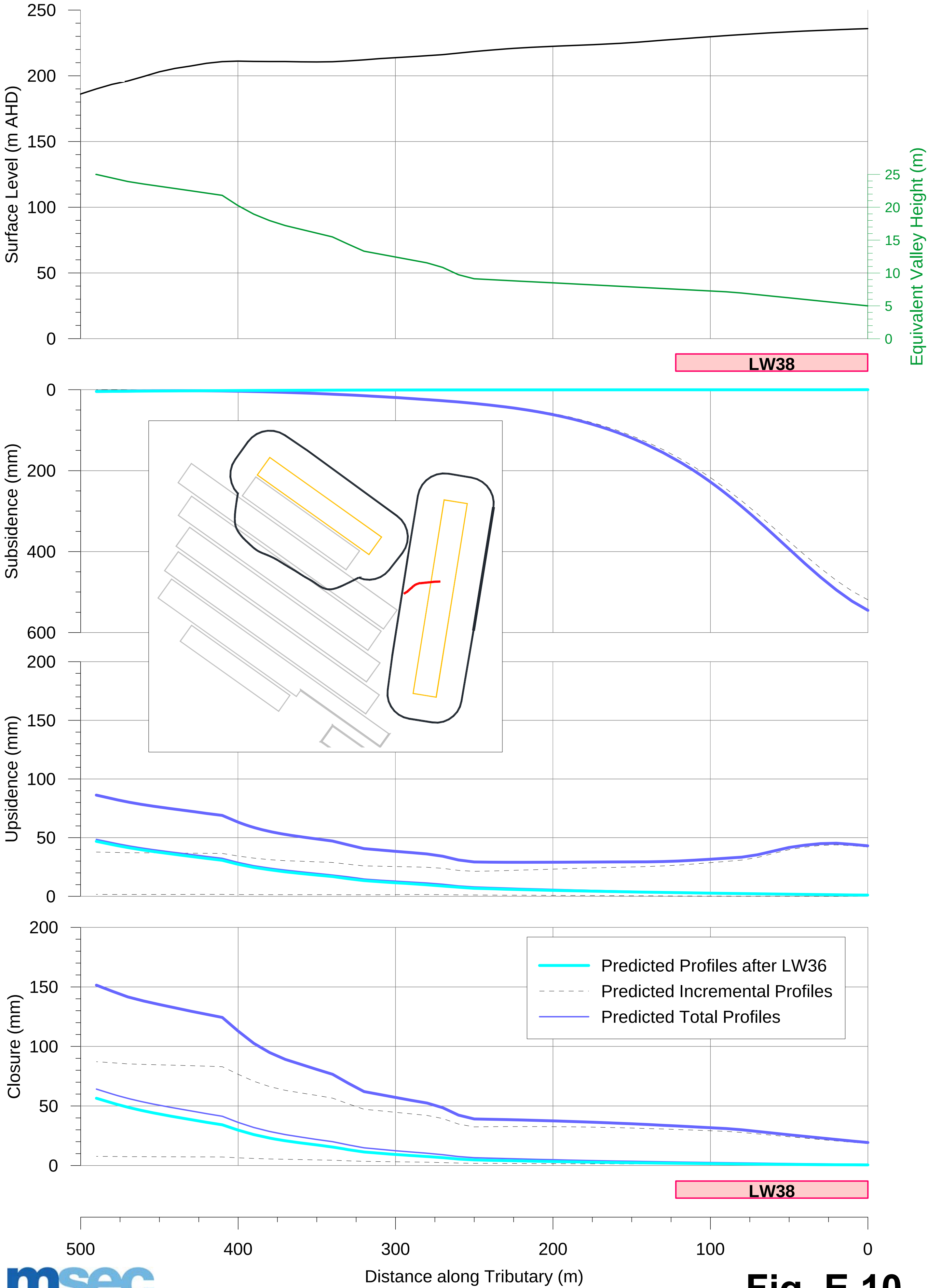
# Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR105 due to Longwalls 29 to 38




msec

Fig. E.09

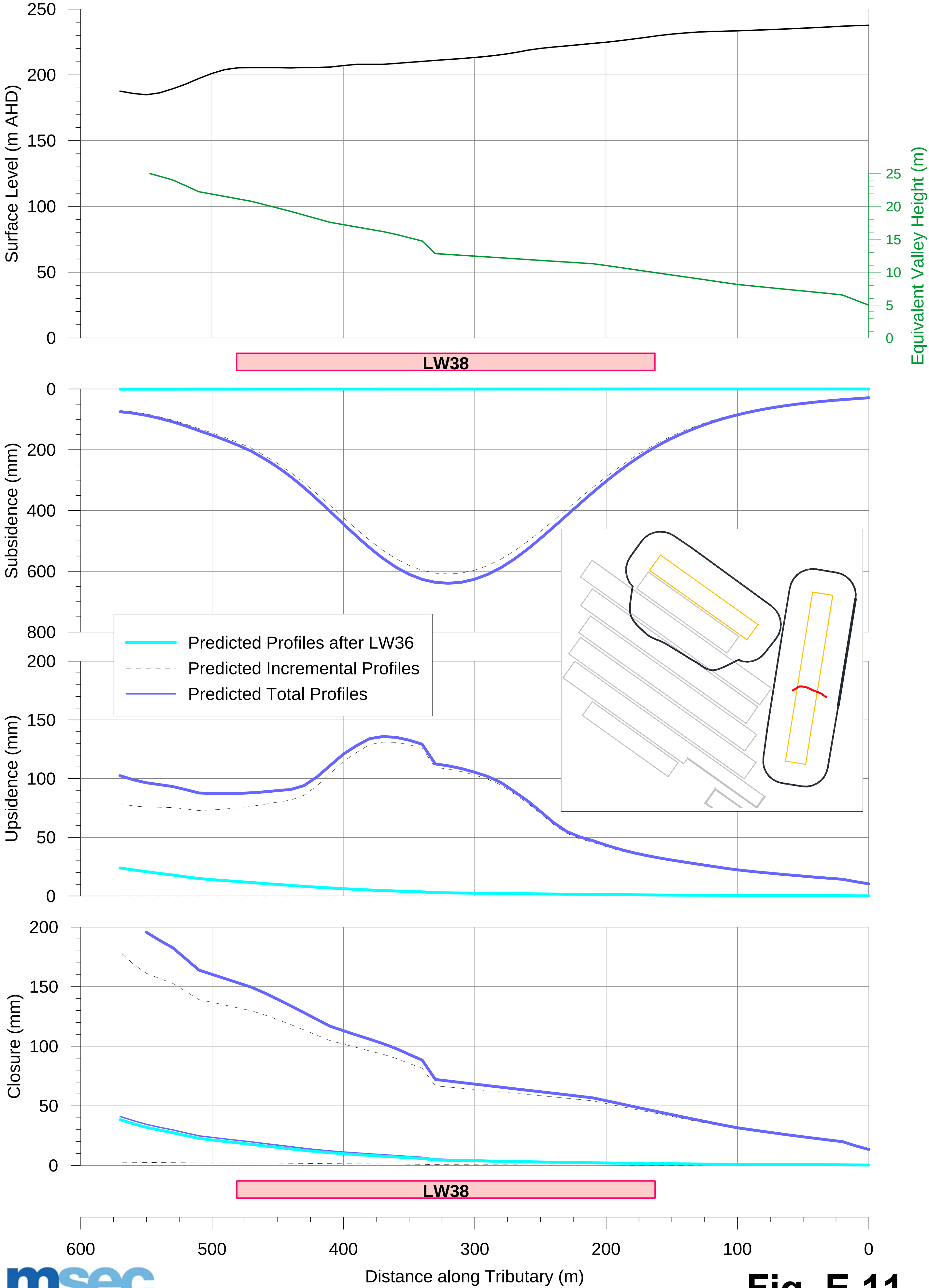
# Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR107 due to Longwalls 29 to 38




msec

**Fig. E.10**

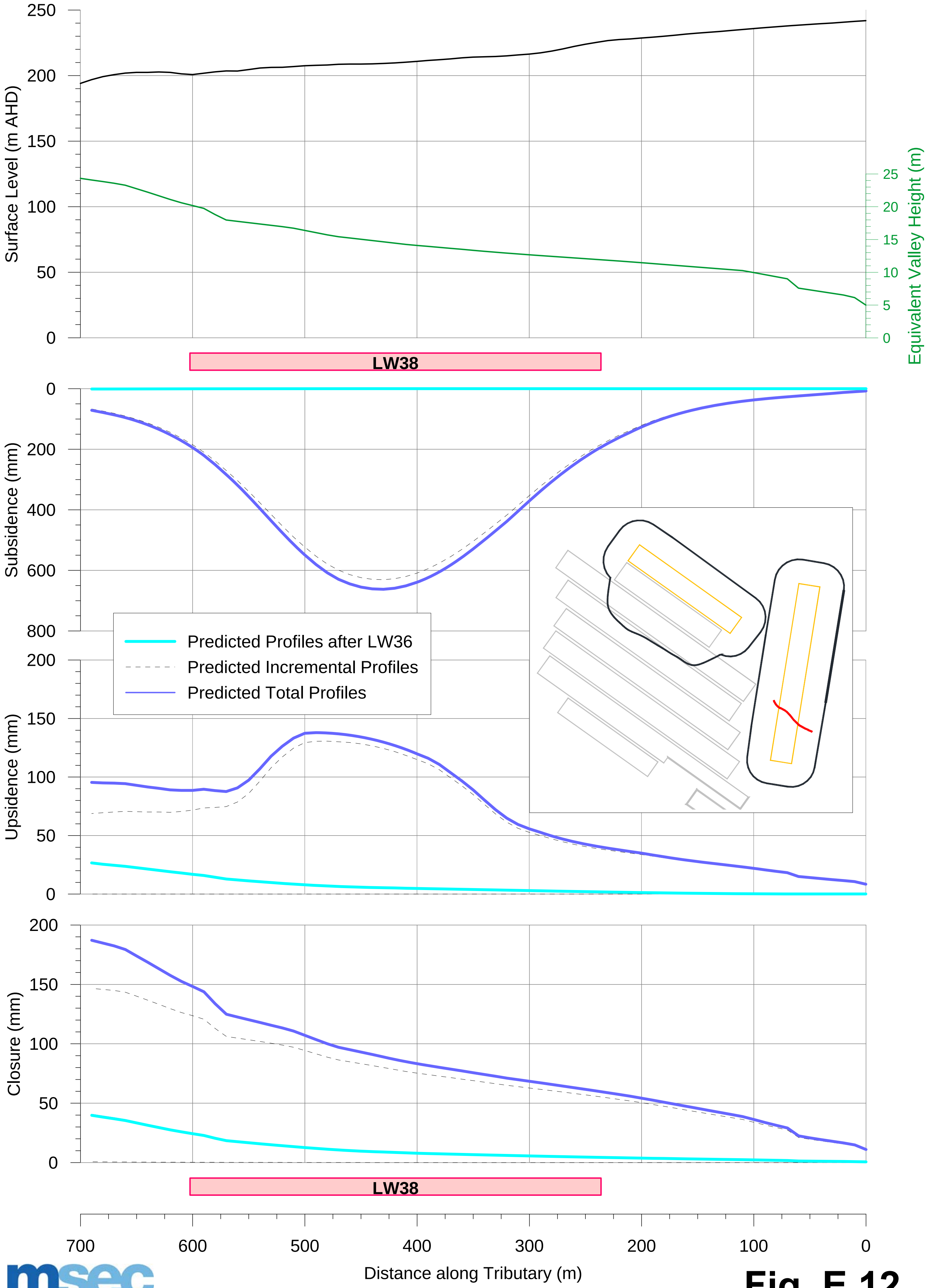
# Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR108 due to Longwalls 29 to 38




msec

Fig. E.11

# Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR110 due to Longwalls 29 to 38




msec

**Fig. E.12**

# Predicted Profiles of Subsidence, Upsidence and Closure along Tributary GR114 due to Longwalls 29 to 38

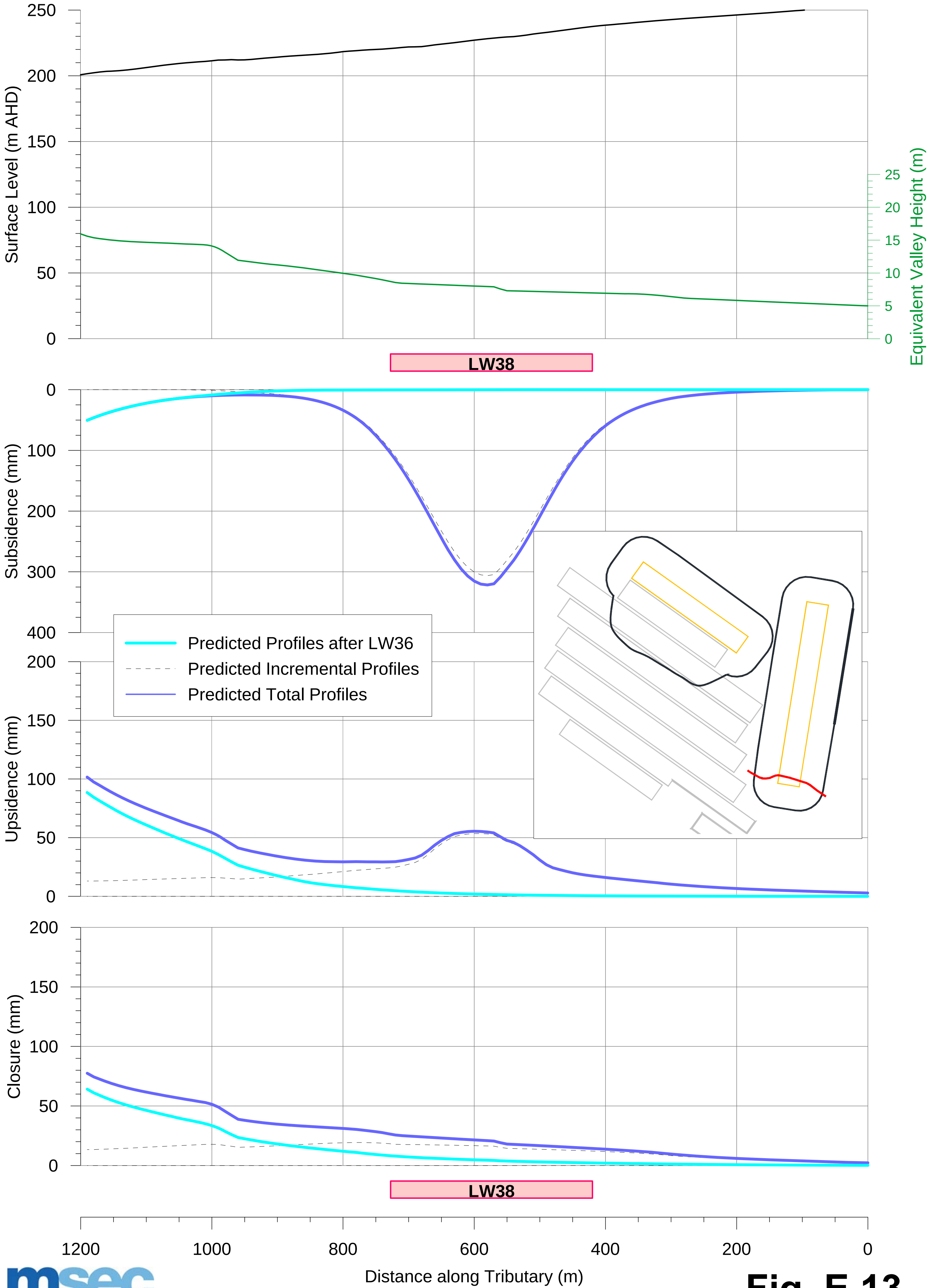
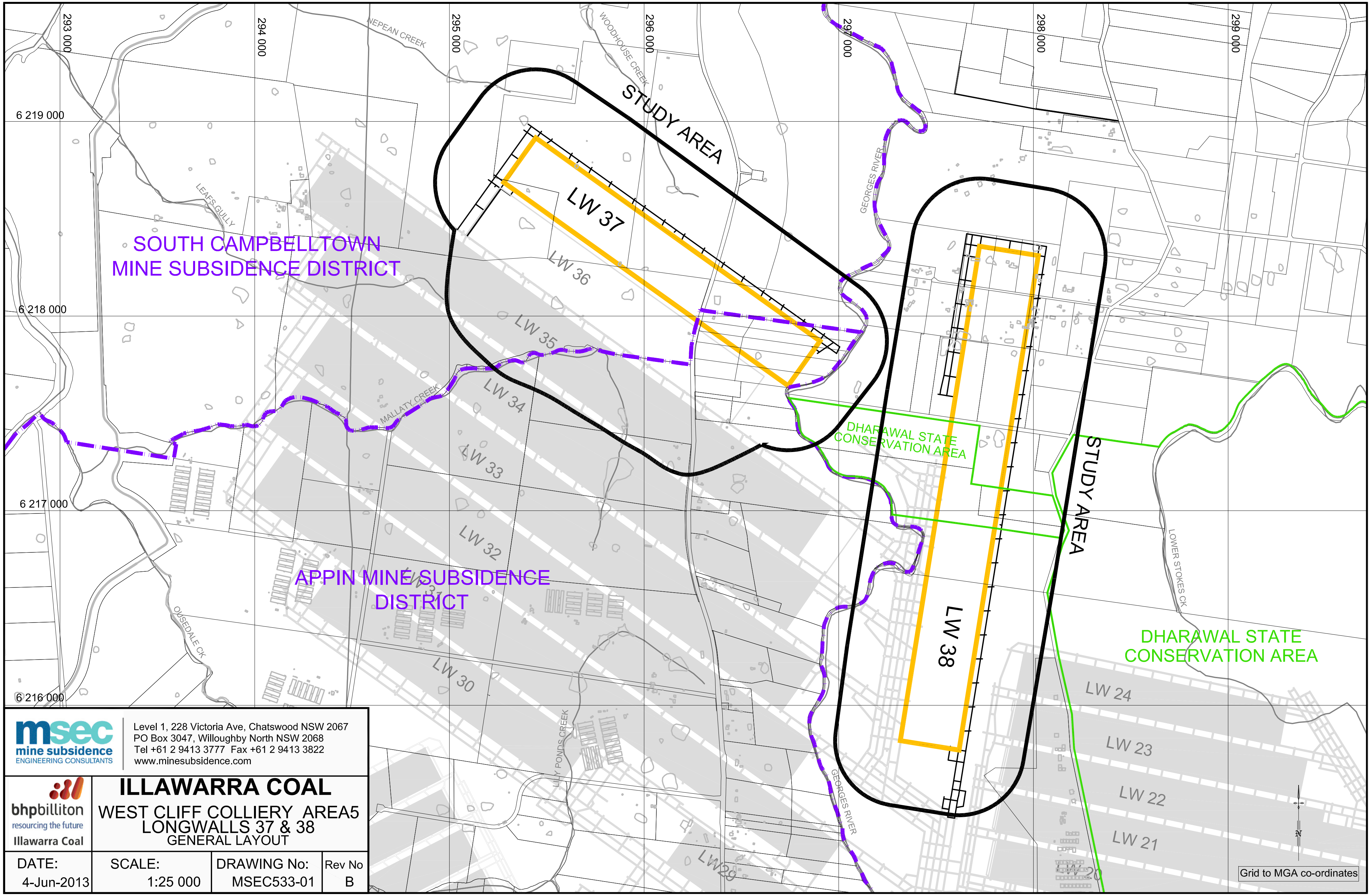



Fig. E.13

# APPENDIX F. DRAWINGS

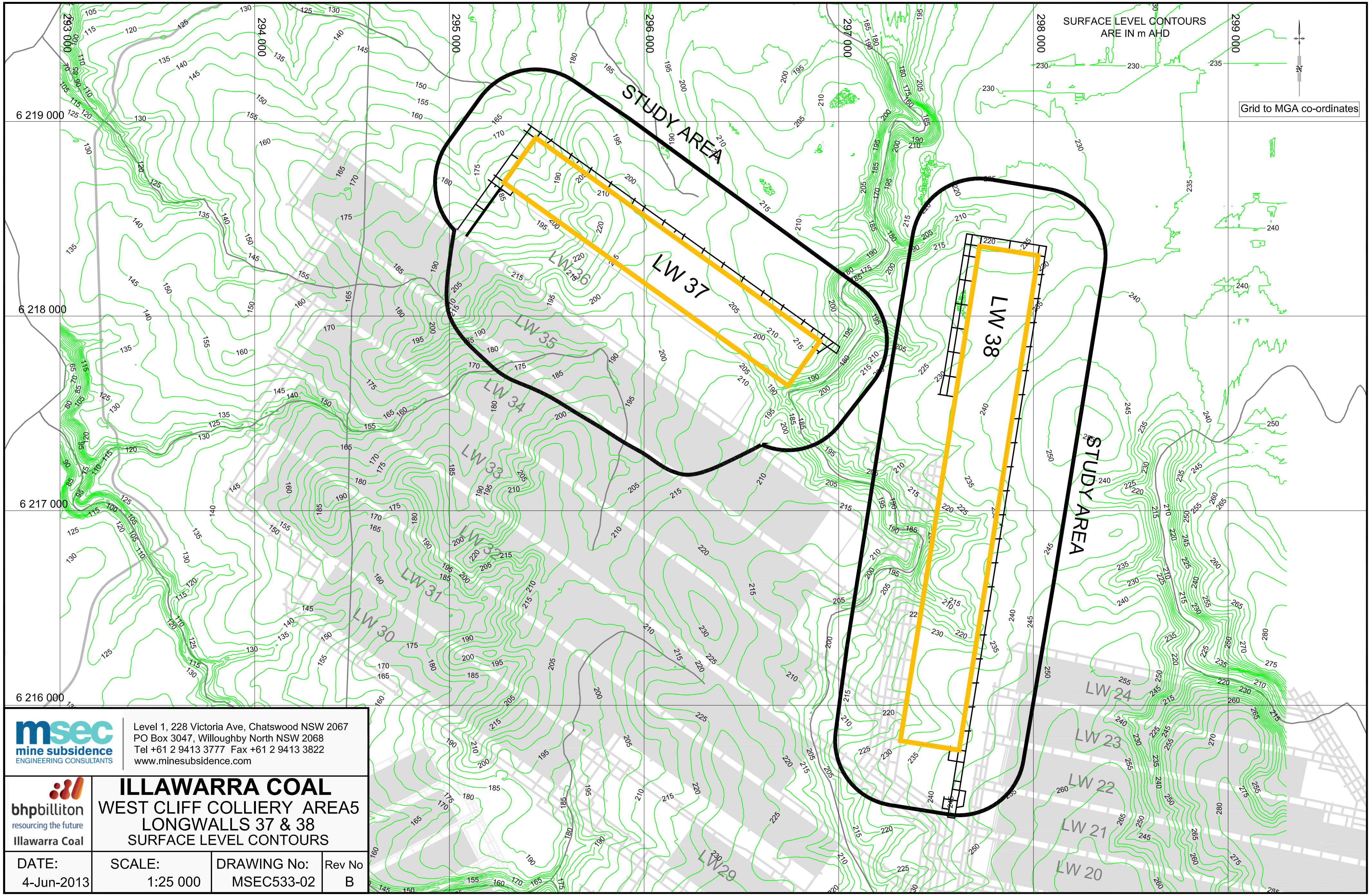
I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-01 dwg




| | |
|---|---|
| msec mine subsidence ENGINEERING CONSULTANTS | Level 1, 228 Victoria Ave, Chatswood NSW 2067<br>PO Box 3047, Willoughby North NSW 2068<br>Tel +61 2 9413 3777 Fax +61 2 9413 3822<br>www.minesubsidence.com |
| bhpbilliton resourcing the future Illawarra Coal | **ILLAWARRA COAL**<br>WEST CLIFF COLLIERY AREA5<br>LONGWALLS 37 & 38<br>GENERAL LAYOUT |

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-01 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-02 dwg




Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

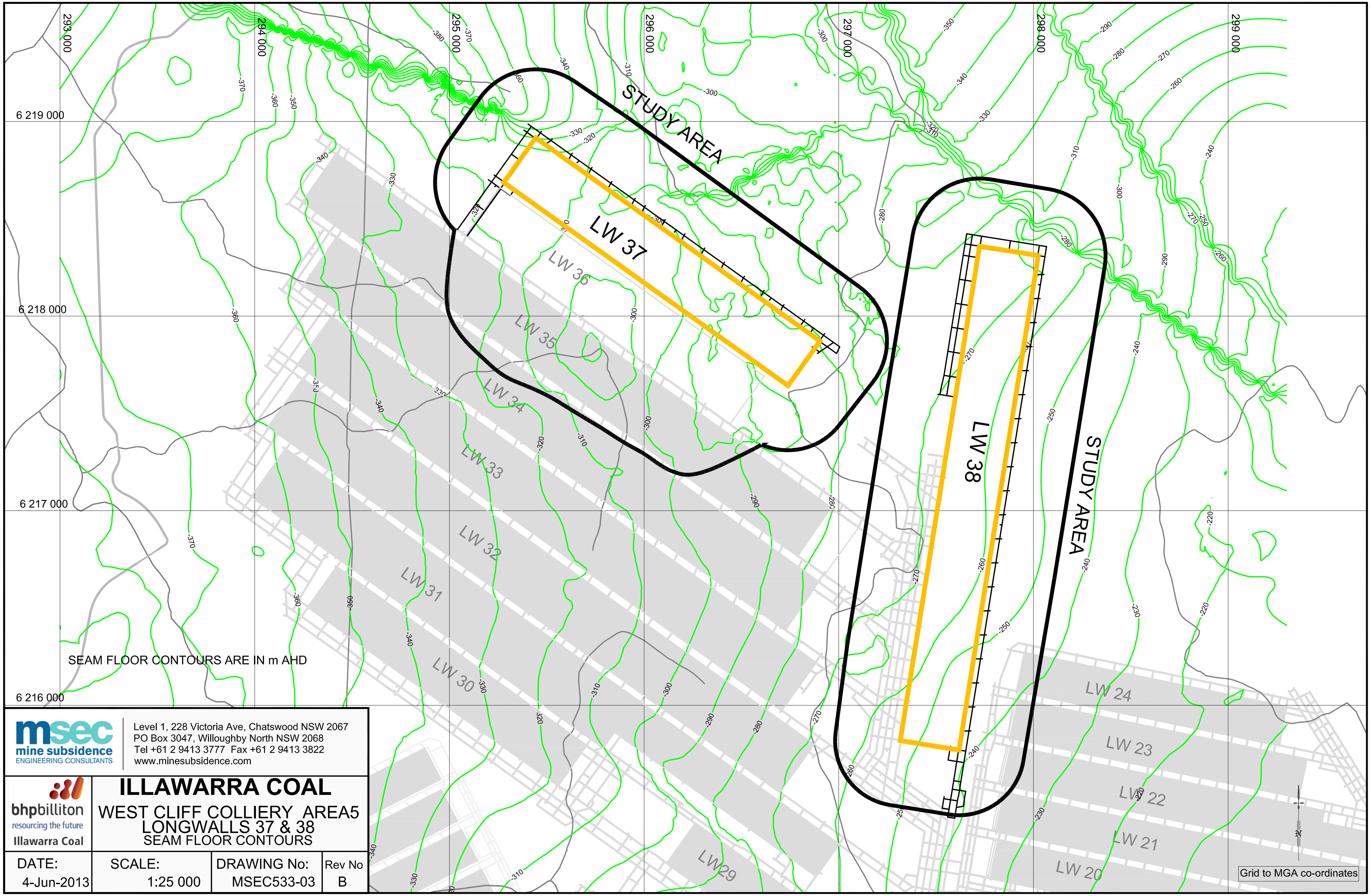
msec mine subsidence ENGINEERING CONSULTANTS

bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL
## WEST CLIFF COLLIERY AREA5
## LONGWALLS 37 & 38
## SURFACE LEVEL CONTOURS

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-02 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-03 dwg




msec mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

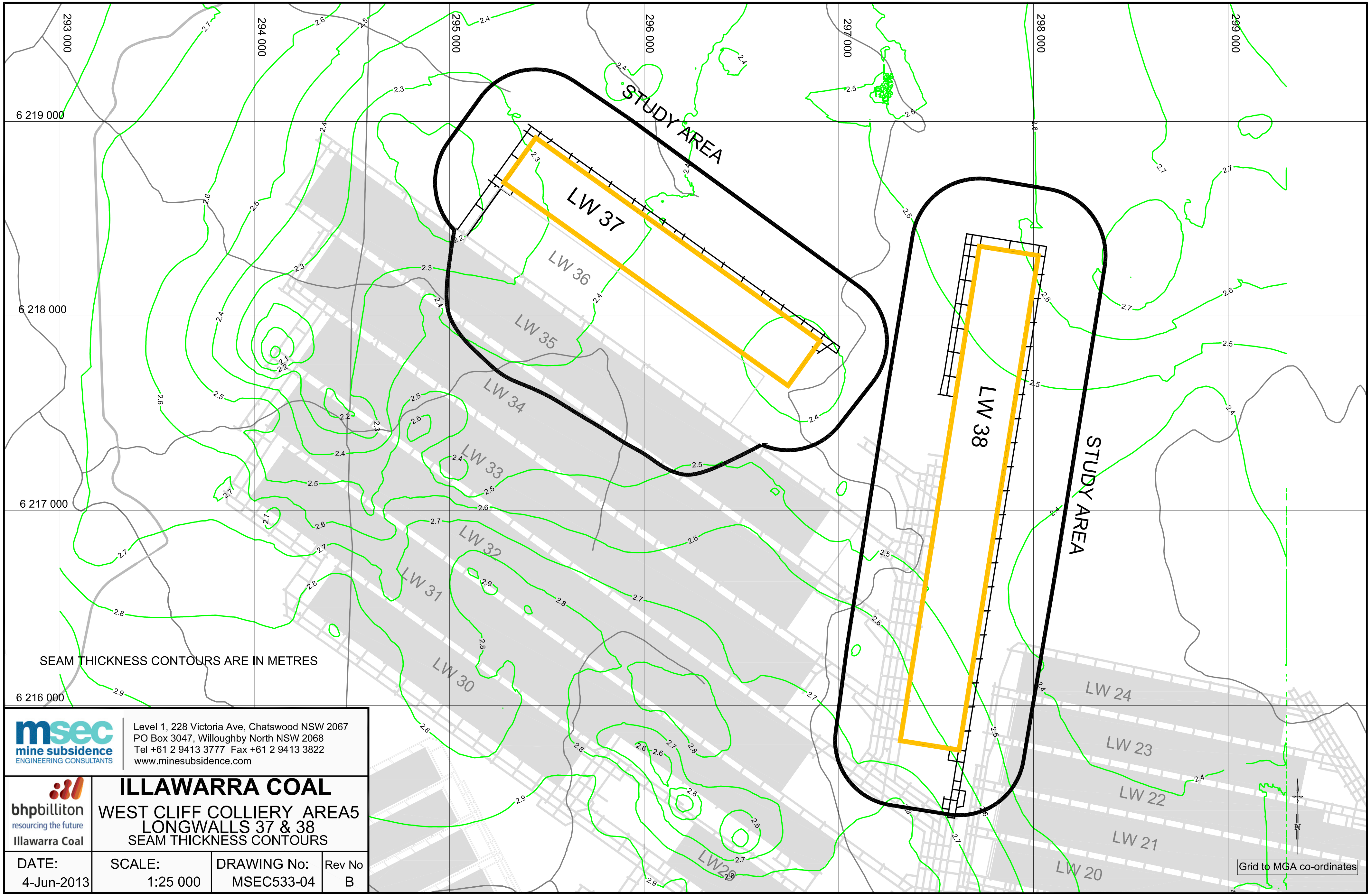
bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL

WEST CLIFF COLLIERY AREA5
LONGWALLS 37 & 38
SEAM FLOOR CONTOURS

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-03 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-04 dwg




msec mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

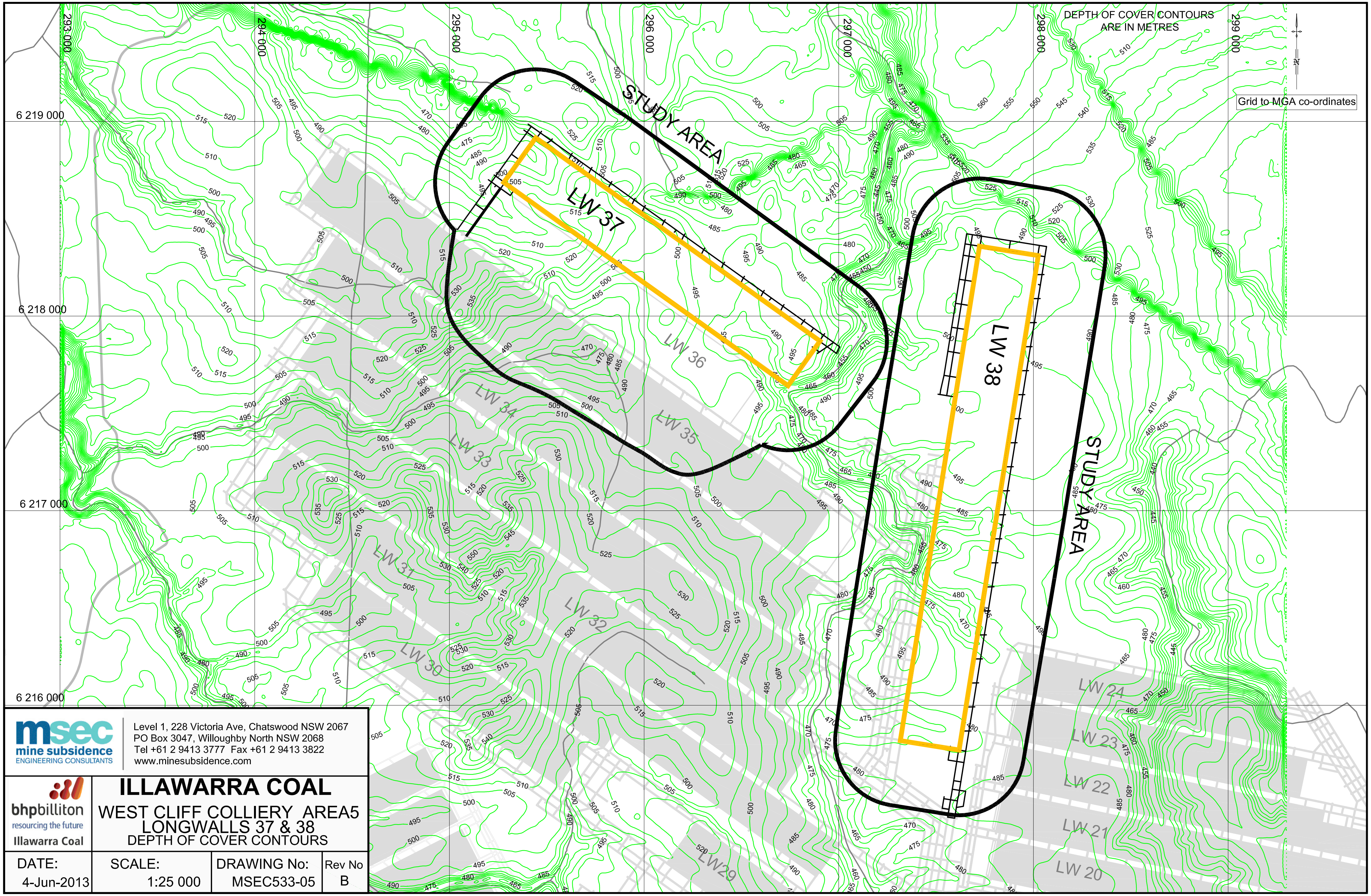
bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL

WEST CLIFF COLLIERY AREA5
LONGWALLS 37 & 38
SEAM THICKNESS CONTOURS

| DATE: | SCALE: | DRAWING No: | Rev No |
| --- | --- | --- | --- |
| 4-Jun-2013 | 1:25 000 | MSEC533-04 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-05 dwg




msec mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

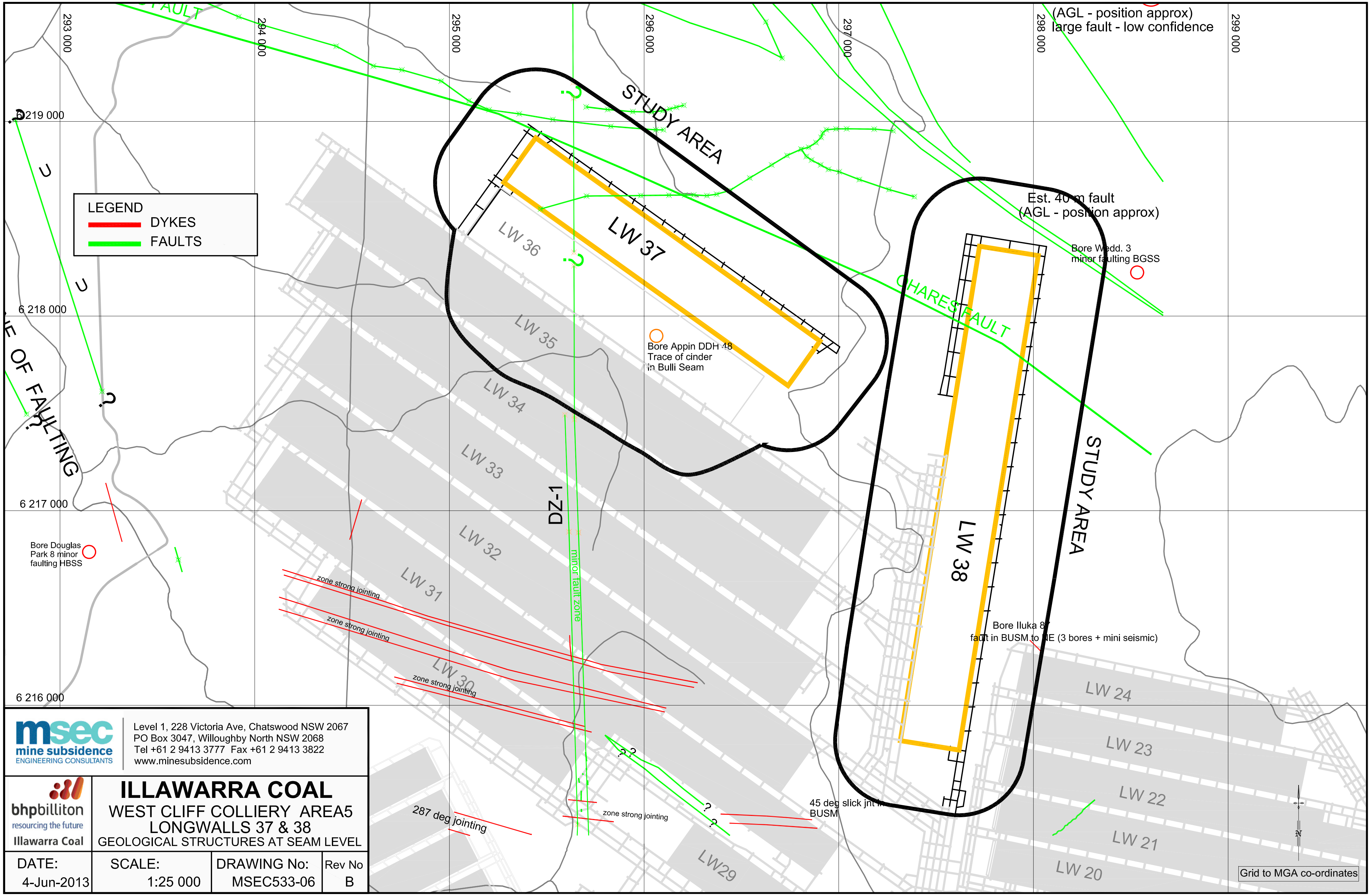
bhpbilliton resourcing the future
Illawarra Coal

**ILLAWARRA COAL**

WEST CLIFF COLLIERY AREA5
LONGWALLS 37 & 38
DEPTH OF COVER CONTOURS

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-05 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-06dwg



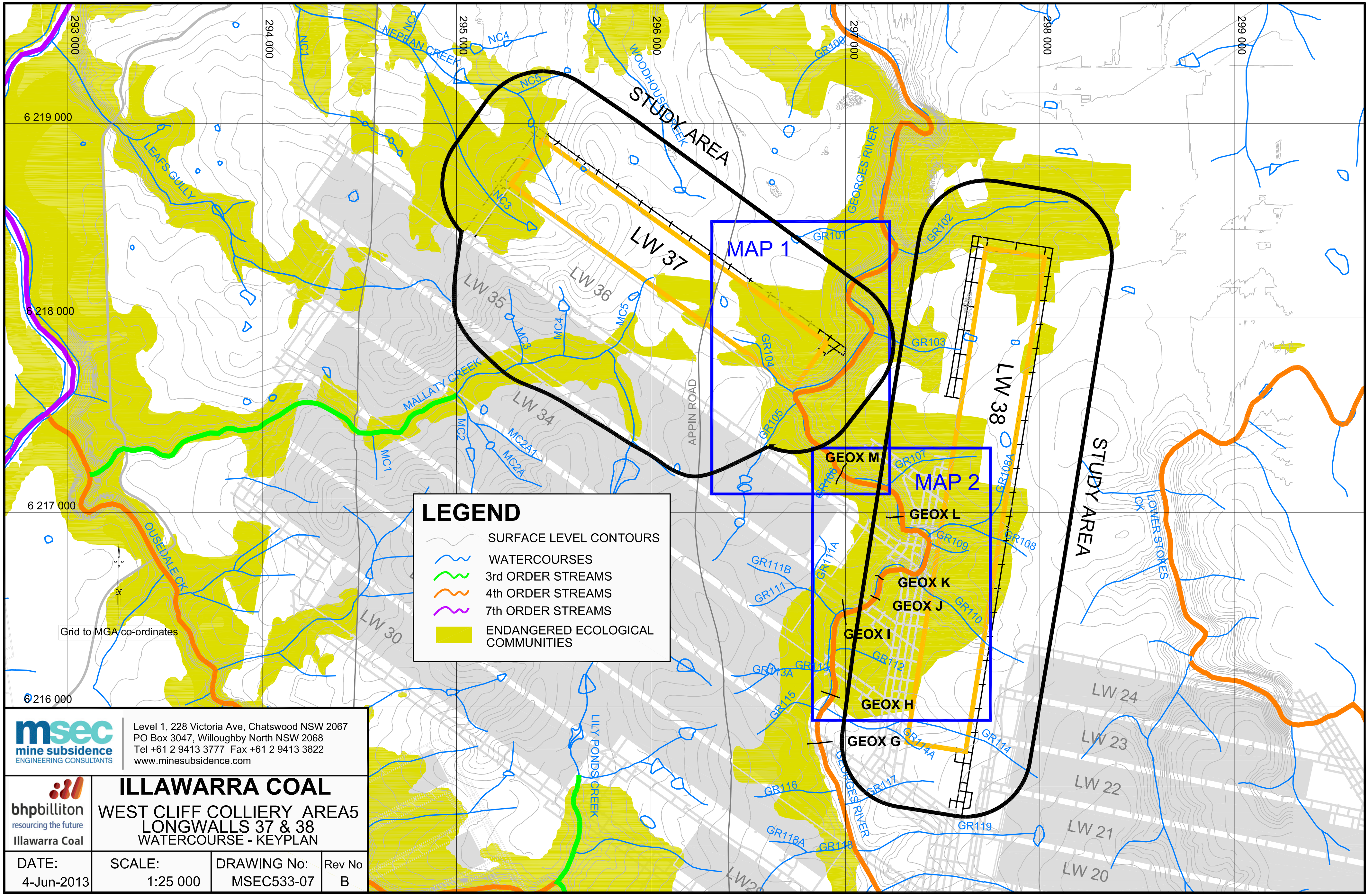

msec
mine subsidence
ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

bhpbilliton
resourcing the future
Illawarra Coal

# ILLAWARRA COAL
## WEST CLIFF COLLIERY AREA5
## LONGWALLS 37 & 38
## GEOLOGICAL STRUCTURES AT SEAM LEVEL

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-06 | B |




## LEGEND

- SURFACE LEVEL CONTOURS
- WATERCOURSES
- 3rd ORDER STREAMS
- 4th ORDER STREAMS
- 7th ORDER STREAMS
- ENDANGERED ECOLOGICAL COMMUNITIES

msec mine subsidence ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

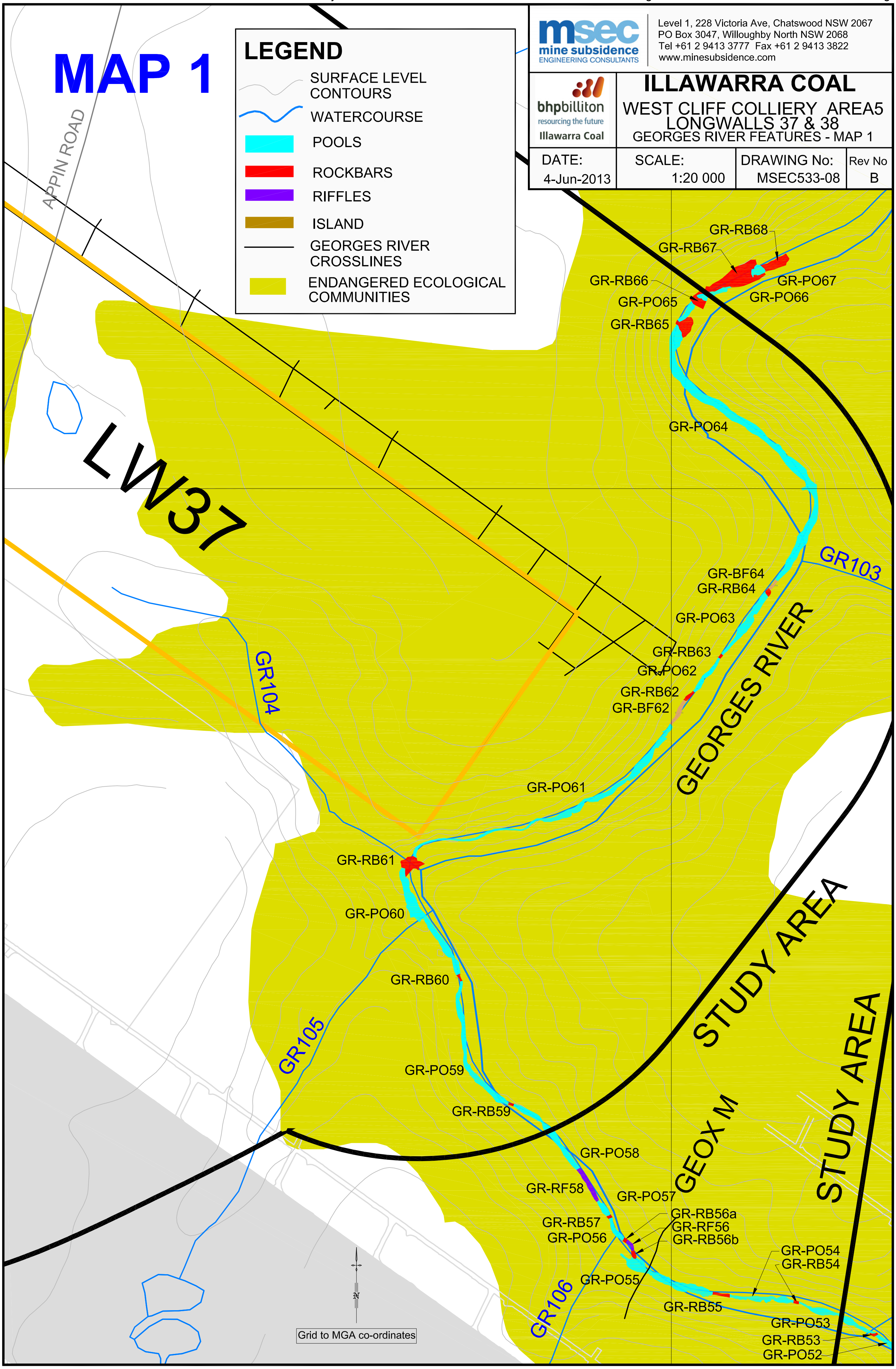
bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL

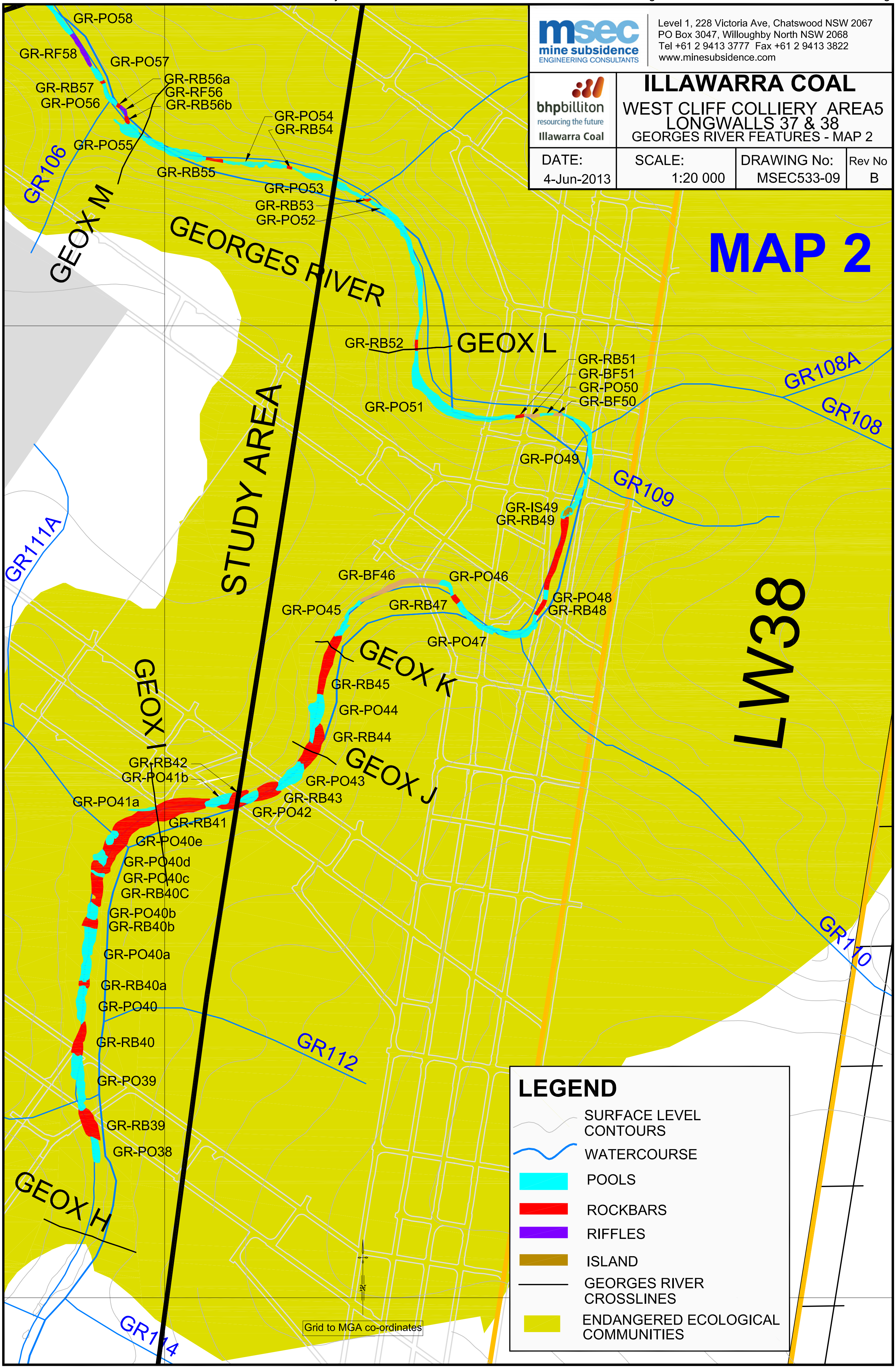
## WEST CLIFF COLLIERY AREA5 LONGWALLS 37 & 38 WATERCOURSE - KEYPLAN

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-07 | B |

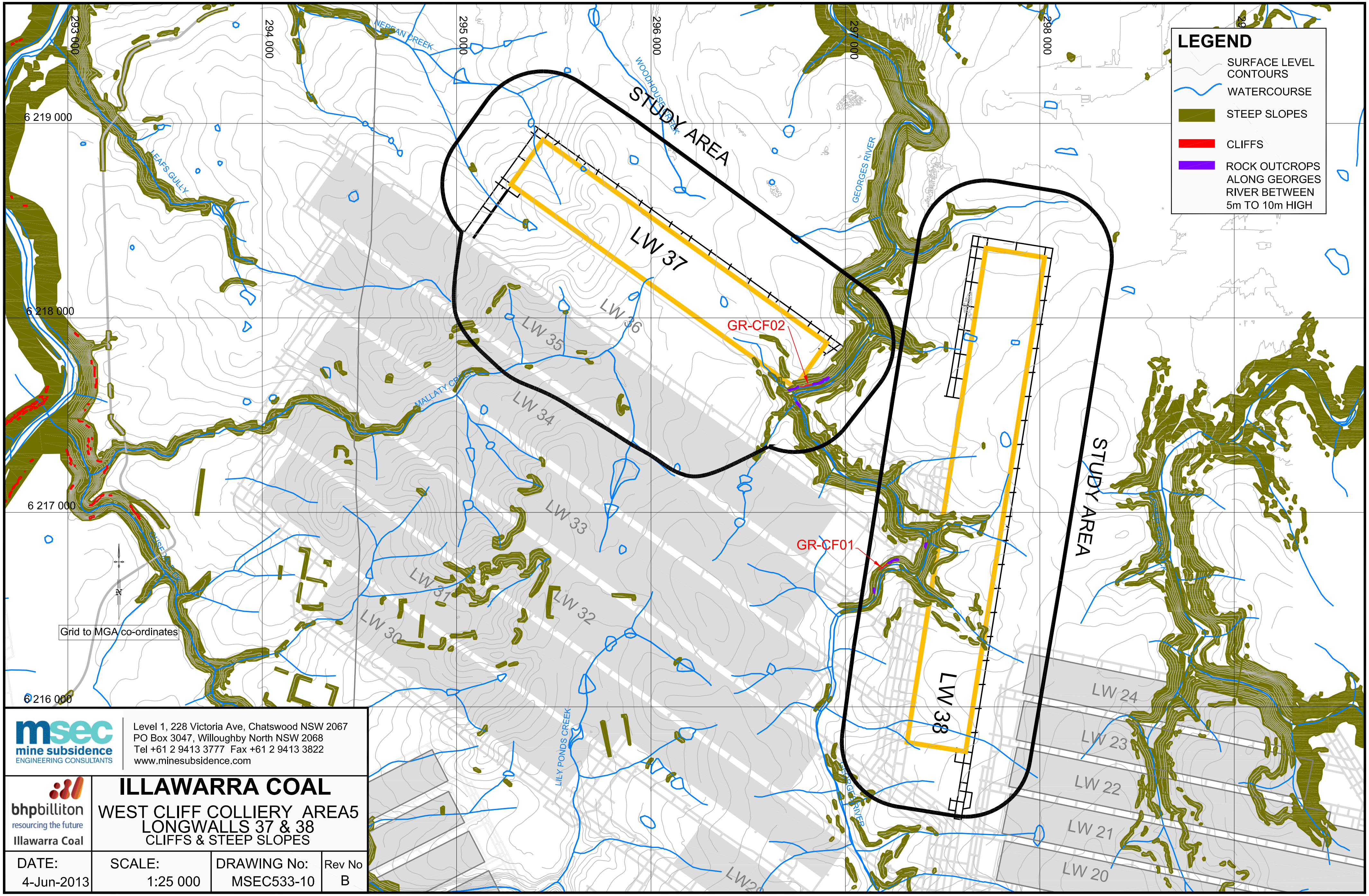
I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-08.dwg



I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-09dwg



I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-10.dwg




**msec** mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

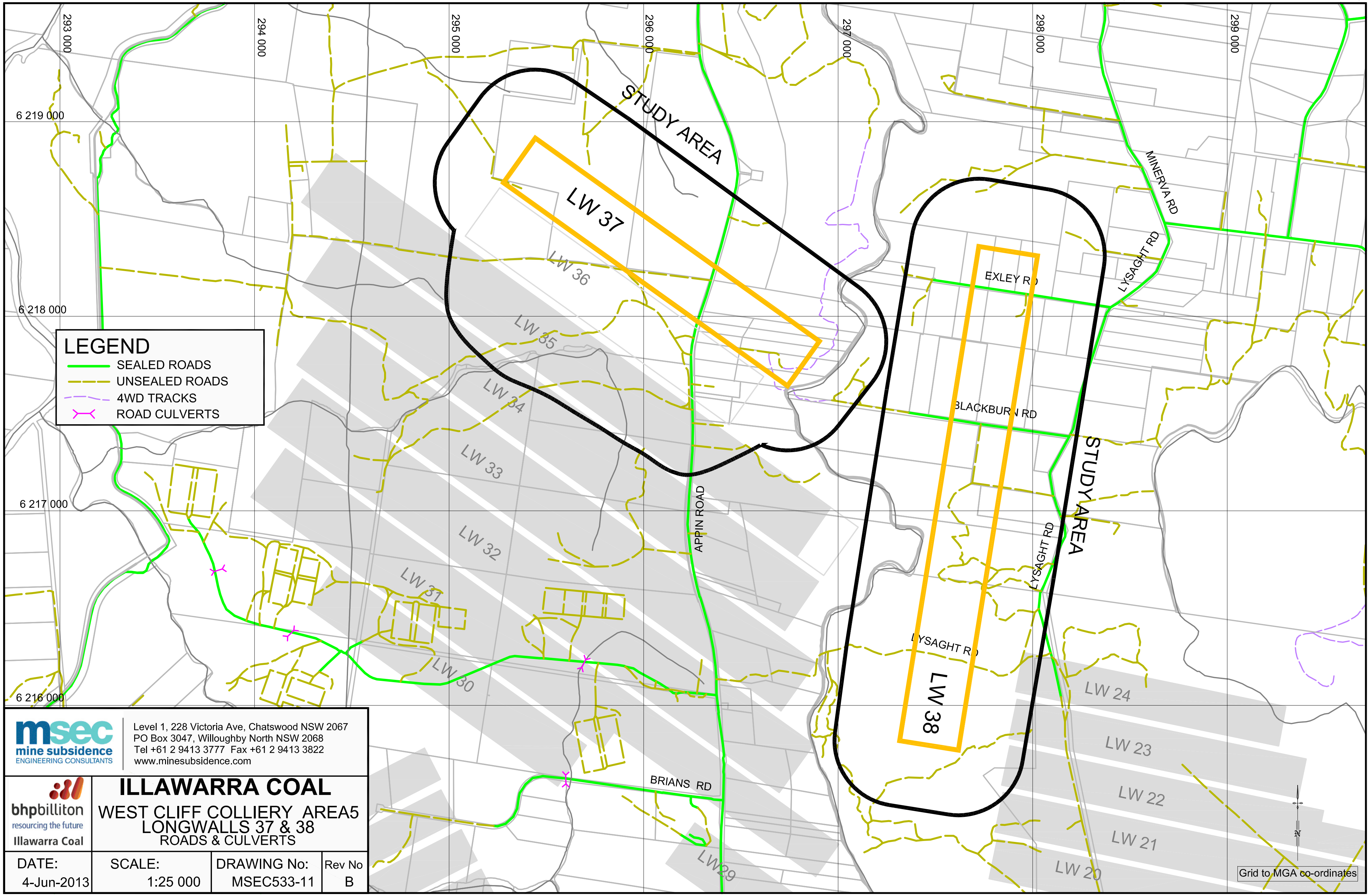
bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL

## WEST CLIFF COLLIERY AREA5 LONGWALLS 37 & 38 CLIFFS & STEEP SLOPES

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-10 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-11dwg




msec mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

bhpbilliton resourcing the future
Illawarra Coal

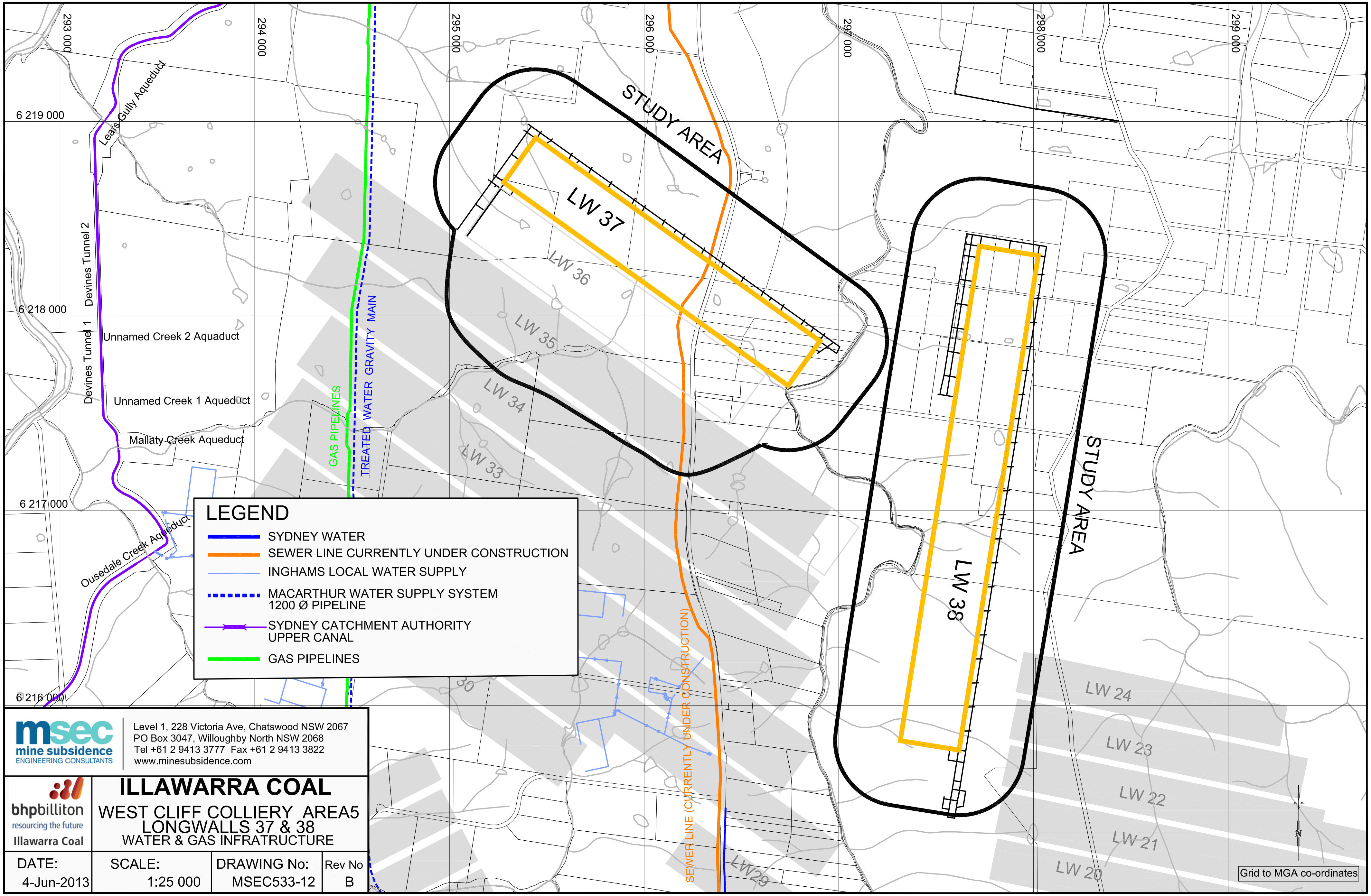
# ILLAWARRA COAL

## WEST CLIFF COLLIERY AREA5 LONGWALLS 37 & 38

ROADS & CULVERTS

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-11 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-12dwg




msec mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

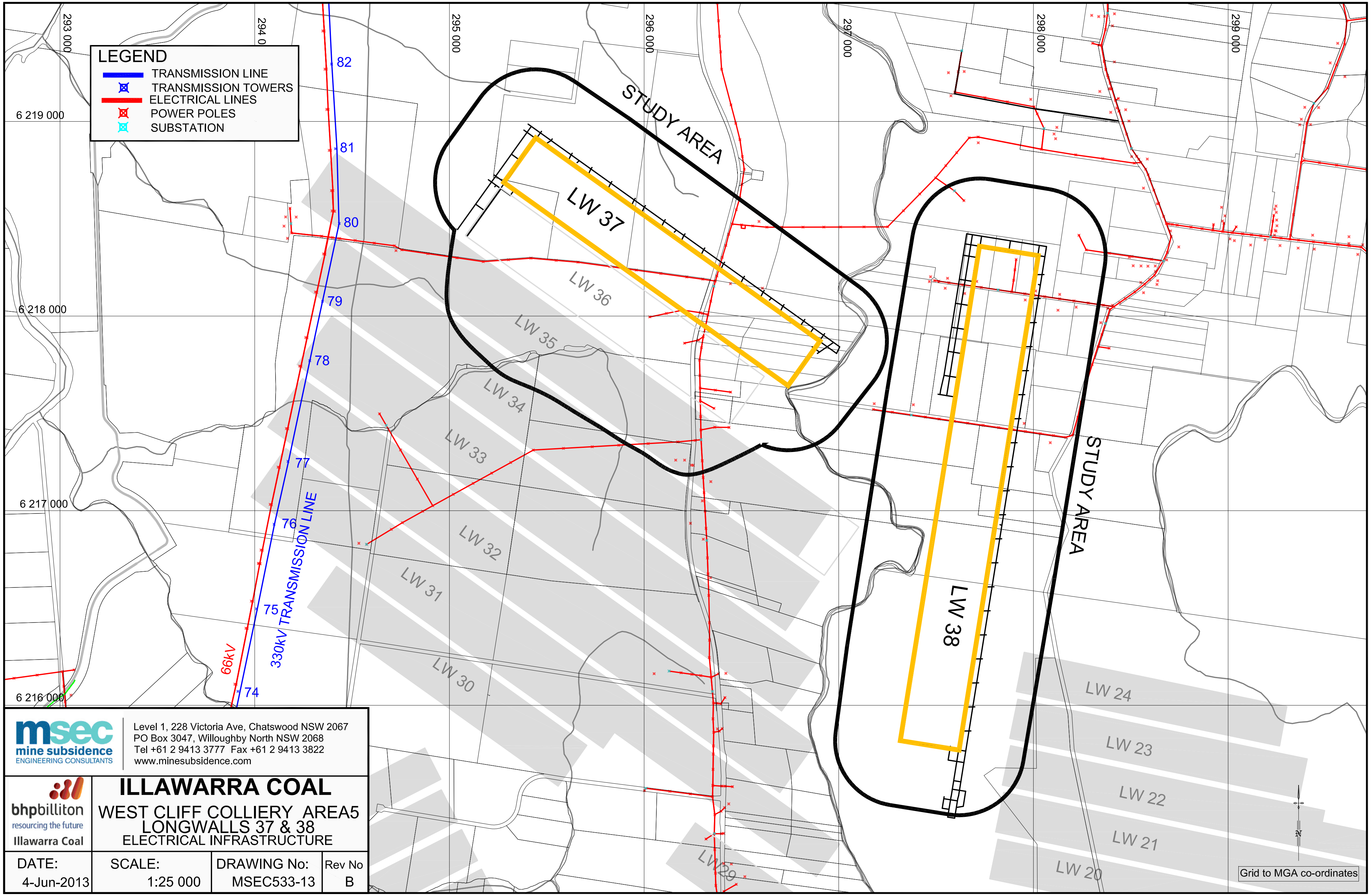
bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL

WEST CLIFF COLLIERY AREA5
LONGWALLS 37 & 38
WATER & GAS INFRATRUCTURE

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-12 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-13dwg




msec mine subsidence ENGINEERING CONSULTANTS

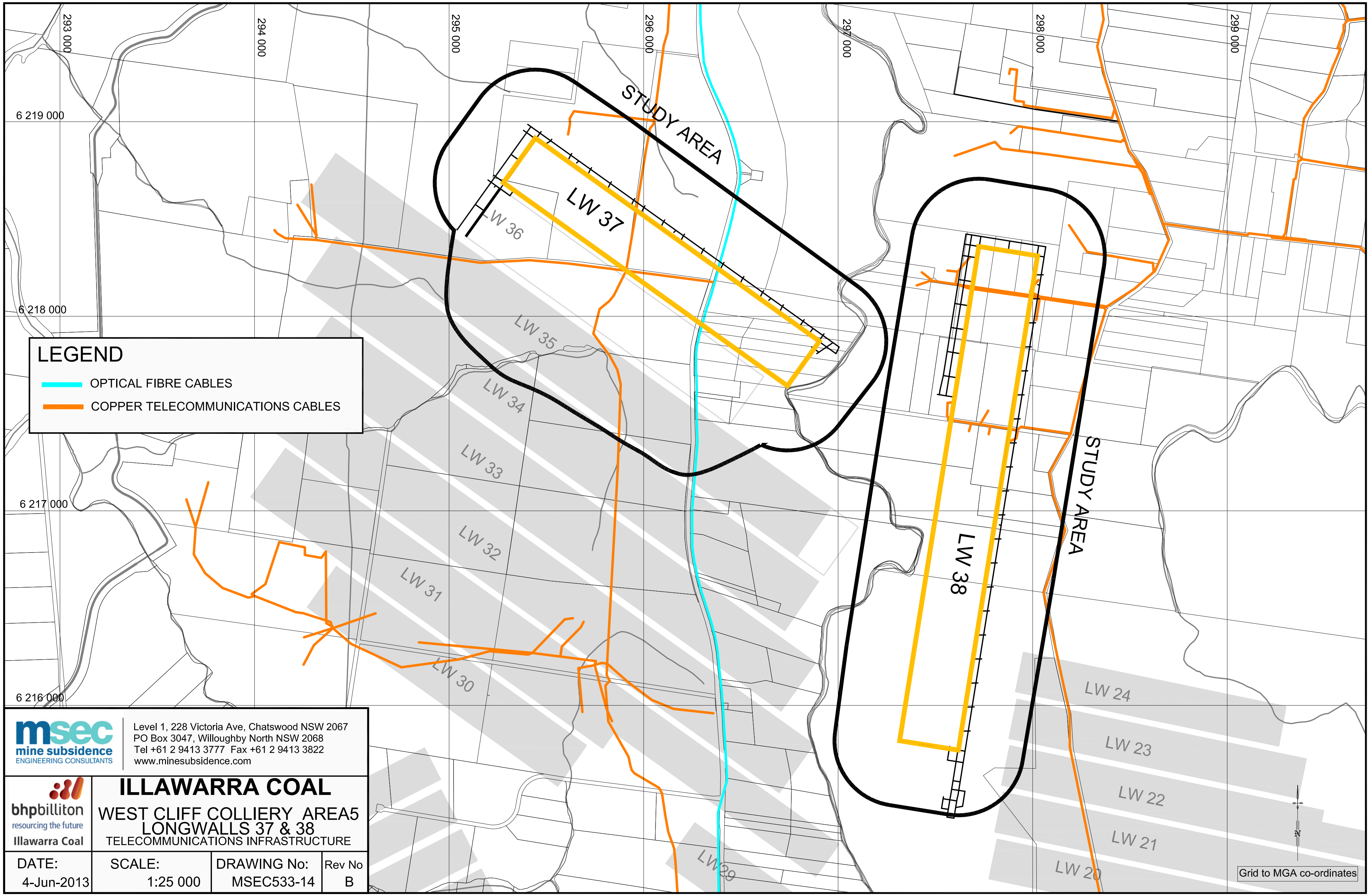
Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

bhpbilliton resourcing the future
Illawarra Coal

**ILLAWARRA COAL**
WEST CLIFF COLLIERY AREA5
LONGWALLS 37 & 38
ELECTRICAL INFRASTRUCTURE

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-13 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-14dwg




msec mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

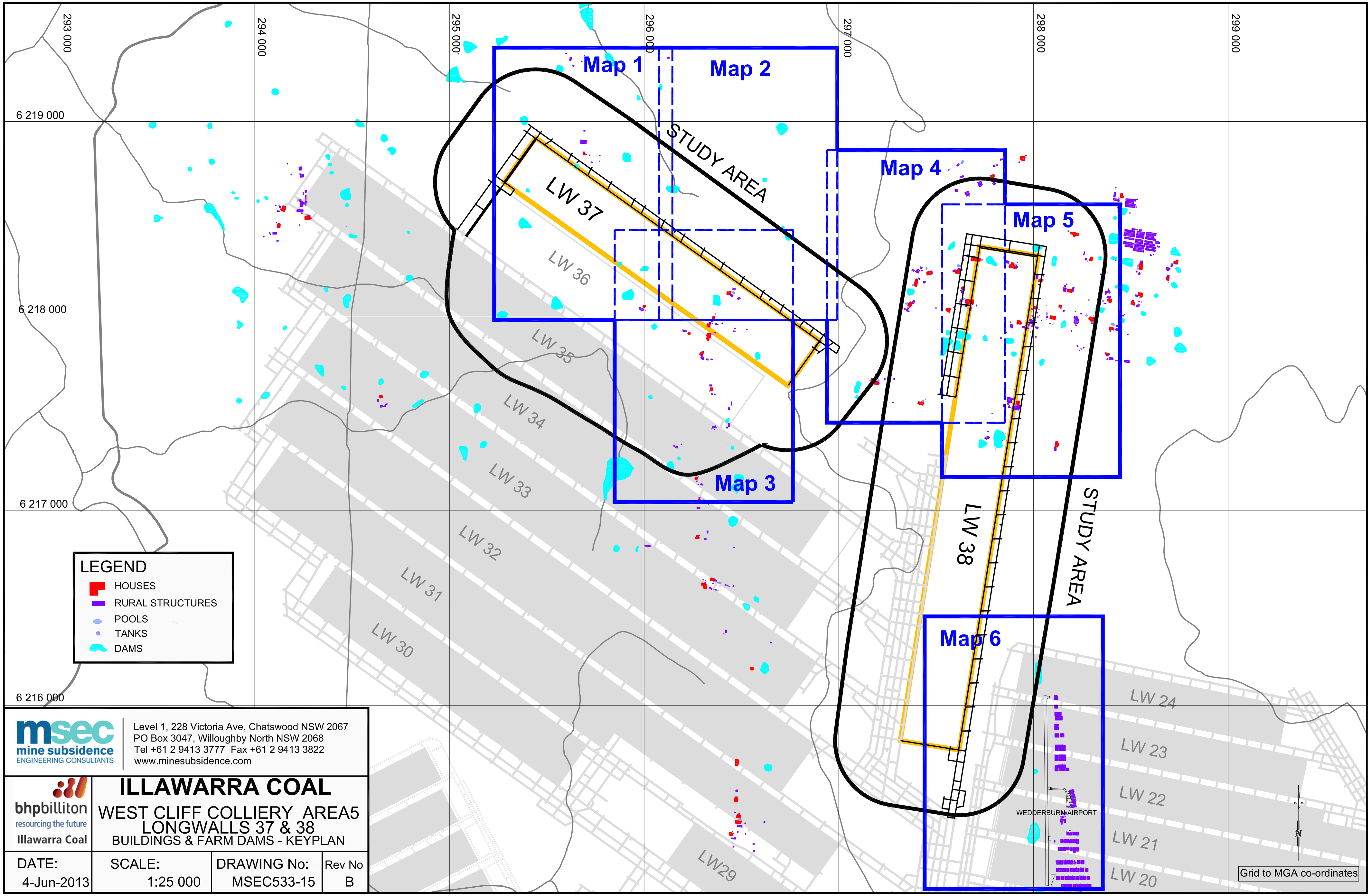
bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL

WEST CLIFF COLLIERY AREA5
LONGWALLS 37 & 38
TELECOMMUNICATIONS INFRASTRUCTURE

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-14 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-15dwg




msec mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

bhpbilliton resourcing the future
Illawarra Coal

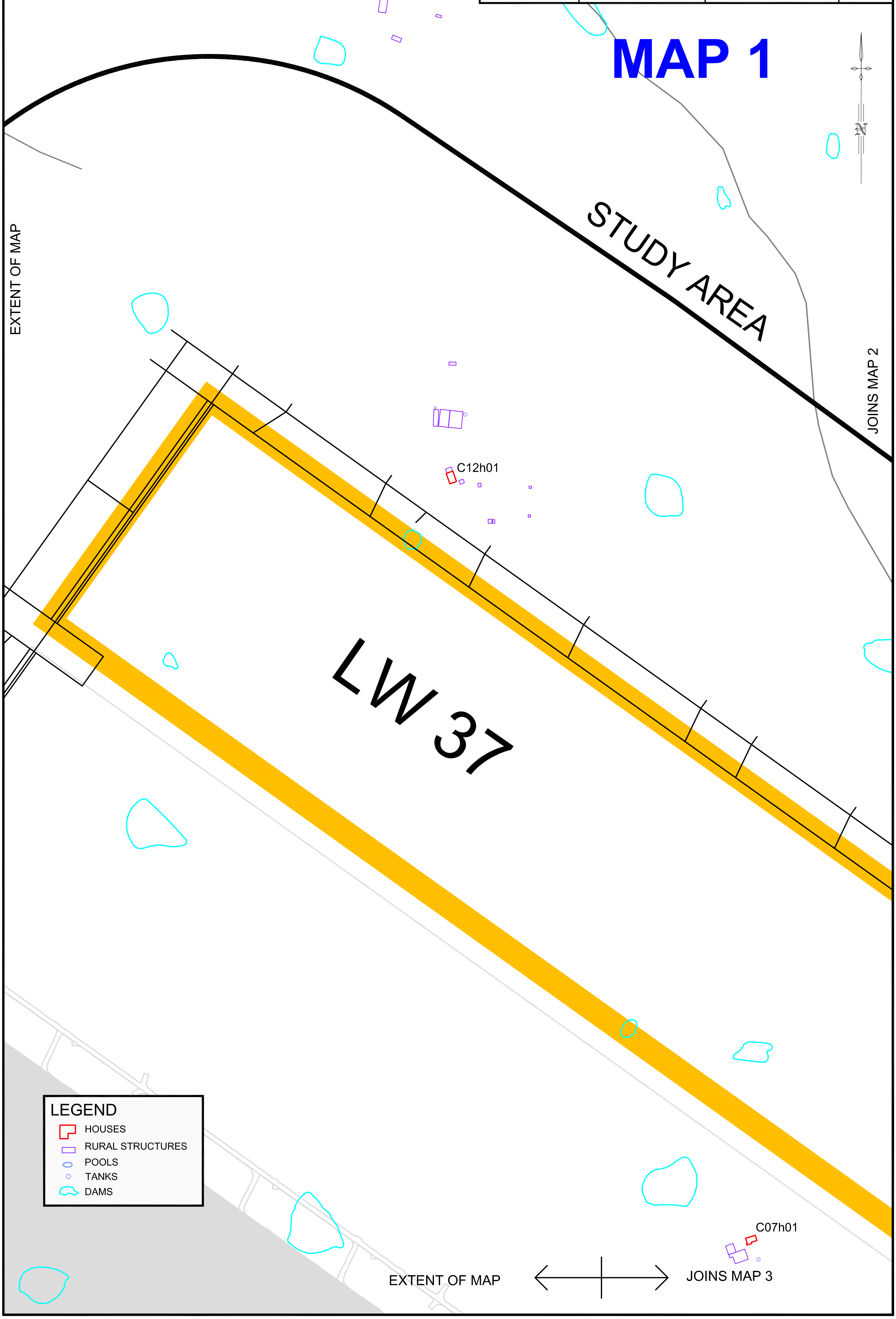
# ILLAWARRA COAL

WEST CLIFF COLLIERY AREA5
LONGWALLS 37 & 38
BUILDINGS & FARM DAMS - KEYPLAN

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-15 | B |

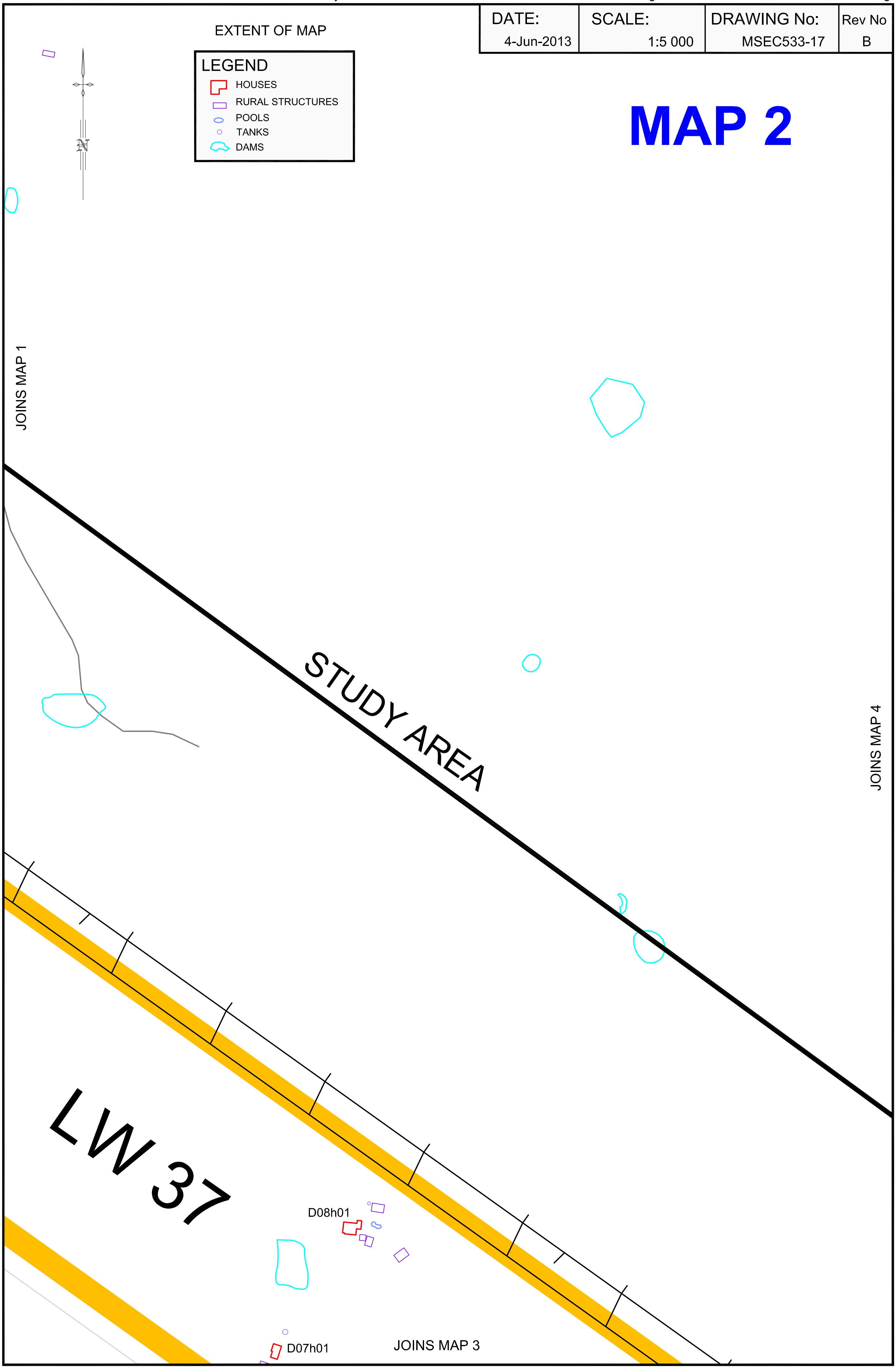
I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-16dwg

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:5 000 | MSEC533-16 | B |

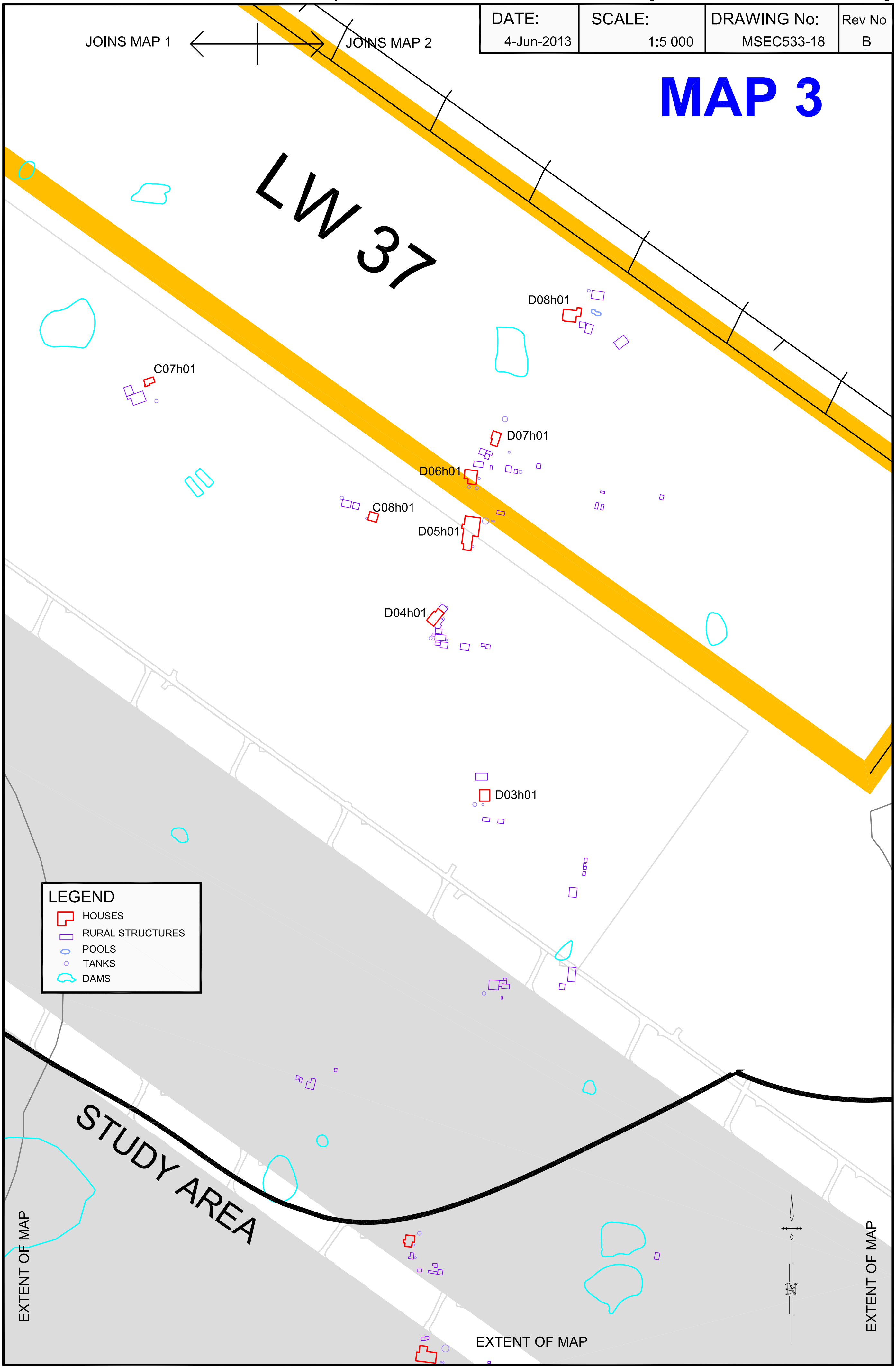


I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-17dwg

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:5 000 | MSEC533-17 | B |



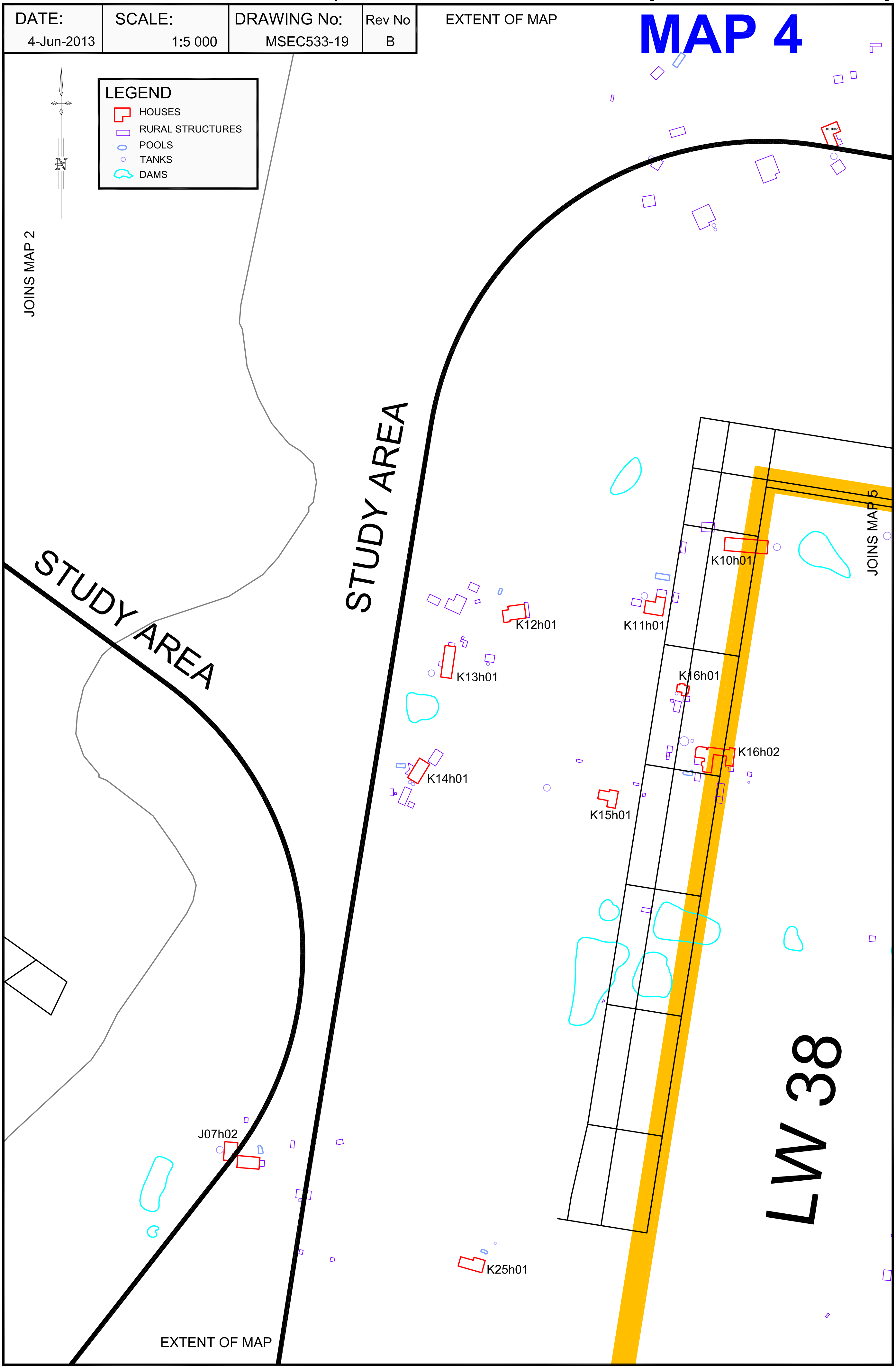
I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-18dwg



I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-19dwg

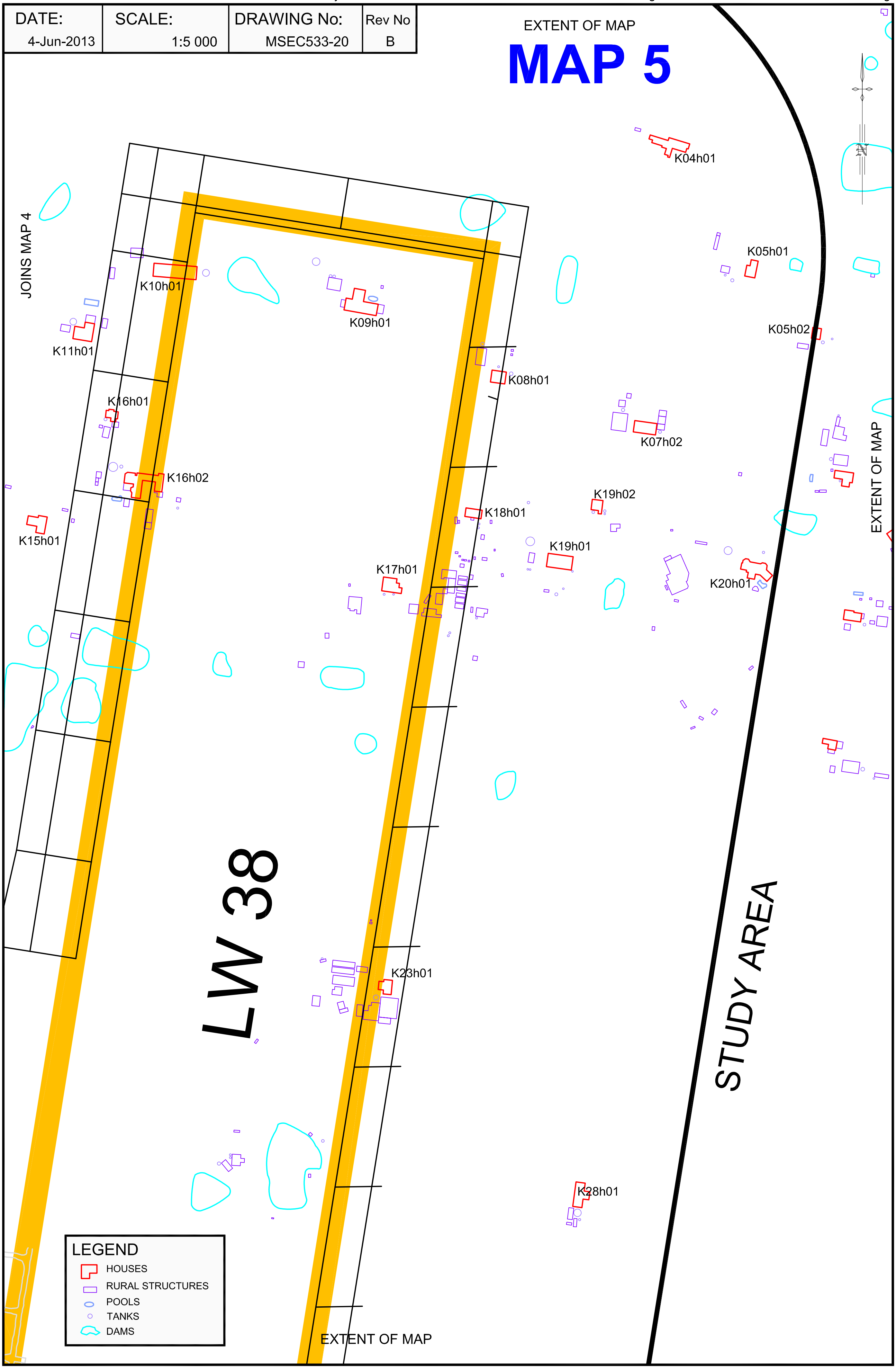
| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:5 000 | MSEC533-19 | B |

# MAP 4



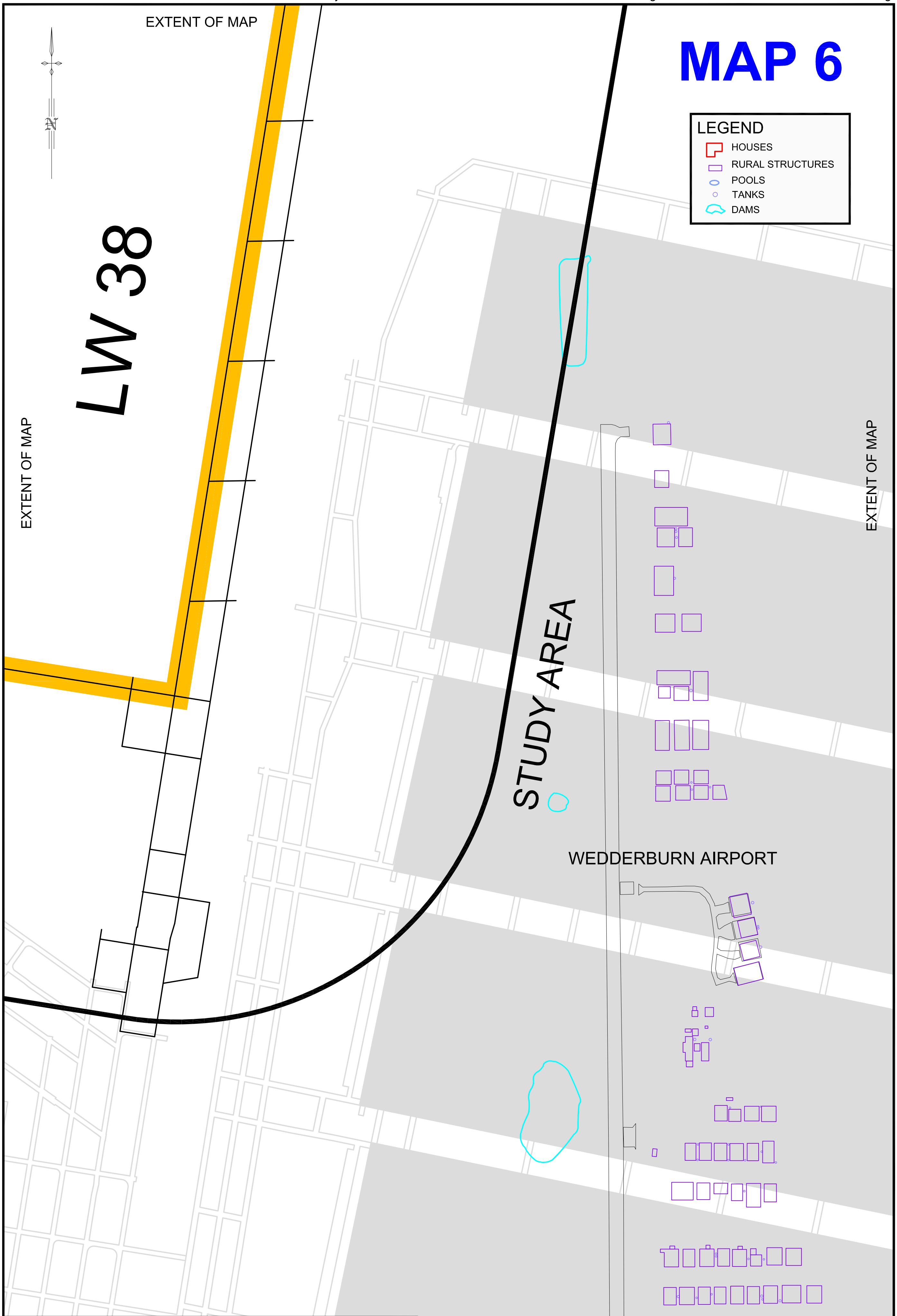
I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-20dwg

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:5 000 | MSEC533-20 | B |



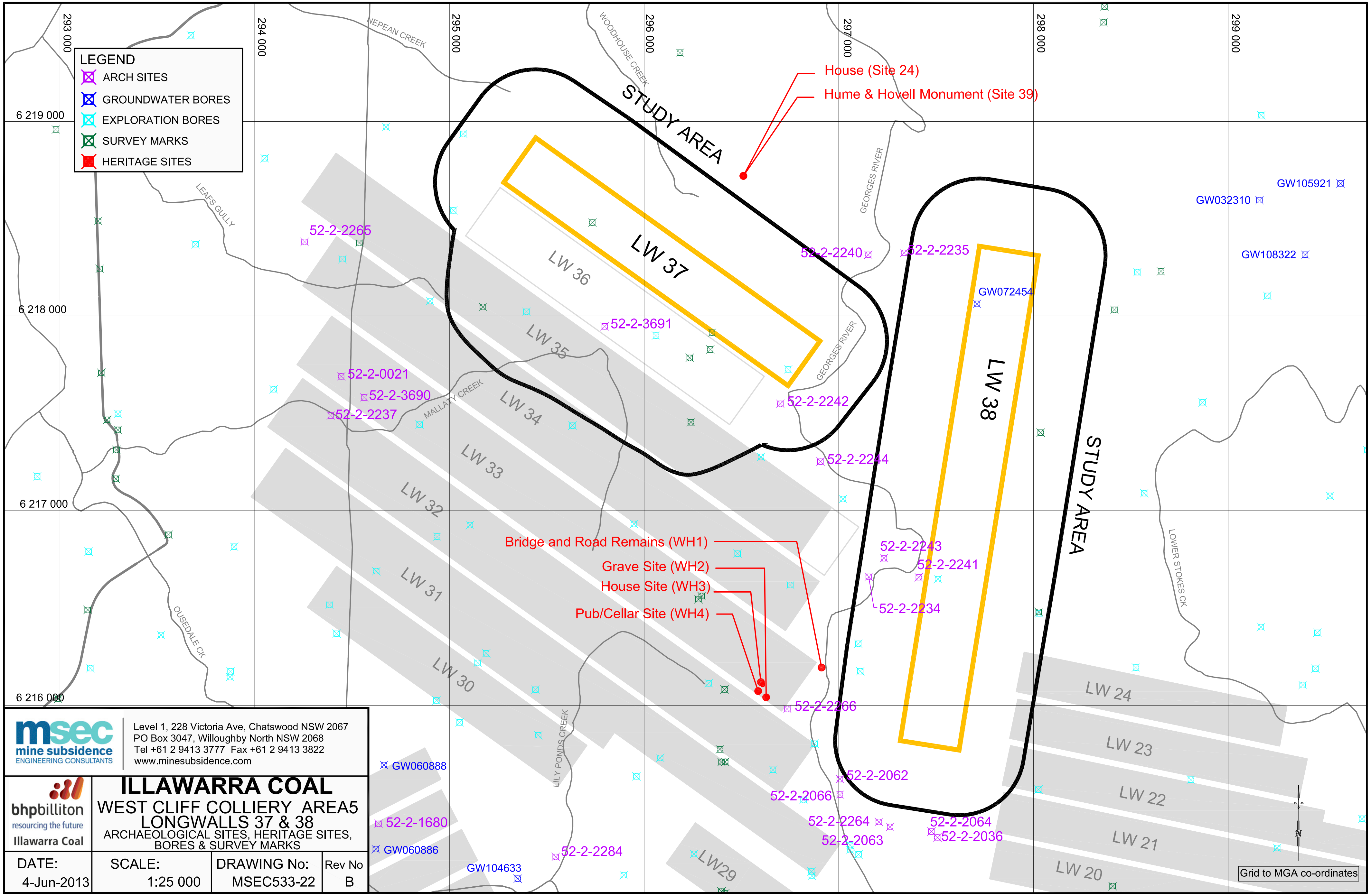
I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-21dwg

# MAP 6




| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:5 000 | MSEC533-21 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-22dwg




msec mine subsidence ENGINEERING CONSULTANTS

Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com

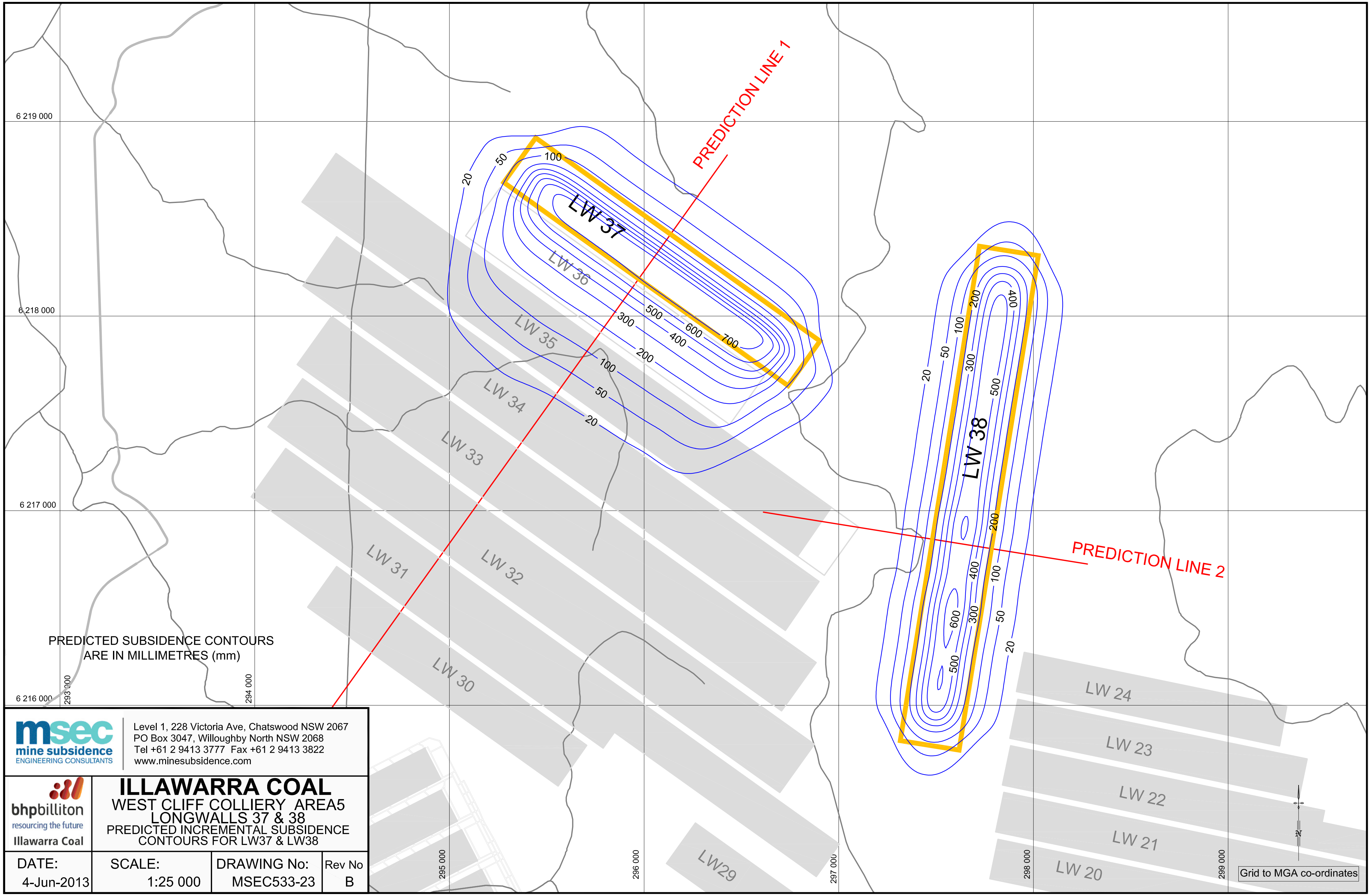
bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL

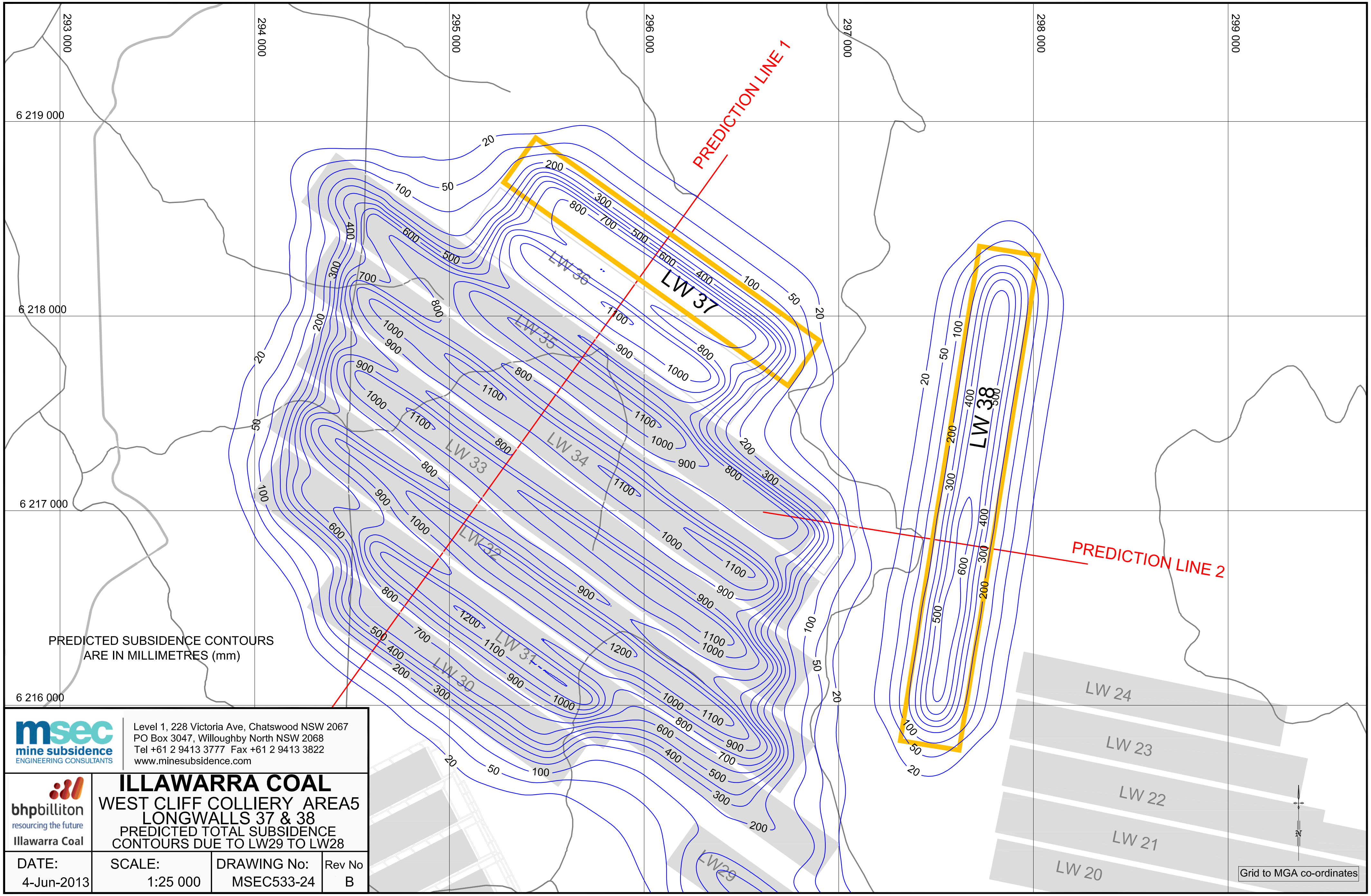
WEST CLIFF COLLIERY AREA5
LONGWALLS 37 & 38
ARCHAEOLOGICAL SITES, HERITAGE SITES, BORES & SURVEY MARKS

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-22 | B |

I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-23dwg



I:\Projects\West Cliff\Area 5\MSEC533 - Extraction Plan for Longwalls 37 and 38\AutoCAD\MSEC533-24dwg




PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)


msec mine subsidence ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood NSW 2067
PO Box 3047, Willoughby North NSW 2068
Tel +61 2 9413 3777 Fax +61 2 9413 3822
www.minesubsidence.com


bhpbilliton resourcing the future
Illawarra Coal

# ILLAWARRA COAL
## WEST CLIFF COLLIERY AREA5
## LONGWALLS 37 & 38
PREDICTED TOTAL SUBSIDENCE CONTOURS DUE TO LW29 TO LW28

| DATE: | SCALE: | DRAWING No: | Rev No |
|---|---|---|---|
| 4-Jun-2013 | 1:25 000 | MSEC533-24 | B |